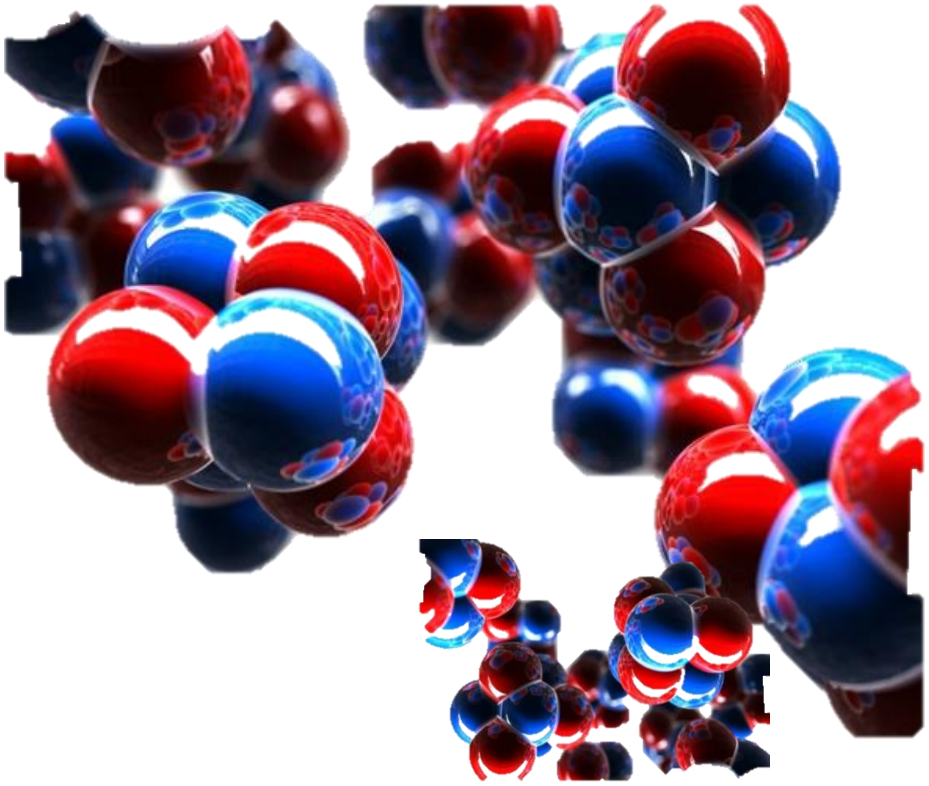
QUESTIONS AND TESTS IN CHEMISTRY

(Applicants for graduate studies and comprehensive exam)



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Contents

CHAPTER ONE
Introduction

This chapter Includes; definition of chemistry, and a brief historical overview of chemistry evolution and its philosophy, and fundamental branches of chemistry, also has a summary of the topics that are the basis of this knowledge.

The most important transfers (SI unit system) and mathematical equations that benefit the individual researcher and student of this science.

يتضمن الفصل الحالي، تعريف علم الكيمياء، ونبذه تاريخية سريعة عن تطور علم الكيمياء وفلسفته، والفروع الأساسية للكيمياء.

كما يضم مختصر للمواضيع التي تعتبر أساس هذه العلم، والنظام الدولي للوحدات (SI units system) والمعادلات الرياضية التي تفيد الباحث والدارس لهذا هذا العلم.

<u>ملاحظة</u>: تم وضع خط تحت الاختيار الصحيح.

Chemistry

Chemistry, changes in phases of matter, and separation of mixtures. Final a branch of physical science, is the study of the composition, structure, properties and change of matter. Chemistry is chiefly concerned with atoms and their interactions with other atoms-for example, the properties of the chemical bonds formed between atoms to create chemical compounds. As well as this, interactions including atoms and other phenomena-electrons and various forms of energy-are considered, such as photochemical reactions, oxidation-reduction reactionsy, properties of matter such as alloys or polymers are considered.

Chemistry is sometimes called "**the central science**" because it bridges other natural sciences like physics, geology and biology with each other. Chemistry is a branch of physical science but distinct from physics.

The etymology of the word chemistry has been much disputed. The origin of chemistry can be traced to certain practices, known as alchemy, which had been practiced for several millennia in various parts of the world, particularly the Middle East.

Fundamentally, chemistry is the study of matter and change. The way that chemists study matter and change and the types of systems that are studied varies dramatically. Traditionally, chemistry has been broken into five main subdisciplines: **Organic, Analytical, Physical, Inorganic, and Biochemistry**. Over the last several years, additional concentrations have begun to emerge, including Nuclear chemistry, Polymer chemistry, Biophysical chemistry, Bioinorganic chemistry, Environmental chemistry, industry chemistry, etceteras. All of these areas of chemistry are defined detail below;

Physical chemistry:
is the study of macroscopic, atomic, subatomic, and particulate phenomena in chemical systems in terms of laws and concepts of physics. It applies the principles, practices and concepts of physics such as motion, energy, force, time, thermodynamics, quantum chemistry, statistical mechanics and dynamics, equilibrium.
Physical chemistry, in contrast to chemical physics, is predominantly (but not always) a macroscopic or supra-molecular science, as the majority of the principles on which physical chemistry was founded, are concepts related to the bulk rather than on molecular/atomic structure alone. For example, chemical equilibrium, and colloids.
Some of the relationships that physical chemistry strives to resolve include the effects of:

1. Intermolecular forces that act upon the physical properties of materials (plasticity, tensile strength, surface tension in liquids).
2. Reaction kinetics on the rate of a reaction.
3. The identity of ions and the electrical conductivity of materials.
4. Surface chemistry and electrochemistry of membranes.
5. Interaction of one body with another in terms of quantities of heat and work called thermodynamics.
6. Transfer of heat between a chemical system and its surroundings during change of phase or chemical reaction taking place called thermochemistry
7. Study of colligative properties of number of species present in solution.
8. Number of phases, number of components and degree of freedom (or variance) can be correlated with one another with help of phase rule.
9. Reactions of electrochemical cells.

Physical means:

1. mass
2. color
3. refractive index
4. thermal conductivity with electromagnetic radiation (Spectroscopy)
5. absorption
6. emission
7. scattering by an electric charge
8. number of phases, number of components and degree of freedom (or variance) can be correlated with one another with help of phase rule.
9. reactions of electrochemical cells.

Biochemistry, sometimes called **biological chemistry**, is the study of chemical process within and relating to, living organisms. By controlling information flow through biochemical signaling and the flow of chemical energy through metabolism, biochemical processes give rise to the complexity of life. Over the last 40 years, biochemistry has become so successful at explaining living processes that now almost all areas of the life sciences from botany to medicine are engaged in biochemical research. Today, the main focus of pure biochemistry is in understanding how biological molecules give rise to the processes that occur within living cells, which in turn relates greatly to the study and understanding of whole organisms.

Biochemistry is closely related to molecular biology, the study of the molecular mechanisms by which genetic information encoded in DNA is able to result in the processes of life. Depending on the exact definition of the terms used, molecular biology can be thought of as a branch of biochemistry, or biochemistry as a tool with which to investigate and study molecular biology.

Much of biochemistry deals with the structures, functions and interactions of biological macromolecules, such as proteins, nucleic acids, carbohydrates and lipids, which provide the structure of cells and perform many of the functions associated with life. The chemistry of the cell also depends on the reactions of smaller molecules and ions. These can be inorganic, for example water and metal ions, or organic, for example the amino acids which are used to synthesize proteins. The mechanisms by which cells harness energy from their environment via chemical reactions are known as metabolism. The findings of biochemistry are applied primarily in medicine, nutrition, and agriculture. In medicine, biochemists investigate the causes and cures of disease. In nutrition, they study how to maintain health and study the effects of nutritional deficiencies. In agriculture, biochemists investigate soil and fertilizers, and try to discover ways to improve crop cultivation, crop storage and pest control.

Industrial Chemistry

Industrial chemistry refers to chemicals that ARE developed or manufactured and they are mainly used in industrial operations or research by industry or government. These chemicals are highly reactive and can cause a lot of damage when they are swallowed accidentally. Industrial chemistry refers to chemicals that ARE developed or manufactured and they are mainly used in industrial operations or research by industry or government. These chemicals are highly reactive and can cause a lot of damage when they are swallowed accidentally.

Organic chemistry is a chemistry subdiscipline involving the scientific study of the structure, properties, and reactions of organic compounds and organic materials, i.e., matter in its various forms that contain carbon atoms. Study of structure includes using spectroscopy and other physical and chemical methods to determine the chemical composition and constitution of organic compounds and materials. Study of properties includes both properties and chemical properties, and uses similar methods as well as methods to evaluate chemical reactivity, with the aim to understand the behavior of the organic matter in its pure form (when possible), but also in solutions, mixtures, and fabricated forms. The study of organic reactions includes both their preparation-by synthesis or by other means-as well as their subsequent reactivities, both in the laboratory and via theoretical (in silicon) study.

The range of chemicals studied in organic chemistry includes hydrocarbons, compounds containing only carbon and hydrogen, as well as compositions based on carbon but containing other elements. Organic chemistry overlaps with many areas including medicinal chemistry, biochemistry, organometallic chemistry, and polymer chemistry, as well as many aspects of materials science.

Organic compounds form the basis of all earthly life. They are structurally diverse. The range of application of organic compounds is enormous. They either

form the basis of, or are important constituents of, many products including plastics, drugs, petrochemicals, food, explosive material, and paints.

Inorganic chemistry is the study of the synthesis and behavior of inorganic and organometallic compounds. This field covers all chemical compo undsexcept the myriad organic compounds (carbon based compounds, usually containing C-H bonds), which are the subjects of organic chemistry. The distinction between the two disciplines is far from absolute, and there is much overlap, most importantly in the sub-discipline of organometallic chemistry. It has applications in every aspect of the chemical industry–including catalysis, materials science, pigments, surfactants, coatings, medicine, fuel, and agriculture. Many inorganic compounds are ionic compounds, consisting of cations and anions joined by ionic bonding. Examples of salts (which are ionic compounds) are magnesium chloride $MgCl_2$, which consists of magnesium cations Mg^{2+} and chloride anions Cl^-; or sodium oxide Na_2O, which consists of sodium cations Na^+ and oxide anions O^{2-}. In any salt, the proportions of the ions are such that the electric charges cancel out, so that the bulk compound is electrically neutral. The ions are described by their oxidation state and their ease of formation can be inferred from the ionization potential (for cations) or from the electron affinity (anions) of the parent elements.
Important classes of inorganic salts are the oxides, the carbonates, the sulfates and the halides. Many inorganic compounds are characterized by high melting points. Inorganic salts typically are poor conductors in the solid state. Other important features include their solubility in water and ease of crystallization. Where some salts (e.g., NaCl) are very soluble in water, others (e.g., SiO_2) are not.
The simplest inorganic reaction is double displacement when in mixing of two salts the ions are swapped without a change in oxidation state. In redox reactions one reactant, the oxidant lowers its oxidation state and another reactant, the reductant, has its oxidation state increased. The net result is an exchange of electrons.

Nuclear chemistry is the subfield of chemistry dealing with radioactivity, nuclear processes and nuclear properties. It is the chemistry of radioactive elements such as the actinides, radium and radon together with the chemistry associated with equipment (such as nuclear reactors) which are designed to perform nuclear processes. This includes the corrosion of surfaces and the behavior under conditions of both normal and abnormal operation (such as during an accident). An important area is the behavior of objects and materials after being placed into nuclear storage or disposal site.
It includes the study of the chemical effects resulting from the absorption of radiation within living animals, plants, and other materials. The radiation chemistry controls much of radiation biology as radiation has an effect on living things at the molecular scale, to explain it another way the radiation alters the biochemicals within an organism, the alteration of the biomolecules then changes the chemistry which occurs within the organism, this change in biochemistry then can lead to a biological outcome. As a result nuclear chemistry greatly assists the

understanding of medical treatments (such as cancer radiotherapy) and has enabled these treatments to improve.

Analytical chemistry is the study of the separation, identification, and quantification of the chemical components of natural and artificial materials. Analysis gives an indication of the identity of the chemical species in the sample, and quantitative analysis determines the amount of certain components in the substance. The separation of components is often performed prior to analysis.
Analytical methods can be separated into classical and instrumental. Classical methods (also known as wet chemistry methods) use separations such as precipitation, extraction, and distillation and qualitative analysis by color, odor, or melting point. Quantitative analysis is achieved by measurement of weight or volume. Instrumental methods use an apparatus to measure physical quantities of the analytic such as light absorption, fluorescence, or conductivity. The separation of materials is accomplished using chromatography, electrophoresis or Field Flow Fractionation methods. Analytical chemistry is also focused on improvements in experimental design, chemometrics, and the creation of new measurement tools to provide better chemical information. Analytical chemistry has applications in forensics, bioanalysis, clinical analysis, environmental analysis, and materials analysis. Analytical chemistry is the science of making quantitative measurements. In practice, quantifying analysts in a complex sample becomes an exercise in problem solving. To be effective and efficient, analyzing samples requires expertise in:
1- The chemistry that can occur in a sample.
2- Analysis and sample handling methods for a wide variety of problems (the tools-of-the-trade). Analytical chemistry requires broad background knowledge of chemical and physical concepts. These hypermedia documents contain links to the fundamental principles that underlay the different analytical methods. As you study the analytical chemistry topics, follow the hyperlinks to the basic concepts with which you are not familiar. With a fundamental understanding of analytical methods, a scientist faced with a difficult analytical problem can apply the most appropriate technique(s). A fundamental understanding also makes it easier to identify when a particular problem cannot be solved by traditional methods, and gives an analyst the knowledge that is needed to develop creative approaches or new analytical methods.

Polymer chemistry or **macromolecular chemistry** is a multidisciplinary science that deals with the chemical synthesis and chemical properties of polymers or macromolecules. According to IUPAC recommendations, macromolecules refer to the individual molecular chains and are the domain of chemistry. Polymers describe the bulk properties of polymer materials and belong to the field of

polymer physics as a subfield of physics. Polymer chemistry is that branch of one, which deals with the study of synthesis and properties of macromolecules.

Polymers are formed by polymerization of monomers. A polymer is chemically described by its degree of polymerisation, molar mass distribution, tacticity, copolymer distribution, the degree of branching, by its end-groups, crosslinks, crystallinity and thermal properties such as its glass transition temperature and melting temperature. Polymers in solution have special characteristics with respect to solubility, viscosity and gelation.

علم الكيمياء:

تغير تعريف الكيمياء عبر العصور بسبب التطور الحاصل في النظريات والاكتشافات التي وسعت من مفهوم هذا العلم، وفيما يلي بعض التعريفات التي استخدمت في كتابات بعض الكيميائيين:

– دراسة تركيب الماء والحركة والنمو والتجسّد واستخراج الأرواح من الأجساد. (زوسيموس 1661)

– موضوع المواد الأساسية للأجسام المتمازجة. (روبرت بويل 1663)

– فن علمي يستطيع الفرد من خلاله حل الأجسام، واستخراج المواد المختلفة المكونة لها، وكيفية دمجها مجدداً، ورفعها إلى مستوى أكثر كمالاً. (كلاسر 1730)

– فن حل الأجسام الممتزجة أو المختلطة أو المجموعة إلى أجزاءها الرئيسية، وتركيب هذه الأجسام من هذه المواد. (جورج ستال 1837)

– هو العلم الذي يهتم بالقوى الجزيئية وتأثيراتها وقوانينها. (دوماس 1947)

– هو علم المواد: بنيتها، خواصها، والتفاعلات التي تحولها إلى مواد أخرى لينوس. (باولنغ 1998)

– هو دراسة المادة والتأثيرات التي تحصل عليها.

الكيمياء التقليدية

تبدأ الكيمياء التقليدية بدراسة الجسيمات الأولية والذرات والجزيئات والمواد الكيميائية والبلورات وأشكال التجمعات الأخرى للمادة وفي الحالة الصلبة والسائلة والغازية معزولة عن بعضها أو متحدة مع بعضها. تنتج التأثرات والتفاعلات والتحولات التي تدرسها الكيمياء من التأثر بين مواد كيميائية مختلفة أو بين المادة والطاقة. يدرس هذا السلوك في المختبر وباستخدام أشكال مختلفة من الأدوات المختبرية.

التفاعل الكيميائي

التفاعل الكيميائي هو تحول بعض المواد إلى مادة أخرى أو أكثر. ويمكن استخدام الرموز للتعبير عنه بواسطة معادلة كيميائية. غالباً ما يكون عدد الذرات في طرفي المعادلة متساوياً، وتكون طبيعة التفاعلات الكيميائية والتغيرات في الطاقة التي تحدث نتيجة لهذه التفاعلات محكومة بقوانين تسمى القوانين الكيميائية، وتعد ملاحظة الطاقة والإنتروبيا من الأمور المهمة في أغلب الدراسات الكيميائية.

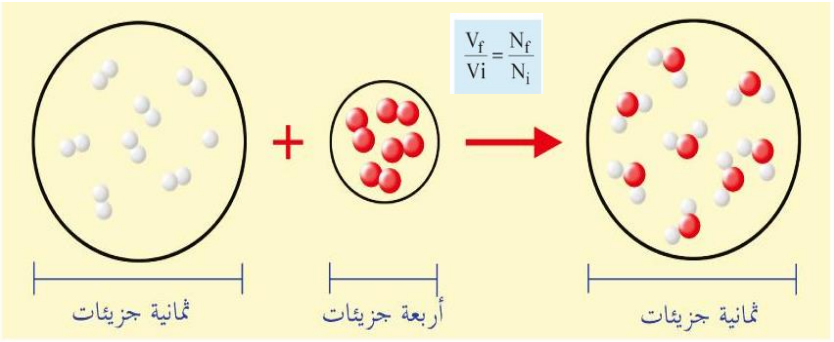
قوانين الكيمياء

تخضع التفاعلات الكيميائية لقوانين محددة، والتي أصبحت مفاهيم أساسية في الكيمياء، وهذه بعض القوانين:

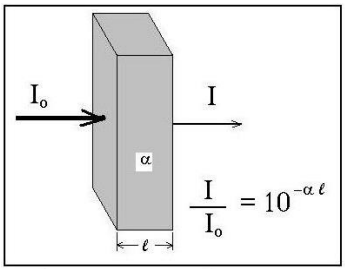
- **قانون أفوكادرو:** الصيغة الرياضية للقانون هي:

$$\frac{V}{n} = k$$

اذ ان V: حجم الغاز. n: كمية المادة للغاز. k: ثابت الغاز.

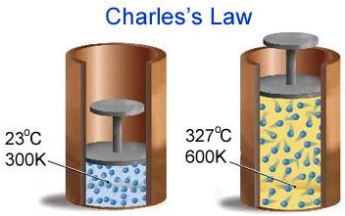


• **قانون بير لامبرت** Beer–Lambert Law: أو قانون بير، أو قانون بير–لامبرت–بوغير، هو علاقة تجريبية تربط امتصاص الضوء بخصائص المادة التي يعبر الضوء من خلالها. تم اكتشاف القانون من قبل الفرنسي بيير بوغير قبل 1729. وغالباً ما يسند القانون إلى جوان لامبرت، الذي استشهد بـ"تجربة بوغير الضوئية عن توهين الضوء في كتابه"Photometria" في عام 1760. لاحقاً قام أوغست بير بتوسيع قانون الامتصاص الأسي في عام 1852 ليتضمن تركيز المحاليل في "معامل الامتصاص".



$$A = -\log_{10}\left(\frac{I_l}{I_0}\right) = \frac{\alpha' \ell}{2.303} = \alpha \ell = \varepsilon \ell c.$$

• **قانون شارل Charles's Law**: قام العالم جاك تشارل بتثبيت ضغط الغاز ودراسة العلاقة بين درجة الحرارة وحجم الغاز. واكتشف عام 1787م ان عند ثبات ضغط كتلة معينة من غاز يتناسب حجمها تناسبا طرديا مع درجة حرارتها المطلقة ونستنتج القانون الاتي:

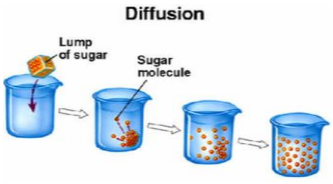


$$\frac{V}{T} = k$$

اذ ان أن V: حجم الغاز. T: درجة حرارة الغاز مقاسة بالكلفن. k ثابت. ومنه ينتج أن:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad \frac{V_2}{V_1} = \frac{T_2}{T_1} \quad \text{or} \quad V_1 \cdot T_2 = V_2 \cdot T_1$$

• **قانون فيك للانتشار** Fick's laws of diffusion: يربط هذه القانون بين تدفق الانتشار مادّة في وسط ما وحقل التركيز لهذه المادّة. الفرضية الكامنة في هذا القانون هو أنّ التدفق يكون من المناطق ذات التركيز المرتفع في الحقل إلى المناطق ذات التركيز المنخفض، بمقدار يتناسب مع تدرج التراكيز في الحقل. لذا، فإذا افترضنا أنّ التدرج موجود فقط على امتداد محور x (أي أنّه لا تغيير في التركيز في المحورين المتعامدين)، فإنّ تدفق الانتشار يحقّق :

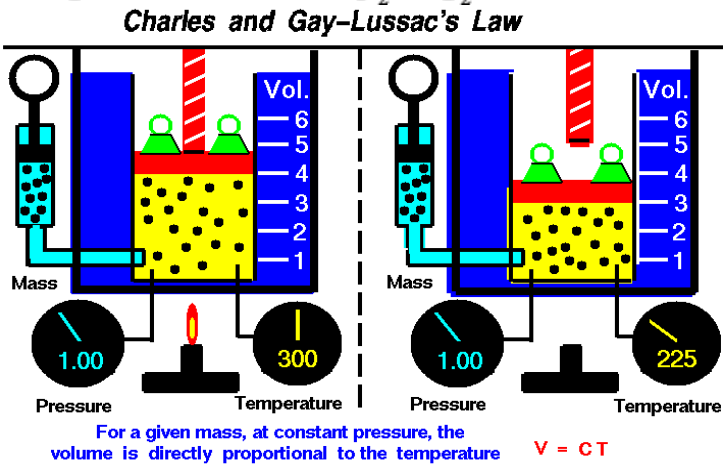


$$J = -D\frac{\partial \phi}{\partial x}$$

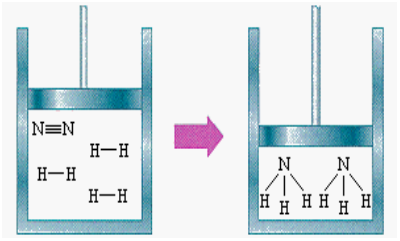
اذ أن J: تدفق الانتشار، بوحدات $\left(\frac{\text{mol}}{m^2 \cdot s}\right)$، وهو يقيس كميّة المادّة المتدفّقة عبر مساحة صغيرة خلال فترة قصيرة من الزمن؛ D معامل الانتشار، أو الانتشارية، بوحدات $\left(\frac{m^2}{s}\right)$ وهو يتعلّق بنوع المادة، ويعبّر عن المساحة التي تنتشر إليها مادّة معيّنة خلال فترة زمنية قصيرة؛ ϕ هو تركيز المادّة، بوحدات $\left(\frac{\text{mol}}{m^3}\right)$؛ x هو إحداثي ويدل على الموقع الذي يتم به حساب التدفق، بوحدات (m).

• **قانون جاي لوساك (Gay-Lussac's law)**: ينص على أن ضغط غاز مثالي يتغير تغيراً طردياً مع درجة الحرارة عند ثبات الحجم تقاس درجة الحرارة هنا بالكلفن كما يفترض ثبات كمية الغاز. معنى ذلك أن ضغط الغاز يزداد بالتسخين ويقل عند فقده حرارة. وقد اكتشف هذا الاعتماد بين ضغط الغاز ودرجة الحرارة جاك شارلز عام 1787 والعالم والفيزيائي الفرنسي جوزيف جاي–لوساك في عام 1802. فعندما يكون الحجم V ثابتاً وكذلك كمية n المادة ثابتة تنطبق المعادلة:

$$P \sim T \qquad \frac{P}{T} = \text{const} \qquad \frac{P_1}{P_2} = \frac{T_1}{T_2}$$



• **مبدأ لو شاتيليه Le Chatelier's Principle:** يسمى أيضا مبدأ لو شاتيليه–براون، يستخدم لتعيين تأثير تغيير أحد دالات الحالة مثل تغيير الضغط أو تغيير درجة الحرارة على التوازن الكيميائي المبدأ يحمل اسمي هنري لوي لو شاتيليه وكارل فرديناند براون الذان اكتشفاه كل على حده. ويمكن تلخيصه كما يأتي:



"إذا حدثت تغييرات في التركيز، أو درجة الحرارة، أو الحجم، أو الضغط الجزئي لأحد المواد في نظام كيميائي موجود في حالة توازن كيميائي فعندها سيتغير التوازن الكيميائي في الاتجاه الذي يُحد من تأثير هذا التغيير". ويستخدم المبدأ في الكيمياء للتحكم في نتيجة التفاعلات العكوسية، عادة لزيادة نتيجة المعادلة. مثلا في التفاعل الاتي:

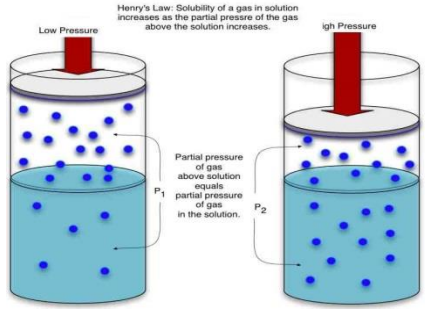
$$2NO_2 \rightarrow N_2O_4 + heat$$

برفع درجة الحرارة يثير التفاعل نحو تكوين N_2O_4. وهذا ينطبق على التفاعلات الطاردة للحرارة، فبزيادة درجة الحرارة يسير التفاعل في الاتجاه من اليسار إلى اليمين.

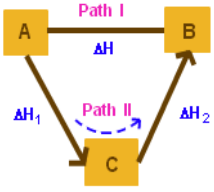
• **قانون هنري Henry's Law:** تتناسب ذوبانية غاز في سائل عند درجة حرارة معينة طردياً مع ضغط الغاز الموجود فوق السائل:

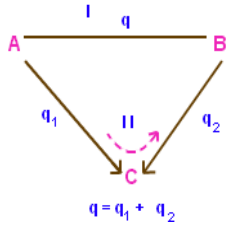
$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

S_2, S_1 ذائبية الغاز الأولى والثانية. P_2, P_1 ضغط الغاز الأول والثاني.



• **قانون هس Hess's Law of Constant Heat Summation:** "التغير في الإنثالبي ΔH الحادث أثناء احدى العمليات التامة هو مجموع تغيرات الإنثالبي لجميع الخطوات المتتالية للعملية". نستنتج من هذا القانون أن إنثالبي التفاعل لا يتغير بتغير مسار التفاعل وإنما يعتمد فقط على الحالة الابتدائية والحالة النهائية للتفاعل.





• **قانون حفظ الطاقة Energy Conservation Law**: ينص على أنه في أي نظام معزول، الطاقة لا تفنى ولا تستحدث من عدم ولكن يمكن تحويلها من صورة لأخرى.

يمكن تحويل الطاقة من صورة إلى أخرى مثل طاقة الحركة يمكن أن تتحول إلى طاقة حرارية، ولكن ليس ممكنا في نظام مغلق معزول أن تخلق طاقة من نفسها أو تفنى. ونقول أن الطاقة تتبع قوانين الحفظ.

نعرف صورا عديدة للطاقة: طاقة حركة، طاقة حرارية، طاقة كهربائية، طاقة ميكانيكية، طاقة إشعاعية وغيرها، ويمكن تحولها من صورة إلى أخرى. ولكن تبقى الطاقة ولا تفنى. كما بينت النظرية النسبية لأينشتاين أن الطاقة يمكن أن تتحول إلى مادة $E=mc^2$.

• **قانون حفظ المادة أو الكتلة:** أو يعرف باسم قانون لافوازييه–لومونوسوف، وينص على "عند حدوث أي تفاعل كيميائي فان كتل المواد المتفاعلة تساوي كتل المواد الناتجة عن التفاعل كما أن يذكر أن أي كتلة في نظام مغلق ستبقى ثابتة مهما حدث داخل النظام. صياغة مكافئة أخرى لهذا القانون تنص على أن المادة في نظام مغلق لا يمكن أن تنشأ أو تفنى، إلا أنه يمكن إعادة ترتيبها. أي أن أي عملية كيميائية في نظام مغلق يجب أن تكون فيها كتلة المواد المتفاعلة مساوية لكتلة المواد الناتجة بعد انتهاء العملية.

• **قانون النسب الثابتة:** أو التركيب المحدد (Law of composition or Definite proportions) أكمل الفرنسي (بروست) دراسات أنطوان لافوازييه بعد وفاته وتبين له أن المركبات تحتوي على نسب ثابتة من العناصر المكونة لها، ولا تتغير هذه النسب مهما اختلفت طرق تحضير المركب. فمثلا ملح الطعام النقي سواء حصلنا عليه من مياه البحار أو تم تحضيره من تفاعل كيميائي فإنه يحتوي دائما على 39,3% من كتلته الصوديوم و60,7% من كتلته كلور ومن خلاصة أبحاث متعددة توصل بروست إلى القانون الذي ينص على أنه: يتألف كل مركب كيميائي نقي من نسب وزنية ثابتة للعناصر المكونة له مهما اختلفت طرق تحضيره.

• **قانون النسب المتضاعفة:**

• **قانون راؤول** RaoulT's Law: قانون في الكيمياء صاغه العالم فرانسوا ماري راؤول. وينص القانون على أن ضغط البخار لسائل مثالي يعتمد على ضغط البخار لكل من مكوناته وأجزائها المولية الموجودة في السائل. عندما تصل جزيئات السائل حالة التوازن الكيميائي فيمكن صياغة ضغط البخار الكلي p للسائل بالمعادلة الآتية:

$$p = p^\star_{\mathrm{A}} x_{\mathrm{A}} + p^\star_{\mathrm{B}} x_{\mathrm{B}} + \cdots$$

ويبلغ ضغط بخار كل من مكوناته:

$$p_i = p_i^\star x_i$$

اذ ان p^*_i: ضغط البخار للمكون النقي، x_i الجزء المولي للمكون النقي.

فروع الكيمياء

تقسم الكيمياء إلى عدة فروع رئيسية، كما يوجد أيضا تفرعات لهذه الفروع، وموضوعات ذات تخصص أكبر داخل هذه الفروع.

- **الكيمياء التحليلية:** هي تحليل عينات من المادة لمعرفة التركيب الكيميائي لها وكيفية بنائها.
- **الكيمياء الحيوية:** هي دراسة المواد الكيميائية، والتفاعلات الكيميائية التي تحدث في الكائنات الحية.
- **الكيمياء غير العضوية:** هي دراسة خواص وتفاعلات المركبات غير العضوية. ولا يوجد هناك حد واضح للتفريق بين الكيمياء العضوية وغير العضوية، كما أن هناك تداخل كبير بينهما، ويكون أهمه في فرع آخر يسمى كيمياء الفلزات العضوية.
- **الكيمياء العضوية:** هي دراسة تركيب، وخواص، وتفاعلات المركبات العضوية.
- **الكيمياء الفيزيائية:** هي دراسة الأصل الفيزيائي للتفاعلات والأنظمة الكيميائية. ولمزيد من التحديد فإنها تدرس تغييرات حالات الطاقة في التفاعلات الكيميائية. ومن الفروع التي تهم الكيميائيين المتخصصين في الكيمياء الحرارية، الكيمياء الحركية، كيمياء الكم، الميكانيكا الإحصائية، علم الأطياف.

الكيمياء الحديثة

يرجع تاريخ الكيمياء الحديثة إلى القرن السابع عشر الميلادي بأبحاث (بويل) الذي قسم الأجسام إلى مواد أولية(عناصر ومركبات ومخاليط) وتلت أبحاث (بلاك، ولافوازييه) عن الاحتراق والتأكسد ثم (برتلي) الذي اكتشف الأكسجين في الهواء، ثم (كافندش) الذي اكتشف تكوين الماء ثم دالتون الذي وضع النظرية الذرية عن تكون المادة وتعرّف الكيمياء الحديثة بأنها: علم طبيعي في تكوين المادة والتغييرات التي تحدث فيها تحت تغييرات مختلفة تفقد الجسم مظهره الخاص وصفاته التي يتميز بها، إذ تتبدل مادته بأخرى ذات خواص وصفات جديدة وتوصف مظاهر المواد وسلوكها بالخواص الكيميائية، أي تعرّف بذلك وتبين تلك الخواص الكيميائية إبان التفاعلات بالمعادلات.

تضم الكيمياء التقليدية دراسة الاتي:

- الجسيمات الأولية والذرات والجزيئات والمواد الكيميائية والبلورات وأشكال التجمعات الأخرى للمادة وفي الحالة الصلبة والسائلة والغازية معزولة عن بعضها أو متحدة مع بعضها. تنتج التأثرات والتفاعلات والتحولات التي تدرسها الكيمياء من التأثر بين مواد كيميائية مختلفة أو بين المادة والطاقة. يدرس هذا السلوك في المختبر وباستخدام أشكال مختلفة من الأدوات المختبرية.

الكيمياء التحليلية (Analytical Chemistry)

يهتم بالتقدير الكمي والنوعي للعناصر أو المركبات المكونة للمادة المراد تحليلها. وينقسم هذا الفرع إلى عدة طرق وأساليب يمكن استخدامها ولكل منها استخداماته وأهميته وهي:

1- **التحليل النوعي أو الوصفي Qualitative Analysis** وهو مجموعة العمليات التي يتم فيها الكشف عن تركيب المواد أو المركبات أو العناصر الداخلة في تركيب مادة معينة أو خليط من المواد سواء أكانت في الحالة الصلبة أو محلول في مذيب معين ولا يتعرض هذا التحليل إطلاقاً إلى كميات هذه المكونات.

2- **التحليل الكمي Quantitative Analysis** ويبحث في تقدير كميات المكونات أو العناصر الداخلة في تركيب المركب الكيميائي أو الخليط، ويتبين من هذا أن التحليل النوعي لمادة مجهولة التركيب يسبق عادة التحليل الكمي لها؛ لأنه لا يجوز تقدير مادة معينة تقديراً كمياً ما لم يتأكد من وجودها وصفياً.

هنالك نوعين رئيسين للتحليل الكمي وهي:

a- التحليل الوزني Analysis Gravimetric

b- التحليل الحجمي Volumetric Analysis

تستعمل في هذه الحالة طرق مباشرة وغير مباشرة لتعيين أوزان المواد أو بعض مكوناتها.

الكيمياء العضوية (Organic Chemistry) هي أحد فروع علم الكيمياء. وهي العلم الذي يدرس بناء وخواص وتركيب وتفاعلات المركبات الكيميائية التي تحتوي على عنصر الكربون كعنصر أساسي بالإضافة إلى عناصر أخرى. ومن النادر وجود مركب من المركبات العضوية خالي من عنصر الهيدروجين، ويمكن أن تحتوى على أي عدد آخر من العناصر، مثل النيتروجين، والأكسجين، والهالوجينات، وأحيانا قليلة الفسفور، أو الكبريت. التعريف الأصلي للكيمياء العضوية تم اختياره بصورة خاطئة اعتمادا على أن هذه المركبات كانت دائماً ما تنتمى بشكل أو بآخر للعمليات الحيوية في الكائنات الحية. ولاحقا تم التعامل مع هذه المركبات التي تنتمى للعمليات الحيوية في فرع من فروع الكيمياء العضوية يسمى الكيمياء الحيوية.

بينما تتعامل الكيمياء غير العضوية بعيداً عن مركبات الكربون المعقدة، والتي لا تحتوى على روابط كربون–كربون (مثل أكسيدات الكربون والأحماض والأملاح والكاربيدات والمعادن). وهذا بالطبع لا ينفى وجود مركبات عضوية غير معقدة لا تحتوى على روابط كربون–كربون (مثل الميثان ومشتقاته البسيطة).

ونظراً للخواص الفريدة للمركبات عديدة الكربون فإنه يوجد مدى بالغ الإتساع لاستخدامات المركبات العضوية. فمثلاً تدخل المركبات العضوية كمكونات أساسية في عديد من المنتجات مثل البويات واللدائن والطعام والمتفجرات والأدوية والمنتجات البتروكيماوية والعديد من المنتجات الأخرى. وبالطبع (بعيداً عن بعض الاستثناءات البسيطة) فإنها تكون أساس كل العمليات الحيوية.

كما أن اختلاف أشكال ونشاط المستبدلات في المركبات العضوية يؤدى لوجود وظائف وأشكال مختلفة لهذه المركبات، مثل حفز الإنزيمات في التفاعلات الحيوية في الأنظمة الحية. وهذه التفاعلات بشكل أو بآخر تعتبر المحور الذي تدور حوله أشكال الحياة.

ونظراً للخواص الفريدة للكربون، فإنه يعتقد أنه يمكن أن يوجد شكل من أشكال الحياة على النجوم الأخرى اعتمادا على الكربون، وذلك على الرغم من احتمالية تغيير ذرة الكربون سيليكون والذي يقع أسفل الكربون في الجدول الدوري.

كما تتضمن أيضا الكيمياء العضوية التصنيع الكايرالي (والذي يسمى أيضا التصنيع غير المتماثل أو التصنيع باختيار المقابل الضوئي هو تصنيع عضوي والذي ينتج مركب له تماثل ضوئي محدد) والكيمياء الخضراء وكيمياء الموجات الصغيرة والفلورين ومطياف الموجات القصيرة. وتعتبر الكيمياء العضوية أحد أهم فروع الكيمياء الحديثة وتدرس كمنهج منفصل في الكثير من الأنظمة التعليمية في أنحاء العالم.

الكيمياء الحياتية (Biochemical)

هي أحد فروع العلوم الطبيعية ويختص بدراسة التركيب الكيميائي لأجزاء الخلية في مختلف الكائنات الحية سواء كانت كائنات دقيقة (بكتيريا، فطريات، طحالب) أو راقية كالإنسان والحيوان والنبات. ويوصف علم الكيمياء الحيوية أحياناً بأنه علم كيمياء الحياة وذلك نظراً لارتباط الكيمياء الحيوية بالحياة، فقد ركز العلماء في هذا المجال على البحث في كيمياء الكائنات الحية على اختلاف أنواعها عن طريق دراسة المكونات الخلوية لهذه الكائنات من حيث التراكيب الكيميائية لهذه المكونات ومناطق تواجدها ووظائفها الحيوية فضلا عن دراسة التفاعلات الحيوية المختلفة التي تحدث داخل هذه الخلايا الحية من حيث البناء والتخليق، أو من حيث الهدم وإنتاج الطاقة.

وهو عِلْم مختبرِ عملي الذي يُطبّقُ النظراتَ الجزيئيةَ للكيمياءِ إلى التَشْكِيلةِ الواسعةِ للأنظمةِ الحيويةِ. المتخصصون في الكيمياء الحيوية يَعْملونَ على كل المستويات وبكُلّ أنواع الكائنات الحية الحيويةِ. هناك ارتباطات وثيقة بعُلومِ الحياةِ الاختصاصية الأخرى، مثل عِلْم حياة الخليةِ، عِلْم وراثة، عِلْم أحياء دقيقة، عِلْم أحياء جزيئي وعِلْم وظائف أعضاء وعِلْم صيدلة. يَستعملونَ تقنياتَ كيماوية حيويةَ وعملَ متخصصون في الكيمياء الحيويةِ في كُلّ هذه المناطقِ. تَعْرضُ الكيمياء الحيويةُ التحدي الكبيرَ للإرادة لفَهْم الأكثر أساسية مِنْ عملياتِ الحياةِ في المستوى الجزيئي، ولاستعمال هذه المعرفةِ لمنفعةِ البشريةِ. طوّرَ المتخصصون في الكيمياء الحيويةُ التقنياتَ الجديدةَ لعِلْمِ الأحياء وهندسة الجيناتِ الجزيئيةِ الذي مَكّننا من إنتاجَ البروتينِ الإنسانيِ المهمِ بشكل علاجي مثل الأنسولين وعواملِ تَخَثُّر الدمِّ باستنساخ الإجراءاتِ، هكذا يفاديان عزلةَ غير كفءَ ومضيعة للوقتَ، هذه الجزيئاتِ مِنْ المصادرِ الحيويةِ؛ التعريف والمُعَالَجَة المحتملة مِنْ المشاكلِ الوراثيةِ؛ واستعمال DNA Fingerprinting في العِلْمِ العدلي.

الحيويةُ مشاكلَ حيويةَ، ثمّ يُطوّرُ ويُطبّقُ تقنياتَ ملائمةَ لحَلّهم في المستوى الجزيئي. يَدْرسُ المتخصصون في الكيمياء الحيويةُ مثل هذه الأشياءِ كالتراكيب والملكيات الطبيعية مِنْ الجزيئاتِ الحيويةِ (يتضمن البروتينِ، كربوهيدرات، Lipids (الشحوم)، وحوامض نووية)؛ آليات عملِ الإنزيمِ؛ التعليمة الكيميائية للأيضِ؛ كيمياء التغذيةِ؛ القاعدة الجزيئية لعِلْمِ الوراثة (ميراث)؛ كيمياء الفيتامينات؛ استخدام طاقةِ في الخليةِ؛ وكيمياء التفاعل المناعي.

وتتعامل الكيمياء الحيوية بشكل كبير مع التركيب والوظيفة والتداخلات بين مكونات الخلية مثل الدهون والكربوهيدرات والبروتينات والأحماض النووية وجزيئات حيوية أخرى. تكون بعض هذه الجزيئات كبيرة ومعقدة وتسمى البوليمرات الحيوية (Biopolymers)، وهذه تتكون من وحدات متكررة متشابهة تسمى كل

وحدة مونومر (Monomer). يحتوي كل جزيء من البوليمرات الحيوية على مجموعات مختلفة من الوحدات، مثلاً يعتبر البروتين بوليمر تتكون وحداته من مجموعة مختلفة من 20 حمض أميني أو أكثر. الكيمياء الحيوية تدرس الخصائص الكيميائية للجزيئات الحيوية الهامة مثل البروتينات وخصوصا التفاعلات التي تحفز عن طريق الإنزيمات. الكيمياء الحيوية المتعلقة بالعمليات الأيضية داخل الخلية والمتعلقة بجهاز الغدد الصماء تمت دراستها بشكل كبير. وهناك مجالات أخرى للكيمياء الحيوية تشمل المادة الوراثية (DNA, RNA)، ونقل المواد من خلال غشاء الخلية، ونقل الإشارات.

• **الكيمياء الفيزيائية** علم يقوم على دراسة خواص وبناء مختلف المواد والجسيمات التي تتكون منها هذه المواد وذلك تبعا لتركيبها وبنائها الكيميائيين وللظروف التي توجد فيها وعلى دراسة التفاعلات الكيميائية والاشكال الأخرى من التأثير المتبادل بين المواد تبعا لتركيبها الكيميائي وبنائها، وللظروف الفيزيائية التي تحدث فيها هذه التفاعلات. يعود نشوء الكيمياء الفيزيائية إلى منتصف القرن الثامن عشر. فقد أدت المعلومات التي تجمعت حتى تلك الفترة في فرعي الفيزياء والكيمياء إلى فصل الكيمياء الفيزيائية كمادة علمية مستقلة، كما ساعدت على تطورها فيما بعد. ولقد وضع العالم الروسي ميخائيل لومونوسوف أول كتاب جامعي في الكيمياء الفيزيائية يعود نشوء الكيمياء الفيزيائية إلى منتصف القرن الثامن عشر. فقد أدت المعلومات التي تجمعت حتى تلك الفترة في فرعي الفيزياء والكيمياء إلى فصل الكيمياء الفيزيائية كمادة علمية مستقلة، كما ساعدت على تطورها فيما بعد. ولقد وضع العالم الروسي ميخائيل لومونوسوف أول كتاب جامعي في الكيمياء الفيزيائية. وهي دراسة الأصل الفيزيائي للتفاعلات والأنظمة الكيميائية. أو بمعنى أخر هو تداخل علم الكيمياء مع علم الفيزياء والطبيعة وكذلك فإنها تدرس تغييرات حالات الطاقة في التفاعلات الكيميائية.

• **الكيمياء الصناعية** تتضمن عمليات التصنيع التي تتم أثناء إنتاج البتروكيماويات، الدواء، البوليمرات، الطلاءات، الزيوت. يتم استخدام علوم الكيمياء والتفاعلات الكيميائية لإنتاج مواد جديدة، أو فصل المواد من بعضها باستخدام خواص عديدة مثل مدى الانحلالية، الشحنة أو التقطير، بالإضافة إلى التحولات التي تتم باستخدام الحرارة وطرق أخرى.

• تتضمن الصناعات الكيميائية تشغيل أو تغيير المواد الأولية التي يتم الحصول عليها من المناجم والزراعة إلى مواد أخرى مفيدة قابلة للاستخدام في حياتنا اليومية أو كمادة خام لصناعات أخرى. ولا يتم اعتبار صناعات الأغذية من ضمن الصناعات الكيمائية.

• يعني هذا التخصص بدراسة التطبيقات العملية لعلم الكيمياء في المصانع المختلفة. يقوم (الكيميائي الصناعي) بـ:

• بناء خلفية نظرية قوية حول التفاعلات الكيميائية التي تستخدم في المصانع لإنتاج مواد كيمائية مهمة للناس.

• تحضير المحاليل الكيمائية الداخلة في التصنيع والموازنة بينا في ضوء المعادلات المحددة أو في ضوء نتائج التجارب المخبرية.
• الإشراف على العمليات التصنيعية التي تستخدم التفاعلات الكيميائية.
• العمل على تحسين وتطوير الإنتاج عبر تحسين أساليب التصنيع الكيميائي خلال مراحل الإنتاج.
• القيام بتنفيذ عمليات كيميائية لمادة ما لإكسابها صفة أو خاصية جديدة.
• التأكد من جودة المنتج وضبط نوعيته.
• العمل على التخلص من النفايات الكيميائية والحد من آثارها في التلوث.
• الاهتمام بإجراءات السلامة والصحة المهنية للعاملين.
• الكيمياء غير العضوية: هي الكيمياء التي تهتم بدراسة المركبات غير العضوية، أي مركباتها لا تحتوي على الكربون والهيدروجين معا ودراسة خواصها الكيميائية والفيزيائية.

تمثل الأملاح الجزء الأكبر في المركبات اللاعضوية، اذ تكون الكاتايونات والأنيونات مرتبطة فيما بينها بالروابط الأيونية.

يتم تصنيف المركبات اللاعضوية إلى الأكاسيد، الكربونات، الهاليدات والكبريتات كما تتميز العديد منها نقطة انصهار عالية وتكون رديئة توصيل للكهرباء في الحالة الصلبة. تتميز المركبات اللاعضوية أيضا بقابلية الذوبان في الماء وسهولة التبلور. تلعب التفاعلات غير عضوية دوراً كبيرا في الكيمياء. ومن اهم تلك التفاعلات تفاعل أكسدة–اختزال وهي تتم في تفاعل حمض–قاعدة. تتم كل تلك التفاعلات تحت ظروف توازن كيميائي، إلا ان توازن التفاعل يكون فيها منحازا لأحد طرفي التفاعل الكيميائي وينتج عنه انثالبي التعادل الكيميائي كبير (حرارة شديدة).

لهذا نجد أن التفاعلات غير العضوية تسر سريعا وتنتج نواتجا وفيرة. وهذا بعكس التفاعلات العضوية فهي تسير ببطء حتى يصل التفاعل إلى حالة التوازن، والتي لا ينتج منها إلا نواتج قليلة.

Useful Constants ثوابت مفيدة

CONSTANTS
$R = 8.314\ \text{J·mol}^{-1}\text{·K}^{-1}$
$R = 0.0821\ \text{L·atm·mol}^{-1}\text{·K}^{-1}$
$1\ F = 96{,}500\ \text{C·mol}^{-1}$
$1\ F = 96{,}500\ \text{J·V}^{-1}\text{·mol}^{-1}$
$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$
$h = 6.626 \times 10^{-34}\ \text{J·s}$
$c = 2.998 \times 10^{8}\ \text{m·s}^{-1}$

ABBREVIATIONS AND SYMBOLS					
amount of substance	n	equilibrium constant	K	milli- prefix	m
ampere	A	Faraday constant	F	molal	m
atmosphere	atm	formula molar mass	M	molar	M
atomic mass unit	u	free energy	G	mole	mol
atomic molar mass	A	frequency	ν	Planck's constant	h
Avogadro constant	N_A	gas constant	R	pressure	P
Celsius temperature	°C	gram	g	rate constant	k
centi- prefix	c	hour	h	second	s
coulomb	C	joule	J	speed of light	c
electromotive force	E	kelvin	K	temperature, K	T
energy of activation	E_a	kilo- prefix	k	time	t
enthalpy	H	liter	L	volt	V
entropy	S	measure of pressure	mmHg	volume	V

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)		114 (289)				

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

Nuclear Symbols

Name	Symbol
Alpha particle	α or $^{4}_{2}\mathrm{He}$
Beta particle	β or $^{0}_{-1}e$
Gamma ray	γ
Neutron	$^{1}_{0}n$

T = temperature
P = pressure
V = volume
S = entropy
H = enthalpy
G = free energy
R = molar gas constant
n = number of moles

M = molar
m = molal
L, mL = liter(s), milliliter(s)
g = gram(s)
nm = nanometer(s)
atm = atmosphere(s)
J, kJ = joule(s), kilojoule(s)
V = volt(s)
mol = mole(s)

Common Polyatomic Ions

Ion	Ionic Formula
Ammonium	NH_4^+
Carbonate	CO_3^{2-}
Hydroxide	OH^-
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}

Combined Gas Law: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Ideal Gas Law: $PV = nRT$

Dilution Formula: $M_1V_1 = M_2V_2$

Molar Volume of Ideal Gas at STP: 22.4 L/mol

Ideal Gas Constant: $R = 0.0821\ \text{L} \cdot \text{atm/mol} \cdot \text{K} = 8.31\ \text{L} \cdot \text{kPa/mol} \cdot \text{K}$

STP: 1 atm (101.3 kPa), 273 K (0°C)

Absolute Temperature Conversion: $K = °C + 273$

Definition of pH: $pH = -\log[H_3O^+] = -\log[H^+]$

Avogadro's Number: 6.02×10^{23} particles/mol

Symbols for Units

A	ampere
Å	ångström
atm	atmosphere
C	coulomb
°C	degree Celsius
eV	electron volt
F	farad
F	faraday
F	formula weight/liter
G	gauss
g	gram
H	henry
hr	hour
Hz	herz
J	joule
°K	degree Kelvin
M	mole/liter
m	meter
min	minute
N	equivalent/liter
s	second
V	volt
W	watt
Ω	(omega) ohm

Multiplicative Prefixes

Prefix	Symbol	Factor
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}

Analytical Signals

Molecules	Chemical reactions	
Atoms		
Ions (solvatized)	Electrochemical processes	
Electrons		
Electron beams	Particle–matter interactions	(a) Inelastic interactions (energy transfer with sample species): *SPECTROSCOPY* (b) Elastic interactions (energy transfer): *DIFFRACTION, MICROSCOPY*
Ion beams		
Electromagnetic radiation	Radiation–matter interactions	
Heat	Thermal interactions	
Directed movement energy	Interaction between phases (partition, adsorption)	

Symbols for Common Physical and Chemical Quantities

A	absorbance, area	*S/N*	signal to noise
a	absorptivity, amplifier gain, activity	*T*	transmittance, temperature
C	capacitance, concentration	*t*	time
D	diffusion coefficient	*V*	dc voltage
d	diameter, spacing	*V*	volume
deg	angular degree	*v*	ac voltage
E	electrical potential, energy	v	velocity
e	electron	*X*	reactance
f	frequency, activity coefficient	$\bar{x}$	mean
G	conductance, free energy	*Z*	impedance
H	magnetic field, enthalpy		
I	dc current		
i	ac current		
K	equilibrium constant		
L	inductance	ε	(epsilon) molar absorptivity
n	refractive index, number of equivalents	λ	(lambda) wavelength
		μ	(mu) mean
n	spectral order	ν	(nu) frequency
P	radiant or electrical power	ρ	(rho) density
Q	quantity of dc electricity	σ	(sigma) standard deviation, wavenumber
q	quantity of ac electricity	τ	(tau) period
R	electrical resistance, gas constant	ϕ	(phi) phase angle
s	standard deviation	ω	(omega) angular velocity

Physical constants

Quantity	Symbol	Value	Units
Speed of light in vacuum	c	2.9979×10^{8}	m/s
Vacuum permittivity	ε_0	8.8542×10^{-12}	F/m
Vacuum permeability	μ_0	$4\pi \times 10^{-7}$	H/m
Elementary charge	e	1.6022×10^{-19}	C
Electron rest mass	m_e	9.1094×10^{-31}	kg
Proton rest mass	m_p	1.6726×10^{-27}	kg
Neutron rest mass	m_n	1.6750×10^{-27}	kg
Atomic mass constant	u	1.6605×10^{-27}	kg
Planck's constant	h	6.6261×10^{-34}	J s
Dirac constant	$\hbar = h/2\pi$	1.0546×10^{-34}	J s
Avogadro number	N_A	6.0221×10^{23}	/mol
Faraday constant	$F = N_A e$	9.6485×10^{4}	C/mol
Boltzmann constant	$k = R/N_A$	1.3807×10^{-23}	J/K
Molar gas constant	$R = N_A k_B$	8.3145	J/K mol
Gravitational constant	G	6.6720×10^{-11}	N m^2/kg^2

Unit conversion

$1\ \text{Å} = 10^{-10}\ \text{m} \quad 1\ \text{cm}^{-1} = 2.9979 \times 10^{10}\ \text{Hz}$

$1\ \text{eV} = 1.6022 \times 10^{-19}\ \text{J} \quad 1\ \text{atm} = 1.0133 \times 10^{5}\ \text{Pa};\ 1\ \text{bar} = 10^{5}\ \text{Pa}$

Prefixes

Symbol	f	p	n	μ	m	c	d	k	M
Name	femto	pico	nano	micro	milli	centi	deci	kilo	mega
Factor	10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}

USEFUL CONVERSION FACTORS AND RELATIONSHIPS

Length

SI unit: Meter (m)

1 kilometer = 1000 meters
= 0.62137 mile
1 meter = 100 centimeters
1 centimeter = 10 millimeters
1 nanometer = 1×10^{-9} meter
1 picometer = 1×10^{-12} meter
1 inch = 2.54 centimeters (exactly)
1 angstrom = 1×10^{-10} meter

Mass

SI unit: Kilogram (kg)

1 kilogram = 1000 grams
1 gram = 1000 milligrams
1 pound = 453.59237 grams = 16 ounces
1 ton = 2000 pounds

Volume

SI unit: Cubic meter (m^3)

1 liter (L) = $1 \times 10^{-3}\ m^3$
= 1000 cm^3
= 1.056688 quarts
1 gallon = 4 quarts

Pressure

SI unit: Pascal (Pa)

1 pascal = 1 N/m^2
= 1 $kg/m \cdot s^2$
1 atmosphere = 101.325 kilopascals
= 760 mmHg = 760 torr
= 14.70 lb/in^2

Energy

SI unit: Joule (J)

1 joule = 1 kg m^2/s^2
= 0.23901 calorie
= 1 C × 1 V
1 calorie = 4.184 joules

Temperature

SI unit: kelvin (K)

T (K) = T(°C)(1 K/°C) + 273.15 K
T (°C) = (5 °C/9 °F)[T(°F) − 32 °F]
T (°F) = (9 °F/5 °C)T(°C) + 32 °F

SYMBOLS FOR COMMON PHYSICAL AND CHEMICAL QUANTITIES

A	absorbance, area	S/N	signal-to-noise ratio
a	absorptivity, activity	T	transmittance, temperature
B	magnetic field strength	t	time
C	capacitance	V	dc voltage, volume
D	diffusion coefficient	v	ac voltage, velocity
d	diameter, spacing	X	reactance
E	electrical potential, energy	$\bar{x}$	sample mean
e	electron	Z	impedance
F	faraday		
f	frequency		
G	conductance, free energy		
H	enthalpy	η	(eta) viscosity
I	dc current	γ	(gamma) activity coefficient
i	ac current	ε	(epsilon) molar absorptivity
K	equilibrium constant	λ	(lambda) wavelength
L	inductance	μ	(mu) population mean
n	number of moles, refractive index	ν	(nu) frequency
n	spectral order	$\bar{\nu}$	wavenumber
P	radiant or electrical power	ρ	(rho) density
Q	quantity of dc charge	σ	(sigma) population standard deviation
q	quantity of ac charge	τ	(tau) period, time constant
R	electrical resistance, gas constant	ϕ	(phi) phase angle
s	sample standard deviation	ω	(omega) angular velocity

Conversion Factors for Electromagnetic Radiation

Units of x	Frequency, Hz	Wavenumber, cm^{-1}	Energy			Wavelength, cm
			kcal/mol	erg	eV	
Hz	$1.00\,x$	$3.34 \times 10^{-11}\,x$	$9.54 \times 10^{-14}\,x$	$6.63 \times 10^{-27}\,x$	$4.14 \times 10^{-15}\,x$	$\frac{3.00 \times 10^{10}}{x}$
cm^{-1}	$3.00 \times 10^{10}\,x$	$1.00\,x$	$2.86 \times 10^{-3}\,x$	$1.99 \times 10^{-16}\,x$	$1.24 \times 10^{-4}\,x$	$\frac{1.00}{x}$
kcal/mol	$1.05 \times 10^{13}\,x$	$3.50 \times 10^{2}\,x$	$1.00\,x$	$6.95 \times 10^{-14}\,x$	$4.34 \times 10^{-2}\,x$	$\frac{2.86 \times 10^{-3}}{x}$
erg	$1.51 \times 10^{26}\,x$	$5.04 \times 10^{15}\,x$	$1.44 \times 10^{13}\,x$	$1.00\,x$	$6.24 \times 10^{11}\,x$	$\frac{1.99 \times 10^{-16}}{x}$
eV	$2.42 \times 10^{14}\,x$	$8.07 \times 10^{3}\,x$	$2.31 \times 10^{1}\,x$	$1.60 \times 10^{-12}\,x$	$1.00\,x$	$\frac{1.24 \times 10^{-4}}{x}$
cm	$\frac{3.00 \times 10^{10}}{x}$	$\frac{1.00}{x}$	$\frac{2.86 \times 10^{-3}}{x}$	$\frac{1.99 \times 10^{-16}}{x}$	$\frac{1.24 \times 10^{-4}}{x}$	$1.00\,x$
nm	$\frac{3.00 \times 10^{17}}{x}$	$\frac{1.00 \times 10^{7}}{x}$	$\frac{2.86 \times 10^{4}}{x}$	$\frac{1.99 \times 10^{-9}}{x}$	$\frac{1.24 \times 10^{3}}{x}$	$1.00 \times 10^{-7}\,x$

Characteristic Infra-red Absorption Wavenumber Ranges
(Stretching modes)

Bond	Compound type	Wavenumber range /cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O–H	Acids (hydrogen-bonded)	2500 to 3300
C–H	Alkanes, alkenes, arenes	2840 to 3095
O–H	Alcohols, phenols (hydrogen-bonded)	3230 to 3670
N–H	Amines	3350 to 3500

ABBREVIATIONS AND SYMBOLS

ampere	A	Faraday constant	F	molal	m
atmosphere	atm	formula molar mass	M	molar	M
atomic mass unit	u	free energy	G	molar mass	M
atomic molar mass	A	frequency	ν	mole	mol
Avogadro constant	N_A	gas constant	R	Planck's constant	h
Celsius temperature	°C	gram	g	pressure	P
centi– prefix	c	heat capacity	C_p	rate constant	k
coulomb	C	hour	h	retention factor	R_f
electromotive force	E	joule	J	second	s
energy of activation	E_a	kelvin	K	temperature, K	T
enthalpy	H	kilo– prefix	k	time	t
entropy	S	liter	L	volt	V
equilibrium constant	K	milli– prefix	m		

Standard Reduction Potentials in Aqueous Solution at 25°C

Half-reaction			$E°$(V)
$Li^+ + e^-$	→	$Li(s)$	−3.05
$Cs^+ + e^-$	→	$Cs(s)$	−2.92
$K^+ + e^-$	→	$K(s)$	−2.92
$Rb^+ + e^-$	→	$Rb(s)$	−2.92
$Ba^{2+} + 2\,e^-$	→	$Ba(s)$	−2.90
$Sr^{2+} + 2\,e^-$	→	$Sr(s)$	−2.89
$Ca^{2+} + 2\,e^-$	→	$Ca(s)$	−2.87
$Na^+ + e^-$	→	$Na(s)$	−2.71
$Mg^{2+} + 2\,e^-$	→	$Mg(s)$	−2.37
$Be^{2+} + 2\,e^-$	→	$Be(s)$	−1.70
$Al^{3+} + 3\,e^-$	→	$Al(s)$	−1.66
$Mn^{2+} + 2\,e^-$	→	$Mn(s)$	−1.18
$Zn^{2+} + 2\,e^-$	→	$Zn(s)$	−0.76
$Cr^{3+} + 3\,e^-$	→	$Cr(s)$	−0.74
$Fe^{2+} + 2\,e^-$	→	$Fe(s)$	−0.44
$Cr^{3+} + e^-$	→	Cr^{2+}	−0.41
$Cd^{2+} + 2\,e^-$	→	$Cd(s)$	−0.40
$Tl^+ + e^-$	→	$Tl(s)$	−0.34
$Co^{2+} + 2\,e^-$	→	$Co(s)$	−0.28
$Ni^{2+} + 2\,e^-$	→	$Ni(s)$	−0.25
$Sn^{2+} + 2\,e^-$	→	$Sn(s)$	−0.14
$Pb^{2+} + 2\,e^-$	→	$Pb(s)$	−0.13
$2\,H^+ + 2\,e^-$	→	$H_2(g)$	0.00
$S(s) + 2\,H^+ + 2\,e^-$	→	$H_2S\,(g)$	0.14
$Sn^{4+} + 2\,e^-$	→	Sn^{2+}	0.15
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Cu^{2+} + 2\,e^-$	→	$Cu(s)$	0.34
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$I_2(s) + 2\,e^-$	→	$2\,I^-$	0.53
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$Hg_2^{2+} + 2\,e^-$	→	$2\,Hg(l)$	0.79
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg^{2+} + 2\,e^-$	→	$Hg(l)$	0.85
$2\,Hg^{2+} + 2\,e^-$	→	Hg_2^{2+}	0.92
$Br_2(l) + 2\,e^-$	→	$2\,Br^-$	1.07
$O_2(g) + 4\,H^+ + 4\,e^-$	→	$2\,H_2O(l)$	1.23
$Cl_2(g) + 2\,e^-$	→	$2\,Cl^-$	1.36
$Au^{3+} + 3\,e^-$	→	$Au(s)$	1.50
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$F_2(g) + 2\,e^-$	→	$2\,F^-$	2.87

ADVANCED PLACEMENT CHEMISTRY EQUATIONS AND CONSTANTS

ATOMIC STRUCTURE

$$\Delta E = h\nu$$
$$c = \lambda\nu$$
$$\lambda = \frac{h}{mv}$$
$$p = mv$$
$$E_n = \frac{-2.178 \times 10^{-18}}{n^2} \text{ joule}$$

EQUILIBRIUM

$$K_a = \frac{[H^+][A^-]}{[HA]}$$
$$K_b = \frac{[OH^-][HB^+]}{[B]}$$
$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \text{ @ } 25°C$$
$$= K_a \times K_b$$
$$pH = -\log [H^+],\ pOH = -\log [OH^-]$$
$$14 = pH + pOH$$
$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$
$$pOH = pK_b + \log \frac{[HB^+]}{[B]}$$
$$pK_a = -\log K_a,\ pK_b = -\log K_b$$
$$K_p = K_c(RT)^{\Delta n},$$

where Δn = moles product gas − moles reactant gas

THERMOCHEMISTRY

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$
$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$
$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$
$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT \ln K = -2.303\ RT \log K$$
$$= -n\mathcal{F}E^\circ$$
$$\Delta G = \Delta G^\circ + RT \ln Q = \Delta G^\circ + 2.303\ RT \log Q$$
$$q = mc\Delta T$$
$$C_p = \frac{\Delta H}{\Delta T}$$

E = energy
ν = frequency
λ = wavelength
p = momentum
v = velocity
n = principal quantum number
m = mass

Speed of light, $c = 3.0 \times 10^8$ m s^{-1}
Planck's constant, $h = 6.63 \times 10^{-34}$ J s
Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J K^{-1}
Avogadro's number $= 6.022 \times 10^{23}$ molecules m
Electron charge, $e = -1.602 \times 10^{-19}$ coulomb
1 electron volt per atom = 96.5 kJ mol^{-1}

Equilibrium Constants
K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressur
1 faraday $\mathcal{F}$ = 96,500 coulombs

UNITS

Name	Symbol
meter	m
kilogram	kg
second	s
ampere	A
kelvin	K
mole	mol
hertz	Hz
newton	N
pascal	Pa
joule	J
watt	W
coulomb	C
volt	V
ohm	Ω
henry	H
farad	F
tesla	T
degree Celsius	°C
electron-volt	eV

SI- Units System

Basic Units		
Quantity	**Unit**	**Symbol**
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Quantity of substance	mole	mol
Luminosity	candle	cd

SI Units prefixes

.

Prefix	Symbol	Factor
Yotta	Y	10^{24}
Zetta	Z	10^{21}
Exa	E	10^{18}
Peta	P	10^{15}
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	K, k	10^{3}
hecto	h	100
deca	da	10
deci	d	0.1
centi	c	0.01
milli	m, k	10^{-3}
micro	µ, u	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yocto	y	10^{-24}

Binary prefixes for Bytes

Prefix	Symbol	Factor	Value	Examples
Kilo	KB	2^{10}	1024	12345 KB = 12 641 280 bytes
Mega	MB	2^{10}	1 048 576	420 MB fits in my PC's dynamic RAM
Giga	GB	2^{30}	1 073 741 824	16 GB flash-memory pen drive costs $20
Tera	TB	2^{40}	1 099 511 627 776	3.9 TB hard disks are a reality
Peta	PB	2^{50}	1 125 899 906 842 624	13.5 PB is the CIA total memory capacity
Exa	EB	2^{60}	1 152 921 504 606 846 976	1 EB is still a bit out of reach (AD 2010)
Zetta	ZB	2^{70}	1 180 591 620 717 411 303 424	How many ZB to hard-copy a human being
Yotta	YB	2^{80}	1 208 925 819 614 629 174 706 176	1 YYB is still nothing compared with the Universe

Accepted non-SI units
compiled according to the US Federal Register

Unit	of	Symbol	Equals
Degree of arc	plain angle	^{o}	(π/180) rad
Minute of arc	plain angle	'	(1/60) ^{o}
Second of arc	plain angle	"	(1/60)'
Minute	time	min	60 s
Hour	time	h	60 min
Day	time	d	24 h
Liter	volume	L, l	0.001 m^3
Gram	mass	g	0.001 kg
Ton	mass	t	1000 kg
Bit	information	bit	-
Baud rate	info flux	Baud	1 $bit.s^{-1}$
Neper	ratio	Np	log(A/B)
Bel	ratio	B	0.5 Np

Quantity	Unit	Symbol	Equals	Definition / Note
Space and time:				
Plane angle	radian	rad		The plain angle which, when entered in a circle, cuts off an arc whose length is equal to the circle radius.
Solid angle	steradian	sr		The solid angle which, when centered in a sphere, cuts off a cap whose surface equals that of a square having the radius as side.
Frequency	hertz	Hz	$1\ s^{-1}$	number of events or cycles/time.
Mechanics:				
Force	newton	N	$1\ kg.m.s^{-2}$	mass.acceleration.
Pressure	pascal	Pa	$1\ N.m^{-2}$	force/area. Also: stress.
Energy	joule	J	1 N.m	force.length. Also: Work, Heat
Power	watt	W	$1\ J.s^{-1}$	energy/time. Also: Radiant flux
Thermodynamics:				
Temperature	celsius	^{o}C	1 K	$T\ ^{o}C = T\ K - 273.15$ (the offset is exact!).
Electromagnetism:				
Charge	coulomb	C	1 A.s	current.time.
Potential	volt	V	$1\ W.A^{-1}$	power/current. Only differences are measurable!
Resistance	ohm	Ω	$1\ V.A^{-1}$	Δpotential/current.
Conductance	siemens	S	$1\ A.V^{-1}$	current/Δpotential.
Capacitance	farad	F	$1\ C.V^{-1}$	charge/Δpotential.
Inductance	henry	H	$1\ V.s.A^{-1}$	Δpotential/rate of change of current.
Magnetic flux	weber	Wb	$1\ J.A^{-1}$	energy/current.
Magnetic flux density	tesla	T	$1\ Wb.m^{-2}$	magnetic flux/area. Also magnetic induction.
Optics:				
Luminous flux	lumen	lm	1 cd.sr	luminosity.solid angle.
Illuminance	lux	lx	$1\ lm.m^{-2}$	luminous flux/area.
Convergence	dioptry	dioptry	$1\ m^{-1}$	Inverse of focal length.

Radioactivity and radiation:				
Activity	becquerel	Bq	1 s^{-1}	[number of decay events]/[time].
Absorbed dose	gray	Gy	1 $J.kg^{-1}$	[energy]/[mass].
Dose equivalent	sievert	Sv	1 $J.kg^{-1}$	[energy]/[mass]. Absorbed dose re-normalized by biological effects.
Chemistry:				
Katalytic activity	katal	kat	1 $mol.s^{-1}$	[quantity of substance]/[time].

Atomic constants

fine-structure constant, $\mu_0 ce^2/(2h)$	α	7.297 353 08(33)	$\times 10^{-3}$
inverse	$1/\alpha$	137.035 989 5(61)	
Rydberg constant, $m_e c\alpha^2/(2h)$	R_∞	1.097 373 153 4(13)	$\times 10^7\ m^{-1}$
in hertz, $R_\infty c$		3.289 841 949 9(39)	$\times 10^{15}$ Hz
in joules, $R_\infty hc$		2.179 874 1(13)	$\times 10^{-18}$ J
in electron volts, $R_\infty hc/e$		1.360 569 81(40)	$\times 10^1$ eV
Bohr radius , $\alpha/(4\pi R_\infty)$	a_0	5.291 772 49(24)	$\times 10^{-11}$ m

Recognised non-SI units

physical quantity	*name*	*symbol*	*SI value*
time	minute	min	60 s
	hour	h	3 600 s
	day	d	86 400 s
plane angle	degree	°	$(\pi/180)$ rad
	minute	′	$(\pi/10\,800)$ rad
	second	″	$(\pi/648\,000)$ rad
length	angstrom	Å	10^{-10} m
	fermi	fm	10^{-15} m
	micron	μm	10^{-6} m
area	barn	b	$10^{-28}\ m^2$
volume	litre	l, L	$10^{-3}\ m^3$
mass	tonne	t	10^3 kg
pressure	bar	bar	$10^5\ N\ m^{-2}$
energy	electron volt	eV	$\simeq 1.602\,18 \times 10^{-19}$ J
mass	unified atomic mass unit	u	$\simeq 1.660\,54 \times 10^{-27}$ kg

Electron constants

electron mass	m_e	9.109 389 7(54)	$\times 10^{-31}$ kg
in electron volts		0.510 999 06(15)	MeV
electron/proton mass ratio	m_e/m_p	5.446 170 13(11)	$\times 10^{-4}$
electron charge	$-e$	−1.602 177 33(49)	$\times 10^{-19}$ C
electron specific charge	$-e/m_e$	−1.758 819 62(53)	$\times 10^{11}$ C kg^{-1}
electron molar mass, $N_A m_e$	M_e	5.485 799 03(13)	$\times 10^{-7}$ kg mol^{-1}
Compton wavelength, $h/(m_e c)$	λ_C	2.426 310 58(22)	$\times 10^{-12}$ m
classical electron radius, $\alpha^2 a_0$	r_e	2.817 940 92(38)	$\times 10^{-15}$ m
Thomson cross section, $(8\pi/3)r_e^2$	σ_T	6.652 461 6(18)	$\times 10^{-29}$ m^2
electron magnetic moment	μ_e	9.284 770 1(31)	$\times 10^{-24}$ J T^{-1}
in Bohr magnetons, μ_e/μ_B		1.001 159 652 193(10)	
in nuclear magnetons, μ_e/μ_N		1838.282 000(37)	
electron g-factor, $2\mu_e/\mu_B$	g_e	2.002 319 304 386(20)	

Proton constants

proton mass	m_p	1.672 623 1(10)	$\times 10^{-27}$ kg
in electron volts		938.272 31(28)	MeV
proton/electron mass ratio	m_p/m_e	1836.152 701(37)	
proton charge	e	1.602 177 33(49)	$\times 10^{-19}$ C
proton specific charge	e/m_p	9.578 830 9(29)	$\times 10^{7}$ C kg^{-1}
proton molar mass, $N_A m_p$	M_p	1.007 276 470(12)	$\times 10^{-3}$ kg mol^{-1}
proton Compton wavelength, $h/(m_p c)$	$\lambda_{C,p}$	1.321 410 02(12)	$\times 10^{-15}$ m
proton magnetic moment	μ_p	1.410 607 61(47)	$\times 10^{-26}$ J T^{-1}
in Bohr magnetons, μ_p/μ_B		1.521 032 202(15)	$\times 10^{-3}$
in nuclear magnetons, μ_p/μ_N		2.792 847 386(63)	
proton gyromagnetic ratio	γ_p	2.675 221 28(81)	$\times 10^{8}$ s^{-1} T^{-1}

Neutron constants

neutron mass	m_n	1.674 928 6(10)	$\times 10^{-27}$ kg
in electron volts		939.565 63(28)	MeV
neutron/electron mass ratio	m_n/m_e	1838.683 662(40)	
neutron/proton mass ratio	m_n/m_p	1.001 378 404(9)	
neutron molar mass, $N_A m_n$	M_n	1.008 664 904(14)	$\times 10^{-3}$ kg mol^{-1}
neutron Compton wavelength, $h/(m_n c)$	$\lambda_{C,n}$	1.319 591 10(12)	$\times 10^{-15}$ m
neutron magnetic moment	μ_n	9.662 370 7(40)	$\times 10^{-27}$ J T^{-1}
in Bohr magnetons	μ_n/μ_B	1.041 875 63(25)	$\times 10^{-3}$
in nuclear magnetons	μ_n/μ_N	1.913 042 75(45)	

Muon constants

muon mass	m_μ	1.883 532 7(11)	$\times 10^{-28}$ kg
in electron volts		105.658 389(34)	MeV
muon/electron mass ratio	m_μ/m_e	206.768 262(30)	
muon charge	$-e$	−1.602 177 33(49)	$\times 10^{-19}$ C
muon magnetic moment	μ_μ	4.490 451 4(15)	$\times 10^{-26}$ J T^{-1}
in Bohr magnetons, μ_μ/μ_B		4.841 970 97(71)	$\times 10^{-3}$
in nuclear magnetons, μ_μ/μ_N		8.890 598 1(13)	
muon g-factor	g_μ	2.002 331 846(17)	

Bulk physical constants

Avogadro constant	N_A	6.022 136 7(36)	$\times 10^{23}$ mol^{-1}
atomic mass constant[a]	m_u	1.660 540 2(10)	$\times 10^{-27}$ kg
in electron volts		931.494 32(28)	MeV
Faraday constant	F	9.648 530 9(29)	$\times 10^{4}$ C mol^{-1}
molar gas constant	R	8.314 510(70)	J mol^{-1} K^{-1}
Boltzmann constant, R/N_A	k	1.380 658(12)	$\times 10^{-23}$ J K^{-1}
in electron volts		8.617 385(73)	$\times 10^{-5}$ eV K^{-1}
molar volume (ideal gas at stp)[b]	V_m	22.414 10(19)	$\times 10^{-3}$ m^3 mol^{-1}
Stefan–Boltzmann constant, $\pi^2 k^4/(60\hbar^3 c^2)$	σ	5.670 51(19)	$\times 10^{-8}$ W m^{-2} K^{-4}
Wien's displacement law constant,[c] $b = \lambda_m T$	b	2.897 756(24)	$\times 10^{-3}$ m K

[a] = mass of ^{12}C/12. Alternative nomenclature for the unified atomic mass unit, u.
[b] Standard temperature and pressure (stp) are $T = 273.15$ K (0°C) and $P = 101\,325$ Pa (1 standard atmosphere).

Mathematical constants

pi (π)	3.141 592 653 589 793 238 462 643 383 279 …
exponential constant (e)	2.718 281 828 459 045 235 360 287 471 352 …
Catalan's constant	0.915 965 594 177 219 015 054 603 514 932 …
Euler's constant[a] (γ)	0.577 215 664 901 532 860 606 512 090 082 …
Feigenbaum's constant (α)	2.502 907 875 095 892 822 283 902 873 218 …
Feigenbaum's constant (δ)	4.669 201 609 102 990 671 853 203 820 466 …
Gibbs constant	1.851 937 051 982 466 170 361 053 370 157 …
golden mean	1.618 033 988 749 894 848 204 586 834 370 …
Madelung constant	1.747 564 594 633 182 190 636 212 035 544 …

كمية المادة بكتلة المادة	n : (mol) M : (g/mol) m : (g)	M_____1mol m _____ n (mol)	$n_{(mol)} = \frac{m}{M}$
كمية المادة بحجم الغاز	n : (mol) V_m : (L/mol) V_g : (L)	V_m = (L) _____ 1mol V_g = (L) _____ n mol	$n_{(mol)} = \frac{V_g}{V_m}$
التركيز الكتلي	m : (g) V : (L) t : (g/L)	$t_{g/L} = \frac{m}{V}$	
التركيز المولي	n : (mol) V : (L) C : (mol/L)	$C_{mol/L} = \frac{n}{V}$ $\frac{\frac{m}{M}}{V} \Rightarrow \frac{m}{M} \times \frac{1}{V}$ $C = \frac{m}{M.V}$	
علاقة التركيز المولي و التركيز الكتلي	$C = \frac{t}{M}$ $t = C.M$		
قانون التمديد	$C.V = C'.V'$		
معامل التمديد	$F = \frac{C}{C'} = \frac{V'}{V}$ $\quad F > 1$		

m الكتلة
n الكمية

Converting between units

unit name	*value in SI units*	
abampere	10.0*	A
abcoulomb	10.0*	C
abfarad	1.0*	$\times 10^{9}$ F
abhenry	1.0*	$\times 10^{-9}$ H
abmho	1.0*	$\times 10^{9}$ S
abohm	1.0*	$\times 10^{-9}$ Ω
abvolt	10.0*	$\times 10^{-8}$ V
acre	4.046 856	$\times 10^{3}$ m^2
amagat (at stp)	44.614 774	mol m^{-3}
ampere hour	3.6*	$\times 10^{3}$ C
ångström	100.0*	$\times 10^{-12}$ m
apostilb	1.0*	lm m^{-2}
arcminute	290.888 2	$\times 10^{-6}$ rad
arcsecond	4.848 137	$\times 10^{-6}$ rad
are	100.0*	m^2
astronomical unit	149.597 9	$\times 10^{9}$ m
atmosphere (standard)	101.325 0*	$\times 10^{3}$ Pa
atomic mass unit	1.660 540	$\times 10^{-27}$ kg
bar	100.0*	$\times 10^{3}$ Pa
barn	100.0*	$\times 10^{-30}$ m^2
baromil	750.1	$\times 10^{-6}$ m
barrel (UK)	163.659 2	$\times 10^{-3}$ m^3
barrel (US dry)	115.627 1	$\times 10^{-3}$ m^3
barrel (US oil)	158.987 3	$\times 10^{-3}$ m^3
barrel (US liquid)	119.240 5	$\times 10^{-3}$ m^3
baud	1.0*	s^{-1}
bayre	100.0*	$\times 10^{-3}$ Pa
biot	10.0	A
bolt (US)	36.576*	m
brewster	1.0*	$\times 10^{-12}$ m^2 N^{-1}
British thermal unit	1.055 056	$\times 10^{3}$ J
bushel (UK)	36.36 872	$\times 10^{-3}$ m^3
bushel (US)	35.23 907	$\times 10^{-3}$ m^3
butt (UK)	477.339 4	$\times 10^{-3}$ m^3
cable (US)	219.456*	m
calorie	4.186 8*	J
candle power (spherical)	4π	lm
carat (metric)	200.0*	$\times 10^{-6}$ kg
cental	45.359 237	kg
centare	1.0*	m^2
centimetre of Hg (0 °C)	1.333 222	$\times 10^{3}$ Pa
centimetre of H_2O (4 °C)	98.060 616	Pa
chain (engineers')	30.48*	m
chain (US)	20.116 8*	m
Chu	1.899 101	$\times 10^{3}$ J
clusec	1.333 224	$\times 10^{-6}$ W
cord	3.624 556	m^3
cubit	457.2*	$\times 10^{-3}$ m
cumec	1.0*	m^3 s^{-1}
cup (US)	236.588 2	$\times 10^{-6}$ m^3
curie	37.0*	$\times 10^{9}$ Bq
darcy	986.923 3	$\times 10^{-15}$ m^2
day	86.4*	$\times 10^{3}$ s
day (sidereal)	86.164 09	$\times 10^{3}$ s
debye	3.335 641	$\times 10^{-30}$ C m
degree (angle)	17.453 29	$\times 10^{-3}$ rad
denier	111.111 1	$\times 10^{-9}$ kg m^{-1}
digit	19.05*	$\times 10^{-3}$ m
dioptre	1.0*	m^{-1}
Dobson unit	10.0*	$\times 10^{-6}$ m
dram (avoirdupois)	1.771 845	$\times 10^{-3}$ kg
dyne	10.0*	$\times 10^{-6}$ N
dyne centimetres	100.0*	$\times 10^{-9}$ J
electron volt	160.217 7	$\times 10^{-21}$ J
ell	1.143*	m
em	4.233 333	$\times 10^{-3}$ m
emu of capacitance	1.0*	$\times 10^{9}$ F
emu of current	10.0*	A
emu of electric potential	10.0*	$\times 10^{-9}$ V
emu of inductance	1.0*	$\times 10^{-9}$ H
emu of resistance	1.0*	$\times 10^{-9}$ Ω
Eötvös unit	1.0*	$\times 10^{-9}$ m s^{-2} m^{-1}

unit name	*value in SI units*	
esu of electric potential	299.792 5	V
esu of inductance	898.755 2	$\times 10^{9}$ H
esu of resistance	898.755 2	$\times 10^{9}$ Ω
erg	100.0*	$\times 10^{-9}$ J
faraday	96.485 3	$\times 10^{3}$ C
fathom	1.828 804	m
fermi	1.0*	$\times 10^{-15}$ m
Finsen unit	10.0*	$\times 10^{-6}$ W m^{-2}
firkin (UK)	40.914 81	$\times 10^{-3}$ m^3
firkin (US)	34.068 71	$\times 10^{-3}$ m^3
fluid ounce (UK)	28.413 08	$\times 10^{-6}$ m^3
fluid ounce (US)	29.573 53	$\times 10^{-6}$ m^3
foot	304.8*	$\times 10^{-3}$ m
foot (US survey)	304.800 6	$\times 10^{-3}$ m
foot of water (4 °C)	2.988 887	$\times 10^{3}$ Pa
footcandle	10.763 91	lx
footlambert	3.426 259	cd m^{-2}
footpoundal	42.140 11	$\times 10^{-3}$ J
footpounds (force)	1.355 818	J
fresnel	1.0*	$\times 10^{12}$ Hz
funal	1.0*	$\times 10^{3}$ N
furlong	201.168*	m
g (standard acceleration)	9.806 65*	m s^{-2}
gal	10.0*	$\times 10^{-3}$ m s^{-2}
gallon (UK)	4.546 09*	$\times 10^{-3}$ m^3
gallon (US liquid)	3.785 412	$\times 10^{-3}$ m^3
gamma	1.0*	$\times 10^{-9}$ T
gauss	100.0*	$\times 10^{-6}$ T
gilbert	795.774 7	$\times 10^{-3}$ A turn
gill (UK)	142.065 4	$\times 10^{-6}$ m^3
gill (US)	118.294 1	$\times 10^{-6}$ m^3
gon	π/200*	rad
grade	15.707 96	$\times 10^{-3}$ rad
grain	64.798 91*	$\times 10^{-6}$ kg
gram	1.0*	$\times 10^{-3}$ kg
gram-rad	100.0*	J kg^{-1}
gray	1.0*	J kg^{-1}
hand	101.6*	$\times 10^{-3}$ m
hartree	4.359 748	$\times 10^{-18}$ J
hectare	10.0*	$\times 10^{3}$ m^2
hefner	902	$\times 10^{-3}$ cd
hogshead	238.669 7	$\times 10^{-3}$ m^3
horsepower (boiler)	9.809 50	$\times 10^{3}$ W
horsepower (electric)	746*	W
horsepower (metric)	735.498 8	W
horsepower (UK)	745.699 9	W
hour	3.6*	$\times 10^{3}$ s
hour (sidereal)	3.590 170	$\times 10^{3}$ s
hundredweight (UK long)	50.802 35	kg
hundredweight (US short)	45.359 24	kg
inch	25.4*	$\times 10^{-3}$ m
inch of mercury (0 °C)	3.386 389	$\times 10^{3}$ Pa
inch of water (4 °C)	249.074 0	Pa
jansky	10.0*	$\times 10^{-27}$ W m^{-2} Hz^{-1}
jar	1.0/9*	$\times 10^{-9}$ F
kayser	100.0*	m^{-1}
unit name	*value in SI units*	
kilocalorie	4.186 8*	$\times 10^{3}$ J
kilogram-force	9.806 65*	N
kilowatt hour	3.6*	$\times 10^{6}$ J
knot (international)	514.444 4	$\times 10^{-3}$ m s^{-1}
lambert	10/π*	$\times 10^{3}$ cd m^{-2}
langley	41.84*	$\times 10^{3}$ J m^{-2}
langmuir	133.322 4	$\times 10^{-6}$ Pa s
league (nautical, int.)	5.556*	$\times 10^{3}$ m
league (nautical, UK)	5.559 552	$\times 10^{3}$ m
league (statute)	4.828 032	$\times 10^{3}$ m
light year	9.460 73*	$\times 10^{15}$ m
ligne	2.256*	$\times 10^{-3}$ m
line	2.116 667	$\times 10^{-3}$ m
line (magnetic flux)	10.0*	$\times 10^{-9}$ Wb
link (engineers')	304.8*	$\times 10^{-3}$ m
link (US)	201.168 0	$\times 10^{-3}$ m
litre	1.0*	$\times 10^{-3}$ m^3

unit name	*value in SI units*	
lumen (at 555 nm)	1.470 588	$\times 10^{-3}$ W
maxwell	10.0*	$\times 10^{-9}$ Wb
mho	1.0*	S
micron	1.0*	$\times 10^{-6}$ m
mil (length)	25.4*	$\times 10^{-6}$ m
mil (volume)	1.0*	$\times 10^{-6}$ m^3
mile (international)	1.609 344*	$\times 10^{3}$ m
mile (nautical, int.)	1.852*	$\times 10^{3}$ m
mile (nautical, UK)	1.853 184*	$\times 10^{3}$ m
mile per hour	447.04*	$\times 10^{-3}$ m s^{-1}
milliard	1.0*	$\times 10^{9}$ m^3
millibar	100.0*	Pa
millimetre of Hg (0 °C)	133.322 4	Pa
minim (UK)	59.193 90	$\times 10^{-9}$ m^3
minim (US)	61.611 51	$\times 10^{-9}$ m^3
minute (angle)	290.888 2	$\times 10^{-6}$ rad
minute	60.0*	s
minute (sidereal)	59.836 17	s
month (lunar)	2.551 444	$\times 10^{6}$ s
nit	1.0*	cd m^{-2}
noggin (UK)	142.065 4	$\times 10^{-6}$ m^3
oersted	1000/(4π)*	A m^{-1}
ounce (avoirdupois)	28.349 52	$\times 10^{-3}$ kg
ounce (UK fluid)	28.413 07	$\times 10^{-6}$ m^3
ounce (US fluid)	29.573 53	$\times 10^{-6}$ m^3
pace	762.0*	$\times 10^{-3}$ m
parsec	30.856 78	$\times 10^{15}$ m
peck (UK)	9.092 18*	$\times 10^{-3}$ m^3
peck (US)	8.809 768	$\times 10^{-3}$ m^3
pennyweight (troy)	1.555 174	$\times 10^{-3}$ kg
perch	5.029 2*	m
phot	10.0*	$\times 10^{3}$ lx
pica (printers')	4.217 518	$\times 10^{-3}$ m
pint (UK)	568.261 2	$\times 10^{-6}$ m^3
pint (US dry)	550.610 5	$\times 10^{-6}$ m^3
pint (US liquid)	473.176 5	$\times 10^{-6}$ m^3
point (printers')	351.459 8*	$\times 10^{-6}$ m
poise	100.0*	$\times 10^{-3}$ Pa s
pole	5.029 2*	m
poncelot	980.665*	W
pottle	2.273 045	$\times 10^{-3}$ m^3
pound (avoirdupois)	453.592 4	$\times 10^{-3}$ kg
poundal	138.255 0	$\times 10^{-3}$ N
pound-force	4.448 222	N
promaxwell	1.0*	Wb
psi	6.894 757	$\times 10^{3}$ Pa
puncheon (UK)	317.974 6	$\times 10^{-3}$ m^3
quad	1.055 056	$\times 10^{18}$ J
quart (UK)	1.136 522	$\times 10^{-3}$ m^3
quart (US dry)	1.101 221	$\times 10^{-3}$ m^3
quart (US liquid)	946.352 9	$\times 10^{-6}$ m^3
quintal (metric)	100.0*	kg
rad	10.0*	$\times 10^{-3}$ Gy
rayleigh	10/(4π)	$\times 10^{9}$ s^{-1} m^{-2} sr^{-1}

unit name	*value in SI units*	
rod	5.029 2*	m
rope (UK)	6.096*	m
roentgen	258.0	$\times 10^{-6}$ C kg^{-1}
rood (UK)	1.011 714	$\times 10^{3}$ m^2
rutherford	1.0*	$\times 10^{6}$ Bq
rydberg	2.179 874	$\times 10^{-18}$ J
scruple	1.295 978	$\times 10^{-3}$ kg
seam	290.949 8	$\times 10^{-3}$ m^3
second (angle)	4.848 137	$\times 10^{-6}$ rad
second (sidereal)	997.269 6	$\times 10^{-3}$ s
shake	100.0*	$\times 10^{-10}$ s
shed	100.0*	$\times 10^{-54}$ m^2
slug	14.593 90	kg
square degree	$(\pi/180)^{2}$*	sr
statampere	333.564 1	$\times 10^{-12}$ A
statcoulomb	333.564 1	$\times 10^{-12}$ C
statfarad	1.112 650	$\times 10^{-12}$ F
stathenry	898.755 2	$\times 10^{9}$ H
rem	10.0*	$\times 10^{-3}$ Sv
REN	1/4 000*	S
reyn	689.5	$\times 10^{3}$ Pa s
rhe	10.0*	Pa^{-1} s^{-1}
statmho	1.112 650	$\times 10^{-12}$ S
statohm	898.755 2	$\times 10^{9}$ Ω
statvolt	299.792 5	V
sthéne	1.0*	$\times 10^{3}$ N
stere	1.0*	m^3
stilb	10.0*	$\times 10^{3}$ cd m^{-2}
stokes	100.0*	$\times 10^{-6}$ m^2 s^{-1}
stone	6.350 293	kg
tablespoon (UK)	14.206 53	$\times 10^{-6}$ m^3
tablespoon (US)	14.786 76	$\times 10^{-6}$ m^3
teaspoon (UK)	4.735 513	$\times 10^{-6}$ m^3
teaspoon (US)	4.928 922	$\times 10^{-6}$ m^3
tex	1.0*	$\times 10^{-6}$ kg m^{-1}
therm (EEC)	105.506*	$\times 10^{6}$ J
therm (US)	105.480 4*	$\times 10^{6}$ J
thermie	4.185 407	$\times 10^{6}$ J
thou	25.4*	$\times 10^{-6}$ m
tog	100.0*	$\times 10^{-3}$ W^{-1} m^2
ton (UK long)	1.016 047	$\times 10^{3}$ kg
ton (US short)	907.184 7	kg
tonne (metric ton)	1.0*	$\times 10^{3}$ kg
ton (of TNT)	4.184*	$\times 10^{9}$ J
torr	133.322 4	Pa
townsend	1.0*	$\times 10^{-21}$ V m^2
troy ounce	31.103 48	$\times 10^{-3}$ kg
troy pound	373.241 7	$\times 10^{-3}$ kg
troy dram	3.887 935	$\times 10^{-3}$ kg
tun	954.678 9	$\times 10^{-3}$ m^3
XU	100.209	$\times 10^{-15}$ m
yard	914.4*	$\times 10^{-3}$ m
year (calendar)	31.536*	$\times 10^{6}$ s
year (sidereal)	31.558 15	$\times 10^{6}$ s
year (tropical)	31.556 93	$\times 10^{6}$ s

unit name	*value in SI units*	
abampere	10.0*	A
abcoulomb	10.0*	C
abfarad	1.0*	$\times 10^{9}$ F
abhenry	1.0*	$\times 10^{-9}$ H
abmho	1.0*	$\times 10^{9}$ S
abohm	1.0*	$\times 10^{-9}$ Ω
abvolt	10.0*	$\times 10^{-9}$ V
acre	4.046 856	$\times 10^{3}$ m^2
amagat (at stp)	44.614 774	mol m^{-3}
ampere hour	3.6*	$\times 10^{3}$ C
ångström	100.0*	$\times 10^{-12}$ m
apostilb	1.0*	lm m^{-2}
arcminute	290.888 2	$\times 10^{-6}$ rad
arcsecond	4.848 137	$\times 10^{-6}$ rad
are	100.0*	m^2
astronomical unit	149.597 9	$\times 10^{9}$ m
atmosphere (standard)	101.325 0*	$\times 10^{3}$ Pa
atomic mass unit	1.660 540	$\times 10^{-27}$ kg
bar	100.0*	$\times 10^{3}$ Pa
barn	100.0*	$\times 10^{-30}$ m^2
baromil	750.1	$\times 10^{-6}$ m
barrel (UK)	163.659 2	$\times 10^{-3}$ m^3
barrel (US dry)	115.627 1	$\times 10^{-3}$ m^3
barrel (US oil)	158.987 3	$\times 10^{-3}$ m^3
barrel (US liquid)	119.240 5	$\times 10^{-3}$ m^3
baud	1.0*	s^{-1}
bayre	100.0*	$\times 10^{-3}$ Pa
biot	10.0	A
bolt (US)	36.576*	m
brewster	1.0*	$\times 10^{-12}$ m^2 N^{-1}
British thermal unit	1.055 056	$\times 10^{3}$ J
bushel (UK)	36.36 872	$\times 10^{-3}$ m^3
bushel (US)	35.23 907	$\times 10^{-3}$ m^3
butt (UK)	477.339 4	$\times 10^{-3}$ m^3
cable (US)	219.456*	m
calorie	4.186 8*	J
candle power (spherical)	4π	lm
carat (metric)	200.0*	$\times 10^{-6}$ kg
cental	45.359 237	kg
centare	1.0*	m^2
centimetre of Hg (0 °C)	1.333 222	$\times 10^{3}$ Pa
centimetre of H_2O (4 °C)	98.060 616	Pa
chain (engineers')	30.48*	m
chain (US)	20.116 8*	m
Chu	1.899 101	$\times 10^{3}$ J
clusec	1.333 224	$\times 10^{-6}$ W
cord	3.624 556	m^3
cubit	457.2*	$\times 10^{-3}$ m
cumec	1.0*	m^3 s^{-1}
cup (US)	236.588 2	$\times 10^{-6}$ m^3
curie	37.0*	$\times 10^{9}$ Bq
darcy	986.923 3	$\times 10^{-15}$ m^2
day	86.4*	$\times 10^{3}$ s
day (sidereal)	86.164 09	$\times 10^{3}$ s
debye	3.335 641	$\times 10^{-30}$ C m
degree (angle)	17.453 29	$\times 10^{-3}$ rad
denier	111.111 1	$\times 10^{-9}$ kg m^{-1}
digit	19.05*	$\times 10^{-3}$ m
dioptre	1.0*	m^{-1}
Dobson unit	10.0*	$\times 10^{-6}$ m
dram (avoirdupois)	1.771 845	$\times 10^{-3}$ kg
dyne	10.0*	$\times 10^{-6}$ N
dyne centimetres	100.0*	$\times 10^{-9}$ J
electron volt	160.217 7	$\times 10^{-21}$ J
ell	1.143*	m
em	4.233 333	$\times 10^{-3}$ m
emu of capacitance	1.0*	$\times 10^{9}$ F
emu of current	10.0*	A
emu of electric potential	10.0*	$\times 10^{-9}$ V
emu of inductance	1.0*	$\times 10^{-9}$ H
emu of resistance	1.0*	$\times 10^{-9}$ Ω
Eötvös unit	1.0*	$\times 10^{-9}$ m s^{-2} m^{-1}

unit name	*value in SI units*	
esu of electric potential	299.792 5	V
esu of inductance	898.755 2	$\times 10^{9}$ H
esu of resistance	898.755 2	$\times 10^{9}$ Ω
erg	100.0*	$\times 10^{-9}$ J
faraday	96.485 3	$\times 10^{3}$ C
fathom	1.828 804	m
fermi	1.0*	$\times 10^{-15}$ m
Finsen unit	10.0*	$\times 10^{-6}$ W m^{-2}
firkin (UK)	40.914 81	$\times 10^{-3}$ m^3
firkin (US)	34.068 71	$\times 10^{-3}$ m^3
fluid ounce (UK)	28.413 08	$\times 10^{-6}$ m^3
fluid ounce (US)	29.573 53	$\times 10^{-6}$ m^3
foot	304.8*	$\times 10^{-3}$ m
foot (US survey)	304.800 6	$\times 10^{-3}$ m
foot of water (4 °C)	2.988 887	$\times 10^{3}$ Pa
footcandle	10.763 91	lx
footlambert	3.426 259	cd m^{-2}
footpoundal	42.140 11	$\times 10^{-3}$ J
footpounds (force)	1.355 818	J
fresnel	1.0*	$\times 10^{12}$ Hz
funal	1.0*	$\times 10^{3}$ N
furlong	201.168*	m
g (standard acceleration)	9.806 65*	m s^{-2}
gal	10.0*	$\times 10^{-3}$ m s^{-2}
gallon (UK)	4.546 09*	$\times 10^{-3}$ m^3
gallon (US liquid)	3.785 412	$\times 10^{-3}$ m^3
gamma	1.0*	$\times 10^{-9}$ T
gauss	100.0*	$\times 10^{-6}$ T
gilbert	795.774 7	$\times 10^{-3}$ A turn
gill (UK)	142.065 4	$\times 10^{-6}$ m^3
gill (US)	118.294 1	$\times 10^{-6}$ m^3
gon	$\pi/200$*	rad
grade	15.707 96	$\times 10^{-3}$ rad
grain	64.798 91*	$\times 10^{-6}$ kg
gram	1.0*	$\times 10^{-3}$ kg
gram-rad	100.0*	J kg^{-1}
gray	1.0*	J kg^{-1}
hand	101.6*	$\times 10^{-3}$ m
hartree	4.359 748	$\times 10^{-18}$ J
hectare	10.0*	$\times 10^{3}$ m^2
hefner	902	$\times 10^{-3}$ cd
hogshead	238.669 7	$\times 10^{-3}$ m^3
horsepower (boiler)	9.809 50	$\times 10^{3}$ W
horsepower (electric)	746*	W
horsepower (metric)	735.498 8	W
horsepower (UK)	745.699 9	W
hour	3.6*	$\times 10^{3}$ s
hour (sidereal)	3.590 170	$\times 10^{3}$ s
hundredweight (UK long)	50.802 35	kg
hundredweight (US short)	45.359 24	kg
inch	25.4*	$\times 10^{-3}$ m
inch of mercury (0 °C)	3.386 389	$\times 10^{3}$ Pa
inch of water (4 °C)	249.074 0	Pa
jansky	10.0*	$\times 10^{-27}$ W m^{-2} Hz^{-1}
jar	1.0/9*	$\times 10^{-9}$ F
kayser	100.0*	m^{-1}
unit name	*value in SI units*	
kilocalorie	4.186 8*	$\times 10^{3}$ J
kilogram-force	9.806 65*	N
kilowatt hour	3.6*	$\times 10^{6}$ J
knot (international)	514.444 4	$\times 10^{-3}$ m s^{-1}
lambert	$10/\pi$*	$\times 10^{3}$ cd m^{-2}
langley	41.84*	$\times 10^{3}$ J m^{-2}
langmuir	133.322 4	$\times 10^{-6}$ Pa s
league (nautical, int.)	5.556*	$\times 10^{3}$ m
league (nautical, UK)	5.559 552	$\times 10^{3}$ m
league (statute)	4.828 032	$\times 10^{3}$ m
light year	9.460 73*	$\times 10^{15}$ m
ligne	2.256*	$\times 10^{-3}$ m
line	2.116 667	$\times 10^{-3}$ m
line (magnetic flux)	10.0*	$\times 10^{-9}$ Wb
link (engineers')	304.8*	$\times 10^{-3}$ m
link (US)	201.168 0	$\times 10^{-3}$ m
litre	1.0*	$\times 10^{-3}$ m^3

unit name	*value in SI units*	
lumen (at 555 nm)	1.470 588	$\times 10^{-3}$ W
maxwell	10.0*	$\times 10^{-9}$ Wb
mho	1.0*	S
micron	1.0*	$\times 10^{-6}$ m
mil (length)	25.4*	$\times 10^{-6}$ m
mil (volume)	1.0*	$\times 10^{-6}$ m^3
mile (international)	1.609 344*	$\times 10^{3}$ m
mile (nautical, int.)	1.852*	$\times 10^{3}$ m
mile (nautical, UK)	1.853 184*	$\times 10^{3}$ m
mile per hour	447.04*	$\times 10^{-3}$ m s^{-1}
milliard	1.0*	$\times 10^{9}$ m^3
millibar	100.0*	Pa
millimetre of Hg (0 °C)	133.322 4	Pa
minim (UK)	59.193 90	$\times 10^{-9}$ m^3
minim (US)	61.611 51	$\times 10^{-9}$ m^3
minute (angle)	290.888 2	$\times 10^{-6}$ rad
minute	60.0*	s
minute (sidereal)	59.836 17	s
month (lunar)	2.551 444	$\times 10^{6}$ s
nit	1.0*	cd m^{-2}
noggin (UK)	142.065 4	$\times 10^{-6}$ m^3
oersted	1000/(4π)*	A m^{-1}
ounce (avoirdupois)	28.349 52	$\times 10^{-3}$ kg
ounce (UK fluid)	28.413 07	$\times 10^{-6}$ m^3
ounce (US fluid)	29.573 53	$\times 10^{-6}$ m^3
pace	762.0*	$\times 10^{-3}$ m
parsec	30.856 78	$\times 10^{15}$ m
peck (UK)	9.092 18*	$\times 10^{-3}$ m^3
peck (US)	8.809 768	$\times 10^{-3}$ m^3
pennyweight (troy)	1.555 174	$\times 10^{-3}$ kg
perch	5.029 2*	m
phot	10.0*	$\times 10^{3}$ lx
pica (printers')	4.217 518	$\times 10^{-3}$ m
pint (UK)	568.261 2	$\times 10^{-6}$ m^3
pint (US dry)	550.610 5	$\times 10^{-6}$ m^3
pint (US liquid)	473.176 5	$\times 10^{-6}$ m^3
point (printers')	351.459 8*	$\times 10^{-6}$ m
poise	100.0*	$\times 10^{-3}$ Pa s
pole	5.029 2*	m
poncelot	980.665*	W
pottle	2.273 045	$\times 10^{-3}$ m^3
pound (avoirdupois)	453.592 4	$\times 10^{-3}$ kg
poundal	138.255 0	$\times 10^{-3}$ N
pound-force	4.448 222	N
promaxwell	1.0*	Wb
psi	6.894 757	$\times 10^{3}$ Pa
puncheon (UK)	317.974 6	$\times 10^{-3}$ m^3
quad	1.055 056	$\times 10^{18}$ J
quart (UK)	1.136 522	$\times 10^{-3}$ m^3
quart (US dry)	1.101 221	$\times 10^{-3}$ m^3
quart (US liquid)	946.352 9	$\times 10^{-6}$ m^3
quintal (metric)	100.0*	kg
rad	10.0*	$\times 10^{-3}$ Gy
rayleigh	10/(4π)	$\times 10^{9}$ s^{-1} m^{-2} sr^{-1}

unit name	*value in SI units*	
rod	5.029 2*	m
rope (UK)	6.096*	m
roentgen	258.0	$\times 10^{-6}$ C kg^{-1}
rood (UK)	1.011 714	$\times 10^{3}$ m^2
rutherford	1.0*	$\times 10^{6}$ Bq
rydberg	2.179 874	$\times 10^{-18}$ J
scruple	1.295 978	$\times 10^{-3}$ kg
seam	290.949 8	$\times 10^{-3}$ m^3
second (angle)	4.848 137	$\times 10^{-6}$ rad
second (sidereal)	997.269 6	$\times 10^{-3}$ s
shake	100.0*	$\times 10^{-10}$ s
shed	100.0*	$\times 10^{-54}$ m^2
slug	14.593 90	kg
square degree	$(\pi/180)^{2}$*	sr
statampere	333.564 1	$\times 10^{-12}$ A
statcoulomb	333.564 1	$\times 10^{-12}$ C
statfarad	1.112 650	$\times 10^{-12}$ F
stathenry	898.755 2	$\times 10^{9}$ H
rem	10.0*	$\times 10^{-3}$ Sv
REN	1/4 000*	S
reyn	689.5	$\times 10^{3}$ Pa s
rhe	10.0*	Pa^{-1} s^{-1}
statmho	1.112 650	$\times 10^{-12}$ S
statohm	898.755 2	$\times 10^{9}$ Ω
statvolt	299.792 5	V
sthéne	1.0*	$\times 10^{3}$ N
stere	1.0*	m^3
stilb	10.0*	$\times 10^{3}$ cd m^{-2}
stokes	100.0*	$\times 10^{-6}$ m^2 s^{-1}
stone	6.350 293	kg
tablespoon (UK)	14.206 53	$\times 10^{-6}$ m^3
tablespoon (US)	14.786 76	$\times 10^{-6}$ m^3
teaspoon (UK)	4.735 513	$\times 10^{-6}$ m^3
teaspoon (US)	4.928 922	$\times 10^{-6}$ m^3
tex	1.0*	$\times 10^{-6}$ kg m^{-1}
therm (EEC)	105.506*	$\times 10^{6}$ J
therm (US)	105.480 4*	$\times 10^{6}$ J
thermie	4.185 407	$\times 10^{6}$ J
thou	25.4*	$\times 10^{-6}$ m
tog	100.0*	$\times 10^{-3}$ W^{-1} m^2
ton (UK long)	1.016 047	$\times 10^{3}$ kg
ton (US short)	907.184 7	kg
tonne (metric ton)	1.0*	$\times 10^{3}$ kg
ton (of TNT)	4.184*	$\times 10^{9}$ J
torr	133.322 4	Pa
townsend	1.0*	$\times 10^{-21}$ V m^2
troy ounce	31.103 48	$\times 10^{-3}$ kg
troy pound	373.241 7	$\times 10^{-3}$ kg
troy dram	3.887 935	$\times 10^{-3}$ kg
tun	954.678 9	$\times 10^{-3}$ m^3
XU	100.209	$\times 10^{-15}$ m
yard	914.4*	$\times 10^{-3}$ m
year (calendar)	31.536*	$\times 10^{6}$ s
year (sidereal)	31.558 15	$\times 10^{6}$ s
year (tropical)	31.556 93	$\times 10^{6}$ s

CHAPTER TWO
Physical Chemistry

الكيمياء الفيزيائية

Tests & Answers

Q1. A 100 mL sample of helium exerts a pressure of 1 atm at 10°C. The volume of the container is reduced to 50 mL and then the temperature is increased to 20°C. The pressure now exerted by the helium, in atmosphere, is closest to:

a. 0.5
b. 1
c. 2
d. 4

Sol. For a fixed amount of gas:

$$\frac{p_2V_2}{T_2} = \frac{p_1V_1}{T_1}$$

$$\frac{p_2 \times 50}{293} = \frac{1 \times 100}{283}$$

$$p_2 = \frac{1 \times 100}{283} \times \frac{293}{50}$$

$$= 2.07 \text{ atm}$$

$$= 2 \text{ atm}$$

With over 1 in 5 students choosing option **d**, there appears to be some issues with understanding the relationships between pressure and volume (pressure increases as volume decreases) and pressure and temperature (an increase in pressure is proportional to an increase in absolute, Kelvin, temperature).

Q2. Sulfur dioxide and oxygen are mixed to form sulfur trioxide according to:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Which one of following best describes the effect of adding the catalyst V_2O_5 to the mixture?

	Equilibrium yield	Reaction rate
a.	increases	increases
b.	no change	increases
c.	no change	no change
d.	increases	no change

Q3. Equal masses of the two gases oxygen (O_2) and sulfur dioxide (SO_2) are placed in separate vessels. Both vessels have the same volume and are at the same temperature. The pressure exerted by the oxygen is 100kPa. The pressures, in kPa, exerted by the SO_2 is closest to:

a. 25
b. 50
c. 100
d. 200

Sol. M(SO_2) =64.1gmol;
M (O_2) = 32.0 g mol^{-1}
Since the M (SO_2) is twice the M (O_2), and there are equal masses of both gases, n (SO_2) = ½ n (O_2). If both gases are at the same temperature and occupy the same volume then the pressure exerted by each gas depends on the number of mol present. Since n (SO_2) = ½ n(O_2) at the same volume and temperature, then: p (SO_2) = ½ x p(O_2)
= ½ x 100 = 50 kPa

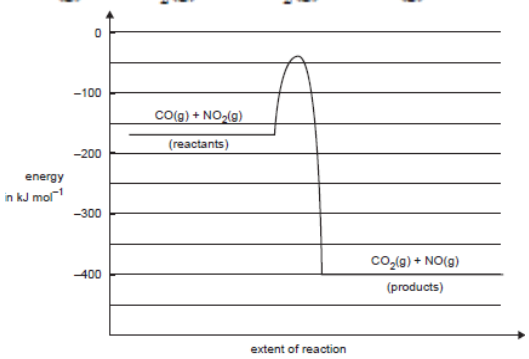
The high proportion of students who selected options **c** and **d** suggests that there was significant confusion between 'mass' and 'number of moles' of the two gases as far as the impact on pressure is concerned. While students are familiar with the general gas equation pV = nRT, there is scope for improved understanding

of the relationships between the four variables: p, V, n and T.

Q4. One liter of air at atmospheric pressure and 25°C is held in a flask. The pressure of oxygen in the flask is 0.201 atm (20.4 kPa).
The concentration of oxygen in the flask, in mole per liter, is:
a. 8.2
b. 0.12
c. 0.098
d. 0.0082
Sol.
$n(O_2)$ =pV/RT= 20.4 x1 / (8.31x298)
= 8.2 x 10^{-3} mol
$c(O_2)$ = n(O2) / V = 8.2 x10^{-3} / 1
= 0.0082 mol L^{-1}

Q5. The graph below represents the energy changes over the course of a chemical reaction:

$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$



a. Given the magnitude and sign of the ΔH for the forward reaction in kJ mol.1
Sol. ΔH = –400 – (–170)
= –230* kJ mol^{-1}.
Allowance was made for variations in reading the energy profile, and answers between -225 and -240 were accepted.

b. Give the activation energy for the reverse reaction in kJ mol.1.
Sol. E_a = -40 - (-400)
= 360* kJ mol^{-1}
Allowance was made for variations in reading the energy profile, and answers between 355 and 370 were accepted.

c. Give two reasons explaining why the rate of this reaction increases with increasing temperature
Sol.
• The fraction (or number) of fruitful collisions (collisions with energy greater than E_a) increases.
• The particles are moving faster (have higher kinetic energy), so there will be more collisions per second.
Many students struggled to give two distinct points. Students should be aware that the key to increasing the rate of reaction is increasing the proportion of fruitful or successful collisions; that is, collisions with energy greater than the activation energy. Qualitative explanations of factors that increase the rate of reaction inevitably include reference, either direct or indirect, to the activation energy.
Common misconceptions included 'rate increasing because the reaction was exothermic' and 'increasing temperature changing the activation energy'.

d. A suitable catalyst is discovered for the reaction. What would be the likely effect of the catalyst on?
i. the activation energy? Explain your answer.

Sol. A catalyst decreases the activation energy by providing an alternative reaction path.

ii. The ΔH? Explain your answer.

Sol. A catalyst has no effect on the ΔH, because it does not alter the extent of reaction or total amount of reactants reacting or energy difference between reactants and products or position of equilibrium.

Only one mark was awarded across parts **i** and **ii** if the student correctly identified both effects but did not provide explanations.

Q6. Dinitrogen tetroxide (N_2O_4) is a colorless gas. It exists in equilibrium with nitrogen dioxide (NO_2), a brown gas. The concentration of NO_2 in a gas mixture can be determined using a spectrophotometer. The equation for the reaction is

$$N_2O_4(g) \rightleftharpoons 2NO_2(g);\ K = 5.5 \times 10^{-3}\ M \text{ at } 25°C$$

a. Write the expression for the equilibrium constant for this reaction

Sol.

$$(K =) \frac{[NO_2]^2}{[N_2O_4]} (= 5.5 \text{ x } 10^{-3})$$

b. Some pure NO_2 is placed in a gas syringe at 25°C and allowed to reach equilibrium.

i. Keeping the volume constant the temperature is then raised to 35°C. The brown color then becomes more intense. Is the above reaction (1) exothermic or endothermic? Explain your answer.

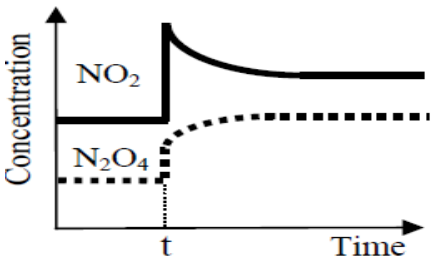
Sol. Endothermic

The position of equilibrium has moved to the right (more NO_2 is produced) at the higher temperature.

ii. Keeping the temperature at 35°C the plunger of the syringe is then pushed in so as to halve the volume. Equilibrium is then re-established. Is the brown color of the mixture more intense or less intense than before the volume was halved?

Sol. More intense:

When the volume of the syringe is halved, the $[NO_2]$ doubles. As the system responds by the position of equilibrium moving to the side with fewer particles the $[NO_2]$ decreases, but not back to its original concentration, so the brown color is more intense at the new equilibrium.



The most common response to part **ii**. was 'less intense'. This would suggest that students identified the equilibrium adjustment in response to the volume change, but not the overall effect on NO_2 concentration.

c. Give the numerical value at 25°C of the equilibrium constant of the reaction

$$NO_2(g) \rightleftharpoons \frac{1}{2}N_2O_4(g)$$

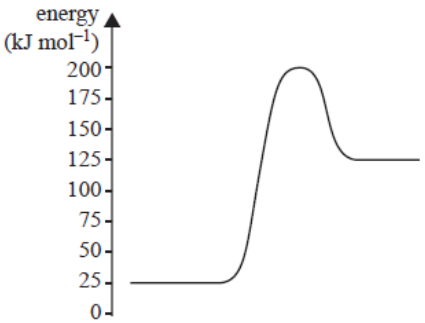
Sol.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g);\ K = \frac{[NO_2]^2}{[N_2O_4]}$$

$$2NO_2(g) \rightleftharpoons N_2O_4(g);\ K_1 = \frac{[N_2O_4]}{[NO_2]^2} = \frac{1}{K}$$

$$NO_2(g) \rightleftharpoons \frac{1}{2} N_2O_4(g);\ K_2 = \left(\frac{[N_2O_4]}{[NO_2]^2}\right)^{\frac{1}{2}}$$
$$= \left(\frac{1}{K}\right)^{\frac{1}{2}} *$$
$$= \left(\frac{1}{5.5 \times 10^{-3}}\right)^{\frac{1}{2}}$$
$$= 13*$$

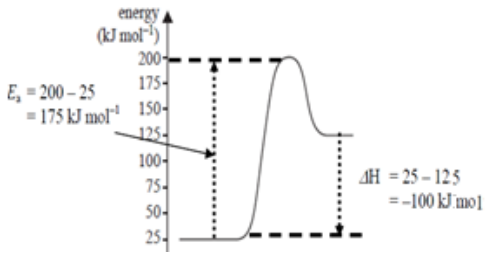
Q7.



Which one of the following provides the correct values of the activation energy and enthalpy for the reaction: X + Y → Z?

	Activation energy (kJ mol^{-1})	Enthalpy (kJ mol^{-1})
A.	+75	+100
B.	+100	+175
C.	+175	+100
D.	+200	−125

Sol.



Q8. When 50 g of water at 90°C is added to a calorimeter containing 50 g of water at 15°C, the temperature increases to 45°C. Assuming no energy is lost to the environment, the energy absorbed by the calorimeter is equal to the:

a. energy lost by the hot water.

b. energy gained by the cold water.

c. sum of the energy gained by the cold water and the energy lost by the hot water.

d. difference between the energy lost by the hot water and the energy gained by the cold water.

Sol. Adding hot water (90°C) to the lower-temperature calorimeter (water and components at 15°C) results in thermal energy being transferred from the hot water to the cold water in the calorimeter and the calorimeter components until all the water and the calorimeter components are at the same temperature (45°C).

The temperature increase (30°C) of the hot water is less than the temperature decrease (45°C) of the hot water because of the energy absorbed by the components of the calorimeter. So the energy absorbed by the calorimeter is equal to the difference between the energy lost by the hot water and the energy gained by the cold water.

Option **a** could apply if the calorimeter and the initial 50 g of water were treated as one entity, but there was a clear distinction made in the equation, which is why option **d** best answers the equation option **b** does not allow for the fact that, although the water in the calorimeter and the calorimeter components end up at the same temperature, they absorb different amounts of energy because of different heat capacities.

Option **c** suggested that more energy was gained by the calorimeter than was lost by the hot water.

Q8. If 54.0 kJ of energy is required to convert 1.00 mol of liquid water to steam at 100 °C, the amount of heat energy, in kilojoule, required to convert 100 g of water at 20 °C to steam at 100 °C is

a. 3.34×10^1 kj
b. 2.67×10^2 kj
c. 3.00×10^2 kj
d. 3.33×10^2 kj

Sol. The energy required to heat 100 g of water from 20 °C to steam at 100 °C is the sum of the energy required to heat 100 g of water from 20 °C to 100 °C and the energy required to convert 100 g of water to steam at 100 °C.

The energy required to heat 100 g of water from 20°C to 100 °C is determined from the specific heat capacity of water:

$E = 4.18 \times 100 \times 80$
$= 3.34 \times 104$ J $= 33.4$ kJ

The energy required to convert 100 g water at 100 °C to steam is determined from energy required to convert 1 mol^{-1} that is, 54.0 kJ mol^{-1}.

$n(H_2O) = 100 \div 18.0 = 5.56$ mol
$E = 5.56 \times 54.0 = 300$ kJ

The total energy required to heat 100 g of water from 20 °C to steam at 100 °C = 33.4 kJ + 300 kJ
$= 333.4$kJ $= 3.33 \times 10^2$ kJ

Option **a** was only the energy required to convert 100 g of water to steam at 100 °C.

Option **c** was only the energy required to heat 100 g of water from 20°C to 100°C.

Option **b** reflected subtraction rather than addition of the energies.

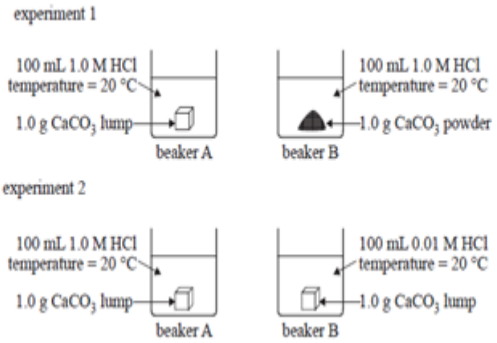
Q9. Which one of the following statements is true for both galvanic cells and electrolytic cells?

a. reduction occurs at the negative electrode in both cells.
b. reduction occurs at the cathode in both cells.
c. anions migrate to the cathode in both cells.
d. The anode is positive in both cells.

Q10. Two experiments were conducted to investigate various factors that affect the rate of reaction between calcium carbonate and dilute hydrochloric acid.

$CaCO_3(s) + 2HCl(aq) \rightleftharpoons CO_2(g) + CaCl_2(aq) + H_2O(l)$

The two experiments are summarised in the diagrams below.



a. How could the rate of this reaction be measured in these experiments?

Sol. Acceptable responses needed to refer to:

- measuring the mass (loss of mass) of the beaker and contents over a time interval.
- measuring the mass/ volume of CO_2 produced over a time interval.
- plotting the mass loss of beaker and contents, or mass/ volume of CO_2 produced against time.

Students were expected to state the quantity being measured and indicate that it was measured at different times.
Responses such as 'measure the rate of production of CO_2 did not address the 'how' component of the equation 'Measure the time taken for all the $CaCO_3$ to react' was an inappropriate response since $CaCO_3$ was in excess in beaker B in experiment 2.

b. i. Identify the rate determining factor that is investigated in experiment 1.

Sol. Acceptable responses included
- surface area
- particle size of $CaCO_3$.

ii. In experiment 2, will the rate of reaction be faster in beaker A or beaker B? Explain your selection in terms of collision theory.

Beaker A, because of the higher concentration of HCl. This will increase the frequency (number) of collisions between reactant particles/ successful collisions/ fruitful collisions/collisions with energy greater than activation energy.
One mark was awarded for recognising that the increased concentration of HCl was the reason why the rate was higher in Beaker A.
The second mark was awarded for recognising the increase in frequency of collisions between reactants.
Students should be careful about using the term 'proportion of successful collisions'. An increase in the 'proportion' of successful collisions occurs if there is an increase in temperature or a decrease in activation energy.

c. Why is the following statement incorrect?
'Collision theory states that all collisions between reactant particles will result in a chemical reaction.'

Sol. Only collisions with energy equal to or greater than the activation energy for the reaction can result in reaction. Chemical reaction requires breaking of bonds in the reactant particles; this requires collisions to have energy greater than or equal to the activation energy, or the reactant particles must collide with the correct orientation.
One mark was awarded for recognising that only collisions with energy > EA can lead to reaction. The second mark was awarded for linking the activation energy to the energy needed to to break the bonds in the reactants or stating that particles must also collide with correct orientation/ equivalent explanation.
Most students were aware that only collisions with energy greater than the activation energy lead to reaction. Why that was the case (bond breaking) or other factors at play (orientation) were less well recognised.

Q11. In an experiment, 1.0 mol of pure phosgene, $COCl_2$, is placed in a 3.0L flask where the following reaction takes place.

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $K = 2.1 \times 10^{-8}$ M

a. It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol.

Sol. On the basis of the data provided, explain why this assumption is justified.

Both of :

- The equilibrium constant is extremely small
- The amount of CO and Cl_2 produced/ $COCl_2$ reacted in getting to equilibrium is so small that (to two significant figures) the n ($COCl_2$) at equilibrium will still be 1.0 mol.

One mark was awarded for recognising the very small K value/ ratio of products to reactants, and the second mark for explaining what the low K value means in terms of extent of reaction.

Overall performance on this equation showed that a large proportion of students did not see the significance of the size of the K value and the implication for extent of reaction. Many students referred to the somewhat arbitrary value of 10^{-4} as the deciding factor in what makes a K value 'small'. Also, a number of students confused the K value with acidity constants and answered, inappropriately, in the context of weak acids. The ability to interpret what a K value implies about the extent of a reaction is an expected skill at this level.

b. i. Calculate the equilibrium concentration, in mol L^{-1}, of carbon monoxide, CO. Assume that the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol.

Sol. At equilibrium,

$[CO]$='y', M = $[Cl_2]$

$[COCl_2] = 1.0 \div 3.0 = 0.33$ M

$K = [CO][Cl_2] \div [COCl_2]$

'y' × 'y' ÷ 0.33 = 2.1×10^{-8}

'y'2 = $2.1 \times 10^{-8} \times 0.33$

'y' = $\sqrt{2.1\times10^{-8}\times0.33}$

'y' = 8.3×10^{-5}

$[CO]=8.3\times10^{-5}$M ($8.3\times10^{-5} - 8.4\times10^{-5}$)

One mark was awarded for recognising that $[CO] = [Cl_2]$. The second mark was awarded for using $[COCl_2]$ – that is, one third or 0.33 in the correct equilibrium law. The third mark was awarded for accurately calculating [CO].

Common errors on this equation included not calculating the $[COCl_2]$, not recognising that $[CO] = [Cl_2]$, dividing rather than multiplying by 0.33, not taking the square root and accuracy errors associated with rounding off one third to 0.3.

ii. What is the equilibrium concentration of chlorine gas?

Sol. 8.3×10^{-5} mol L^{-1} (M)

The required answer was effectively the answer to part bi. With appropriate units. If no units are specified in the equation, as in bii, they must be included as part of the answer.

Q12 Methanol, CH_3OH, undergoes combustion according to the equation:
$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

In an experiment to determine its suitability as a fuel, a sample of methanol underwent complete oxidation in a bomb calorimeter.

The calorimeter was first calibrated by passing a current through an electric heater placed in the water surrounding the reaction vessel. A potential of 5.25 volts was applied for 3.00 minutes. The measured current was 1.50 amperes and the temperature of the water and reaction vessel increased by 0.593 °C.

a. i. Determine the calibration constant, in kJ $°C^{-1}$, for the calorimeter and its contents.

Sol.

$E = VIt = 5.25 \times 1.50 \times 3.00 \times 60 = 1.42 \times 103$ J

Calorimeter constant = $E \div \Delta T$

$=1.42\times103 \div 0.593 = 2.39\times103$J $°C^{-1}$

$= 2.39$ (kJ $°C^{-1}$)

One mark was awarded for accurately calculating the energy, and the second mark for accurately calculating the calorimeter constant (calibration factor), in kJ $°C^{-1}$, from the energy.

The most common error was not converting the energy from joules to kilojoules, or assuming that the unit of electrical energy in the VIt calculation was joules.

A student then used this calorimeter to determine the molar heat of combustion of methanol.

0.934g of methanol was placed in the reaction vessel and excess oxygen was added. An electric ignition heater provided the energy required to initiate the combustion reaction. On this occasion, the temperature of the water increased by 8.63 °C.

ii. Use this experimental data to determine the value of ΔH for the combustion of methanol given by the following equation.

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

Sol.

n (CH_3OH) reacting = $0.934 \div 32.0$

$= 0.0292$ mol

Energy released by methanol = CC × $\Delta T = 2.39 \times 8.63 = 20.6$ kJ

Energy from 1 mol $CH_3OH = 20.6 \div 0.0292 = 706$ kJ

$\Delta H = -2 \times -706$ kJ mol^{-1}

$= -1.41 \times 10^3$ kJ mol^{-1}

$= -1.41 \times 10^6$ J mol^{-1}

One mark each was awarded for

- Accurately calculating n(CH3OH)
- Accurately calculating the energy released using the calorimeter constant from part ai.
- Accurately calculating the energy for 2 mol of CH_3OH.
- including the negative sign and giving the answer to three significant figures.
- correct units on ΔH.

This equation was generally well handled; however, some common errors included:

- using the molar enthalpy of combustion from the References, rather than the temperature change during combustion and the calibration constant, to calculate the energy released by the methanol.

- Not determining the energy for 2mol CH_3OH.
- Inconsistent significant figures and/ or units.

b. The value of ΔH, calculated using the enthalpy of combustion provided in the references, is different from the value of ΔH calculated from the experimental data provided in part a. ii.

Sol. Provide a reason for this difference. The calculated energy released in combustion is lower due to loss of heat/ energy to the surroundings during combustion.

The better responses indicated that a lower temperature change during combustion due to loss of heat would lead to a lower calculated energy released.

Students should avoid stating learned responses that are not relevant in this context; for example, as the equation states that 'methanol underwent complete combustion', responses such as 'incomplete combustion' were not appropriate.

Statements such as 'the References gives the energy for one mole of methanol' indicated that some students were comparing the ΔH for the reaction with the molar enthalpy of combustion from the References rather than with 'the value of ΔH, calculated using the enthalpy of combustion provided in the References'.

Statements such as 'the conditions of the experiment may not have been the same as those used to determine the values in the References' were not accepted because there was no indication of why or how this would reduce the calculated energy released.

Methanol is suitable for use in a micro fuel cell that is used to power laptop computers and similar small electrical items. The methanol is oxidised to carbon dioxide and water.

The half-equation for the anode reaction is

$CH_3OH(l) + H_2O(l) \rightarrow 6H^+(aq) + CO_2(g) + 6e^-$

c. i. Write a balanced half-equation for the cathode reaction.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

Given that students would have been well exposed to the half-equation for the reduction of oxygen in fuel cells, performance on this equation was expected to be stronger. Students should know that reduction occurs at the cathode. The acidic electrolyte was implied in the given half-equation for oxidation.

ii. A finely divided platinum/ ruthenium catalyst is used in this cell.

Give a reason why it is important to have a catalyst that will significantly reduce the activation energy for the cell reaction.

Sol. Either of:

- a fast rate of reaction is necessary for efficient current flow/ instantaneous current in the computer.
- Since the computer is being used at room temperature, the catalyst will increase the reaction rate to an acceptable level in the fuel cell.

Some logical indication of the 'benefit/ advantage' of a faster reaction rate in the context of the

laptop computer was required. Most students simply explained, often very well, why or how a catalyst reduces the activation reaction and increases reaction rate, but did not give any explanation of why it is important to have a catalyst in the context of laptop computers. Some responses suggested that the presence of the catalyst.

Q13. One possible reaction that occurs when trinitrotoluene (TNT), $C_7H_5N_3O_6$, explodes is:

$2C_7H_5N_3O_6(s) \rightarrow 2C(s) + 12CO(g) + 5H_2(g) + 3N_2(g)$

When one mole of TNT explodes the total volume of the gases produced from this reaction, measured at 27 °C and 1.00×10^2 kPa, is closest to:

a. 0.249 l
b. 22.7 l
c. 249 l
d. 274 l

Sol. According to the equation, the explosion of 2 mol of $C_7H_5N_3O_6$ produces 20 mol of gaseous products (12 mol CO + 5 mol H_2 + 3 mol N_2).

Hence 1 mol $C_7H_5N_3O_6 \rightarrow$ 10 mol gases.

$V(gas) = n(gas) \times RT / p$

$=10x8.31x(27+273)/ 1.0x10^2$

$= 249$ L

Option **b** (22.7 L) was 249 L divided by 11, suggesting that students who chose this option realised that there was 10 mol of gases produced from 1 mol TNT, but then divided the total volume by 11 because there was a total of 11 mol of products formed for each 1 mol of TNT reacting.

Option **a** was consistent with using Pa rather than kPa for pressure, while option **d** assumed 11 mol of gas, overlooking that carbon was a solid.

Q14-15 the following equilibrium:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ mol^{-1}; $K = 4.5$ at 600 K

In a particular exercise, a mixture of 4.0 mol of sulfur dioxide and 1.0 mol of oxygen is allowed to reach equilibrium at 600 K.

Q14 The amount of sulfur trioxide present at equilibrium would be

a. 5 mol
b. 4 mol
c. 2 mol
d. less than 2 mol

Sol. d. There were two points in particular that caused consternation. The limiting reactant was O_2 so that there could never be any more than 2 mole of SO_3 produced. Secondly, this is an equilibrium system so that there would always be a bit less that 2 mole of SO_3 present at equilibrium.

Q15. In a second exercise, the same initial amounts of reactants are mixed at 600 K in a well-insulated container of the same size.

In this case, the amount of sulfur trioxide present when the mixture reaches equilibrium would be

a. equal to the amount produced in the previous exercise.
b. less than the amount produced in the previous exercise.
c. more than the amount produced in the previous exercise.

d. impossible to predict from the information given.

Sol. b. The point of using the well-insulated container was to ensure that the heat of reaction remained with the reactants and products. Since the reaction is given as exothermic, clearly the reaction mixture must rise in temperature and the position of equilibrium must therefore shift to the left. Perhaps the,use of 'same size' in the stem stuck in the minds of those who chose A and they did not think any more about the significance of 'well-insulated'.

Q16. The decomposition of water can be represented by the chemical equation:

$2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$ $\Delta H = +571.8$ kJ mol^{-1}

From this equation, it can be concluded that the formation of two moles of liquid water from gaseous hydrogen and oxygen is an:

a. exothermic process releasing 571.8 kj of heat energy.

b. exothermic process releasing 1143.6 kj of heat energy.

c. endothermic process absorbing 571.8 kj of heat energy.

d. endothermic process absorbing 1143.6 kj of heat energy.

Q17. A VCE chemistry student sets up a galvanic cell using two standard half cells with half reactions.

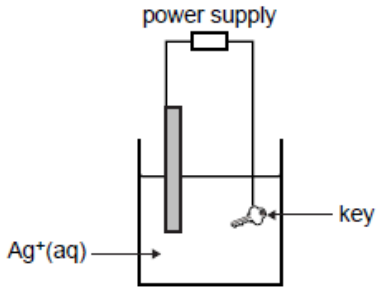
Half cell 1: $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$

Half cell 2: $Cr(s) \rightarrow Cr_2+(aq) + 2e^-$

Suitable materials for the electrodes of the two half cells are:

	Half cell 1	Half cell 2
a.	Platinum	Platinum
b.	Platinum	Chromium
c.	Chromium	Chromium
d.	Chromium	Platinum

Q18. A student decided to silver-plate a locker key using the apparatus shown.



In this cell, the key is the:

a. anode and is connected to the positive terminal of the power supply.

b. anode and is connected to the negative terminal of the power supply.

c. cathode and is connected to the positive terminal of the power supply.

d. cathode and is connected to the negative terminal of the power supply.

Sol. d. The Down's cell is used for the industrial preparation of sodium and chlorine. The reaction occurring in the Down's cell is:

$2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

Q19. An iron mesh screen is a necessary part of the Down's cell. The primary role of the screen is to:

a. allows electric current to flow from the anode compartment to the cathode compartment.

b. provides a way for the liquid sodium to be run into a collection vessel.
c. prevent the chlorine and sodium from coming into contact and thereby exploding.
d. prevent chloride ions from moving from the anode into the cathode compartment.

Q20. Pure NaCl is not used in a Down's cell. The liquid that is in a Down's cell is a mixture of $CaCl_2$ and NaCl. The $CaCl_2$/NaCl mixture is used instead of pure NaCl because it:
a. has a higher melting temperature.
b. improves the yield of chlorine produced.
c. improves the purity of the sodium produced.
d. enables the process to be carried out at a lower temperature.

Q21. A particular Down's cell operates for 1.00×10^4s at a current of 96.5 A. The amount of chlorine produced, in mole, is:
a. 0.050
b. 5.00
c. 10.0
d. 20.0

Q22 Hydrogen peroxide can act as a reductant according to the half equation:
$O2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq)$; $E_o = +0.68$ V
Which of the following could all be reduced by hydrogen peroxide?
a. $Fe^{2+}(aq)$, Cu(s), $I^-(aq)$
b. Ag+(aq), $Br_2(aq)$, $H_2O_2(aq)$
c. Ag(s), $Br^-(aq)$, $Fe^{2+}(aq)$
d. I2(s), $Cu^{2+}(aq)$, $Fe3^+(aq)$

Q23. High energy sparks discharged through hydrogen produce hydrogen atoms in an excited state. Light is then emitted. If the light is viewed through a spectroscope, lines of an emission spectrum are visible.
a. Explain why the spectrum is made up of discrete lines.
Sol. Electrons moving higher to lower energy levels give out specific wavelengths.
b. When white light from the sun passes through hydrogen in the outer layers of the sun's atmosphere, and is viewed through a spectroscope, a set of dark lines appears superimposed on a continuous spectrum. The wavelengths corresponding to the dark lines match the lines in the emission spectrum of hydrogen.
Explain why the wavelengths of these dark lines correspond to those of the emission spectrum. In your answer you should also.
• give the name of the type of spectrum that produces the dark lines.
• explain how the dark lines are produced.
Sol. The dark lines are an absorption spectrum, the energy levels of H are the same as those seen in the emission spectrum except the electrons are moving up rather than down (like in AA spectroscopy).
This last equation of the paper was not particularly well done but it is a genuinely hard equation. Questions of this nature needing simple written explanations often generate responses that are both confused and confusing.

In this case, many students 'had a go' and collected a mark or two. The term 'absorption spectrum' frequently picked up a mark in an answer that had little else to recommend it.

c. Write an equation for the nuclear fusion of hydrogen to form helium in the sun.

Sol. $4^1H \rightarrow 4He + 2e^-$(or 2oe1) or $4^1H^+ \rightarrow 4He^{2+} + 2e^-$

($_2H + 2H \rightarrow 4He$ was also acceptable).

Q24-25: 0.12g of a metal was reacted with excess hydrochloric acid. 125 mL of hydrogen gas was collected at 27ºC and 100 kPa.

Q24 The amount of hydrogen gas, in mol, would be closest to:

a. 5.0
b. 0.52
c. 0.052
d. 0.0050

Sol. d. $n(H_2) = pV / RT = 0.125 \times 100 / (8.31 \times 300) = 0.0050$ mol

Q25. The metal involved could be:

a. zinc.
b. sodium.
c. calcium.
d. magnesium.

Sol. d. When Zn, Ca and Mg react with HCl to produce H2 then:

$M + 2HCl \rightarrow MCl_2 + H_2$

$n(H_2)$ produced = n(metal) reacting

When Na reacts with HCl to produce H_2 then:

$2Na + 2HCl \rightarrow 2NaCl + H_2$

$n(H_2)$ produced = ½ x n(Na) reacting

0.12 g Zn → 0.12 / 65.4 = 0.0018 mol → 0.0018 mol H_2

0.12 g Na → 0.12 / 23.0 = 0.0052 mol → 0.0026 mol H_2

0.12 g Ca → 0.12 / 40.0 = 0.0030 mol → 0.0030 mol H2

0.12 g Mg → 0.12 / 24.3 = 0.0049 mol → 0.0049 mol H2

Q26-27: Consider the equilibrium:

$2ClF_3(g) \rightleftharpoons 3F_2(g) + Cl_2(g)$ ΔH = negative.

Q26. An expression for the equilibrium constant for this reaction is:

A. $\frac{[ClF_3]^2}{[F_2]^3\,[Cl_2]}$ **C.** $\frac{[F_2]^3\,[Cl_2]}{[ClF_3]^2}$

B. $\frac{3[F_2]\,[Cl_2]}{2[ClF_3]}$ **D.** $\frac{2[ClF_3]}{3[F_2]\,[Cl_2]}$

Q27. For a particular equilibrium mixture, the temperature is lowered and the amount of ClF_3 changes by 0.010 mol. The changes occurring would be

	ClF_3	F_2	Cl_2
A.	increase by 0.010 mol	decrease by 0.015 mol	decrease by 0.0050 mol
B.	increase by 0.010 mol	decrease by 0.0067 mol	decrease by 0.020 mol
C.	decrease by 0.010 mol	increase by 0.015 mol	increase by 0.0050 mol
D.	decrease by 0.010 mol	increase by 0.067 mol	increase by 0.020 mol

Sol. c. The forward reaction is exothermic, so lowering the temperature favours the forward reaction and 0.010 mol ClF3 is used up. According to:

$2ClF_3 \rightarrow 3F_2 + Cl_2$

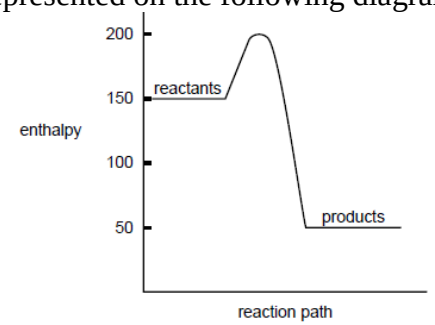
0.010 mol $ClF_3 \rightarrow$ 0.015 mol F_2 and 0.00050 mol Cl_2

Q28. Oxides of nitrogen are formed in air at the high temperatures

generated in lightning flashes according to the equation:
$N_2(g) + O_2(g)$ 2NO(g) K1 = 5×10^{-3} at 3000ºC
At 3000ºC, the equilibrium constant K_2 for the reaction
4NO(g) $2N_2$ (g) + $2O_2$(g)
would be
a. 4×10^4
b. 1×10^2
c. 1×10^{-2}
d. 5×10^{-3}
Sol. a.
$N_2 + O_2 \rightleftharpoons 2NO$; K1 = $5x10^{-3}$
$2NO \rightleftharpoons N_2 + O_2$; $K_2 = 1 / K1$
$= 1 / 5x10^{-3} = 2x10^2$
$4NO \rightleftharpoons 2N_2 + 2O_2$, $K_3 = K_2^2 = (2x10^2)^2 = 4x10^4$

Q29. 947 J of energy is required to raise the temperature of 125g of stainless steel by 15.7°C. The specific heat capacity of the stainless steel, in $J.g^{-1}°C^{-1}$, is
a. 8.41×10^{-3}
b. 0.483
c. 7.54
d. 119

Q30-31. The relative enthalpies, on an arbitrary scale, of the reactants and products of a chemical reaction, are represented on the following diagram.



Q30. The numerical value of enthalpy change, ΔH, for the forward reaction, is
a. +150
b. +50
c. –50
d. –100

Q31. The numerical value of the activation energy for the reverse reaction is
a. +150
b. +50
c. –50
d. –100

Q32. The combustion of octane can be represented by the equation:
$2C_8H_{18}(g) + 25O_2(g)$ Õ $16CO_2(g) + 18H_2O(g)$ ΔH = –10 108 kJ mol^{-1}
The energy produced, in kJ, by complete oxidation of 45kg of octane is:
a. 2.0×10^3
b. 4.0×10^3
c. 2.0×10^6
d. 4.0×10^6

Q33. The energy released in a chemical reaction is directly converted to electrical energy in a:
a. solar cell.
b. electrolytic cell.
c. fossil-fuel power station.
d. hydrogen/oxygen fuel cell.

Q34. The cell reaction when a car battery releases energy is given by the equation below.
$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

When the battery is being recharged, the reaction that occurs at the negative electrode is

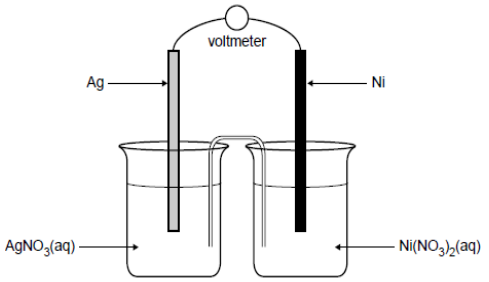
a. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO4(s) + 2e^-$

b. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e- \rightarrow PbSO4(s) + 2H_2O(l)$

c. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO4^{2-}(aq)$

d. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

Q35.



The experimental arrangement shows a:

• silver rod dipping into a 1.0 M solution of $AgNO_3(aq)$

• nickel rod dipping into a 1.0 M solution of $Ni(NO_3)_2(aq)$

The solutions are connected to each other with a salt bridge consisting of an inverted U-tube containing ammonium nitrate solution;

Which of the following alternatives correctly describes the polarity of, and the reaction that occurs at, the anode of this cell?

anode polarity reaction at the anode

a. negative $Ag+(aq) + e- \rightarrow Ag(s)$

b. negative $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$

c. positive $Ag^+(aq) + e^- \rightarrow Ag(s)$

d. positive $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$

Q36. A piece of silver jewellery is coated with gold (Au) in an electrolytic cell that contains gold ions in an aqueous solution. Use the information below to determine the oxidation number of the gold ions in the aqueous solution.

- Volume of gold deposited 0.150 cm^3
- density of gold 19.3g.cm^{-3}
- cell current 4.00A
- time taken to plate jewellery 17.75 minutes

a. Calculate the amount of electrons, in mole, passed through the cell.

Sol. Charge = 4.00x17.75 x 60 = 4260 C; $n(e^-)$ = 4260/ 96 500 = 0.0442 mol.

b. Calculate the amount of gold, in mole, deposited on the jewellery.

Sol. Mass of Au = 19.3 x 0.150 = 2.895 g; n(Au) = 2.895/197.0 = 0.0147 mol.

0.04415/ 0.01470 = 3.00.

c. Hence give the oxidation state of gold in the gold ions in this solution.

Sol. = 3 (or +3)

Q37. In a chemical reaction at constant temperature the addition of a catalyst

a. affects the equilibrium constant.

b. provides an alternative reaction pathway.

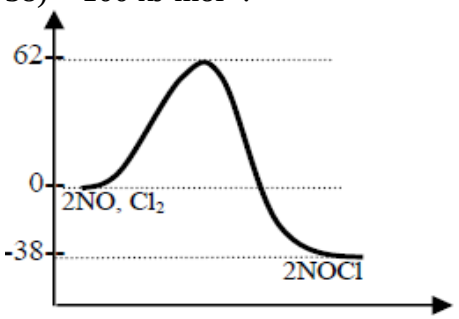
c. increases the percentage yield at equilibrium.

d. increases the fraction of molecules with more than a given kinetic energy.

Sol. b. A catalyst increases the rate of a reaction by lowering the activation energy, and hence increasing the number of collisions with energy greater than the activation energy, i.e.

fruitful or successful collisions. It provides an alternative reaction pathway.

Q38. Nitrogen(II) oxide and chlorine react according to the equation:
$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$; $\Delta H = -38$ kJ mol^{-1}
The activation energy for the forward reaction is 62 kJ mol^{-1}.
The activation energy of the reverse reaction, in kJ mol^{-1}, is:
a. –62
b. 24
c. 38
d. 100
Sol. d. According to the energy profile for the reaction:
$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$
The activation energy for the reaction
$2NOCl(g) \rightarrow 2NO(g) + Cl_2(g)$. is 62 – (-38) = 100 kJ mol^{-1}.



Q39. A fuel cell is set up based on the oxidation of methane. Again, the equation for the anode half reaction is:
$CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$
Assuming that all the energy of the oxidation reaction is converted to electricity, the amount of electric charge, in coulomb, obtained from the oxidation of one mole of methane is closest to
a. 8×10^2
b. 1×10^3
c. 8×10^5
d. 1×10^6
Sol. c. One mol of CH_4 uses eight mol of electrons. This generates 8x96 500 C of electric charge ≅ 7.7 x 10^5.

Q40. In which one of the following sets of substances are all members of the set able to undergo a spontaneous redox reaction with pure water?
a. Fe, Co^{2+}, Cl_2
b. F_2, Mg, Au^+
c. H+, Na+, Br_2
d. Li, F_2, Ag+
Sol. b. From the electrochemical series, F_2 (+2.87) and Au^+ (+1.68) will oxidise water to O_2 (+1.23) while the reducing agent Mg (-2.36) will reduce water (-0.83) to H2 and OH-.

Q41 The main source of the sun's energy is:
a. fusion of hydrogen to form helium.
b. fusion of helium to form carbon.
c. fusion of carbon to form heavier atoms.
d. All of the above.

Q42. **a.** A bomb calorimeter may be calibrated using a substance with a well-known heat of combustion. A commonly used calibrating agent is benzoic acid ($C_7H_6O_2$) which has a heat of combustion of 3227 kJ for each mole of benzoic acid.
i. 2.50 g of pure solid benzoic acid is placed in a calorimeter and completely reacted with oxygen. The

temperature rise of the calorimeter is observed to be 8.90°C. Calculate the calibration factor of the calorimeter in $kJ°C^{-1}$.

Sol. 7.43

RMM benzoic acid = 122

amount of benzoic acid = 2.50/122 = 0.0205 mol.

energy released = 0.0205 x 3227 = 66.13 kJ.

calibration factor = 66.13/8.90=7.43.

ii. Give a chemical equation for the reaction of benzoic acid with oxygen. Include the correct sign and magnitude of the ΔH for the reaction.

Sol.

$2C_7H_6O_2(s) + 15O_2(g) \rightarrow 14CO_2(g) + 6H_2O(l)$; $\Delta H = -6454$ kJ mol^{-1}

b. A second bomb calorimeter is used for the following two experiments. The calibration factor for this calorimeter is 5.56 $kJ°C^{-1}$.

A lump of lignite (brown coal) is freshly taken from the ground and crushed into a powder.

Two samples of this powdered lignite are weighed. Each sample has a mass of 3.20 g.

i. Sample 1 is placed in the calorimeter and completely reacted with oxygen.

The temperature rise of the calorimeter is found to be 2.21°C**.**

Calculate the heat of combustion of the fresh lignite in kJ g^{-1}.

Sol. 3.84kJg^{-1}

energy released =2.21x5.56=12.29 kJ

heat of combustion of lignite= 12.29/3.20 3.84

ii. Sample 2 is placed in an oven for 2 hours where it is kept at a temperature of 100°C**.**

It is cooled and weighed. Its mass decreases to 2.15 g after heating. It is then completely reacted with oxygen in the calorimeter. The temperature rise of the calorimeter is found to be 2.66°C.

Explain why the combustion of the second sample of lignite appears to release significantly more energy than the first sample.

Sol. The first sample contains water so that some of the energy released is used to heat this extra water. The extra water in sample 1 would absorb more heat, so the temperature would not rise quite as high as sample 2.

Q43. A small electric vehicle is powered by rechargeable lead-acid car batteries. The energy that drives the vehicle comes from the cell reaction:

$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

The equation for the anode half reaction is:

$Pb(s) + H_2SO_4(aq) \rightarrow PbSO_4(s) + 2H^+(aq) + 2e^-$

a. Write the equation for the cathode half reaction

Sol. $PbO_2 + H_2SO_4 + 2H^+ + 2e^- \rightarrow PbSO_4 + 2H_2O$

b. In this vehicle, each battery operates at 12.0V. When fully charged, the vehicle can travel on a level surface for 2.5 hours with an average energy consumption of 1.0 kJ s^{-1}, after which time the batteries must be recharged.

i. How much energy, in kJ, is used by the vehicle in travelling for 2.5 hours?

Sol. 2.5 x 3600 x 1.0 = 9000 kJ

ii. Write the equation for the overall chemical reaction that occurs when the battery is being recharged.

Sol. $2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2H_2SO_4$

iii. What voltage should be used to recharge each battery?

Sol. Greater than 12 volts (any voltage greater than 12V was accepted).

Q44. The reaction between solutions of hydrochloric acid and sodium hydroxide can be represented by the following equation.

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H = 0.56$ kJ mol.1

60.0 mL of 2.0 M HCl, at 21°C, is mixed with 40.0 mL of 2.0 M NaOH, also at 21°C, in a well-insulated calorimeter. The calibration factor for the calorimeter and contents is 420 J K.1.

The final temperature, in °C, of the resultant solution in the calorimeter would be closest to

a. 11

b. 32

c. 37

d. 52

Sol. There is an excess of 20mL of the 2.0 M HCl. Only 40 mL of the HCl is needed to react with the 40mL of NaOH. The amount of heat evolved will thus be:

$$\left(\frac{40}{1000}\right) \times 2 \times 56\,000 = 4480 \text{ J.}$$

The temperature rise must then be:

$$\frac{4480}{420} = 10.7^{o}\text{C.}$$

This is added to the initial temperature to give 21+10.7= 31.7^{o}C, which is the closest to the correct response, **b.**

Q45. The rechargeable nickel-cadmium cell is used to power small appliances such as portable computers. When the cell is being used, the electrode reactions are represented by the following equations.

$NiO_2(s)+2H_2O(l) +2e. \rightarrow Ni(OH)_2(s) + 2OH.(aq)$

$Cd(s) + 2OH.(aq) \rightarrow Cd(OH)_2(s) + 2e.$

Which of the following occurs during the recharging of the nickel-cadmium cell?

I cadmium is deposited on the negative electrode.

II the pH of the electrolyte increases.

III the direction of electron blow in the external circuit is from the anode to the cathode:

a. I only

b. I and II only

c. II and III only

d. I and III only

The half cell reaction, $Cd(s) + 2OH^{-}(aq) \rightarrow Cd(OH)2(s) + 2e^{-}$, is an oxidation reaction and the electrode is therefore an anode (and also the negative electrode) of the cell. During the recharging process, this reaction must be reversed to become a reduction reaction. Thus the electrode will be then a cathode and a negative electrode with the half reaction: $Cd(OH)_2(s) + 2e^{-} \rightarrow Cd(s) + 2OH–(aq)$, depositing cadmium. Therefore, Option **I** is correct.

In the case of the cell reaction (in either direction), the same numbers of OH^- ions are formed and consumed – thus, when the cathode is generating OH^- ions the anode is consuming them at the same rate. Therefore, Option **II** is incorrect.

Finally, in the recharging process, electrons are generated at the anode (the oxidation reaction) and consumed at the cathode (the reduction process) so that electrons will flow through the external circuit from the anode to the cathode. Therefore, Option **III** is correct.

As options **I** and **III** are correct, response **d** was the correct answer

Q46. A galvanic cell consists of one half cell that is made up of an inert graphite electrode in a solution containing:

1.0 M Fe^{2+}(aq) and 1.0 M Fe^{3+}(aq) at 25°C**.**

Which one of the following could be used as the second half cell so that the polarity of the electrode in this second half cell is positive?

a. a lead electrode in a solution of 1.0 M Pb^{2+}(aq)

b. a silver electrode in a solution of 1.0 M Ag^+(aq)

c. an iron electrode in a solution of 1.0 M Fe^{2+}(aq)

d. an inert graphite electrode in a solution of 1.0 M Br.(aq)

Sol. b. a and **c** would be negative relative to the Fe^{3+}/Fe^{2+} half cell and **d** is not a proper half cell, so response **b** is correct.

Q47–48. A copper disc is to be silver-plated in an electrolytic cell. The disc forms one electrode and a silver rod the other electrode. The electrolyte provides a source of Ag^+(aq).

Q47. The disc to be plated is connected to the:

a. positive terminal of a battery so that oxidation occurs at the disc.

b. positive terminal of a battery so that reduction occurs at the disc.

c. negative terminal of a battery so that oxidation occurs at the disc.

d. negative terminal of a battery so that reduction occurs at the disc.

Sol. d. The deposition of a metal from metal ions in solution onto an inert electrode is a reduction reaction and requires that the copper disc be made negative.

Q48. The mass of silver to be deposited is 0.150 g. If the current is held steady at 1.50 amps, the time, in seconds, that it takes to complete the plating is closest to:

a. 90

b. 180

c. 200

d. 360

Sol. a. $0.150/\ 107.9 = 1.39 \times 10^{-3}$ mol of Ag to be deposited. This requires $1.39 \times 10^{-3} \times 96\ 500 = 134.1$ C, since each mole of Ag deposited requires one mole of electrons. Thus the time taken will be 134.1/1.5= 89.4s, so 90 seconds (response **a**) is the closest answer.

Q49. An identical disc is to be gold-plated with a solution containing Au^{3+}(aq) as the electrolyte using a

current of 1.50 amps. The ratio of the time that is needed to plate the disc with 0.150 g of gold to the time needed to plate the disc with 0.150 g of silver is closest to:

a. 1 to 3
b. 1 to 1.6
c. 1.6 to 1
d. 3 to 1

Sol. c. Every mole of Au deposited requires three mole of electrons. 0.15 g of Ag requires 1.39×10^{-3} mole of Ag and hence 1.39×10^{-3} mole of electrons. 0.15 g of Au is $0.15/197 = 7.61 \times 10^{-4}$ mol. This will need $3 \times 7.61 \times 10^{-4} = 2.28 \times$ 10–3 mole of electrons. Thus, the Au will need $2.28\times 10^{-3}/ 1.39\times 10^{-3} = 1.67$ times the number of electrons as Ag. Since the current is the same for both electrolyses, the time ratio will be closest to 1.6 to 1 (response **c**)

Responses **b** and **d** both attracted a significant proportion of responses; **b** is the reverse of the correct result and **d** confuses mass with the number of mole.

Q50. An electrolytic cell is used commercially to extract aluminum from its ore. The anode and cathode of this electrolytic cell are composed of:

	Anode	**cathode**
a.	carbon	carbon
b.	carbon	iron
c.	iron	carbon
d.	iron	iron

Sol. a. This is a direct reference to the standard electrolytic method of producing aluminum commercially. In this process, the anode is carbon and the cathode is a carbon lining over a steel base. Response **b** incorrectly indicated a steel cathode.

Q51. In which one of the following processes will the ΔH have the opposite sign to that of the other three?

a. $I_2(s) \rightarrow I_2(g)$
b. $Na+(g) + e.(g) \rightarrow Na(g)$
c. $CO_2(g) \rightarrow C(s) + O_2(g)$
d. $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

Sol. b. Response **a** gives the conversion of molecular iodine from solid to gas, obviously a reaction with a positive ΔH (a reaction that absorbs heat).

Response **c** is the reverse of the exothermic reaction of carbon with O_2 to produce CO_2 so that the reaction as given must have a positive ΔH.

The reverse of the reaction in **d** is the exothermic reaction between sodium and chlorine to make NaCl(s) so that the reaction as given must have a positive ΔH. In response **b**, the reaction is $Na^+(g)$ plus a gaseous electron to give Na(g). Students should know that the reverse of this reaction is the ionisation of a sodium atom, which has a positive ΔH; hence the reaction as given will be exothermic and have a negative ΔH. Thus the endothermic reaction B is correct.

Q52. Zinc metal reacts with 0.1 M hydrochloric acid to form hydrogen gas and zinc chloride solution. The production of hydrogen gas is more vigorous if the zinc is powdered, rather than in large pieces, because the:

a. activation energy of the reaction is lower.
b. activation energy of the reaction is higher.
c. frequency of collisions between zinc metal and hydrogen ions is higher.
d. fraction of reactant particles with sufficient energy to react is higher

Sol. The reaction rate increases when the number of fruitful collisions (collisions with energy greater than the activation energy) per second increases. Powdered Zn provides a greater surface area for reaction, leading to more fruitful collisions.

Q53. $Cl_2(g)$ 2Cl(g); K = 1.13×10^{-6} M at 1100°C, what would be the numerical value of the equilibrium constant for the reaction: 2Cl(g) $Cl_2(g)$ at the same temperature?
a. 8.85×10^{-5}
b. 4.42×10^{-5}
c. 2.26×10^{-6}
d. 1.13×1
Sol. a. Reverse the equation and take reciprocal of K value.

$$2Cl(g) \rightleftharpoons Cl_2(g);\ K = \frac{1}{1.13\times10^{-6}} = 8.85 \times 10^{-5}\ M^{-1}$$

Q54. Carbon monoxide can be oxidised to carbon dioxide.
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
3 mol of CO and 2 mol of O_2 are mixed. When the reaction is complete there will be:
a. 4 mol of CO_2 produced.
b. 2 mol of CO_2 produced.
c. 1 mol of CO unreacted.
d. 0.5 mol of O_2 unreacted.
Sol. $CO(g) + O_2(g) \rightarrow 2CO_2(g)$

Initially	3 mol	2 mol	
Reacting	3 mol	1.5 mol	→ 3 mol
Finally	0 mol	0.5 mol	3 mol

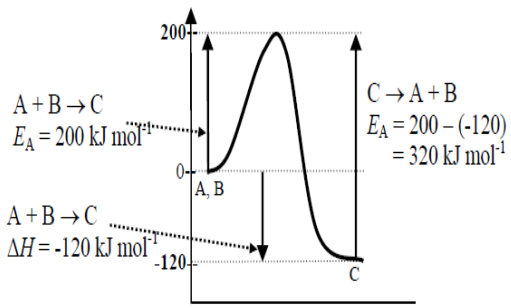
Q.55-56: Methanol can be produced in a reaction between carbon monoxide and hydrogen according to the following equation:
$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$;
$\Delta H = .90$ kJ mol.1

Q55. Which one of the following changes would occur when a catalyst is added to an equilibrium mixture of carbon monoxide, hydrogen and methanol?
a. The value of ΔH would increase.
b. The amount of methanol would increase.
c. The temperature of the surroundings would increase.
d. The rates of both the forward and reverse reactions would increase.
Sol. d. The rates of both the forward and reverse reactions would increase.

Q56. Which statement about the behaviour of a catalyst in this reaction is correct?
a. It decreases the activation energy of the forward reaction only.
b. It increases the activation energy of the forward reaction only.
c. It decreases the activation energies of both the forward and back reactions.
d. It increases the activation energies of both the forward and back reactions.

Sol. b. It increases the activation energy of the forward reaction only.

Q57. Consider the following information for the reaction A+B→C.
heat of reaction .120 kJ mol.1
activation energy +200 kJ mol.1
The activation energy, in kJ mol.1, for the reaction C → A + B, is:
a. 320
b. 80
c. +80
d. +320
Sol.



Q58. Hydrogen iodide (HI) is formed from the reaction of the elements hydrogen and iodine:
$H_2(g) + I_2(g) \rightarrow 2HI(g)$; $\Delta H = +52$ kJ mol.1
When two moles of HI decompose
a. 52 kJ of energy is released.
b. 52 kJ of energy is absorbed.
c. 104 kJ of energy is released.
d. 104 kJ of energy is absorbed
Sol. a. The reaction has a positive ΔH and must therefore absorb energy from the surroundings. The decomposition of 2 mole of HI is the reverse of the reaction provided, so that its ΔH must be negative and energy will be released.

Q.59-60: A galvanic cell is constructed from the following half cells, at 25°C.

	electrode	half cell solution (all concentrations 1.0 M)
half cell 1	silver	colourless solution of $AgNO_3$
half cell 2	copper	blue-coloured solution of $CuCl_2$

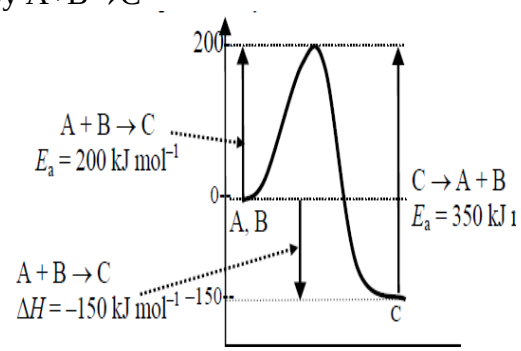
The half cells are connected with a salt bridge and the electrodes are joined by a wire.

Q59. Which one of the following is likely to occur?
a. The copper electrode will increase in mass.
b. Bubbles of gas will form at the copper electrode.
c. The concentration of silver ions in solution will increase.
d. The blue color of the copper (II) chloride solution will become more intense.
Sol. d. The galvanic cell described has the cell reaction
$2Ag^+ + Cu \rightarrow Cu^{2+} + 2Ag$ so that the intensity of the blue color of Cu^{2+} will increase.

Q60. When the current is following:
a. the anode is positive and the cathode is negative.
b. an oxidation reaction occurs at the positive electrode.
c. anions in the salt bridge move towards the negative electrode.
d. electrons travel in the external circuit from the cathode to the anode.
Sol. c. In the cell described, the positive electrode is the cathode and the negative electrode is the anode

(where oxidation is occurring). Thus, at the negative electrode the reaction occurring is $Cu \rightarrow Cu^{2+} + 2e^{-}$ so that the anions must be moving towards this electrode in the same direction as the electrons in the external circuit and, at the same time, maintaining electrical neutrality around the anode where Cu_2^{+} ions are collecting

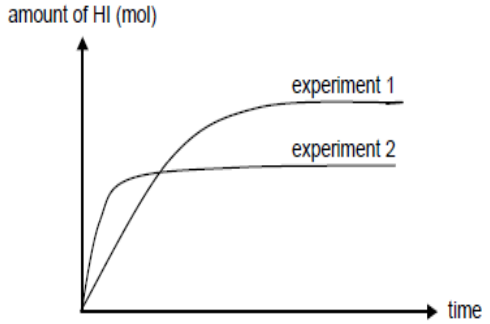
Q61. A chemical reaction has a ΔH of -150kJ mol.1 and the activation energy for its reverse reaction is 350kJ mol.1.
The activation energy, in kJ mol.1, of the forward reaction is
a. +500
b. +200
c. +150
d. -200
Sol. b. Let the reaction be represented by A+B→C



Q62. Hydrogen iodide is produced by the reaction between hydrogen and iodine.

$$H_2(g) + I_2(g)\ 2HI(g)$$

Two experiments were conducted.
Experiment 1: quantities of $H_2(g)$ and I2(g) were placed in a sealed vessel and the reaction allowed to proceed at constant temperature.
Experiment 2: experiment 1 was repeated, but at a different temperature.
The graph below shows the amount of hydrogen iodide produced over the course of experiments 1 and 2.

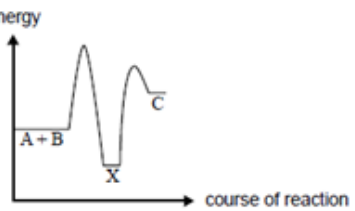


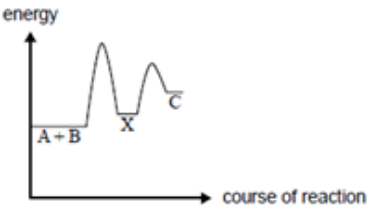
These results show that experiment 2 was conducted at a
a. lower temperature than experiment 1 and the reaction is endothermic.
b. lower temperature than experiment 1 and the reaction is exothermic.
c. higher temperature than experiment 1 and the reaction is endothermic.
d. higher temperature than experiment 1 and the reaction is exothermic.

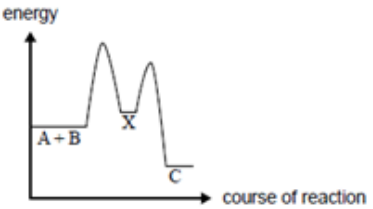
Sol. d. Experiment 2 has a higher initial rate of reaction and so occurs at the higher temperature. Experiment 1 produces more HI by the time equilibrium is established, so the forward reaction is favored at lower temperatures, indicating that the reaction is exothermic.

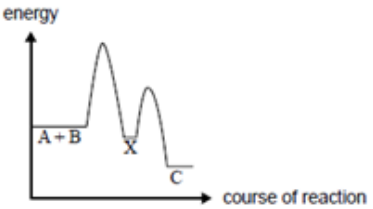
Q63. The reaction:
A + B → C; ΔH negative involves a two-step process:
A + B → X; ΔH positive
X → C; ΔH negative

Which one of the following diagrams best represents the energy changes during the course of the reaction?

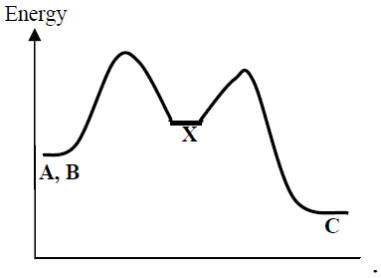
A.


B.


D.


C.


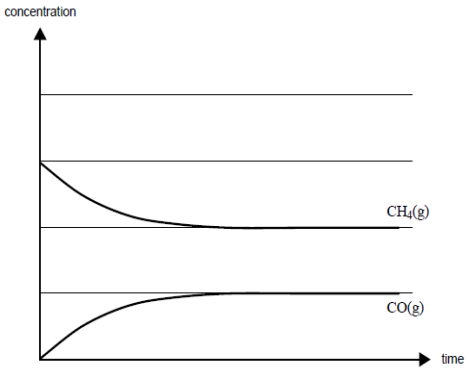
Sol. d. The reaction A + B → C; (ΔH negative) is exothermic, so on an energy profile the product (C) is below the reactants (A, B). The reaction A + B → X; (ΔH positive) is endothermic, so on an energy profile the product (X) is above the reactants (A, B). The reaction X → C; (ΔH negative) is exothermic, so on an energy profile the product (C) is below the reactant (X)



Q64. Carbon monoxide and hydrogen can be produced from the reaction of methane with steam according to the equation:

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$; $\Delta H = +206$ kJ mol.1

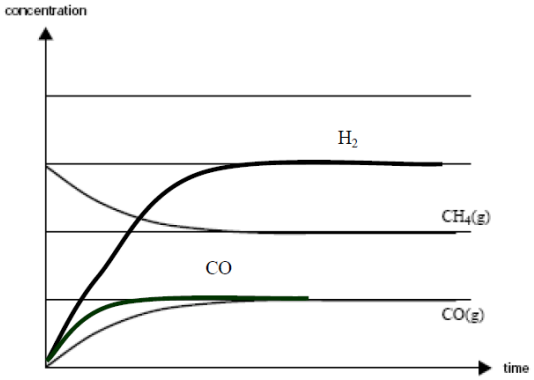
Some methane and steam are placed in a closed container and allowed to react at a fixed temperature. The following graph shows the change in concentration of methane and carbon monoxide as the reaction progresses.



a. i. On the graph above, draw a line to show the change in concentration of hydrogen gas as the reaction progresses.

ii. On the graph above, draw a line to show how the formation of carbon monoxide would differ over time in the presence of a catalyst.

Sol.



b. Great care must be taken when handling carbon monoxide as it is a highly poisonous gas. Even at low concentrations it competes very successfully with oxygen for haemoglobin, the oxygen carrier in the blood. The reactions can be written as:

haemoglobin + oxygen⇌ oxyhaemoglobin; K1

haemoglobin + carbon monoxide⇌ carbon monoxide. haemoglobin; K_2

What does the above information indicate about the magnitude of the equilibrium constant K_1 compared with the magnitude of the equilibrium constant K2?

Sol. K_1 is smaller than K_2 (or $K_1 < K_2$ or $K_2 > K_1$).

c. The rates of chemical reactions may be explained using the collision theory model. Indicate whether the following statements about rates and the collision theory model are true or false by placing ticks in the appropriate boxes.

Statement	True	False
i. Endothermic reactions are always slower than exothermic reactions.		
ii. All particles have the same kinetic energy at a fixed temperature.		
iii. Reactant particles need to collide with sufficient energy to react.		
iv. The rate of a reaction at a constant temperature increases as the reaction proceeds.		
v. Increasing the temperature increases the fraction of collisions with energy above the activation energy.		

Sol.

Statement	True	False
i. Endothermic reactions are always slower than exothermic reactions.		✓
ii. All particles have the same kinetic energy at a fixed temperature.		✓
iii. Reactant particles need to collide with sufficient energy at a fixed temperature.	✓	
iv. The rate of a reaction at a constant temperature increases as the reaction proceeds.		✓
v. Increasing the temperature increases the fraction of collisions with energy above the activation energy.	✓	

Q65. Consider the following half cells which are set up under standard conditions.

half cell	electrode	electrolyte
I	metal A	$A^{2+}(aq)$
II	platinum	$B^{2+}(aq)$ and $B^{3+}(aq)$
III	metal C	$C^{+}(aq)$

- When a galvanic cell is constructed from half cell I and half cell II, the electrode in half cell II is negative.
- When a galvanic cell is constructed from half cell II and half cell III, the electrode in half cell III is negative.

The strongest oxidant is

a. $A^{2+}(aq)$

b. $B^{2+}(aq)$

c. $B^{3+}(aq)$

d. $C^{+}(aq)$

Q66-67. A rechargeable cell, used in laptop computers, contains a metal alloy (designated M) which has hydrogen atoms adsorbed on its surface, and nickel in the form of NiO(OH)(s) and $Ni(OH)_2$(s). The half reactions, written as reduction reactions, are

$H_2O(l) + e. \leftrightarrow H$ (adsorbed on M) + OH.(aq)

$NiO(OH)(s) + H_2O(l) + e. \leftrightarrow Ni(OH)_2(s) + OH.(aq)$

While this cell is generating electricity, the metal alloy acts as the negative electrode.

Q66. When this cell is generating electricity

a. NiO(OH) acts as the oxidant.

b. the concentration of OH. ions in the cell increases as the cell discharges.

c. OH. ions produced at the negative electrode migrate to the positive electrode.

d. electrons flow in the external circuit from the positive to the negative electrode.

Sol. a. Confusion between 'positive' and 'negative' and between 'anode' and 'cathode' is compounded by students not fully understanding the difference between galvanic cells (which generate energy and electricity) and electrolytic cells (in which energy is consumed). Students should have identified at the outset that the NiO(OH) etc. electrode must have been the cathode (because the positive electrode in a galvanic cell is always the cathode at which reduction occurs); therefore the NiO(OH) must have been undergoing reduction (option **a**).

Q67. When the cell is recharged, which one of the following processes occurs at the electrode connected to the positive terminal of the external power source?

a. reduction of $H_2O(l)$

b. reduction of NiO(OH)(s)

c. oxidation of $Ni(OH)_2$(s)

d. oxidation of H (adsorbed on M)

Q68. When the cell is recharged, which one of the following processes occurs at the electrode connected to the positive terminal of the external power source?

a. reduction of $H_2O(l)$

b. reduction of NiO(OH)(s)

c. oxidation of $Ni(OH)_2$(s)

d. oxidation of H (adsorbed on M)

Sol. c. Responses to this item suggest an ongoing need for close attention to understanding of the terms 'oxidation', 'reduction', 'positive', 'negative', 'anode' and 'cathode' when dealing with galvanic and electrolytic cells.

Q69. A fuel cell currently under development for powering small electronic devices is based on the reaction of methanol and oxygen using an acidic electrolyte. The reluctant in the cell reaction and the half reaction at the anode are reluctant anode reaction:

a. methanol $O_2(g) + 4H+(aq) + 4e \rightarrow 2H_2O(l)$

b. oxygen $O_2(g) + 4H+(aq) + 4e \rightarrow 2H_2O(l)$

c. methanol $CH_3OH(g) + H_2O(l) \rightarrow CO_2(g) + 6H+(aq) + 6e$
d. oxygen $CH_3OH(g) + H_2O(l) \rightarrow CO_2(g) + 6H+(aq) + 6e$
Sol. c. Responses to this item suggest an ongoing need for close attention to understanding of the terms 'oxidation', 'reduction', 'positive', 'negative', 'anode' and 'cathode' when dealing with galvanic and electrolytic cells.

Q70-71. A chemist used bomb calorimetry to measure the enthalpy change (ΔH) for the combustion of butane.
Q70. The calibration factor (CF) of the calorimeter was determined by measuring the temperature rise (ΔT1) that occurred when a known amount of charge (Q) was passed through the heating element in the calorimeter at a measured voltage (V).
The CF in J^oC^{-1}, is:

A. $\frac{Q}{V \times \Delta T_1}$ **C.** $V \times Q \times \Delta T_1$

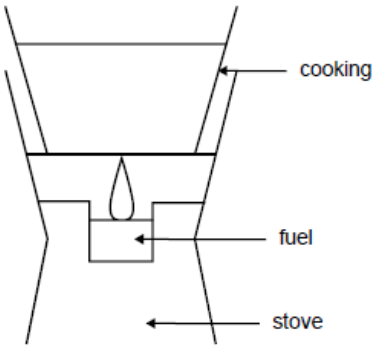
B. $\frac{\Delta T_1}{Q \times V}$ **D.** $\frac{V \times Q}{\Delta T_1}$

Q71. In the calorimeter (calibration factor, CF), n mol of butane was then burnt and the resulting temperature rise (ΔT_2) was measured. The ΔH, in J mol.1, for the reaction:
$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$, Is:

A. $2 \times CF \times \Delta T_2 \times n$ **C.** $\frac{CF \times \Delta T_2}{2 \times n}$

B. $\frac{2 \times CF \times \Delta T_2}{n}$ **D.** $\frac{CF \times \Delta T_2}{n}$

Q72. Ethanol (C_2H_5OH) is a common fuel burnt in some lightweight, compact stoves suitable for use when hiking and camping. A diagram of such a stove is given below.



a. Consider the following information.
- Ethanol burns in excess air according to the following equation:
$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ ΔH = 0.1364 kJ mol.1
- The cooking pot is made from aluminum and has a mass of 150 g.
- The specie c heat capacity of aluminum is 0.900 J g.1°C.1.
- The specip c heat capacity of water is 4.18 J g.1°C.1.

i. Calculate the minimum amount of energy, in kJ, required to heat 550 g of water and the pot from 18.5°C to 100.0°C.
Sol. Energy needed to heat the pot = $550 \times 4.18 \times (100.0 – 18.5) + 150 \times 0.900 \times (100.0 – 18.5) = 198$ kJ
ii. Calculate the mass, in g, of ethanol that needs to be completely burnt to provide this energy.
Sol.

$$\frac{198}{1364} = 0.145 \text{ mol}$$

Mass of ethanol = 0.145×46= 6.67 g

iii. Only 35% of the energy released by the combustion of ethanol is transferred to the cooking pot and contents. Calculate the mass, in g, of ethanol that needs to be burnt in practice to heat the water and the pot from 18.5°C to 100.0°C.

Sol.

$$\frac{6.67}{0.35*} = 19.1 \text{ g}$$

Q73. The rate of a reaction generally increases with temperature. The factor that has the biggest effect on the increase in reaction rate is that with increasing temperature:

a. the activation energy of the reaction increases.

b. the activation energy of the reaction decreases.

c. the number of collisions between particles increases.

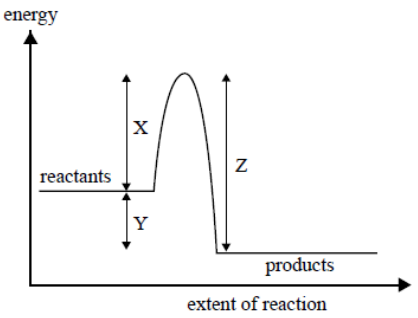
d. the proportion of particles with high kinetic energy increases.

Sol. d. The factor with the 'biggest effect' is the one that is most likely to increase the proportion of collisions with energy greater than the activation energy. This occurs because an increase in temperature increases the kinetic energy of the particles.

Q74–75. The following reaction can occur to completion in aqueous solution.

$CH_3Cl(aq) + OH^-(aq) \rightarrow CH_3OH(aq) + Cl^-(aq)$

The energy change during this process is illustrated by



Q74. A reaction can occur between a CH_3Cl molecule and a hydroxide ion

a. every time they collide.

b. only when they collide with exactly the energy X.

c. only when they collide with an energy equal to Y–Z.

d. only when they collide with an energy greater than or equal to energy X.

Q80. A catalyst appropriate for this reaction will affect the value of:

a. X only.

b. Y only.

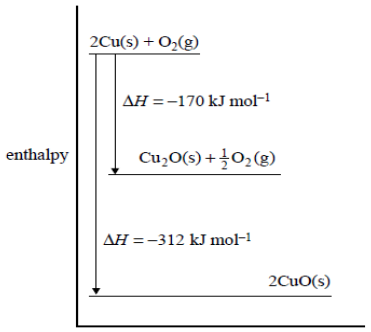
c. X and Z only.

d. X, Y and Z.

Q75. The following energy profile relates to the two reactions:

$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$ $\Delta H = -312$ kJ mol^{-1}

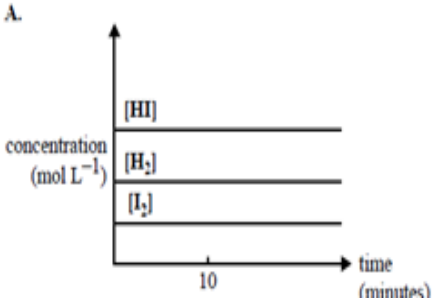
$2Cu(s) + 12\ O_2(g) \rightarrow Cu_2O(s)$ $\Delta H = -170$ kJ mol^{-1}



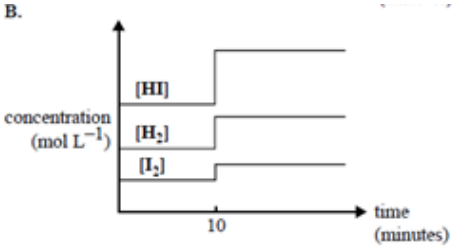
The value of ΔH, in kJ mol^{-1}, for the reaction:
$4CuO(s) \rightarrow 2Cu_2O(s) + O_2(g)$; is:
a. +284
b. +142
c. –142
d. –284
Sol. a. There were three steps in obtaining the required ΔH
1. $Cu_2O(s) + ½O_2(g) \rightarrow 2CuO(s)$; ΔH = -312 – (-170) = -142 kJ mol^{-1}.
2. $2CuO(s) \rightarrow Cu_2O(s) + ½O2(g)$; ΔH = +142 kJ mol^{-1}
3. $4CuO(s) \rightarrow 2Cu_2O(s) + O_2(g)$; ΔH = +284 kJ mol^{-1}

Q76. Hydrogen iodide dissociates into its elements according to the following equation.
$2HI(g)\ H_2(g) + I_2(g)$ ΔH=+9 kJ mol^{-1}
A mixture of H2(g), I2(g) and HI(g) rapidly comes to equilibrium in a 2.0 L container. After the reaction has been at equilibrium for 10 minutes, the volume of the container is suddenly reduced to 1.3 L at constant temperature.
Which one of the following graphs best represents the effect of this decrease in volume on the concentration of the gases in the mixture?

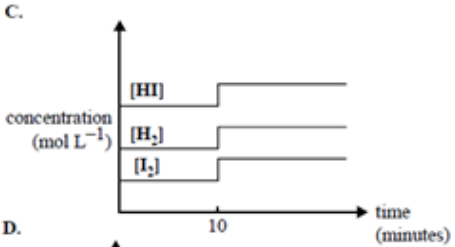
A.



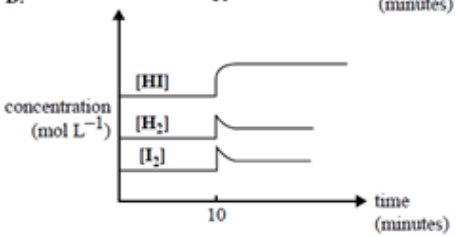
B.



C.



D.



Sol. b. As there are the same number of molecules on both sides of the equilibrium, the decrease in volume (increase in pressure) has no impact on the position of equilibrium. However, because of the volume decrease, all concentrations increase by the same factor (2.0/1.3). This means that the higher the initial concentration (in mol L^{-1}), the greater the actual change in concentration (in mol L^{-1}). Hence the change in concentration is greatest for HI and least for I_2.

Q77. A foam cup calorimeter containing 100 mL of water is calibrated by passing an electric current through a small heater placed in the solution. Assuming that all measurements are accurate, which one of the following is the most likely

calibration factor (in $J°C^{-1}$) for the calorimeter and contents?

a. 120
b. 240
c. 480
d. 960

Sol. c. From the specific heat capacity of water:
– 4.18 J mL^{-1} K^{-1}
– we can deduce that 418 J is required to raise the temperature of 100 ml of water by one degree. However, during calibration, factors such as heat loss from the calorimeter and energy required to also raise the other calorimeter contents by one degree must also be considered. Hence slightly more than 418 J is required to increase the temperature of the calorimeter and its contents by one degree.

Q78. Two experiments are carried out. Both involve the combustion of 2.09 g of ethanol.

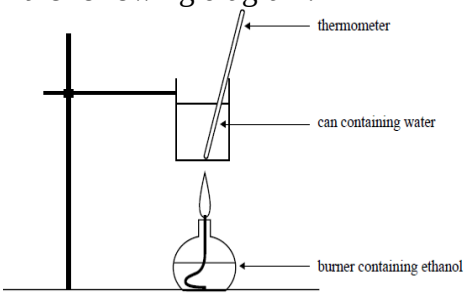
a. Experiment 1

Ethanol is used to calibrate a bomb calorimeter. 2.09g of ethanol is placed in the bomb calorimeter and reacted with excess oxygen. After the reaction is complete, the temperature of the water surrounding the bomb in the calorimeter has increased by 33.2°C**.** Calculate, to an appropriate number of significant figures, the calibration factor of the calorimeter, in $kJ°C^{-1}$.

Sol. $n(CH_3CH_2OH) = 2.09 / 46.0$
$= 0.0454$ mol
Energy released = 0.0454 x 1364
= 62.0 kJ
CF = 62.0/ 33.2 = 1.87

b. Experiment 2

The same mass of ethanol is burnt to heat 200 g of water in a can as shown in the following diagram.



Initial temperature of water in the can: 25.3°C
Mass of water in the can: 200g.
Mass of ethanol burnt: 2.09g.
Calculate the final temperature of the water in the can. Assume that 60% of the heat from the burning ethanol is transferred to the water.

Sol.
E = 0.60 x 62.0
= 37.2 kJ ($37.2x10^3$ J)
E = 4.18 x m(H_2O) x ΔT
ΔT = E / (4.18 x m(H_2O)
ΔT = $37.2x10^3$ / (4.18 x 200)
= 44.5 °C
Final T = 25.3 + 44.5
= 69.8°C

Q79. Dinitrogen tetroxide, $N_2O_4(g)$, dissociates to form nitrogen dioxide, $NO_2(g)$, according to the equation:
$N_2O_4(g) \rightarrow 2NO_2(g)$
0.45 mol of N_2O_4 gas is placed in an empty 1.00 L vessel at 100° C. When the system reaches equilibrium, there is 0.36 mol of NO_2 gas present in the vessel.

a. Calculate the numerical value of the equilibrium constant for this reaction at 100° C.

Sol. $n(NO_2)eqm = 0.36$ mol
$n(N_2O_4)$ reacted = 0.18 ***** mol
$n(N_2O_4)eqm = 0.45 - 0.18$
$= 0.27$ ***** (mol)
$K = 0.362 / 0.27 = 0.48$ *****

b. At 25°C, the numerical value of the equilibrium constant for this reaction is 0.144.
Is this reaction endothermic or exothermic? Give an explanation for your answer.

Sol. K value is lower at the lower temperature/ reverse reaction favoured at lower temperature

Q80. A research chemist is working on developing a catalytic electrode that makes possible the formation of methanol (CH_3OH) in an electrolytic cell using carbon dioxide from the air. The electrode reactions in the electrolytic cell are:
Cathode: $CO_2(g) + 6H^+(aq) + 6e^- \rightarrow CH_3OH(aq) + H_2O(l)$
Anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
The aim of the research is to use electricity generated from a solar cell to produce the methanol. The resulting methanol could then be extracted and used as a fuel by burning it in air.

a. Give:

i. a balanced equation for the complete combustion of methanol with oxygen.

Sol.
$2CH_3OH(l \text{ or } g) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$ / $CH_3OH(l \text{ or } g) + 1½O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

ii. the value in kJ mol–1, and sign, of ΔH for the reaction you have written.

Sol. $\Delta H = -1450$ kJ mol-1/$\Delta H = -725$ kJ mol^{-1}

b. A particular experimental electrolytic cell operates for 24.0 hours at a constant current of 25.5 a.

i. Calculate the amount of electricity, in coulomb, that passes through the cell.

Sol. $Q = 25.5 \times 24 \times 60 \times 60$
$= 2.20 \times 10^6$ * C

ii. Calculate the mass, in grams, of methanol that forms during that time, assuming that all the electricity that passes through the cell is used to produce methanol.

Sol.
$n(e-) = 2.20 \times 10^6 / 96500 = 22.8$ mol
$n(CH_3OH) = 22.8 / 6$
$= 3.81$ mol $m(CH_3OH) = 3.81 \times 32.0 = 122$g

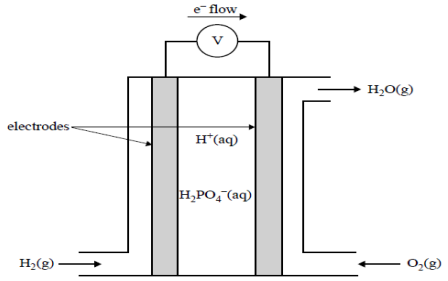
iii. Given that the experimental readings of current, time and mass of methanol obtained are accurate, give one reason why the amount of methanol is lower than predicted.

Sol. Side reactions occur/ loss of methanol by evaporation/methanol escapes from the cell.

c. Predict the overall effect on atmospheric carbon dioxide levels of producing and then using, as an energy source, the methanol generated by this method. Justify your answer.

Sol. No change in total CO_2 levels because the $n(CO_2)$ required to produce 1 mol CH_3OH is the same as the $n(CO_2)$ produced when 1 mol CH_3OH undergoes complete combustion.

Q81. A fuel cell that can provide power for buses is the phosphoric acid fuel cell, PAFC. The electrolyte is concentrated phosphoric acid and the reactants are hydrogen and oxygen gases. A simplified sketch of a phosphoric acid fuel cell is given below.



a. Give the equation for the half reaction that takes place at the:

i. anode of this cell

Sol. $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

ii. cathode of this cell.

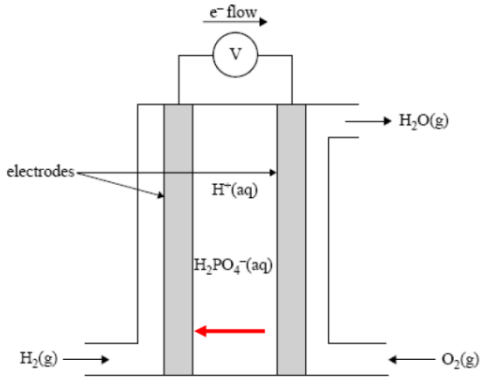
Sol.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

b. On the diagram of the fuel cell, draw an arrow to show the direction in which the H_2PO_4

– ion moves as the cell delivers an electrical current.

Sol.



c. i. A particular cell operates at 0.92 V. How much energy, in kJ, is delivered per mole of hydrogen in this fuel cell?

Sol. $n(e^-) = 2$ mol

$Q = 2 \times 96500$* C

$E = QV = 2 \times 96500 \times 0.92 = 1.78 \times 105$ J $= 1.8 \times 10^2$* (kJ)

ii. By comparing the energy delivered per mole of hydrogen in the fuel cell and the heat of combustion of hydrogen, calculate the energy efficiency of this fuel cell.

Sol. Efficiency= (178/286) x100

= 62.0% 6

d. Describe one advantage and one disadvantage of such a fuel cell compared with a petrol-driven car engine.

Advantage

Disadvantage

Sol.

• advantage: Less energy is lost as heat/less noisy/ more efficient energy conversion/ no CO_2 produced/only product is H_2O*

• disadvantage: Cost/ hydrogen is difficult to produce/store/ distribute*****

Q82. The level of carbon dioxide in the air in a spacecraft can be controlled by passing the air through canisters containing lithium hydroxide, LiOH.

In a laboratory trial, the air in a 5.00 L container at 1.10×10^2kPa and 25.0°C was passed through a canister of LiOH. The pressure of the air in the container decreased to 1.00×10^2 kPa, measured at 25.0°C.

The mass of CO_2 absorbed from the air sample by the LiOH in the canister was:

a. 0.89 g

b. 9.77 g
c. 10.6 g
d. 116 g

Sol. The change in pressure in the container when the air is passed through LiOH is the same as the pressure exerted by the CO_2 in the air, that is, the partial pressure of the CO_2.

$p(CO_2) = 1.10x10^2 – 1.00x10^2$
$= 0.10x10^2 = 10$ kPa

$n(CO_2) = p(CO_2) \times V(container) / RT$
$=10x5.00/ (8.31 \times 298) = 0.0202$ mol
$m(CO_2) = 0.0202 \times 44.0 = 0.89$ g

Option **b** is consistent with using the total pressure in the container, that is, of the air before CO_2 removal, in the calculation.

Q83. The addition of a catalyst to a chemical reaction:

a. lowers the activation energy required for the reaction to occur.
b. lowers the chemical energy of the products.
c. lowers the chemical energy of the reactants.
d. lowers the value of the enthalpy change for the reaction.

Q84. The two statements below give possible explanations for changes that occur when the temperature of a reaction mixture is increased.

I. At a higher temperature, particles move faster and the reactant particles collide more frequently.
II. At a higher temperature, more particles have energy greater than the activation energy.

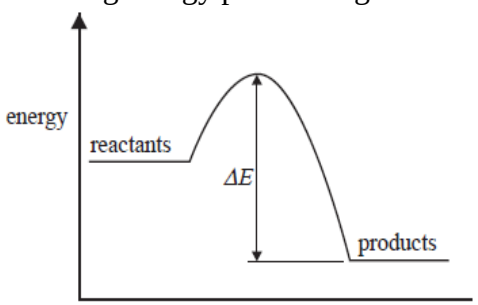
Which alternative below best explains why the observed reaction rate is greater at higher temperatures?

a. I only
b. II only
c. I and II to an equal extent
d. I and II, but II to a greater extent than I

Sol. d. As the temperature increases, so does the kinetic energy of the particles and hence the faster-moving particles collide more frequently. However, 'more frequent collisions' is not the determining factor in increasing the rate of reaction.

Rather it is an increase in 'fruitful collisions', that is, collisions involving particles with energy greater than the activation energy. The increase in the number of particles with energy greater than the activation energy is more significant than the increase in the frequency of collisions between faster-moving particles. Students who chose options **a** and **c** did not make this subtle distinction. While more frequent collisions will occur as the temperature is raised, the rate increase is mainly due to the increased proportion of 'fruitful collisions'.

Q85. The change in energy during a reaction is represented in the following energy profile diagram.



The change in energy labelled ΔE above is:
a. the energy absorbed when bonds in the reactants break.
b. the activation energy of the forward reaction.
c. the activation energy for the reverse reaction.
d. the heat of reaction.

Q86. If, for the reaction:
$C_2H_5OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$; $\Delta H = -1364$ kJ mol^{-1}
then the ΔH value for
$4CO_2(g) + 6H_2O(l) \rightarrow 2C_2H_5OH(g) + 6O_2(g)$, would be:
a. +2728 kJ mol^{-1}
b. +1364 kJ mol^{-1}
c. +682 kJ mol^{-1}
d. –1364 kJ mol^{-1}

Q87. The concentrations of reactants and products were studied for the following reaction.
$H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$; K = 313 at 25°C
In an experiment, the initial concentrations of the gases were
$[H_2] = 0.0200$ M, $[F_2] = 0.0100$ M and [HF] = 0.400 M
When the reaction reaches equilibrium at 25°C, the concentration of HF will be:
a. 0.400 M
b. 0.420 M
c. between 0.400 M and 0.420 M
d. less than 0.400 M
Sol. **d.** To check the direction the reaction is moving in heading towards equilibrium, compare the reaction quotient (Q) with the equilibrium constant.
$Q = [HF]_2 / \{[H_2][F_2]$
$= 0.4002 / \{0.0200 \times 0.0100\} = 800$
Since Q> K (313), the reverse reaction dominates as Q decreases on the way to equilibrium. Hence, [HF] will be < 0.400 M at equilibrium.

Q88. The anaesthetic, nitrous oxide, N_2O, decomposes to form an equilibrium mixture of N_2O, N_2 and O_2 according to the following equation: $2N_2O(g)$ $2N_2(g) + O_2(g)$
At 25°C, $K = 7.3 \times 10^{37}$ M and at 40°C, $K = 2.7 \times 10^{36}$ M
What valid conclusion can be made from this?
a. The equilibrium concentrations of N_2 and O_2 are equal at 25°C.
b. The equilibrium concentration of N_2O is higher at 25°C than at 40°C.
c. N_2O is less stable at the higher temperature.
d. The forward reaction is exothermic.
Sol. d. Since K is lower at the higher temperature, the forward reaction is exothermic. The popularity of option **b** was unexpected given that the K values suggest that if an equilibrium mixture at 25°C is heated to 40°C, the position of equilibrium will shift to the left, giving a higher equilibrium concentration of N_2O at 40°C**.**

Q89. Potassium hydroxide and hydrochloric acid react in aqueous solution according to the following equation.
$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$
A 50 mL solution containing 0.025 mol of KOH was mixed rapidly in an

insulated vessel with a 50 mL solution containing 0.025 mol of HCl. The temperature increased by 3.5°C**.** Assuming that the specific heat capacity of the solution is the same as that of water, the enthalpy change, ΔH, of this reaction, in kJ mol^{-1}, is closest to:

a. –29

b. –59

c. -2.9×10^4

d. -5.9×10^4

Sol. Energy released during the reaction raises the temperature of 100 mL of solution:

E =4.18 Jg^{-1} $°C^{-1}$ x m(solution) x ΔT = 4.18 x 100 x3.5= 1463J =1.463 x 103 kJ.

ΔH is determined from the energy released by one mole of KOH or HCl.

Energy per mole = $1.463x10^3$ kJ/ 0.025 mol = 59 kJ mol^{-1}

Since the reaction is exothermic, ΔH = -59 kJ mol^{-1}.

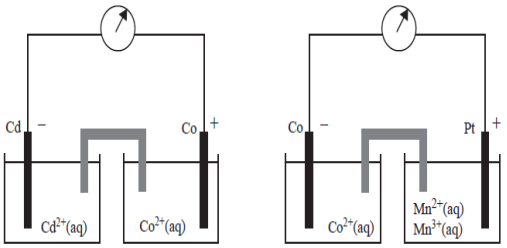
Possible errors leading to the choice of options **a,** **c** or **d** could have included:

• calculating energy released for 50 mL of solution rather than 100 mL – options **a** and **c**.

• dividing the energy released by 0.050 mol rather than 0.025 mol – options **a** and **c**.

• not converting the energy from J to kJ – options **c** and **d**.

Q90. Two standard galvanic cells are shown below.



On the basis of the polarity of the electrodes shown above, which one of the following reactions would not be expected to occur spontaneously?

a. $Co^{2+}(aq) + Cd(s) \rightarrow Co(s) + Cd^{2+}(aq)$

b. $2Mn^{3+}(aq) + Co(s) \rightarrow 2Mn^{2+}(aq) + Co^{2+}(aq)$

c. $2Mn^{3+}(aq) + Cd(s) \rightarrow 2Mn^{2+}(aq) + Cd^{2+}(aq)$

d. $2Mn^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Mn^{3+}(aq) + Co(s)$

Sol.

Since electrons move spontaneously from the strongest reductant to the strongest oxidant, then, according to the electrode signs, $Co^{2+}(aq)$ is a stronger oxidant than $Cd^{2+}(aq)$ and $Mn^{3+}(aq)$ is a stronger oxidant than $Co^{2+}(aq)$. Hence, on the electrochemical series $Mn^{3+}(aq)$ is above $Co^{2}+(aq)$, which is above $Cd^{2+}(aq)$.

$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$

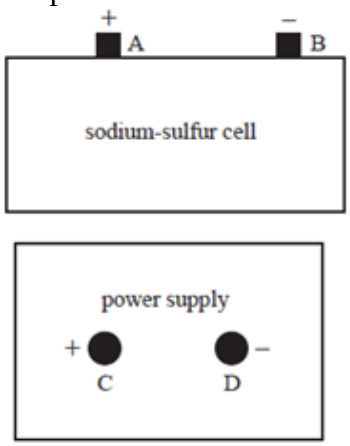
$Co^{2+}(aq) + 2e \rightleftharpoons Co(s)$

$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$

$Mn^{2+}(aq)$ will not react spontaneously with $Co^{2+}(aq)$ because the reductant $Mn^{2+}(aq)$ is higher on the electrochemical series than the oxidant $Co^{2+}(aq)$.

Q91. The sodium-sulfur cell shown below is a secondary galvanic cell with the overall cell reaction:

$2Na(l) + S(l)\ Na_2S(l)$
The cell produces 2.1 volts.

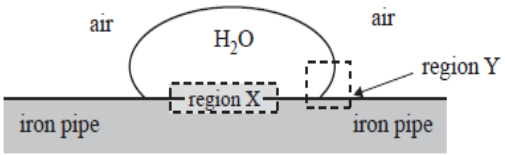


The cell is to be recharged by connecting it to the power supply.
Which one of the following best describes the arrangement for recharging the cell?

	Power supply voltage	Connect terminals
a.	2.1 volts	A to C and B to D
b.	2.1 volts	A to D and B to C
c.	more than 2.1 volts	A to C and B to D.
d.	more than 2.1 volts	A to D and B to C.

Sol. d. The fundamental rule of recharging is that the positive terminal of the power supply is connected to the positive electrode of the cell (and negative terminal to negative electrode) and a voltage greater than the discharge voltage of the cell is applied. It was surprising that many students did not choose a (+) to (+) and (-) to (-) option.

Q92–93. Iron pipes are used to transport natural gas to cities. Corrosion occurs when water droplets sit on the outer surface of the iron pipe. Miniature galvanic cells are created, with regions such as those shown below, that act as anodes and cathodes.



Q92. The type of region and reaction occurring at X in the cell is:
Region Reaction
a. anode $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
b. cathode $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
c. anode $O_2(g) + 2H2O(l) + 4e^- \rightarrow 4OH^-(aq)$
d. cathode $O_2(g) + 2H2O(l) + 4e^- \rightarrow 4OH^-(aq)$
Sol. a. X: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
Oxidation at the anode.
Y: $O_2(g)+2H_2O(l) +2e^- \rightarrow 4OH\text{-}(aq)$
Reduction at the cathode.

Q93. Corrosion of an iron pipe can be prevented by connecting it to a magnesium bar buried in the ground. The magnesium corrodes in preference to the iron.
If the average current flowing between the two metals is 2.0×10^{-6} A, the amount of magnesium metal, in mol, reacting each second, would be:
a. 1.0×10^{-11}
b. 2.1×10^{-11}
c. 4.1×10^{-11}
d. 0.19
Sol. a. $Mg(s) \rightarrow Mg2+(aq) + 2e\text{-}$
$Q = It = 2.0x10^{-6} \times 1 = 2.0x10^{-6}$ C
$n(e\text{-}) = Q/F = 2.0x10^{-6} / 96500 = 2.07x10^{-11}$ mol

n(Mg) = ½ x $2.07x10^{-11}$ = $1.0x10^{-11}$ mol

Options **b** and **c** are consistent with mole ratio errors in determining the n(Mg) from the n(e-).

Q94-95: A fuel cells can be constructed that uses the following two half-reactions.

$CO_2(g) + 6H+(aq) + 6e^-$ $CH_3OH(aq) + H_2O(l)$ E_o = + 0.05 V

$O_2(g) + 4H^+(aq) + 4e^-$ $2H_2O(l)$ E_o = +1.23 V

Q94. Which one of the following would occur at the negative electrode of the cell as it generates electricity?

a. production of H+

b. formation of H_2O

c. consumption of CO_2

d. reduction of CH_3OH

Sol. CH_3OH is the fuel and O_2 is the oxidant. The fuel is oxidised at the negative electrode, according to the half equation:

$CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H+(aq) + 6e^-$.

O_2 is reduced at the (+) electrode.

Q95. Which one of the following statements about this fuel cell is most likely to be correct?

a. An external power supply is used to recharge the cell.

b. Gaseous products are recycled into the cell to improve efficiency.

c. Chemical energy is not completely converted into electrical energy.

d. More H+ ions are produced at the anode than are consumed at the cathode.

Sol. c. Fuel cells are not 100 per cent efficient in the conversion of chemical energy to electrical energy. Some chemical energy is converted into thermal energy.

This equation proved more challenging for students than expected. Students should be aware that, while fuel cells are more efficient in the conversion of chemical energy to thermal energy than using the same fuel in a power station, they are not 100 per cent efficient.

Q96. Which one of the following describes the polarity of the anodes in electrolytic and galvanic cells?

	electrolytic cells	**galvanic cells**
a.	positive	positive
b.	positive	negative
c.	negative	negative
d.	negative	positive

Q97. An aqueous solution containing a mixture of 1.0 M KI and 1.0 M $CaBr_2$ was electrolysed using unreactive electrodes.

Which one of the following reactions is most likely to occur at the anode?

a. $2H_2O(l)+2e^- \rightarrow H_2(g) + 2OH–(aq)$

b. $2Br–(aq) \rightarrow Br_2(aq) + 2e^-$

c. $Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$

d. $2I^-(aq) \rightarrow I_2(aq) + 2e^-$

Sol. d. Species present in the mixture: $K^+(aq)$, $I^-(aq)$, $Ca^{2+}(aq)$, $Br^-(aq)$, $H_2O(l)$ On the basis of the electrochemical species:

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

$Br_2(l) + 2e^- \rightarrow 2Br-(aq)$

$I2(aq) + 2e^- \rightarrow 2I-(aq)$

$2H_2O(l) + 2e- \rightarrow H_2(g) + 2OH^-(aq)$

$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$
$K^+(aq) + e^- \rightarrow K(s)$
The strongest reductant present in the mixture, $I^-(aq)$, is oxidised at the anode according to
$2I^-(aq) \rightarrow I_2(aq) + 2e^-$.

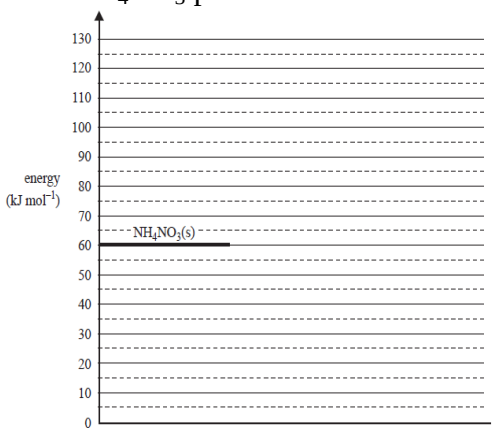
Q98. Lithium metal is manufactured by electrolysis of lithium salts. Which of the following would be the best choice for the electrolyte and the anode in a commercial cell?

Electrolyte	**anode**
a. LiCl solution	iron rod
b. molten LiCl	iron rod
c. LiCl solution	carbon rod
d. molten LiCl	carbon rod

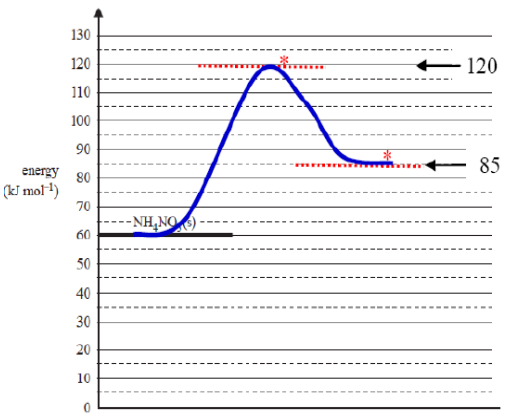
Sol. d.
$Cl_2(g) + 2e- \rightarrow 2Cl-(aq)$
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH-(aq)$
$Li^+(aq) + e^- \rightarrow Li(s)$
The electrochemical series indicates that an aqueous solution cannot be used because H_2O is a stronger oxidant than Li+ and would be preferentially reduced at the cathode. An Fe rod cannot be used as the anode because Fe is a stronger reluctant than Cl^- and would be preferentially oxidised.

Q99. A 'QwikCure' pack, used to treat sporting injuries, contains a bag of water inside a larger bag of finely powdered ammonium nitrate, NH_4NO_3. Squeezing the pack causes the bag of water to break and the NH_4NO_3 to dissolve. The change of energy that occurs can be used to treat an injury.

$NH_4NO_3(s) \rightarrow NH_4NO_3(aq)$;
$NH = +25$ kJ mol^{-1}
a. Suppose the activation energy of the reverse reaction is 35 kJ mol^{-1}.
i. Explain the meaning of the term 'activation energy'.
Sol. Acceptable responses included:
• minimum amount of energy needed for reaction to occur
• minimum amount of energy colliding particles must have for reaction
• minimum amount of energy needed to break bonds in reactants.
ii. On the graph below, sketch an energy profile diagram showing the changes that occur in chemical energy as the NH_4NO_3 powder dissolves.



Sol.



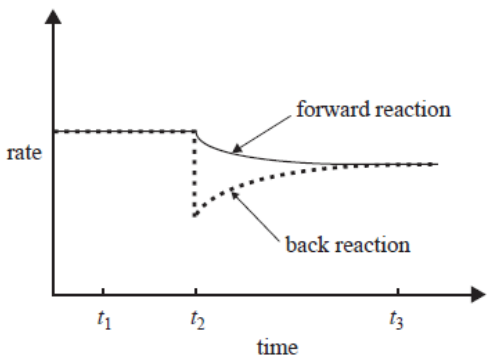
In this equation the accurate use of the activation energy proved challenging for students, with the most common error being using 35 kJ mol^{-1} as the activation energy of the forward reaction. Endothermic profiles were relatively common, suggesting that students focused on the 'reverse' reaction, despite $NH_4NO_3(s)$ being the reactant on the profile.

b. A chemist investigates the equilibrium reaction of ammonium ions with water. In this reaction the ammonium ion acts as a weak acid.

i. Write an equation for the equilibrium reaction of ammonium ions with water.

Sol. $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$*****

While keeping the temperature constant, the chemist makes a change to a solution of ammonium ions in water that is initially at equilibrium. The following graph shows the effect of this change, which was made at time t_2, on the rates of the forward and back reactions.



ii. What could have caused the change that occurred at time t_2? Explain why the rate of the back reaction is affected by this change.

Sol. The most likely change at t_2 was a decrease in product concentration. Removal of NH_3 or removal of H_3O^+ was also acceptable.

The rate of reverse reaction decreases due to a drop in product concentration/ number of collisions, and then increases (and the rate of the forward reaction decreases) as the system returns to equilibrium.

iii. Would the value of the equilibrium constant at time t_3 be less than, equal to or greater than the value of the equilibrium constant at time t_1? Circle the correct response. less than equal to greater than

Sol. Equal to:

A significant number of students suggested that the equilibrium constant would change, seemingly ignoring the constant temperature highlighted in the equation.

c. The NH_4NO_3 powder in a QwikCure pack dissolves completely to form 300 mL of solution, with a pH of 5.04.

i. Write an expression for the acidity constant, Ka, for the reaction between ammonium ions and water.

Sol. Any one of:

- $Ka = [H_3O^+][NH_3] / [NH4^+]$
- $Ka = [H+][NH_3] / [NH4^+]$
- $[H_3O^+][NH_3] / [NH4^+] = 5.6x10^{-10}$.

ii. Calculate the concentration, in mol L^{-1}, of H_3O+ ions in the 300 mL of solution.

Sol. $[H_3O^+]=10^{-5}.04=9.1x10^{-6}$ mol L^{-1}

iii. Calculate the mass, in grams, of NH_4NO_3 in the pack.

Sol. $5.6x10^{-10} = (9.1x10^{-6})^2 / [NH4^+]$*
$[NH4^+] = (9.1x10^{-6})^2 / 5.6x10^{-10} = 0.148$ M
$n(NH_4NO_3) = n(NH4^+)$
$= 0.148 \times 300x10^{-3} = 0.0444$ mol
$m(NH_4NO_3) = 0.0444 \times 80.0 = 3.6$g

Q100. Dimethyl ether, CH_3OCH_3, is used as an environmentally friendly propellant in spray cans. It can be synthesized from methanol according to the following equation.
$2CH_3OH(g)$ $CH_3OCH_3(g) + H_2O(g)$; $\Delta H = -24$ kJ mol–1
The equilibrium constant, K, for this reaction at 350°C is 5.74.
a. Write an expression for K for this reaction.
Sol. Any one of:
• $K = [CH_3OCH_3][H_2O] / [CH_3OH]_2$
• $5.74 = [CH_3OCH_3][H_2O] / [CH_3OH]_2$
• $[CH_3OCH_3][H_2O] / [CH_3OH]_2$.
b. Calculate the value of K at 350°C for the following reaction.
$CH_3OCH_3(g) + H_2O(g)$ $2CH_3OH(g)$
Sol.
$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g)$; K = 5.74
$CH_3OCH_3(g) + H_2O(g) \leftrightarrow 2CH_3OH(g)$;
K = 1 / 5.74 = 0.174
c. Methanol is pumped into an empty 20.0 L reactor vessel. At equilibrium the vessel contains 0.340 mol of methanol at 350°C**.**
i. Calculate the concentration, in mol L^{-1}, of methanol at equilibrium.
Sol. $[CH_3OH] = 0.340 / 20.0$
$= 0.0170$ (M)
ii. Calculate the amount, in mol, of dimethyl ether present at equilibrium.
Sol. $[CH_3OCH_3] = [H_2O]$
$5.74 = [CH_3OCH_3]^2 / (0.0170)^2$
$[CH_3OCH_3]^2 = 5.74 \times (0.0170)^2$
$[CH_3OCH_3] = \sqrt{5.74 \times (0.0170)^2}$ *
$= 0.0407$ M
$n(CH_3OCH_3) = 0.0407 \times 20.0$
$= 0.815$ (mol)
iii. Calculate the amount, in mol, of methanol initially pumped into the reaction vessel.
Sol. $n(CH_3OH)$ reacted $= 2 \times n(CH_3OCH_3)$
$= 2 \times 0.815* = 1.630$ (mol)
$n(CH_3OH)$ at eqm = 0.340 mol
$n(CH_3OH)$ initially = 1.630 + 0.340
= 1.970 (mol)

Q101. Methyl palmitate, $C1_7H_{34}O_2$, is a component of one type of biochemical fuel. It is a liquid at room temperature.
The molar enthalpy of combustion of methyl palmitate was determined using a bomb calorimeter.
The calorimeter was calibrated by passing a current of 4.40 amperes at a potential difference of 5.61 volts through an electric heater for 240 seconds. The temperature of the calorimeter rose by 1.75°C**.**
a. Calculate the calibration factor of the calorimeter. Include the units of the calibration factor with your answer.
Sol. CF = VIt/ΔT
$= 5.61 \times 4.40 \times 240/1.75$
$= 3.39x10^3$ J°C^{-1}
or $3.39x10^3$ J K^{-1}
or 3.39 kJ°C^{-1} or 3.39 kJ K^{-1}
A 0.529 g sample of methyl palmitate was then burned in excess oxygen in

the calorimeter and the temperature rose by a further 6.19°**c.** The molar mass of methyl palmitate is 270 g mol^{-1}.

b. Calculate the amount of energy, in kJ, absorbed by the calorimeter when the sample of methyl palmitate was burned.

Sol. E = 3.39 x 6.19 = 21.0 (kJ)

c. Calculate the amount of energy released, in kJ, by the combustion of 1.00 mol of methyl palmitate.

Sol.

n(methyl palmitate) = 0.529 / 270

= $1.96x10^{-3}$ (mol)

Energy per mol = 21.0 / $1.96x10^{-3}$

= $1.07x10^{4}$* (kJ)

d. The balanced equation for the combustion of liquid methyl palmitate in excess oxygen is

$2C_{17}H_{34}O_2(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(l)$.

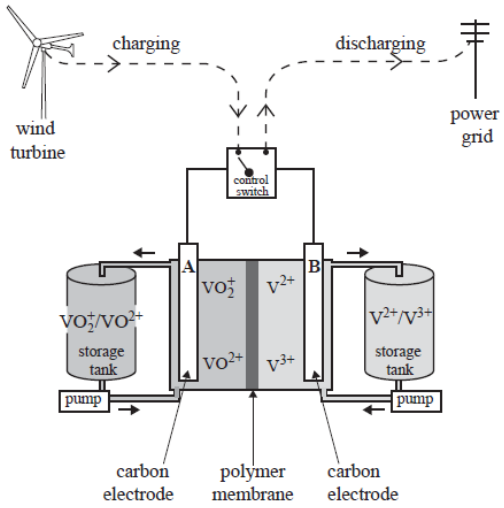
Write the value of ΔH for this reaction, in kJ mol^{-1}.

Sol. ΔH = (-) $1.07x10^{4}$ x 2

= -2.14x104 (kJ mol^{-1})

Q102. A vanadium redox battery is used to store electrical energy generated at a wind farm in Tasmania. The battery supplies electricity to the power grid as required through a control switch.

The diagram below shows the structure of a cell in a vanadium redox battery. The reactants are dissolved in an acidic solution, stored in large tanks and pumped through the cell. The cell is recharged using electricity generated by the wind turbines. A polymer membrane allows the movement of particular ions.



The two relevant half-equations for the vanadium redox battery are

$VO^{2+}(aq) + 2H^+(aq) + e^-$ $VO^{2+}(aq) + H_2O(l)$ Eo = +1.004 V

$V^{3+}(aq) + e^-$ $V^{2+}(aq)$ Eo = – 0.255 V

a. State the polarity of each electrode as the battery is discharged.

Electrode A

Electrode B

Sol.

Electrode A – positive/(+)

Electrode B – negative/(-)*

b. Circle the vanadium-containing ion that would have the highest concentration at the anode when the cell is fully charged.

VO^{2+} VO^{2+} V^{3+} V^{2+}

Sol.

VO_2^+* VO^{2+} V^{3+} V^{2+}

c. Write a balanced overall equation for the reaction that occurs when the cell is being recharged.

Sol.
$VO^{2+}(aq) + H_2O(l) + V^{3+}(aq) \rightarrow VO^{2+}(aq) + V^{2+}(aq) + 2H^+(aq)$*****
The discharge equation was prevalent in responses to this equation:

d. Compare the vanadium redox cell to a fuel cell by describing **one** major way in which they differ.

Sol. Acceptable responses included:
• fuel cells are not rechargeable
• fuel cells needs continuous supply of reactants
• fuels in fuel cells are molecular, not ionic
• products of fuel cells are not recycled
• some fuel cells produce CO_2
• fuel cell electrodes are porous.

e. Write a balanced overall equation to show why iron would be an unsuitable material to use as electrode B in the vanadium redox cell.

Sol. One of:
• $2V^{3+}(aq) + Fe(s) \rightarrow 2V^{2+}(aq) + Fe^{2+}(aq)$
• $2VO_2$ +(aq) + $4H^+(aq) + Fe(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Fe^{2+}(aq)$
• $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$.
The three equations accepted were based on the possibilities of:
• Fe(s) being oxidised by $V^{3+}(aq)$ in the $V^{3+}(aq)/V^{2+}(aq)$ half-cell.
• Fe(s) being oxidised by $H^+(aq)$ in the half-cell.

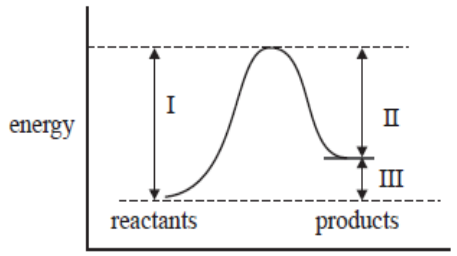
Q103. One possible reaction that occurs when trinitrotoluene (TNT), $C_7H_5N_3O_6$, explodes is:
$2C_7H_5N_3O_6(s) \rightarrow 2C(s) + 12CO(g) + 5H_2(g) + 3N_2(g)$

When one mole of TNT explodes the total volume of the gases produced from this reaction, measured at 27 °C and 1.00×10^2 kPa, is closest to:
a. 0.249 L
b. 22.7 L
c. 249 L
d. 274 L

Sol. c. According to the equation, the explosion of 2 mol of $C_7H_5N_3O_6$ produces 20 mol of gaseous products (12 mol CO + 5 mol H_2 + 3 mol N_2).
Hence 1 mol $C_7H_5N_3O_6 \rightarrow$ 10 mol gases.
V(gas) = n(gas) x RT / p
= 10 x 8.31 x (27+273) / $1.00x10^2$
= 249 L

Q104. For an endothermic reaction
a. the enthalpy change is negative.
b. equilibrium can never be achieved.
c. the reaction absorbs energy from its surroundings.
d. the enthalpy of the reactants is higher than the enthalpy of the products.

Q105. For a gas phase reaction, which of the quantities (I, II and III) in the energy profile diagram above are affected by decreasing the volume of the reaction vessel at constant temperature?



a. I and II only

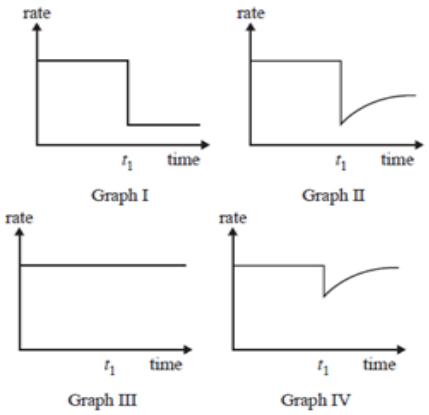
b. I and III only
c. I, II and III
d. none of the quantities
Sol. d. Decreasing the volume of a vessel in which a gas phase reaction is occurring will increase the rate of the reaction because the partial pressures and concentrations of the reactants increase, thus increasing the frequency of fruitful collisions. However, this has no effect on the activation energy (I), energy released when product bonds are formed (II) or the ΔH for the reaction.

Q106-107. Reactants A and B are placed in a sealed container with a suitable catalyst where they react according to the equation:

$$A(g) + B(g) \; C(g)$$

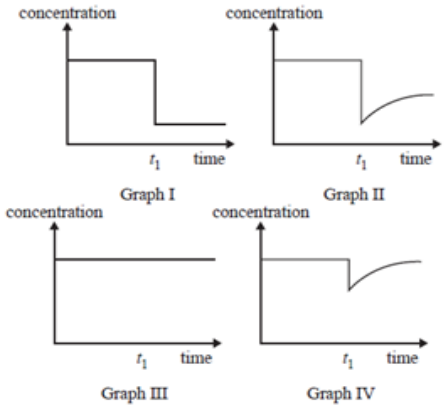
After the reaction reaches equilibrium, a small amount of a compound is added to the container at time t_1.
The compound 'poisons' the catalyst and stops it working.

Q106. Which one of the graphs best represents the rate of the forward reaction versus time?



a. Graph I
b. Graph II
c. Graph III
d. Graph IV
Sol. a. Once the reaction has reached equilibrium, the forward reaction proceeds at a constant rate – the same rate as the reverse reaction. The addition of a compound that poisons the catalyst and stops it from working will increase the activation energy but does not push the system out of equilibrium. So the rate of the forward reaction (and reverse reaction) drops to a lower constant value. Option **b** implied that the rate of the forward reaction decreases then increases. This could only apply if there was an increase in reactant concentration or temperature, which is not consistent with the system being at equilibrium.

Q107. Which one of the graphs best represents the concentration of product C versus time?



a. Graph I
b. Graph II
c. Graph III
d. Graph IV

Sol. c. Because the system was at equilibrium when the catalyst stopped working, the concentrations of A, B and C were all constant. Although the rates of the forward and reverse reactions decrease, they remain equal and at the same value as they were immediately before the catalyst stopped working, because the system is not pushed out of equilibrium.

Q108. Nitrosyl chloride (NOCl) is a highly toxic gas that decomposes according to the equation:

$$2NOCl(g) \leftrightarrow 2NO(g) + Cl_2(g)$$

To investigate the reaction, 1.2 mol of NOCl(g) is placed in an empty 1.0 L flask and allowed to reach equilibrium. The flask and its contents are kept at a constant temperature. If $[Cl_2]$ = 0.20 M at equilibrium, what is the equilibrium concentration of NOCl(g)?

a. 0.80 M
b. 1.00 M
c. 1.10 M
d. 1.40 M

Sol. a. $2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$
Initially 1.2 M
Reacting 0.40 M → 0.40 M 0.20 M
Equilibrium 0.80M 0.40M 0.20M
The 0.20 mol Cl_2 present in the 1.0 L flask at equilibrium was produced by the reaction of 0.40 mol NOCl, leaving 0.80 mol NOCl at equilibrium.

Q109. The following reaction systems are at equilibrium in separate sealed containers. The volumes of the containers are halved at constant temperature.

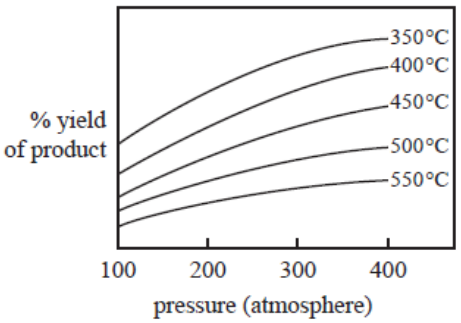
Which reaction has the largest percentage change in the concentration fraction (reaction quotient) immediately after the volume change?

A. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$
B. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
C. $2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$
D. $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

Sol. When volumes of the containers halve, all concentrations double.
a. $N_2O4(g) \leftrightarrow 2NO_2(g)$
Concentration Fraction (CF) = $[NO_2]_2/ [N_2O_4]$
Initially:
$[NO_2] = x$, $[N_2O_4] = y$
After V change: $[NO_2]=2x$, $[N_2O_4]=2y$
CF changes from x2/y to (2x2)/2y, i.e. 2x2/y CF increases by a factor of 2, i.e. by 100 %
b. $H2(g) + I2(g) \rightleftharpoons 2HI(g)$
$CF = [HI]_2 / [H_2][I_2]$ Because there is the same number of particles on both sides of the reaction, the CF is not affected by changes in volume.
c. $2CO_2(g) \rightleftharpoons 2CO(g) + O_2(g)$
$CF = [CO]_2[O_2] / [CO_2]^2$
Initially: $[CO_2] = x$, $[CO] = y$, $[O_2]= z$
After V change: $[CO_2] = 2x$, $[CO]= 2y$, $[O_2] = 2z$
CF changes from y2z/x to (2y)2x2z/(2x2), i.e. 2y2z/x CF increases by a factor of 2 – that is, by 100 %
d. $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$
$CF = [CH_3OH] / [CO][H_2]_2$
Initially: $[CO] = x$, $[H_2] = y$, $[CH_3OH] = z$
After V change: $[CO] = 2x$, $[H_2] = 2y$, $[CH_3OH] = 2z$
CF changes from z/xy2 to 2z/2x(2y2) – that is, z/4xy2

CF decreases by a factor of 4 – that is, by 75 %

Q110-111. The graph below refers to the following gaseous reaction.
aA(g) + bB(g) cC(g) + dD(g)
The effect of increasing pressure and temperature on the equilibrium yield of the products is shown in the graph below.



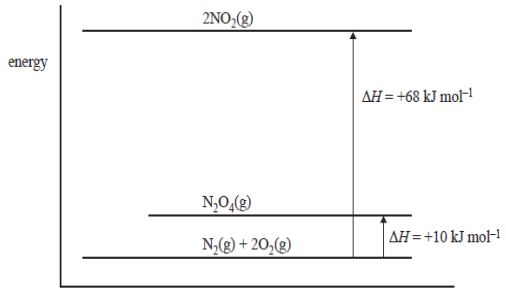
Q110 Which one of the following statements about the relative number of reactant and product molecules in the balanced equation is true?
a. The number of reactant molecules is equal to the number of product molecules.
b. The number of reactant molecules is greater than the number of product molecules.
c. The number of reactant molecules is less than the number of product molecules.
d. The relative number of reactant and product molecules cannot be determined from the data provided.
Sol. b.
The graph indicated that the % yield:
• increases as the pressure increases
• increases as the temperature decreases.
An equilibrium system responds to increased pressure by favouring the reaction that forms fewer particles. Since the % yield increases as the pressure increases, there will be fewer particles on the product side of the equilibrium/more particles on the reactant side of the equilibrium.

Q111. Which one of the following statements about this gaseous reaction is true?
a. The reaction is exothermic because the yield increases as the temperature increases.
b. The reaction is endothermic because the yield increases as the temperature increases.
c. The reaction is exothermic because the yield decreases as the temperature increases.
d. The reaction is endothermic because the yield decreases as the temperature increases.
Sol. c. Since the % yield increases as the temperature decreases, the forward reaction is exothermic.

Q112. Magnesium metal burns in air with an intense bright light according to the equation:
$2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)\ \Delta H = -1200\ kJ\ mol^{-1}$
How much energy is released when 7.29 g of magnesium is burned?
a. 8 kJ
b. 16 kJ
c. 180 kJ
d. 360 kJ
Sol. c. n(Mg) = 7.29/24.3
Energy released = (7.29/24.3) x (1200/2) = 180 kJ

Q113. The combustion of ethanol occurs according to the equation
$C_2H_5OH(1) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ $\Delta H = -1364$ kJ mol^{-1}
This means that
a. burning 1.0 g of liquid ethanol produces 1364 kJ of energy.
b. two moles of liquid ethanol burns to produce 2728 kJ of energy.
c. 1364 kJ of energy is produced when one mole of gaseous ethanol is burned.
d. the activation energy for the combustion of one mole of liquid ethanol is 1364 kJ.

Q114. The energy diagram below relates to the following two reactions.
$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = +68$ kJ mol^{-1}
$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ $\Delta H = +10$ kJ mol^{-1}



The enthalpy change for the reaction $NO_2(g) \rightarrow 1/2\ N_2O_4(g)$ will be
a. +58 kJ mol^{-1}
b. +29 kJ mol^{-1}
c. –58 kJ mol^{-1}
d. –29 kJ mol^{-1}
Sol. d. The energy profile showed that 58 kJ of energy was absorbed when 1 mol $N_2O_4(g)$ is converted to 2 mol $NO_2(g)$.
i.e. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = +58$ kJ mol^{-1}
$2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -58$ kJ mol^{-1}
$NO2(g) \rightleftharpoons \frac{1}{2}NO2(g)$ $\Delta H = -29$ kJ mol^{-1}

Q115. A direct electric current is passed through 1.0 M K_2SO_4 solution using inert electrodes. The following standard reduction potential is provided in addition to those in the References.
$S_2O_8^{2-}(aq) + 2e^- \rightleftharpoons 2SO_4^{2-}(aq)$
$E_o = 2.01$ V
Which one of the following equations represents the reaction that occurs at the anode?
a. $2SO_4^{2-}(aq) \rightleftharpoons S2O_8^{2-}(aq) + 2e^-$
b. $2H_2O(l) \rightleftharpoons O2(g) + 4H^+ + 4e^-$
c. $2H_2O(l) + 2e- \rightleftharpoons H_2(g) + 2OH^-(aq)$
d. $K^+(aq) + e^- \rightleftharpoons K(s)$
Sol. b. Species present in the solution prior to electrolysis:
K+(aq), SO4 2-(aq), $H_2O(l)$
On the basis of the electrochemical series:
$S_2O_8^{2-}(aq) + 2e- \rightleftharpoons 2SO_4^{2-}(aq)$
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$
$K+(aq) + e^- \rightleftharpoons K(s)$
The strongest reductant present in the solution – $H_2O(l)$ – is oxidised at the anode according to:
$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$.

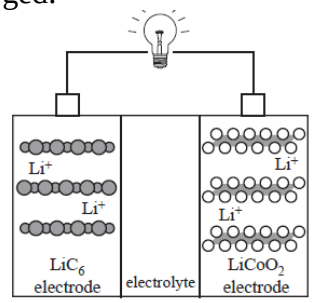
Q116. Which one of the following statements is true for both fuel cells and rechargeable cells?
a. All reactants are stored within the cell.
b. Reaction products are continuously removed from the cell.

c. Electrons pass from the reductant to the anode as electricity is produced.
d. Electrical energy is converted to chemical energy as the cell is recharged.
Sol. Students may have answered this equation via the elimination of alternatives. Option **a** was incorrect because reactants are not stored in a fuel cell; option **b** was incorrect because products of discharge must remain at the electrodes for cells to be rechargeable; and option **d** was incorrect because fuel cells are not recharged.
Students who did not choose option **c** may have been familiar with the 'electrons pass from the anode to cathode' principle of electron movement in an electrochemical cell, but may not have thought about the wording of the option. Before electrons can pass from the anode to the cathode through the external circuit of an electrochemical cell they must first be released onto the anode in an oxidation halfequation. Since the reductant is oxidised at the anode, the statement 'electrons pass from the reductant to the anode as electricity is produced' (option **c**) is accurate for electrochemical cells.

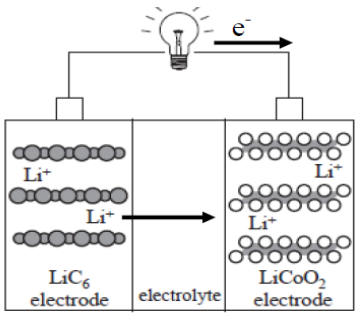
Q117. The lithium button cell, used to power watches and calculators, is a primary cell containing lithium metal. The lithium ion cell is a secondary cell that is used to power laptop computers.
a. What is the difference between a primary and secondary cell?
Sol. Acceptable reponses included:
• a primary cell cannot be recharged
• a secondary cell can be recharged
• in a primary cell, the products of the discharge move away from the electrodes.
b. By referring to information provided in the References, give one reason why lithium is used as a reactant in these galvanic cells.
Sol. Acceptable responses included:
• lithium is a strong reductant.
• Li+(aq)/ Li(s) has the lowest E_o.
• lithium is more readily oxidised that other reductants.
• lithium cells produce higher voltages.
• lithium has a low molar mass.
Some early lithium metal batteries exploded when exposed to water.
c. Write a balanced equation, including states, for the reaction between lithium metal and water to explain why an explosion might occur.
Sol. Two marks were awarded for a correctly balanced equation (one of):
• $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$
• $2Li(s) + 2H_2O(l) \rightarrow 2Li^+(aq) + 2OH\text{-}(aq) + H_2(g)$
• $Li(s) + H_2O(l) \rightarrow Li^+(aq) + OH^-(aq) + ½H_2(g)$.
Acceptable responses for the third mark included:
• $H_2(g)$ is flammable and may be ignited by an electric spark, causing the battery to explode
• a build up of pressure in the battery due to the production of $H_2(g)$ causes it to explode.

In lithium ion cells, lithium ions move between the electrodes as the cell is discharged and recharged. The negative
electrode consists of lithiated graphite, LiC_6, and the positive electrode consists of lithium cobalt oxide, $LiCoO_2$.
The chemical reactions that take place in the lithium ion cell are complex. The following equations present a simplified description of the reactions that occur at the electrodes as the cell is recharged.
positive electrode $LiCoO_2 \rightarrow CoO_2 + Li^+ + e^-$
negative electrode $6C + Li^+ + e^- \rightarrow LiC_6$

d. On the diagram below, use arrows to indicate the directions of movement of electrons, e^-, and Li^+ ions as the lithium ion cell is discharged.



Sol.



Lithium metal is produced by the electrolysis of molten lithium chloride, LiCl.

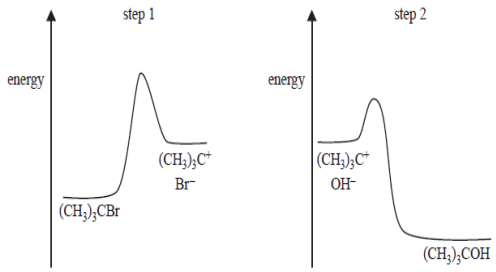
e. Calculate the mass of lithium metal produced in 48.0 hours using a current of 6.50 amps.

Sol. $Li(l)\ ^+ e^- \rightarrow Li(l)$
$Q=It=6.50x48.0x60x60 = 1.1232x10^6$ C
$n(e^-) = Q/F = 1.1232x10^6/96500 = 11.64$ mol
$n(Li) = 11.64$ mol
$m(Li) = 11.64 \times 6.9 = 80$ g

Q118. The reaction between 2-bromo-2-methylpropane and hydroxide ions occurs in two steps.
step 1: $(CH_3)_3\ CBr(aq) \rightarrow (CH_3)_3C^+(aq) + Br^-(aq)$
step 2: $(CH_3)_3C^+(aq) + OH^-(aq) \rightarrow (CH3)_3COH(aq)$

a. Write an equation that represents the overall reaction between 2-bromo-2-methylpropane and hydroxide ions.

Sol.
$(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3 COH(aq) + Br^-(aq)$
The energy profi le diagrams for step 1 and step 2 are shown below. Both are drawn to the same scale.



b. i. Which step involves an endothermic reaction? Provide a reason for your answer.

Sol. Step 1, because the energy (enthalpy) of the products, $[(CH_3)_3C^+$,

Br^-], is higher than that of the reactant $(CH_3)_3CBr$.

The reaction at step 1 occurs at a different rate to the reaction at step 2.

ii. Which step is slower? Justify your answer.

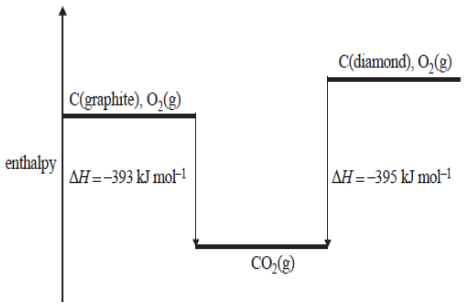
Sol. Step 2, because it has the higher activation energy or because a smaller proportion of the collisions between reactant particles will result in reaction

Q119. Consider the following combustion reactions for graphite and diamond:

$C(graphite) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393\ kJ\ mol^{-1}$

$C(diamond) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395\ kJ\ mol^{-1}$

The following diagram summaries information:



From the adta provided it can be determained that the enthaply cahange. DH, for graphine diamofe: C(graphine) C(diamofe), is:

A. $-2\ kJ\ mol^{-1}$

B. $+2\ kJ\ mol^{-1}$

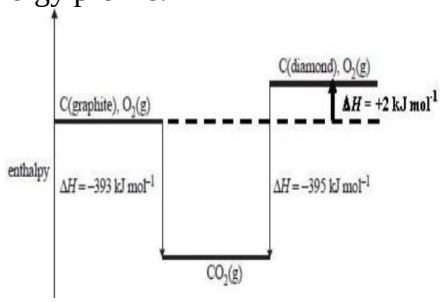
C. $-788\ kJ\ mol^{-1}$

D. $+788\ kJ\ mol^{-1}$

Sol. b. To get C(diamond) on the product side, combine the equations: $C(graphite) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = 393\ kJ\ mol^{-1}$ and $CO_2(g) \rightarrow C(diamond) + O_2(g)$ $\Delta H = +395\ kJ\ mol^{-1}$ to give:

$C(graphite) \rightarrow C(diamond)$ $\Delta H = +2\ kJ\ mol^{-1}$

ΔH for $C(graphite) \rightarrow C(diamond)$ can also be deduced from the supplied energy profile.



Q120. Methanol, CH_3OH, undergoes combustion according to the equation: $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

In an experiment to determine its suitability as a fuel, a sample of methanol underwent complete oxidation in a bomb calorimeter.

The calorimeter was fi rst calibrated by passing a current through an electric heater placed in the water surrounding the reaction vessel. A potential of 5.25 volts was applied for 3.00 minutes. The measured current was 1.50 amperes and the temperature of the water and reaction vessel increased by 0.593°C.

a.i. Determine calibration constant, in $kJ°C^{-1}$, for the calorimeter and its contents.

Sol. E = VIt

$= 5.25 \times 1.50 \times 3.00 \times 60$

$= 1.42 \times 103\ J$

Calorimeter constant $= E \div \Delta T = 1.42 \times 103 \div 0.593 = 2.39 \times 103\ J\ ºC^{-1}$

$= 2.39\ (kJ\ ºC^{-1})$

A student then used this calorimeter to determine the molar heat of combustion of methanol.

0.934 g of methanol was placed in the reaction vessel and excess oxygen was added. An electric ignition heater provided the energy required to initiate the combustion reaction. On this occasion, the temperature of the water increased by 8.63 °C.

ii. Use this experimental data to determine the value of ΔH for the combustion of methanol given by the following equation.

$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(g)$

Include appropriate units in your answer.

Sol. n(CH_3OH) reacting = 0.934 ÷ 32.0 = 0.0292 mol

Energy released by methanol = CC × ΔT=2.39×8.63= 20.6 kJ

Energy from 1 mol CH_3OH = 20.6 ÷ 0.0292 = 706 kJ

$\Delta H = -2 \times -706$ kJ $mol^{-1} = -1.41 \times 103$ kJ mol^{-1} (-1.41×10^6 J mol^{-1})

b. The value of ΔH, calculated using the enthalpy of combustion provided in the references, is different from the value of ΔH calculated from the experimental data provided in part **a.ii.**

Provide a reason for this difference.

Sol. The calculated energy released in combustion is lower due to loss of heat/energy to the surroundings during combustion.

The better responses indicated that a lower temperature change during combustion due to loss of heat would lead to a lower calculated energy released.

Methanol is suitable for use in a micro fuel cell that is used to power laptop computers and similar small electrical items. The methanol is oxidised to carbon dioxide and water. The half-equation for the anode reaction is:

$CH_3OH(l) + H_2O(l) \rightarrow 6H^+(aq) + CO_2(g) + 6e^-$

c. i. Write a balanced half-equation for the cathode reaction.

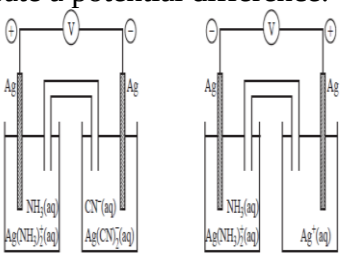
Sol. $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

ii. A finely divided platinum/ ruthenium catalyst is used in this cell. Give a reason why it is important to have a catalyst that will significantly reduce the activation energy for the cell reaction.

Sol. Either of

- a fast rate of reaction is necessary for efficient current flow/ instantaneous current in the computer
- since the computer is being used at room temperature, the catalyst will increase the reaction rate to an acceptable level in the fuel cell.

Q121. Two galvanic cells were constructed under standard conditions in an experiment to determine the relative positions in the electrochemical series of the standards potential. E^o, for the following reactions. Both cells generate a potential difference.



$Ag(NH_3)_2^+(aq) + e^- \rightleftharpoons Ag(s) + 2NH_3(aq)$ E°_1

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ E°_2

$Ag(CN)_2^-(aq) + e^- \rightleftharpoons Ag(s) + 2CN^-(aq)$ E°_3

The values of the electrode potential in order from to lowest would be:

A. $E^\circ_1, E^\circ_2, E^\circ_3$

B. $E^\circ_1, E^\circ_3, E^\circ_2$

C. $E^\circ_2, E^\circ_1, E^\circ_3$

D. $E^\circ_3, E^\circ_2, E^\circ_1$

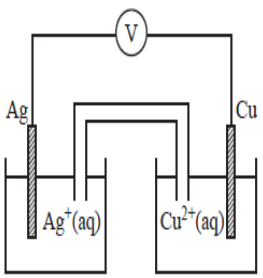
Sol. c. In galvanic cells, electrons flow from the (-) electrode to the (+) electrode. Since electrons always move from the site of oxidation to the site of reduction, the stronger oxidant – the species that is reduced – must be in the half-cell containing the (+) electrode. In the galvanic cell on the left, $Ag(NH_3)^{2+}(aq)$ is the strongest oxidant – stronger than $Ag(CN)^{2-}(aq)$. In the galvanic cell on the right, $Ag^+(aq)$ is the stronger oxidant – stronger than $Ag(NH_3)^{2+}(aq)$.
Hence, the correct order of the reduction half-equations in order of decreasing electrode potentials is

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ E°_2

$Ag(NH_3)_2^+(aq) + e^- \rightleftharpoons Ag(s) + 2NH_3(aq)$ E°_1

$Ag(CN)_2^-(aq) + e^- \rightleftharpoons Ag(s) + 2CN^-(aq)$ E°_3

Q122-123.



Q122. The over equation for the reaction occurring in this galvanic cell is**:**

A. $Ag^+(aq) + Cu(s) \rightarrow Ag(s) + Cu^{2+}(aq)$

B. $Ag(s) + Cu^{2+}(aq) \rightarrow Ag^+(aq) + Cu(s)$

C. $2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$

D. $2Ag(s) + Cu^{2+}(aq) \rightarrow 2Ag^+(aq) + Cu(s)$

Sol. c. As it was a galvanic cell, the reactants were the strongest oxidant, $Ag^+(aq)$, and the strongest reluctant, Cu(s)– identified from the electrochemical series, with the equation balanced for charge.

Q123. The predicated maximum voltage produced bt this crlluder standard condition is:

A. 0.46 V

B. 1.14 V

C. 1.26 V

D. 1.94 V

Sol. a. The predicted voltage, under standard conditions as:
E = E°(half-cell containing the oxidant) - E°(half-cell containing the reductant) = 0.80 – 0.34 = 0.46 V.

Q124. The reaction which occurs at the anode when the battery is recharging is:**:**

A. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

B. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

C. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

D. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

Sol. c. During recharging, the direction of electron flow is reversed (compared to discharging) and electrons are 'forced' to flow from the

(+) electrode to the (-) electrode. Since electrons always leave the anode (site of oxidation), then the (+) electrode is the anode during recharging.

The half-reaction occurring at the (+) electrode during discharging was:

$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$.

So the half-reaction occurring at the (+) electrode during recharging is

$PbSO_4(s) + 2H_2O(l) \rightleftharpoons Pb_{O2}(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$.

Q125. Fuel cells have a number of applications that offer advantages over conventional methods of electricity generation.

Which one of the following is not a feature of modern fuel cells?

a. They generate very little noise.

b. They are a cheap source of electricity.

c. They enable electricity to be generated on site.

d. They have the potential to reduce emissions of carbon dioxide into the atmosphere.

a. How could the rate of this reaction be measured in these experiments?

Sol. b. At this stage, fuels cell are not a cheap source of electricity, therefore option **b** was correct.

Fuel cells are quiet because they do not involve combustion but rather a quiet chemical to electrical energy conversion. Most fuel cells are hydrogen-oxygen fuel cells in which the only product is water. So the use of a hydrogen-oxygen fuel cell as an energy source instead of the combustion of a carbon based fuel will reduce emissions of carbon dioxide.

Q126. The reaction between 2-bromo-2-methylpropane and hydroxide ions occurs in two steps.

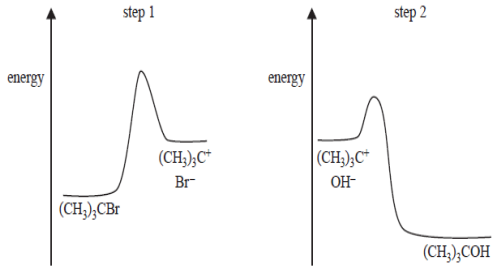
step 1 $(CH_3)_3$ CBr(aq) → $(CH_3)_3C^+$ (aq) + Br^-(aq)

step 2 $(CH_3)_3C^+$ (aq) + OH^-(aq) → $(CH3)_3COH$(aq)

a. Write an equation that represents the overall reaction between 2-bromo-2-methylpropane and hydroxide ions.

Sol. $(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br^-(aq)$

The energy profile diagrams for step 1 and step 2 are shown below. Both are drawn to the same scale.



b. i. Which step involves an endothermic reaction? Provide a reason for your answer.

Sol.

Step 1, because the energy (enthalpy) of the products, $[(CH_3)_3C^+, Br^-]$, is higher than that of the reactant $(CH_3)_3CBr$.

The reaction at step 1 occurs at a different rate to the reaction at step 2.

ii. Which step is slower? Justify your answer.

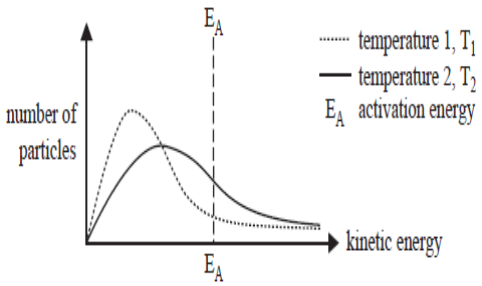
Sol. Step 1, because it has the higher activation energy or because a smaller proportion of the collisions between

reactant particles will result in reaction.

Q127. Which one of the following statements is true for both galvanic cells and electrolytic cells?
a. Reduction occurs at the negative electrode in both cells.
b. Reduction occurs at the cathode in both cells.
c. Anions migrate to the cathode in both cells.
d. The anode is positive in both cells.

Q128. A helium balloon is inflated to a volume of 5.65 L and a pressure of 10.2 atm at a temperature of 25°C**.** The amount of helium, in moles, in the balloon is
a. 0.023
b. 0.276
c. 2.36
d. 27.95
Sol. c. 2.36
$V = nRT \div p$
$n(He) = pV \div RT$
$= (10.2 \times 101.3) \times 5.65 \div (8.31 \times 298) = 2.36$ L
Option **a** was consistent with not converting the pressure to Pa.

Q129. The diagram below represents the distribution of the kinetic energy of reactant particles at two different temperatures. Assume that the areas under the curves are equal.



From this diagram it can be concluded that
a. at T_1 a greater number of particles have sufficient energy to react. T_1 is greater than T_2.
b. at T_1 a greater number of particles have sufficient energy to react. T_2 is greater than T_1.
c. at T_2 a greater number of particles have sufficient energy to react. T_1 is greater than T_2.
d. at T_2 a greater number of particles have sufficient energy to react. T_2 is greater than T_1
Sol. d. The graph indicates the average kinetic energy of the particles is greater at temperature 2 (T_2) than at temperature 1 (T_1). Hence, T_2 is greater than T_1. The area under the graphs for energy equal to or greater than the activation energy (required for reaction to occur) is larger on the T_2 graph than on the T_1 graph. Hence, at T_2 a greater number of particles have sufficient energy to react (option **d**).

Q130. Enthalpy changes for the melting of iodine, I_2, and for the sublimation of iodine are provided below:
$I_2(s) \rightarrow I_2(l)$ $\Delta H = +16$ kJ mol^{-1}
$I_2(s) \rightarrow I_2(g)$ $\Delta H = +62$ kJ mol^{-1}

The enthalpy change for the vaporisation of iodine that is represented by the equation $I_2(l) \rightarrow I_2(g)$ is

a. -78 kJ mol^{-1}
b. -46 kJ mol^{-1}
c. $+46$ kJ mol^{-1}
d. $+78$ kJ mol^{-1}

Sol. c.

$I_2(l) \rightarrow I_2(s)$; $\Delta H = -16$ kJ mol^{-1}
$I_2(s) \rightarrow I_2(g)$; $\Delta H = +62$ kJ mol^{-1}
Hence $I_2(l) \rightarrow I_2(g)$; $\Delta H = -16 + 62$
$= +46$ kJ mol^{-1}

Q131. Nitrogen dioxide decomposes as follows.

$2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$ $\Delta H = -66$ kJ mol^{-1}

The enthalpy change for the reaction represented by the equation:

$1/2\ N_2(g) + O_2(g) \rightarrow NO_2(g)$ is

a. -66 kJ mol^{-1}
b. -33 kJ mol^{-1}
c. $+33$ kJ mol^{-1}
d. $+66$ kJ mol^{-1}

Sol. c.

$1/2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$; $\Delta H = -66$ kJ mol^{-1}

$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$; $\Delta H = +66$ kJ mol^{-1}

$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$; $\Delta H = +33$ kJ mol^{-1}

1.30 g of glucose (M = 180 g mol^{-1}) underwent complete combustion. The energy released was used to heat an unknown mass of water.

If the temperature of the water increased by 24.3°C and it is assumed no heat was lost, the mass of the water heated was

a. 2.00×10^{-1} g
b. 1.02×10^{2} g
c. 2.00×10^{2} g
d. 3.84×10^{3} g

Sol. c. n(glucose) required = 1.30 g ÷ 180.0 g mol^{-1} = 7.33×10^{-3} mol

Energy released = n(glucose) × ΔHc(glucose) = 7.33×10^{-3} mol × 2816 kJ mol^{-1} = 20.3 kJ

Energy added to water = 4.18J g^{-1} K^{-1} × m(H_2O) × ΔT

20.3×10^3 J = 4.18 × m(H_2O) × 24.3

m(H_2O)=20.3×10^3 ÷(4.18×24.3) = 200 g = 2.00×10^2 g

Q132. When 50 g of water at 90 °C is added to a calorimeter containing 50 g of water at 15°C, the temperature increases to 45°C**.** Assuming no energy is lost to the environment, the energy absorbed by the calorimeter is equal to the:

a. energy lost by the hot water.
b. energy gained by the cold water.
c. sum of the energy gained by the cold water and the energy lost by the hot water.
d. difference between the energy lost by the hot water and the energy gained by the cold water.

Sol. d. Adding hot water (90ºC) to the lower-temperature calorimeter (water and components at 15ºC) results in thermal energy being transferred from the hot water to the cold water in the calorimeter and the calorimeter components until all the water and the calorimeter components are at the same temperature (45ºC).

The temperature increase (30ºC) of the hot water is less than the temperature decrease (45ºC) of the hot water because of the energy

absorbed by the components of the calorimeter. So the energy absorbed by the calorimeter is equal to the difference between the energy lost by the hot water and the energy gained by the cold water.

Q133. If 54.0 kJ of energy is required to convert 1.00 mol of liquid water to steam at 100 °C, the amount of heat energy, in kilojoule, required to convert 100 g of water at 20 °C to steam at 100 °C is

a. 3.34×10^1 kJ
b. 2.67×10^2 kJ
c. 3.00×10^2 kJ
d. 3.33×10^2 kJ

Sol. d. The energy required to heat 100g of water from 20°C to steam at 100°C is the sum of the energy required to heat 100g of water from 20°C to 100°C and the energy required to convert 100 g of water to steam at 100 °**c.** The energy required to heat 100g of water from 20°C to 100°C is determined from the specific heat capacity of water.

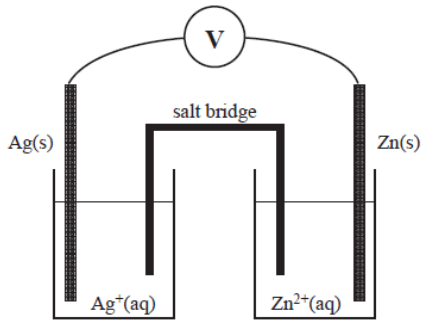
$E = 4.18 \times 100 \times 80$
$= 3.34 \times 10^4$ J = 33.4 kJ

The energy required to convert 100 g water at 100°C to steam is determined from the energy required to convert 1 mol – that is, 54.0kJ mol^{-1}.

$n(H_2O) = 100 \div 18.0 = 5.56$ mol
$E = 5.56 \times 54.0 = 300$ kJ

The total energy required to heat 100 g of water from 20 °C to steam at 100°C = 33.4 kJ + 300 kJ = 333.4kJ = 3.33×10^2 kJ

Q134–135. A galvanic cell set up under standard conditions is shown below.



Q134 Which one of the following is correct? As the cell discharges

	electrons would flow from the	in the salt bridge
A.	zinc electrode to the silver electrode.	anions migrate to the Ag^+/Ag half-cell.
B.	silver electrode to the zinc electrode.	cations migrate to the Zn^{2+}/Zn half-cell.
C.	silver electrode to the zinc electrode.	cations migrate to the Ag^+/Ag half-cell.
D.	zinc electrode to the silver electrode.	anions migrate to the Zn^{2+}/Zn half-cell.

Sol. d. According to the electrochemical series,

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $E^o = 0.80$ V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$ $E^o = -0.76$ V

The strongest oxidant, $Ag^+(aq)$, will react with the strongest reductant, Zn(s).

Anode (–): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
Cathode (+): $Ag^+(aq) + e^- \rightarrow Ag(s)$

Electrons flow from the site of oxidation (anode) to the site of reduction (cathode) – that is, from the Zn electrode to the Ag electrode. Anions migrate towards the anode, Zn^{2+}/Zn half-cell. Cations migrate towards the cathode, Ag^+/Ag half-cell.

Q141 In this cell:

a. $Ag^+(aq)$ is reduced and the Zn(s) is oxidised.

b. Ag(s) is oxidised and the Zn^{2+}(aq) is reduced.
c. Ag(s) is reduced and the Zn^{2+}(aq) is oxidised.
d. Ag^{+}(aq) is oxidised and the Zn(s) is reduced.
Sol. a. The strongest oxidant, Ag+(aq), is reduced at the cathode; the strongest reductant, Zn(s) is oxidised at the anode.
Anode (–): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$
Cathode (+): $Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$

Q135. The cathode in this cell and the maximum voltage produced by this cell, under standard conditions, are respectively:
a. Ag and 0.16 V
b. Ag and 1.56 V
c. Zn and 0.16 V
d. Zn and 1.56 V
Sol. b. The predicted voltage, under standard conditions is
$E = E^{o}$ (half-cell containing the oxidant) – E^{o} (half-cell containing the reductant) = 0.80 – (–0.76) = 1.56 V

CHAPTER THREE
Biochemistry
الكيمياء الحياتية

Tests & Answers

Q1. Which of the following statements is false with respect to an enzyme's ability to catalyse a reaction?
a. An enzyme provides a reaction surface and a suitable environment for the reaction to take place.
b. An enzyme binds reactants such that they are positioned correctly and can attain their transition-state configurations.
c. An enzyme allows the reaction to go through a less stable transition state than would normally be the case.
d. An enzyme can weaken bonds in reactants through the binding process.

Q2. Which of the following statements is not true regarding the active site of an enzyme?
a. An active site is normally a hollow or cleft on the surface of an enzyme.
b. An active site is normally hydrophilic in nature.
c. Substrates fit into active sites and bind to functional groups within the active site.
d. An active site contains amino acids which are important to the binding process and the catalytic mechanism.

Q3. Which of the following statements best describes an allosteric binding site?
a. It is a binding site containing amino acids with aliphatic side chains.
b. It is a binding site that can accept a wide variety of differently shaped molecules.
c. It is a binding site, which is separate from the active site, and affects the activity of an enzyme when it is occupied by a ligand.
d. It is a description of an active site which has undergone an induced fit.

Q4. Which of the following descriptions best describes an induced fit?
a. The process by which an active site alters shape such that it is ready to accept a substrate.
b. The process by which a substrate adopts the correct binding conformation before entering an active site.
c. The process by which a substrate binds to an active site and alters the shape of the active site.
d. The process by which an active site alters the shape of the substrate such that it can adopt the necessary active conformation for binding.

Q5. Some enzymes require the presence of a non-protein substance if they are to catalyse a reaction. Which of the following terms is the best general term for such a substance?
a. prosthetic group
b. cofactor
c. co-enzyme
d. modulator

Q6. What term is used for a non-protein organic molecule that is required by some enzymes in order to catalyse a reaction on a substrate?
a. prosthetic group
b. cofactor

c. co-enzyme
d. modulator

Q7. Some enzymes covalently bind a non-protein organic molecule to the active site. The organic molecule concerned is required if the enzyme is to catalyse a reaction on a substrate. What is the term used for such a molecule?

a. prosthetic group
b. cofactor
c. co-enzyme
d. modulator

Q8. Which of the following molecules is involved in the feedback control of the enzyme phosphorylate a?
a. glucose-1-phosphate
b. adrenaline
c. glycogen
d. AMP

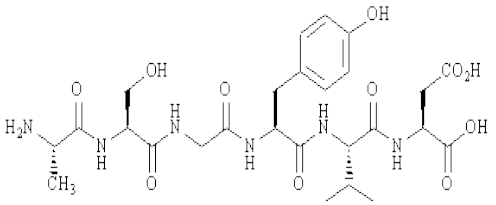
Q9. What secondary messenger is generated as a result of the action of nitrous oxide?

a. GTP
b. cyclic GMP
c. ATP
d. cyclic AMP

Q10. From which amino acid is nitrous oxide generated?
a. arginine
b. aspartic acid
c. asparagine
d. lysine

Q11. The Michaelis-Menton equation relates the rate of en enzyme-catalysed reaction to which of the following?
a. Substrate concentration
b. Product concentration
c. Activation energy
d. Inhibitor concentration

Q12. Which of the following single letter codes represents the structure below?



a. DVYGSA
b. ASGYVD
c. EVFGSA
d. ASGFVE

Feedback: The order of the amino acids from the N-terminal end of the peptide is alanine (A), serine (S), glycine (G), tyrosine (Y), valine (V) and aspartic acid (D).
Option **a.** is wrong since the amino acids are labelled from the C-terminal end. Option **d.** is wrong since it mislabels tyrosine as phenylalanine, and aspartic acid as glutamic acid. Option **c.** has the same mistakes as option **d.** and is also labelled from the wrong end.

Q13. Which of the following statements is true about a peptide bond (RCONHR')?
a. It is non-planar.
b. It is capable of forming a hydrogen bond.
c. The cis configuration is favoured over the trans configuration

d. Single bond rotation is permitted between nitrogen and the carbonyl group.

Feedback:
Statement **b.** is correct. The NH of the amide can act as a hydrogen bond donor and the carbonyl group can act as a hydrogen bond acceptor. Statements **a.**, **c.** and **d.** are false. The peptide bond has double bond character due to the interaction of the nitrogen lone pair with the carbonyl group. This prevents bond rotation and makes the bond planar. The trans isomer is favoured over the cis isomer.

Q14. Which of the following statements is untrue about protein secondary structure?
a. The alpha helix, beta pleated sheet and beta turns are examples of protein secondary structure.
b. The ability of peptide bonds to form intramolecular hydrogen bonds is important to secondary structure.
c. The steric influence of amino acid residues is important to secondary structure.
d. The hydrophilic/hydrophobic character of amino acid residues is important to secondary structure.

Feedback: The hydrophilic/ hydrophobic character of amino acid residues is important to protein tertiary structure rather than to secondary structure. In secondary structure, it is the steric size of the residues that is important and residues are positioned to minimise interactions between each other and the peptide chain.

Q15. Identify which of the following terms refers to the arrangement of different protein subunits in a multiprotein complex.

a. primary structure
b. secondary structure
c. tertiary structure
d. quaternary structure
Feedback: Primary, secondary and tertiary structure refers to the different structural levels of a single protein. Quaternary structure refers to the overall structure of a multiprotein complex.

Q16. Identify which of the following terms refers to the order in which amino acids are linked together in a protein.

a. primary structure
b. secondary structure
c. tertiary structure
d. quaternary structure

Q17. Identify which of the following terms refers to the overall three dimensional shape of a protein.
a. primary structure
b. secondary structure
c. tertiary structure
d. quaternary structure

Feedback: Primary structure refers to the order of the amino acids in a protein. Secondary structure indicates regions of ordered structure, and tertiary structure is the overall structure of the protein. Quaternary structure refers to the structure of a

multi-protein complex.

Q18. Identify which of the following terms refers to 'regions of ordered structure within a protein'.
a. primary structure
b. secondary structure
c. tertiary structure
d. quaternary structure

Feedback: Primary structure refers to the order of the amino acids in a protein. Secondary structure indicates regions of ordered structure, and tertiary structure is the overall structure of the protein. Quaternary structure refers to the structure of a multi-protein complex.

Q19. Identify the strongest form of intermolecular bonding that could be formed involving the residue of the amino acid serine.
a. ionic bond
b. hydrogen bond
c. van der Waals interactions
d. None of the above.

Feedback: Serine contains a hydroxyl functional group on its side chain and so the strongest possible interaction will be hydrogen bonding where the hydroxyl group could act as a hydrogen bond donor or hydrogen bond acceptor.

Q20. Identify the strongest form of intermolecular bonding that could be formed involving the residue of the amino acid valine.
a. ionic bond
b. hydrogen bond
c. van der Waals interactions.
d. None of the above.

Feedback: Valine has no functional groups on its side chain. There is only an alkyl group and so only van der Waals interactions are possible.

Q21. Identify the strongest form of intermolecular bonding that could be formed involving the residue of the amino acid glutamic acid.
a. ionic bond
b. hydrogen bond
c. van der Waals interactions
d. None of the above.

Feedback: Glutamic acid contains a carboxylic acid functional group which could act as a hydrogen bond donor or hydrogen bond acceptor. However the group could lose its acidic proton to gain a negative charge allowing a stronger ionic interaction to take place.

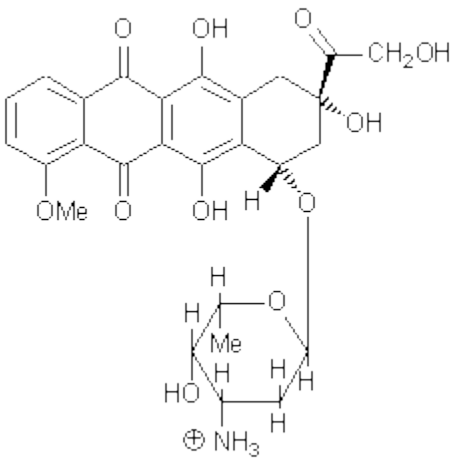
Q22. Identify the strongest form of intermolecular bonding that could be formed involving the residue of the amino acid tyrosine.
a. ionic bond
b. hydrogen bond
c. van der Waals interactions
d. None of the above.

Feedback: Tyrosine contains an aromatic ring and a phenol group. The aromatic ring could form van der Waals interactions, but the phenol group could form stronger hydrogen bonds as a hydrogen bond donor or hydrogen bond acceptor.

Q23. Which of the following statements is incorrect regarding transport proteins?

a. They are present in cell membranes.
b. They serve to carry polar molecules across the hydrophobic cell membrane.
c. They are required to transport amino acids across cell membranes.
d. They are required to transport hydrophobic steroids across cell membranes.
Feedback: Steroids are hydrophobic molecules which can pass through the cell membrane without the need for a transport protein.

Q24. The following antibiotic structure is an intercalating agent. What role does the ionic group serve in making this molecule an effective intercalating agent?



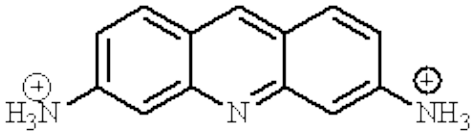
a. It increases water solubility allowing high dose levels to be used.
b. It interacts with charged phosphate groups in DNA to stabilise intercalation.
c. It acts as a strong hydrogen bond donor with nucleic acid bases to stabilise intercalation.
d. It only becomes protonated when it enters cells and so becomes trapped within the cell leading to high concentrations of drug.

Feedback: An ionic interaction can be formed between the positively charged nitrogen of the antibiotic and the negatively charged phosphate groups of the DNA sugar phosphate backbone. Statement **a.** is correct in the sense that the ionic charge will increase water solubility but it does not enhance intercalation. Statements **c.** and **d.** are incorrect.

Q25. Which term best describes the mechanism of action for fluoroquinolones?
a. Alkylating agent
b. Antisense agent
c. Chain cutter
d. Topoisomerase poison

Feedback: The fluoroquinolones stabilise a DNA / topoisomerase complex and prevent the mechanism by which tension is eased in the DNA strand during transcription and replication. This results in the inhibition of these processes.

Q26. The following antibacterial agent was used in the second world war.

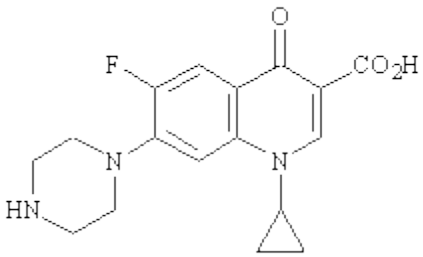


What is the name of the structure?

a. Erythromycin
b. Proflavine
c. Chloramphenicol
d. Rifampicin

Feedback: The structure is proflavine which acts as an intercalating agent. The other structures are natural products with more complex structures.

Q27. The following structure is a synthetic antibacterial agent called ciprofloxacin.

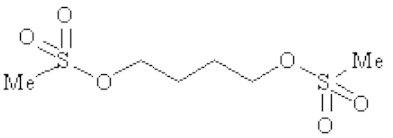


What is its mechanism of action?

a. Topoisomerase poison
b. Metallating agent
c. Chain terminator
d. Antisense agent.

Feedback: Ciprofloxacin is a member of a group of compounds called fluoroquinolones which act by stabilizing a complex between the topoisomerase enzyme and DNA. This blocks transcription and replication.

Q28. The following anticancer agent is called busulfan.

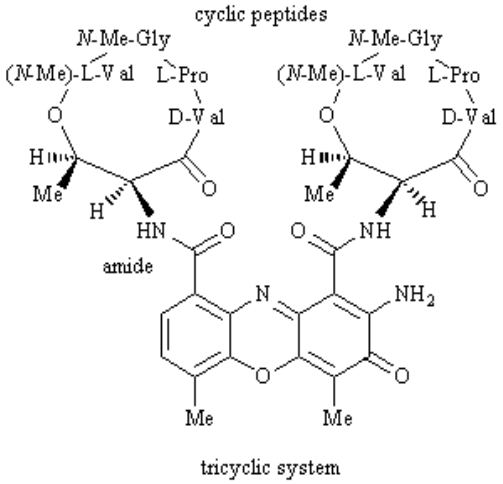


What is the drug's mode of action?

a. Metallating agent
b. Intercalator
c. Chain terminator
d. Alkylating agent.

Feedback: Busulfan acts as an alkylating agent. It contains two sulfonyloxy groups which act as good leaving groups when the drug reacts with a nucleophile.

Q29. The following structure is an intercalating anticancer agent.



What is it called?

a. Doxorubicin
b. Dactinomycin
c. Mitoxantrone
d. Bleomycin

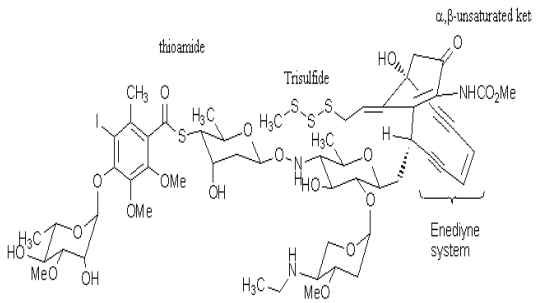
Feedback: The other agents mentioned are also intercalating agents.

Q30. What is the mode of action of the anticancer agent calicheamicin γ^1?

a. Alkylating agent
b. Chain cutting agent
c. Antisense agent
d. Intercalating agent.

Feedback:
Alkylating agents are drugs which have a good leaving group and which can form a strong covalent bond to their target. Chain cutting agents usually bind to DNA and generate radical species which result in the cutting of the DNA chain. Antisense agents bind to messenger RNA and prevent its message being decoded during translation. Intercalating agents are agents that can bind to DNA and insert planar regions of their skeleton between the base pairs of DNA**.**

Q31. The following structure is an antitumour agent derived from a bacterium.

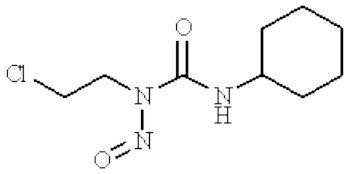


What is the name of the agent?

a. Calicheamicin γ^1
b. Adozelesin
c. Dacarbazine
d. Oblimersen

Q32. What is the mode of action for the anthracycline anticancer agents?
a. Alkylating agents
b. Chain cutting agents
c. Antisense agents
d. Intercalating agents.

Q33. The following structure is used in the treatment of brain tumours.

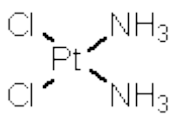


What is the structure called?

a. Carmustine
b. Lomustine
c. Streptozotocin
d. Cyclophosphamide

Feedback: Lomustine decomposes in the body to form an alkylating agent and a carbamoylating agent.

Q34. The following agent is used for the treatment of testicular and ovarian cancers.



Which of the following statements is untrue regarding the above structure?
a. The chlorine groups are displaced before the drug becomes active.
b. Intrastrand cross linking of DNA results from the action of the agent.
c. Base pairing between adenine and thymine is disrupted by the agent.
d. The compound acts as a metallating agent.
Feedback: The structure is cisplatin. All the statements are true except option **c**. It is the base pairing

between cytosine and guanine that is disrupted.

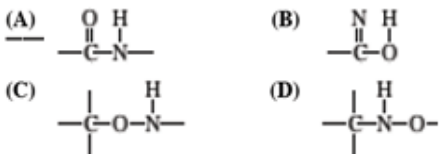
Q35. Sucrose, ordinary table sugar, may be classified as a:
a. Monosaccharide
b. Disaccharide
c. Polysaccharide
d. Oligosaccharide

Q36. What is the most abundant element in the human body, weight?
Sol. oxygen

Q37. Most enzymes are a type of
a. carbohydrate
b. lipid
c. nucleic acid
d. protein

Q38. In addition to carbon, hydrogen and oxygen, which element is found in all amino acids?
a. chlorine
b. nitrogen
c. phosphorus
d. sulfur

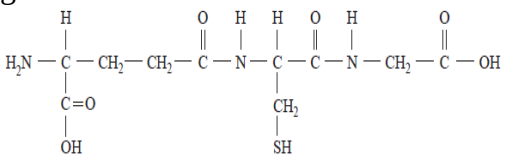
Q39. Which structure represents a peptide bond?



Q40. Which vitamin is the most soluble in water?
a. A
b. K
c. C

Q41. 1.30g of glucose ($M=180 g.mol^{-1}$) underwent complete combustion. The energy released was used to heat an unknown mass of water. If the temperature of the water increased by 24.3 °C and it is assumed no heat was lost, the mass of the water heated was
a. 2.00×10^{-1} g
b. 1.02×10^{2} g
c. 2.00×10^{2} g
d. 3.84×10^{3} g
Sol. **c.** n(glucose) required = 1.30 g÷180.0 g mol^{-1} = 7.33×10^{-3} mol
Energy released = n(glucose) × ΔHc(glucose) = 7.33×10^{-3} mol × 2816 kJ mol^{-1} = 20.3 kJ
Energy added to water = 4.18 J g^{-1} K–1 × m(H2O) × ΔT
20.3×10^{3} J = 4.18 × m(H2O) × 24.3
m(H2O) = 20.3 × 103 ÷ (4.18 × 24.3) = 200 g = 2.00×10^{2} g

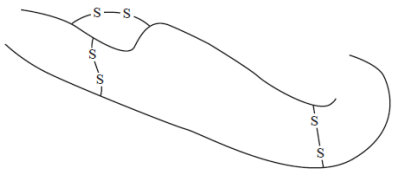
Q42. The side chains of some amino acids are able to form amide (peptide) bonds. Glutathione is a tripeptide that protects cells in humans by acting as an antioxidant. The structure of glutathione is



The molecule of glutathione contains residues from the amino acids cysteine and glycine.
The name of the third amino acid found in glutathione is
a. asparagine.
b. aspartic acid.
c. glutamine.
d. glutamic acid.

Sol. The first sentence in this equation was the key. Students needed to recognise that it was the side chain on the first amino acid that had reacted, and that this side chain would have to be CH_2CH_2COOH. Effective use of Table 8 in the Data Book would have allowed identification of the amino acid as glutamic acid.

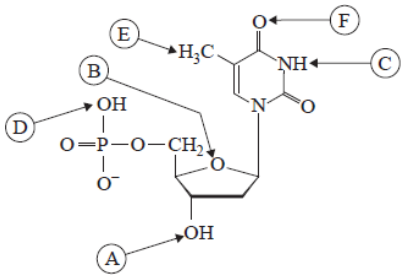
Q43-44. The following diagram is a simplified illustration of the protein insulin. Insulin consists of 51 amino acids arranged in two individual chains linked by disulfide bridges.



Q43. How many peptide links are present in one molecule of insulin?
a. 48
b. 49
c. 50
d. 51
Sol. A single protein chain consisting of n amino acids will contain n–1 peptide links. So a single protein chain of 51 amino acids will contain 50 peptide links. However, the 51 amino acids in insulin are arranged in two individual chains, containing 21 and 30 amino acids respectively. Hence the total number of peptide links present is (21–1) + (30–1) =49.
The popularity of option **c** suggests that most students did not pick up on the significance of the 'two individual chains'.

Q44. Disulfide bridges are formed when the side chains of two amino acid residues react.
The pair of amino acids that form the disulfide bridges could be:
a. cysteine and serine.
b. cysteine and glycine.
c. cysteine and cysteine.
d. cysteine and glutamic acid.
Sol. Dilsulfide bridges are formed when –SH (thiol) groups on the side chains of two cysteine molecules react together.

Q45. A single strand of DNA consists of a long chain of monomers called nucleotides. The structure of one of these nucleotides of DNA is shown below.



Each nucleotide will polymerise with other nucleotides to form a single strand of DNA**.** Part of this nucleotide will also form bonds with a complementary nucleotide on a parallel strand of DNA forming the double helix structure.

a. Circle only the letters which represent the sites where this nucleotide can form bonds with other nucleotides to form a single strand of DNA**.**

A B C D E F

Sol.

A B C D E F

b. i. Name the type of bonding that holds the two strands in human DNA together.

Sol. Hydrogen bonding

ii. Circle only the letters that represent the locations where these bonds between the two strands of DNA are formed. A B C D E F

Sol.

A B C D E F

The majority of students were well versed in key structural and bonding aspects of DNA**.** A reasonable number of students also identified the hydroxyl groups at either A and or D as sites for hydrogen bonding, perhaps not focusing on 'between the two strands' as stated in the equation.

Q46. Enzymes are complex protein structures that function as biological catalysts.

a. Why does a particular enzyme generally only catalyse a specific reaction?

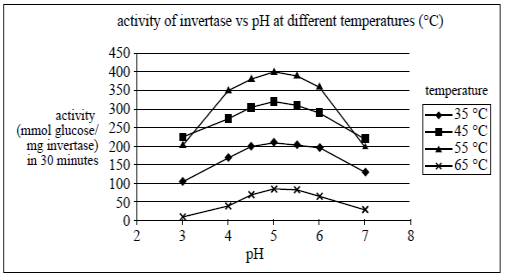
Sol. Acceptable responses included:

• enzyme function is determined by the shape of the active site.

• enzyme shape is complementary to a specific substrate.

• 'lock and key' effect – the substrate (reactant) is the 'key' and the active site of the enzyme is the 'lock'.

Invertase is an enzyme which catalyses the conversion of sucrose to glucose and fructose. Invertase has a maximum activity temperature different from many other enzymes. The graph below shows the results of a study into the effects of both pH and temperature on the activity of inverses in sucrose solution.



b. At what temperature and pH does the enzyme in the study have maximum activity?

Temperature ____ pH _____

Sol. Temperature 55* (°C**)**, pH 5*

c. Why does changing the pH from the optimum value cause a decrease in the activity of the enzyme?

Sol. Acceptable responses included:

• the tertiary structure of the enzyme changes with change in pH

• change in $[H^+]$ may change the charge on side chain groups.

• the enzyme is denatured so the shape of the active site changes.

To access the mark for this equation, students needed to indicate that the change in pH affects the enzyme/active site structure and/ or charge. Denaturing in isolation was not accepted; some appropriate link to change in enzyme structure was required.

d. In this study the activity of the enzyme was measured as the number of millimole of glucose produced per milligram of enzyme (mmol glucose/ mg invertase) in 30 minutes.

Assuming excess sucrose, calculate the mass of glucose (Mr=180)

produced in 30 minutes from a sucrose solution containing 1.00×10^{-4}g of invertase if the measured activity is 300 mmol glucose/mg invertase.

Sol. $n(C_6H_{12}O_6) = 300x10^{-3}$ mol mg^{-1} x $1.00x10^{-1}$ mg

$m(C_6H_{12}O_6) = 3.00 \times 10^{-2} \times 180.0$

= 5.40g

Effective interpretation of the data proved challenging for most students, perhaps confused by having the mass of invertase in grams but the activity in mmol glucose/mg invertase. A significant proportion of students used an incorrect conversion factor in changing g to mg or vice versa.

Some astute students realised that mmol glucose/mg invertase equates to mol glucose/g invertase and obtained the correct Answer via $300x1.0x10^{-4}$ x 180.

Q47. In living things, glycine can react with other amino acids to form polypeptides and proteins.

This reaction between two or more amino acids to form a polypeptide is classified as:

a. condensation.

b. esterification.

c. hydrolysis.

d. nitrification.

Q48. All of the individual α-amino acids that make up human proteins

a. have an $-NH_2$ and a $-CO_2H$ group attached to the same carbon atom.

b. can be made naturally in the human body.

c. contain the peptide group.

d. have an $-NH_2$ and an –OH group attached to the same carbon atom.

Q49. The amino acid, alanine, dissolves in water.

In an aqueous solution with a pH = 7, alanine is acting as:

a. an acid only.

b. a base only.

c. neither an acid nor a base.

d. both an acid and a base.

Q50. The excess amino acids not required for protein synthesis are broken down in the liver.

The nitrogen atoms from the excess amino acids are removed from the human body as

a. N_2

b. NH_3

c. NH_4NO_3

d. $CO(NH_2)_2$

Q51. A substance that could be formed as a product, when a polysaccharide undergoes enzyme catalysed hydrolysis, is:

a. H_2O

b. CO_2

c. $C_6H_{12}O_6$

d. $CH_2OH.CHOH.CH_2OH$

Q52. Cellulose cannot be digested by humans because:

a. it is insoluble in water.

b. it contains no glucose.

c. it is not a carbohydrate.

d. the enzymes required to catalyse its hydrolysis are not present in humans.

Q53. Most of the formulas below represent elements and compounds that are important in:

i. the production of food, or

ii. the chemical processes these foods undergo in our bodies.

NH_3 NH_2CH_2COOH $C_6H_{12}O_6$ $HNOCH_2OH$ $C_{16}H_{33}COOH$ NO CO CHOH H_2O N_2 O_2 CH_2OH

Select only substances from this list as reactants to write an equation for each of the following reactions. The products of the reactions may not all be in the list.

a. The production of an artificial fertiliser that can be used to increase the nitrogen available to crops

Sol. $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$

Surprisingly few students could find ammonium nitrate.

b. The respiration reaction which results in the release of energy for life processes

Sol. $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Nearly all students knew about the oxidation of glucose. Most of those who were in error had messed up the stoichiometry.

c. The formation of a dipeptide during protein synthesis Circle the peptide link in the product.

Sol.

• any one of the (highlighted **CON**) were circled

$NH_2CH2COOH + NH_2CH_2COOH \rightarrow NH_2CH_2\mathbf{CON}HCH_2COOH + H_2O(l)$

• for a correct structure of the dipaptide.

d. A condensation reaction in which a fat is produced Circle an ester link in the product.

Sol.

• the (highlighted **CHOCO** or **OCO**) were circled

• for selecting the correct formula for the lipid

• the correct reactants, balanced as for an equation.

CH_2OH $CH_2\mathbf{OCO}C1_6H_{33}$

| |

$CHOH + 3C_{16}H_{33}COOH \rightarrow$ $CH\mathbf{OCO}C_{16}H_{33}$

| |

CH_2OH $CH_2\mathbf{OCO}C_{16}H_{33}$

Q54.

a. A balanced diet contains proteins and fats as well as carbohydrates. Although carbohydrates are the immediate energy source for living things, both proteins and fats can also be used as energy sources.

Give two functions, other than energy sources, for each of proteins and fats in humans.

Proteins 1

2

Fats 1

2

Sol. Any two of muscles, enzymes, haemoglobin, tissue repair, building of tissue and any two of lipids, protection of organs, insulation, essential fatty acids, transport of fat soluble vitamins.

Note this equation refers to the function of proteins and fats already in the human body – not to the use of proteins and fats in food.

b. The energy content of some vegetable oil is determined using a bomb calorimeter. A sample of oil, mass 4.75 g, was completely burnt in a calorimeter containing 1.00 L of water originally at 21.0°C. When burning was completed, the final temperature of the water was 56.8°C**.** Calculate the energy content of the oil in kJ g^{-1}. Assume that 4.18 J is required to raise the temperature of 1.0 mL of water by exactly 1°C**.**

Sol. $\Delta T = 56.8 - 21.0 = 35.8$ K

$\Delta H = 35.8 \times 4.18 \times 1000 = 149.6$ kJ

energy content = (149.6/4.75) = 31.5 kJ g^{-1}.

c. Salad dressing is poured onto and mixed with a salad to improve its flavour. The list of ingredients on the label of a brand of salad dressing sold in Victoria includes 'water, polyunsaturated vegetable oils, emulsifier (soya bean lecithin) and antioxidant'.

i. What is the function of an emulsifier in salad dressing and how does it achieve this function?

Sol. To keep the oil and water mixed, acting as a surface active agent.

ii. What is the function of an antioxidant in salad dressing and how does it achieve this function?

Sol. To prevent spoilage of the oil (salad dressing), by removing O_2.

Q55-56. Glycine, alanine and serine are three of the amino acids found in human proteins. Amino acids can react together to form polypeptides of varying length and composition. A **tripeptide** contains residues from three amino acids.

Q55. If three glycine molecules (relative molecular mass 75) react together to form a tripeptide, the relative molecular mass of the product would be

a. 171

b. 189

c. 207

d. 225

Q56. The number of different tripeptides that can be formed containing all three amino acids, glycine, alanine and serine, is

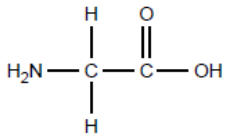
a. 2

b. 3

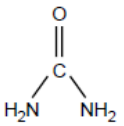
c. 4

d. 6

Q57. Glycine is one of the amino acids that forms proteins. Protein that is not required in the body is broken down in the liver. Unwanted nitrogen is converted to urea and eliminated in the urine.



glycine



urea

The maximum mass of urea (relative molecular mass = 60) that could be eliminated as a result of the breakdown of 1.00 g of glycine (relative molecular mass = 75) is, in gram,

a. 0.40

b. 0.80

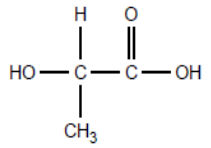
c. 1.00

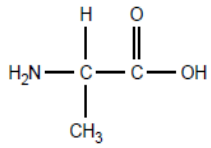
d. 1.60

Q58. The carbon and nitrogen cycles both play an important role in food production. Which of the following processes is part of both the nitrogen and carbon cycles?
a. animal respiration
b. denitrification in soil
c. plant photosynthesis
d. breakdown of urea fertiliser in soil

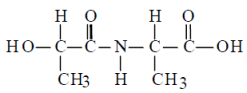
Q59. Stearic acid, $CH_3(CH_2)_{16}COOH$, is a common saturated fatty acid.
a. What is meant by the term 'saturated'?
Sol. No C to C double bonds.
b. Stearic acid can be used as a source of energy. Write a chemical equation for the complete reaction between oxygen and stearic acid.
Sol. $CH_3(CH_2)_{16}COOH + 26O_2 \rightarrow 18CO_2 + 18H2O$; correct reagents and products, correct stoichiometry
c. The fats and oils in food are usually made up of a complex mixture of saturated and unsaturated fatty acids. During processing, additives are often added to prevent spoiling.
i. What class of food additive is used specifically to prevent oils becoming rancid?
Sol. Antioxidants
ii. How does the additive prevent oils becoming rancid?
Sol. Reacting preferentially with O_2

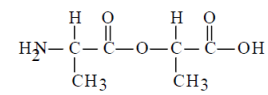
Q60. Lactic acid and alanine are both important chemicals in living systems. Their structures are


lactic acid


alanine

a. Give the name of the functional group common to both compounds.
Sol. Carboxy (no other choice acceptable)
b. Why is alanine classified as an amino acid but lactic acid is not?
Sol. Lactic acid has no amino group (must mention lactic acid**.**
c. In the below, draw structures of two different possible organic molecules formed by a condensation reaction between lactic acid and alanine.
Sol.





d. For one of the structures given in part **c.**
i. circle the new functional group formed.
Sol. Circle either -CONH-OR-COO-
ii. name the functional group that you have circled.
Sol. Peptide OR ester

Q61. The energy content of food can be determined by completely burning a sample of the food in a bomb calorimeter and then calculating the energy released.
a. The calorimeter must first be calibrated by passing an electric current through the calorimeter for a known period of time and measuring the resultant temperature rise. The

data relevant to such a calibration is given below.
Current 1.78 A
Potential difference 5.65 V
Time 135 s
Temperature rise 1.15°C
Use the data above to calculate the calibration factor, in kJ $°C^{-1}$, for this calorimeter
Sol. E =1.78 x 5.65 x 135=1358 J; calibration constant = 1358/1.15 = 1.18 kJ $^{o}C^{-1}$
b. The carbohydrate, glucose, burns in excess oxygen according to the following equation.
$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$
When a 1.324 g sample of glucose was burned in the calorimeter calibrated in part **a.** above, the temperature increased from 18.23°C to 35.55°C**.**
Calculate the molar heat of combustion of glucose in kJ mol^{-1}.
Sol. E=(35.55-18.23)x1.18=20.45 kJ; ΔH = (20.45/(1.324/180)) = 2.78 x 103 kJ mol^{-1} (+ or – one ok)
c. The carbohydrate, sucrose, is a disaccharide. Predict the approximate value of the ratio molar heat of combustion sucrose molar heat of combustion glucose
Approximate value of the above ratio is:
Sol. 2; sucrose is made of two monosaccharides (2 'glucoses+ fructose') (or, for example, has double the C atoms)

Q62. Give a concise answer to each of the following equations.

a. The Downs Cell uses a molten electrolyte containing NaC1 to produce sodium at an iron cathode. Explain why an aqueous solution of NaC1 cannot be used to produce sodium at an iron cathode.
Sol. H_2O is preferentially reduced (OR H_2 is formed – but not just 'Na^+ is not reduced')
b. Alumina dissolved in molten cryolite is used in preference to molten alumina in the electrolytic production of aluminum. Explain why.
Sol. Achieves a lower temperature ('use of cryolite saves energy' is ok)
c. If the tertiary structure of an enzyme is disrupted, the enzyme is no longer active. Explain why.
Sol. Tertiary structure is needed to provide the active site (beware any repeat of the stem)
d. When a solution of the enzyme amylase is boiled at 100°C for several minutes, the enzyme loses its tertiary structure yet its primary structure remains intact. Explain why.
Sol. Tertiary structure held by H-bonds; primary structure held by covalent bonds; covalent bonding stronger that H-bonding (OR H-bonds disrupted at 100^{o}C, but not covalent bonds.

Q63. A traffic warden working at a busy city intersection becomes sleepy after a few hours work. The atmosphere at the intersection is found to contain several parts per million of carbon monoxide (CO). Carbon monoxide in the traffic

warden's blood reacts according to the equation

$HbO_2 + CO(g) \rightarrow HbCO + O_2(g)$

Hb represents haemoglobin.

On the basis of this information, the equilibrium constant for the forward reaction of this equation is

a. less than one.

b. greater than one.

c. one.

d. unable to be estimated from the information.

Sol. b. The sleepiness of the traffic warden is consistent with the behaviour of the equilibrium

$HbO_2 + CO(g) \rightleftharpoons HbCO + O_2(g)$

which, because of the greater affinity of CO for haemoglobin, has a high equilibrium constant.

Q64. An enzyme is heated from 25°C to 100°C**.** The part that is least affected by the increase in temperature is the

a. primary structure.

b. secondary structure.

c. tertiary structure.

d. active site.

Q65. Maltose is a disaccharide formed by a condensation reaction between glucose ($C_6H_{12}O_6$) molecules. The molar mass of maltose, in g mol^{-1}, is:

a. 180

b. 324

c. 342

d. 360

The molar mass of glucose is 180. The condensation of glucose to form a disaccharide will lead to the loss of one water molecule (molar mass = 18) so that the molar mass of maltose is: (2x180) - 18 = 342.

Q66. Which of the following can be stored in the human body for use as an energy reserve?

I glucose

II fat

III glycogen

a. I only

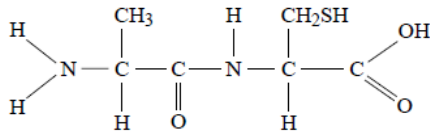
b. I and II only

c. II and III only

d. I and III only

Sol. c. Both fat and glycogen are stored in the human body, but glucose is for current use. This was a recall equation.

Q67. Consider the dipeptide with the following structural formula



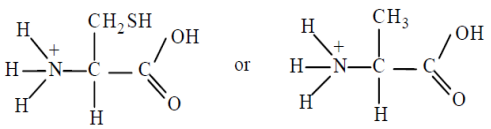
a. On the above formula, circle the peptide link.

Sol. CONH (the whole group must have been circled)**.**

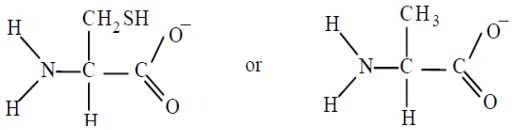
b. When this dipeptide is hydrolysed, two amino acids are formed.

• Draw a structural formula for one of these amino acids as it would exist in a solution of pH2.

Sol.



• Draw a structural formula for the other amino acid as it would exist in a solution of pH 12.



c. Nitrogen gas in the atmosphere cannot be used directly by plants to make amino acids. Give the formula of a nitrogen-containing molecule or ion which can be taken up by plants. Describe one process by which nitrogen in the atmosphere is converted into that molecule or ion.

Sol.

• $NH4^+$ (or NH_3 or NO_2^- or NO_3^-)

• Bacterial fixing of nitrogen (or NH3/Haber process, or NO/lightning flashes as appropriate).

Q68. a. The label on a packet of dry biscuits gives the following nutritional information.

– serving size 35 g

– protein 3.7 g

–fat saturated 0.80 g

– unsaturated 0.10 g

carbohydrates – sugars and starches 26.0 g

– cellulose fiber 3.5 g

i. Given that the energy available to the body per gram of:

– protein is 16 kJ

– fat is 37 kJ

– digestible carbohydrate is 17 kJ

calculate the total possible energy available to the body per gram of biscuit.

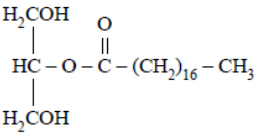
Sol. Energy per 35 g of biscuit = 3.7x16 + 0.9x37 + 26x17 = 543.7 kJ

Energy per gram = 534.7/35 = 15kJ

ii. A sample of the biscuit is burned in a bomb calorimeter to determine its energy value. The result indicated that 1g of biscuit releases 17 kJ. Give a possible explanation for the difference between this value and that calculated in part **i**.

Sol. Cellulose provides extra energy in the calorimeter.

b. Glycerol monostearate is used as an emulsifying agent in some ice creams. It can be formed from the reaction between glycerol and stearic acid. It has the semi-structural formula.



i. What features must be present in a molecule such as glycerol monostearate for it to be able to act as an emulsifying agent?

Sol. Hydrophilic (or polar) and hydrophobic (or non-polar) groupings.

ii. Glycerol and stearic acid can also react to form a triglyceride.

Write an equation for the reaction between glycerol and stearic acid to form a triglyceride.

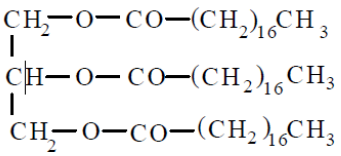
Sol. $C_3H_8O_3 + 3CH_3(CH_2)_{16}COOH = C_{57}H_{110}O_6 + 3H_2O$

iii. Is stearic acid a saturated or unsaturated carboxylic acid? Give a reason for your Answer.

Sol.

• Saturated

• There are no carbon-carbon double bonds.



Q69. To live, the human body needs a regular supply of oxygen, which is distributed throughout the body by the red pigment, haemoglobin (Hb). Hb is carried around the body by the red blood cells in the blood.

a. Write a simple equation showing oxygen reacting with haemoglobin.

Sol. Any of:

• $Hb + O_2 \rightleftharpoons HbO_2$

• $Hb_4 + 4O_2 \rightleftharpoons Hb4O_8$

• haemoglobin + O_2 ⇌ oxyhaemoglobin.

b. Using this equation explain, in terms of equilibrium principles, how a low oxygen concentration can lead to the cells in a human body being deprived of oxygen.

Sol. If the oxygen concentration drops, the position of equilibrium moves left and less oxygen is carried to the cells/ less oxyhaemoglobin is formed.

c. At high altitudes, the pressure of atmospheric oxygen is significantly less than it is at sea level. People who live most of their lives on very high mountains normally have a number of special adaptations to living at high altitudes. One such adaptation is the possession of a significantly higher red blood count (that is, a larger number of red blood cells in the blood)**.** Compared with people living at sea level. Explain how a high blood count is a useful adaptation to high altitude living.

Sol. A high blood count means there is a higher concentration of haemoglobin in the blood, so the position of equilibrium moves right/ more oxyhaemoglobin is formed.

Q70. The trisaccharide formed from the reaction of three glucose ($C_6H_{12}O_6$) molecules has the formula

a. $C_{18}H_{36}O_{18}$

b. $C_{18}H_{34}O_{17}$

c. $C_{18}H_{32}O_{16}$

d. $C_{18}H_{30}O_{15}$

Given the molecular formula $C_6H_{12}O_6$ of the monosaccharide, glucose, the condensation of three of these molecules to form a trisaccharide must be a condensation reaction that should eliminate two water molecules. The most common error was to conclude that three water molecules were eliminated (response **d**).

Q71. The substances below are present in the food we eat.

Which one provides the lowest amount of energy per gram for the human body?

a. tristearin (a triglyceride)

b. glycine (an amino acid).

c. cellulose (a polysaccharide)

d. glucose (a monosaccharide)

Sol. c. provides the lowest amount of energy per gram as it is not significantly digested in the human body.

Q72. Nitrifying and denitrifying bacteria play important roles in the nitrogen cycle. They are involved in the following reactions.

$NH_4^+(aq) \xrightarrow{\textit{nitrifying bacteria}} NO_3^-(aq)$ reaction 1

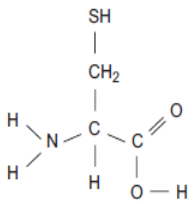
$NO_3^-(aq) \xrightarrow{\textit{denitrifying bacteria}} N_2(g)$ reaction 2

Which one of the following alternatives correctly describes both of these reactions?

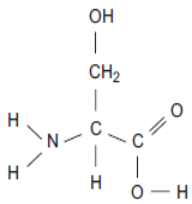
	Reaction 1	Reaction 2
a.	nitrogen fixation	oxidation
b.	oxidation	nitrogen fixation
c.	nitrogen fixation	reduction
d.	oxidation	reduction

Q73. a. Two common α amino acids (2-amino acids) are cysteine and serine. Their structural formulas are given below

cysteine



serine

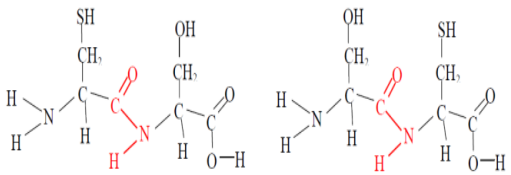


i. What chemical feature must an amino acid have in order to be classified as an α amino acid?

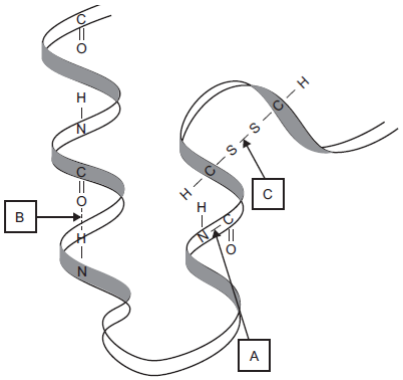
Sol. It must have carboxy and amino groups attached/bonded to the same carbon atom.

ii. Cysteine and serine can combine together to form two different dipeptides. Draw the structural formulas of these two dipeptides.

Sol.



b. Enzymes, which are composed mostly of protein, catalyse many chemical reactions. The structure of a portion of an enzyme, with some of its constituent atoms shown, is represented below.



i. Name the type of chemical bond present in the parts labelled.

A--------

B--------

C---------

Sol. A: covalent bond and/ or peptide (amide) link/ bond

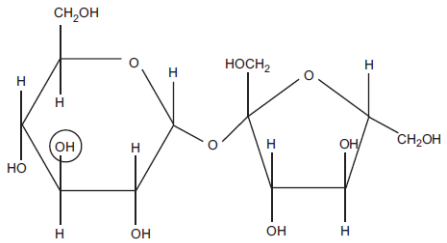
B: a hydrogen bond/ dipole-dipole bonding

C: a covalent bond and/ or a disulfide link/ bond

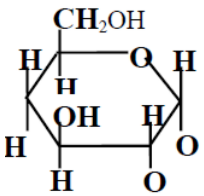
ii. Why is the tertiary structure of an enzyme essential to its function?

Sol. It provides a site at which a chemical reaction can occur/an active site.

Q74. Sucrose is a disaccharide. Bees use an invertase enzyme to convert sucrose to an equimolar mixture of glucose and fructose. The structural formula of sucrose is given below and one of the functional groups in the molecule has been circled.



a. i. Give the name of the functional group circled in the structural formula of sucrose.
Sol. hydroxyl group
ii. To which of the major food groups does sucrose belong?
Sol. Carbohydrate
iii. Given that glucose has a six-membered ring structure, draw the structural formula of glucose.
Sol.



b. What simple molecule is the other reactant in the conversion of sucrose to glucose and fructose?
Sol. Water
c. The invertase enzyme can be isolated and used in the laboratory to form glucose and fructose from sucrose.
In a particular set of experiments, equivalent amounts of the enzyme were mixed with three sucrose solutions of equal concentrations. One of the solutions was kept at 5°C throughout the experiment, one at 35°C and the last at 95°C.
The following gives the percentage yield of glucose after 30 minutes.

Temperature at which the experiment was carried out	Percentage yield of glucose
5°C	10
35°C	95
95°C	2

Explain why the percentage yield is higher at 35°C than at:
i. 5°C
Sol. There are more effective/fruitful collisions between reactants at 35°C, **or** reactions occur faster at a higher temperature
ii. 95°C
Sol. The enzyme would have partly denatured/degraded at 95°C**.**

Q75. Give concise explanations for the following.
a. Food chemists quote the energy content of food in kJ g.1, rather than kJ mol.1.
Sol. Most foods are not pure substances.

Q76. Transport of oxygen in the body involves the complex molecules haemoglobin and oxyhaemoglobin.
haemoglobin + oxygen oxyhaemoglobin
If carbon monoxide (CO) is present in the air, poisoning can occur because
a. the equilibrium constant, K, for the reaction is reduced.
b. CO reacts with oxygen to form CO2, driving the equilibrium to the left.
c. the equilibrium shifts to the left because haemoglobin bonds strongly with CO.
d. CO catalyses the decomposition of oxyhaemoglobin into haemoglobin and oxygen.
Sol. c. The greater affinity of CO for haemoglobin forces the equilibrium
haemoglobin + oxygen⇌ oxyhaemoglobin to the left as the equilibrium
haemoglobin + carbon monoxide⇌ carboxyhaemoglobin is established.

Q77. Which one of the following is **least** likely to be an amino acid obtained by the hydrolysis of protein in food?
a. H_2NCH_2COOH
b. $H_2NCH(CH_2SH)COOH$
c. $H_2NCH_2CH(CH_3)COOH$
d. $H_2NCH(CH_2COOH)COOH$
Sol. c. was the only amino acid given that was not an α-amino acid.

Q78. Humans obtain all of their energy requirements from the food they eat. The amount of energy in food can be measured using a bomb calorimeter.
The following are steps, in random order, that are taken to determine experimentally the energy content of a sample of a food, using a bomb calorimeter.
1. Measure the rise in temperature
2. Fill the calorimeter with water and wait until the temperature has reached a steady value.
3. Accurately weigh the sample of the food and place it inside the sealed compartment or .bomb. in the presence of excess oxygen
4. Measure the rise in temperature again.
5. Pass a measured amount of electrical energy into the system.
6. Ignite the sample with electrical ignition wires.
Which one of the following alternatives best presents an appropriate sequence of procedures?
a. 5, 1, 3, 2, 4, 6
b. 2, 3, 1, 5, 6, 4
c. 3, 2, 5, 1, 6, 4
d. 3, 6, 1, 2, 5, 4

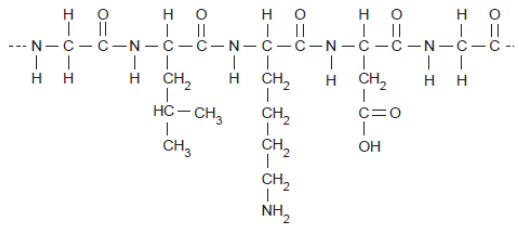
Q79. When adults consume more food than their energy requirements, the extra energy is stored by the body. In adults this excess energy is usually stored as:
a. glucose and fats.
b. glycogen and fats.
c. starch and glucose.
d. protein and carbohydrates.

Q80. Amylase is an enzyme that specifically digests starch in humans. A major product of this starch hydrolysis reaction is
a. maltose.
b. glycogen.
c. cellulose.
d. glycerol.
Sol. a. A significant percentage of students chose option **b**, perhaps because glycogen looked a little more familiar than maltose. However, glycogen and cellulose should have been recognised as being polymers and glycerol is familiar as a component of lipids.

Q81. The function of a protein is dependent on its three-dimensional structure. This structure can be disrupted, denaturing the protein. Which of the following changes could cause this denaturing?
I the addition of a strong acid
II the addition of a strong base
III a significant increase in temperature
a. I only
b. I and II only
c. III only
d. I, II and III

Sol. d. The only choice should have been between options **c** and **d**, since it should be known that III (temperature) causes denaturation. It should also be known that proteins can be hydrolysed by strong acids, so option **d** is left as the only possible choice. Alternatively, it could be argued that strong acidic or basic media will affect the degree of protonation of such groupings as $-NH_2$ and –COOH and their acid-base conjugates and thereby disrupt the hydrogen bonding that maintains the three dimensional structure of a natural.

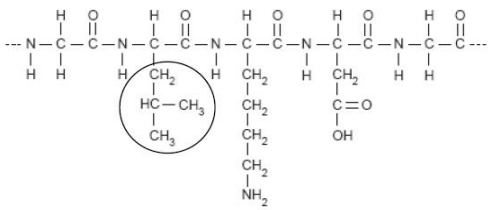
Q82. The structure of a section of a protein chain is shown in the diagram below.



a. In water, protein molecules often adopt a roughly spherical tertiary structure in which the side chain groups play an important role in influencing shape and solubility.

i. On the above structure of the portion of the protein chain, circle the side chain group that is hydrophobic.

Sol.



ii. In general, would you expect hydrophobic groups to be in the interior or to be on the external surface of water soluble proteins? Explain your reasoning.

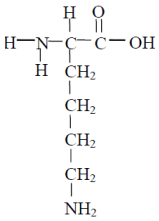
Sol. Interior, since the hydrophilic bits interact more strongly with water **or** as this makes the protein more soluble in water.

b. During digestion, the section of the protein shown above undergoes hydrolysis to form amino acids.

i. When this section of the protein is hydrolysed, one of the amino acids formed has a carbon to nitrogen ratio of 3:1.

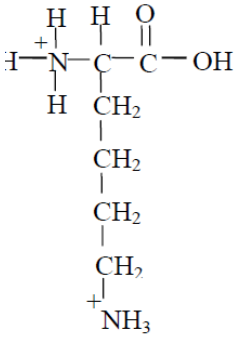
In figure A below, draw the structure of this amino acid.

Sol.



ii. In figure B below, draw the structural formula of this same amino acid as it would most likely exist at pH 2.

Sol.



c. When vegetables such as potatoes are cut and exposed to air, a browning reaction takes place. This is caused by the enzyme, polyphenol oxidase, interacting with oxygen and polyphenols present in the vegetable. The browning reaction may be prevented by placing the vegetable in boiling water for a short time. When removed from the boiling water and cooled, browning no longer takes place. Explain the chemical basis of this observation.

Sol. The high temperature denatures protein.

d. Living things require a source of nitrogen in order to form proteins. Plants obtain their nitrogen from nitrogen-containing ions present in the soil.

Give the formula for an ion present in the soil in which nitrogen has an oxidation number of **+5**.

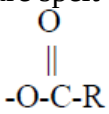
Sol. NO_3^-

Q83. a.

i. A long chain carboxylic acid can be represented by the general formula RCOOH where R represents a hydrocarbon group.

In the space below, show the structure of a fat formed by the reaction between glycerol and three molecules of RCOOH. Clearly show the structure of all ester groups in the fat.

Sol. correct structure of the lipid with the ester structure spelt out; that is, as



ii. Palmitic acid ($C_{16}H_{32}O_2$) and oleic acid ($C_{18}H_{34}O_2$) are both long chain carboxylic acids.

Which one of them is classified as an **unsaturated** carboxylic acid?

Sol. Oleic acid or $C_{18}H_{34}O_2$

b. Unsaturated fats can be converted into saturated fats by reaction with hydrogen gas in the presence of a metallic catalyst. In one such conversion, 2.50 mole of an unsaturated fat is converted to a saturated fat by reaction with 15.0 g of H_2 gas. Calculate the number of carbon to carbon double bonds present in a molecule of the unsaturated fat.

Sol.

Mol of $H_2(15/2)$= 7.5, which gives (7.5/2.5) mol of H_2 per mol of fat, =3 double bonds per molecule.

c. The heat of combustion of palmitic acid ($C_{16}H_{32}O_2$) may be determined by burning it in a bomb calorimeter in the presence of excess oxygen. Write a balanced equation for the complete combustion (burning) of palmitic acid in the presence of excess oxygen.

Sol. $C_{16}H_{32}O_2$(s or l) + $23O_2$(g) → $16CO_2$(g) + $16H_2O$(g or l).

d. Vitamin C is an antioxidant that is often added to margarine to prevent it from becoming rancid. Explain how vitamin C acts as an antioxidant.

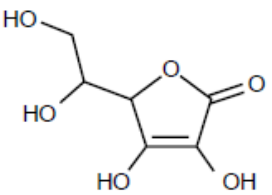
Sol. Vitamin C preferentially reacts with O_2.

Q84. Which of the following statements about enzymes are correct?

I Enzymes are proteins.

II Enzymes increase the rate of biochemical reactions.
III Enzymes increase the equilibrium constant of biochemical reactions.
a. I and II only
b. I and III only
c. II and III only
d. I, II and III

Q85. A structure of vitamin C is given below.

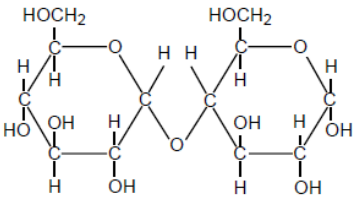


Vitamin C is an important biological molecule. It is often added to foods as an antioxidant.
Based on this information, and on the structure of vitamin C shown above, it can be predicted that vitamin C
is more soluble in
a. fats than in water and is a good oxidant.
b. fats than in water and is a good reductant.
c. water than in fats and is a good oxidant.
d. water than in fats and is a good reductant.

Q86. The types of compounds that comprise the major food groups include carbohydrates, fats and proteins. A sample, containing only one of these three types of compounds, is analysed and found to contain the following percentages by mass.
Carbon 76.2%
Oxygen 11.3%
Nitrogen 0%
The compound
a is likely to be a fat.
b. is likely to be a protein.
c. is likely to be a carbohydrate.
d. cannot be identified as the percentage composition of other elements has not been given.

Q87. The following two unbalanced equations represent processes which are part of the nitrogen cycle.
I $NH_3(aq) \rightarrow NH_4^+(aq)$
II $NH_4^+(aq) \rightarrow NO_3(aq)$
Which one of the following alternatives correctly describes the reactants in each of these processes?
In process I, NH3 (aq) is In process II, the $NH4^+(aq)$ ion is
a. an acid reduced
b. a base reduced
c. an acid oxidised
d. a base oxidised

Q88. a. A structure for the disaccharide maltose ($C_{12}H_{22}O_{11}$) is given below.



i. Maltose undergoes enzyme-catalysed hydrolysis during digestion. Give the molecular formula of theproduct of this hydrolysis.
Sol. $C_6H_{12}O_6$
ii. Write a balanced equation for the combustion of one mole of maltose

($C_{12}H_{22}O_{11}$) in the presence of excess oxygen.

Sol. $C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(g)$ or (l)

iii. The monosaccharide from the hydrolysis of maltose also undergoes combustion in excess oxygen. Combustion of one mole of this monosaccharide releases 2816 kJ. Give a numerical estimate for the value of ΔH for the combustion of one mole of maltose and explain the reasoning behind your estimate.

Sol. 5632 or –5632 (2816×2), since maltose contains two monosaccharide/ glucose molecules.

Any numerical value of approximately 5500 was accepted.

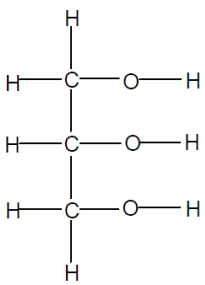
b. Most fats and oils contain the ester functional group formed by a condensation reaction between 1 molecule of glycerol and 3 molecules of fatty acids.

i. How many hydrogen atoms are there in a molecule of a monounsaturated fatty acid with 16 carbon atoms?

Sol. 3. The correct formula for the appropriate acid (for example, $C_{15}H_{29}COOH$) was also accepted.

ii. In the space below, clearly draw a structural formula for glycerol. Show **all** bonds.

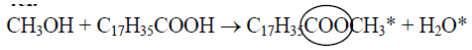
Sol.



c. A potentially useful vehicle fuel is manufactured by a condensation reaction between one molecule of methanol (CH_3OH) and one molecule of a fatty acid. A particular fuel, methyl stearate, is produced when the fatty acid stearic acid ($C_{17}H_{35}COOH$) reacts with methanol.

i. Write a balanced equation for the formation of methyl stearate from methanol and stearic acid.

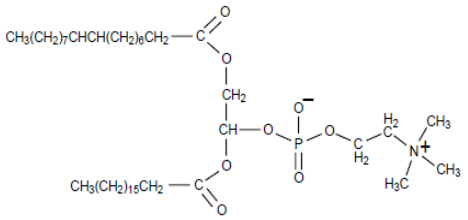
Sol.



ii. On the product formed in part **i**, clearly circle a complete ester group.

Sol. This mark was awarded for correctly circling the ester (COO) part of the methyl stearate (see above).

d. Mayonnaise is an example of an oil-in-water emulsion. It is stabilised by the addition of egg yolk, which contains the emulsifier lecithin (structure below).

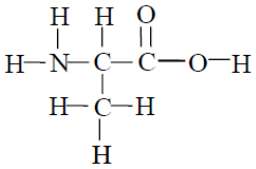


In terms of its structure, explain why the lecithin molecule is able to act as an emulsifier.

Sol. It contains both hydrophilic and hydrophobic parts/components

Q89. a. i. Draw the full structural formula of the 2-amino acid (α. amino acid**)** which has the molecular formula $C_3H_7NO_2$. Clearly show all bonds.

Sol.

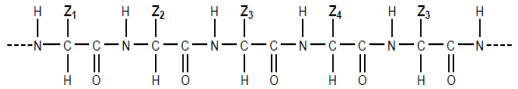


All bonds were to be shown; except –OH was accepted for –O–H.

ii. The amino acid drawn in part **i.** can form two different dipeptides as a result of condensation reactions with the 2-amino acid $C_2H_5NO_2$. Draw a structural formula of one of the dipeptides formed in the reaction between one molecule of each of these two amino acids.

Sol. $H_2CH(CH_3)CONHCH_2CO_2H$ or $NH_2CH_2CONHCH(CH_3)CO_2H$.

b. The primary structure of a section of a food protein chain is shown below. The formulas of the side chain groups Z1, Z2, Z3 and Z4 are also given.

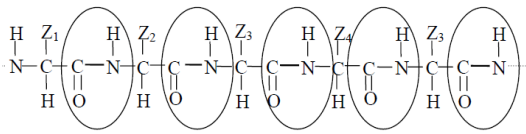


$Z_1 = -CH_2SH$ $Z_2 = -CH_2CH_2CH_2CH_2NH_2$

$Z_3 = -CH_2CO_2H$ $Z_4 = -CH_2CH_2CH_3$

i. On the above section of the protein chain, circle one complete peptide link.

Sol.



ii. Which one of the side chain groups, Z_1 to Z_4, would be positively charged at pH 2?

Sol. Z_2 or $–CH_2CH_2CH_2CH_2NH_2$

iii. Which one of the side chain groups, Z_1 to Z_4, is often involved in the formation of covalent cross links which stabilise the tertiary structure of a protein?

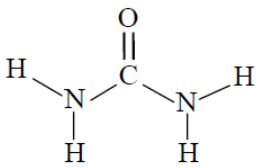
Sol. Z_1 or $–CH_2SH$

iv. Carboxypeptidase is an enzyme that catalyses the digestion of food protein in the small intestine where the pH is approximately 8. However, it does not catalyse the digestion of food protein in the stomach where the pH is very low. Suggest a reason for this difference.

Sol. The different pH will change (or denature) the structure of the active site in the enzyme.

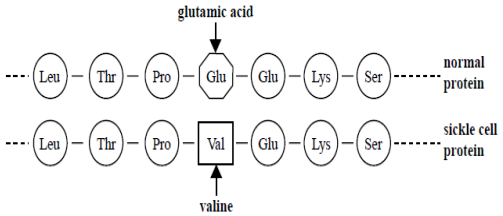
v. Following digestion of this protein, nitrogen containing wastes will be produced. This waste nitrogen is excreted largely as urea. In the space below draw the full structural formula of the urea molecule. Clearly show all bonds.

Sol.



Q90. The disease sickle cell anaemia is marked by the presence of an abnormal protein in the blood of people with this disease. The sixth position in the normal protein chain is occupied by the amino acid, glutamic acid. The sickle cell protein chain has the amino acid, valine, in the sixth position. This is the only difference between the two protein chains.

A section of each protein chain containing glutamic acid and valine is shown below.

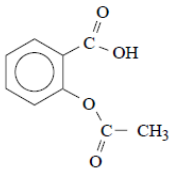


	molecular mass	^{1}H NMR spectrum
A.	Sickle cell protein chain has the greater molecular mass.	Both protein chains have the same ^{1}H NMR spectrum.
B.	Sickle cell protein chain has the greater molecular mass.	The protein chains have different ^{1}H NMR spectra.
C.	Normal protein chain has the greater molecular mass.	Both protein chains have the same ^{1}H NMR spectrum.
D.	Normal protein chain has the greater molecular mass.	The protein chains have different ^{1}H NMR spectra.

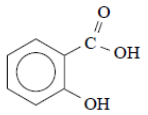
Sol. d. The only difference between the two protein chains was valine in place of glutamic acid. Since the glutamic acid side group $-CH_2CH_2COOH$ has a greater relative mass than the valine side group $-CH(CH3)_2$ (as seen in Table 8 of the data book), the normal protein chain has the greater molecular mass. The structural differences in the glutamic acid and valine side group would suggest that the two proteins would have a difference in their NMR spectra.

Q91. Aspirin is a compound widely used as a painkiller and to relieve the symptoms of fever. It can be produced by means of a reaction in which salicylic acid is one of the reagents.

The structures of aspirin and salicylic acid are shown below.



aspirin



salicylic acid

Which one of the following statements about aspirin is not correct?

a. Aspirin may be prepared by reaction between salicylic acid and CH3OH.

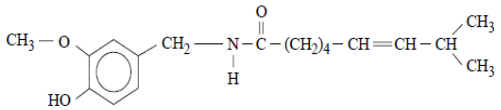
b. Aspirin contains both an ester and a carboxylic acid functional group.

c. Aspirin can undergo an acid-base reaction with $NaHCO_3$.

d. Aspirin may be prepared by reaction between salicylic acid and CH3COOH.

Q92. Capsaicin is an important component of some pain relief ointments. It is also the major compound responsible for the burning sensation of chili peppers.

A structure for capsaicin is given below.



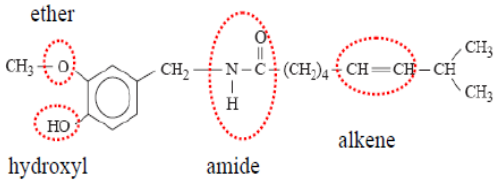
A molecule of capsaicin contains

a. an ester functional group and an amide functional group.

b. an ester functional group and an alcohol functional group.

c. an alkene functional group and an amide functional group.

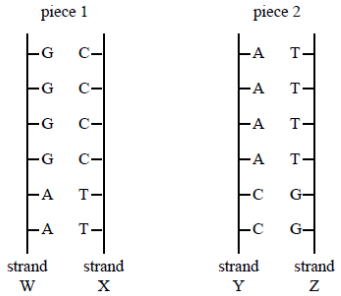
d. a carboxylic acid functional group and an alcohol functional group.



Q93. A biomolecule is chemically analysed and found to contain only the elements carbon, hydrogen, oxygen, nitrogen and phosphorus.
The biomolecule is most likely to be
a. DNA.
b. a protein.
c. a polysaccharide.
d. a fat formed by condensation of glycerol with stearic acid.

Q94. A piece of double-stranded DNA, which is 200 base pairs in length, contains 50 thymine bases.
The number of guanine bases in the piece of DNA is:
a. 50
b. 100
c. 125
d. 150
200 base pairs means a total of 400 bases: 50 thymine, 50 adenine, 150 cytosine and 150 guanine. Option **a** overlooks the significance of the base 'pairs'.

Q95. In the pieces of double-stranded DNA shown below, the letters A, C, G and T represent the bases adenine, cytosine, guanine and thymine respectively. Each vertical line represents a sugar-phosphate backbone.



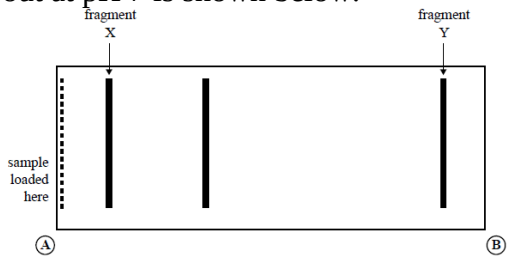
Which one of the following alternatives correctly identifies the DNA piece that is most readily separated by heating and the strand of highest molecular mass?

	piece most readily separated by heating	strand of highest molecular mass
A.	1	X
B.	2	W
C.	2	X
D.	1	W

Sol. b. G–C bonds (three sites of hydrogen bonding) are stronger than A–T bonds (two sites of hydrogen bonding), so piece 1 has the stronger bonds between the strands. Therefore, piece 2 is more readily separated by heating.
Relative molecular masses of the bases are Guanine (151), Adenine (135), Thymine (126) and Cytosine (111) (as per Table 10 of the data book). So strand W has the highest relative molecular mass. This could be deduced by inspecting the relative sizes of the bases with guanine and adenine significantly larger than cytosine and thymine.

Q96. Gel electrophoresis is a technique that can be used to separate DNA fragments in forensic chemistry. The gel resulting from

such a separation experiment carried out at pH 7 is shown below.



Which one of the following statements about the experiment is not correct?

a. Fragment X has a higher molecular mass than fragment Y.

b. Fragment Y moves through the gel at a faster rate than fragment X.

c. The negative terminal of the power supply is connected to end A of the gel.

d. Under the conditions of this experiment, the DNA fragments are positively charged.

Sol. d. DNA fragments assume an overall 'negative' charge because of the phosphate groups. Fragments move from the negative terminal to the positive terminal and the smaller fragments move through the gel faster than the larger fragments.

Q97. When molecular iodine, I2, reacts with an unsaturated compound, one molecule of iodine adds across each double bond. Unsaturated fatty acids react in this way with iodine. 0.150 mol of a particular fatty acid reacts with exactly 0.300 mol of I2. The fatty acid could be

a. lauric.

b. linoleic.

c. palmitoleic.

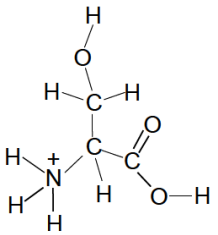
d. arachidonic.

Sol. b. The reaction of 0.150 mol of the fatty acid with 0.300 mol I_2 indicates that each molecule of the fatty acid contains 2 (C=C) double bonds. Saturated fatty acids have the general formulae $C_nH_{2n}O_2$ or $CnH_{2n+1}COOH$, so fatty acids with 2 (C=C) double bonds will have the general formulae $CnH_{2n-4}O_2$ or $CnH_{2n-3}COOH$. Only linoleic acid (option **b**), $C_{17}H_{31}COOH$ (that is, $C_{18}H_{32}O_2$), fits the general formula. Lauric acid is saturated, palmitoleic acid is monounsaturated and arachidonic acid has 4 (C=C) double bonds.

Q98. a.

i. Draw the structure, showing all bonds, of the amino acid serine as it would exist in solution at pH 2.

Sol.



ii. Name the functional group on the side chain of serine.

Sol. hydroxyl (hydroxy)

b. Write the molecular formula of the amino acid phenylalanine.

Sol. $C_9H_{11}NO_2$

Responses to this equation displayed a number of consistent errors, including:

-having 12 H in molecular formula, probably because the students did not

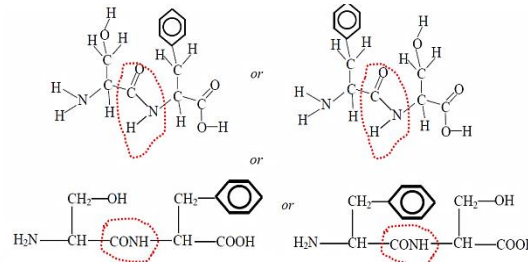
recognise that for the C atom on the CH_2 to bond benzene it has substituted for a H atom on C_6H_6, converting it to C_6H_5
- leaving N out of the molecular formula
- providing a semi structural formula rather than a molecular formula.

Two different dipeptides can form between phenylalanine and serine.

c. i. Draw the structure of one of these dipeptides.

ii. Circle the peptide (amide) functional group in the dipeptide you have drawn in part **i.** above.

Sol.



d. In the space below, sketch a covalent link that can form between the side chains of two cysteine residues.Only the relevant atoms that form the link need to be shown.

Sol. S-S

Q99. The most appropriate technique to determine levels of the Pb^{2+} ion in blood is

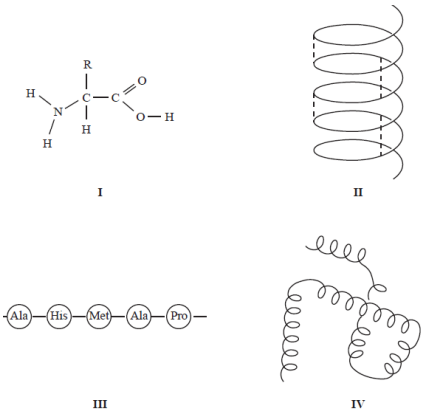
a. mass spectrometry.

b. infrared spectroscopy.

c. atomic absorption spectroscopy.

d. high-performance liquid chromatography.

Q100. A student's study notes on protein structure included these four unlabelled sketches.



Which sketches best represent the primary, secondary and tertiary structure of proteins?

primary secondary tertiary
structure structure structure

a. I II IV

b. I IV II

c. III IV II

d. III II IV

Q101. The tertiary structure of proteins may be maintained by

a. hydrogen bonding.

b. ionic interactions.

c. covalent bonds.

d. all of the above.

Q102. In response to a pain stimulus, the brain produces small polypeptide molecules called enkephalins. These molecules block the transmission of pain through the central nervous system.

The amino acid sequence in one such compound, methionine enkephalin, is:

Tyr – Gly – Gly – Phe – Met

The number of amine, carboxylic acid and amide (peptide) functional groups in this polypeptide is:

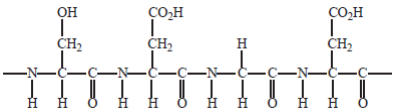
$-NH_2$ –COOH –CONH

a. 0 0 5
b. 1 1 4
c. 1 1 5
d. 0 2 4
Sol. b. Strong performance on this equation reflects effective use of the Data Book.

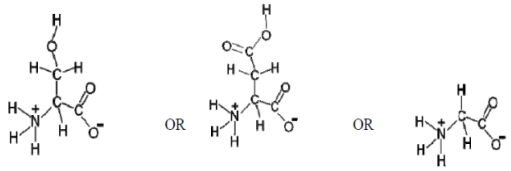
Q103. Which one of the following statements about enzymes is not true?
a. Enzymes can only be denatured by an increase in temperature.
b. Enzymes may form temporary ion-dipole bonds with substrate molecules.
c. Enzymes speed up reactions by holding substrate molecules in positions necessary for reaction.
d. The tertiary structure of an enzyme may be altered if one amino acid in its primary structure is substituted for another, different amino acid.

Q104. The separation and identification of proteins that can be used as disease markers is an exciting area of research. Researchers must separate and identify proteins that could be used as disease markers from the many thousands of proteins that exist in our bodies.
Which of the following sequence of techniques could be used to
i. separate these molecules, then
ii. accurately determine their molecular mass, and then
iii. determine their molecular structure.
a. NMR spectroscopy, followed by mass spectrometry, followed by high-performance liquid chromatography.
b. high-performance liquid chromatography, followed by mass spectrometry, followed by NMR spectroscopy
c. high-performance liquid chromatography, followed by infrared spectroscopy, followed by mass spectrometry
d. mass spectrometry, followed by high-performance liquid chromatography, followed by infrared spectroscopy

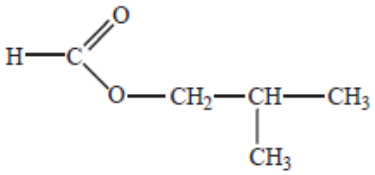
Q105. a. The following structure shows part of a polypeptide.



i. Name the amino acids that make up this section of the polypeptide.
Sol. Serine, glycine, aspartic acid
At a particular pH, an amino acid in solution can exist as ions that have both a negative and positive charge. These ions are called zwitterions.
ii. Choose one of the amino acids in this section of polypeptide and draw the structure of its zwitterion clearly showing all bonds.
Sol.



b. Many esters are used as flavouring agents in food. The structure of the ester used in raspberry flavouring is provided below.

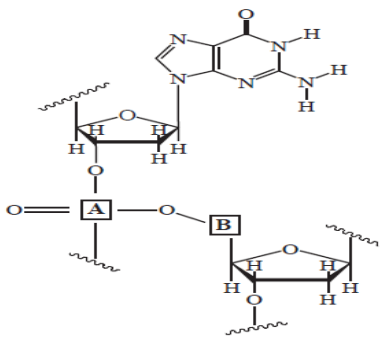


Give the names of two carbon compounds that can be used to synthesise this ester.

Sol. Methanoic acid*
Methylpropan-1-ol/methyl-1-propanol/2-methylpropan-1-ol/2-methyl-1-propanol*

The most common error in this equation was in the naming of the alcohol. Methylpropanol was common but not acceptable. Students should be aware that there are two possible alcohols derived from methylpropane, methylpropan-1-ol and methylpropan-2-ol, and the location of the –OH group should be reflected in the name. It was not essential to include '2-' in front of 'methyl' because on methylpropane, there is no other possible location for the methyl group.

Q106. a. The diagram below represents part of the DNA double helix.



i. Write down the formula of the atom or groups of atoms represented by A and B**.**

Sol. A – P
B – CH_2

ii. Name the base that is complementary to the base shown.

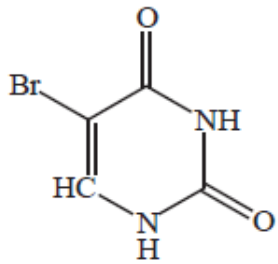
Sol. cytosine

The temperature at which 50% of a piece of double-stranded DNA separates into single strands is known as the melting temperature. A certain human viral DNA contains a greater percentage of adenine than a monkey viral DNA**.** The lengths of the human and monkey viral DNA molecules are equal.

b. Explain why the human viral DNA has a lower melting temperature than the monkey viral DNA**.**

Sol. Human DNA has a greater proportion of A-T (adenine-thymine) base pairs which have fewer hydrogen bonds.

Under certain circumstances the compound 5-bromouracil (shown below) is incorporated into the DNA structure in place of one of the normal DNA bases.



c. Which DNA base is likely to be replaced by 5-bromouracil?

Sol. Thymine

Q107. Many reactions occurring in plant and animal cells involve a chemical called nicotinamide adenine dinucleotide,
NAD^+. One such reaction is
$2NADH(aq) + 2H^+(aq) + O2(g) \rightarrow 2NAD^+(aq) + 2H_2O(l)$
It has been suggested that this reaction could be used in biochemical fuel cells to power pacemakers used to control irregular heartbeats.
If this reaction were performed in a fuel cell, NADH would
a. undergo oxidation at the anode.
b. undergo reduction at the cathode.
c. undergo reduction at the anode.
d. undergo oxidation at the cathode
Sol. a. The half equation can be deduced from the overall equation.
Oxidation: $NADH(aq) \rightarrow NAD^+(aq) + H^+(aq) + 2e^-$
Reduction: $O_2(g) + 2H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

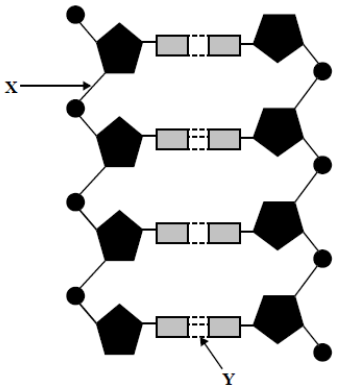
Q108. a. Biodiesel is an alternative to standard diesel fuel. Biodiesel is made from biological ingredients instead of petroleum. Biodiesel is usually made from plant oils or animal fats through a series of chemical reactions. In one process a common triglyceride in palm oil, known as POP, is reacted with methanol in the presence of potassium hydroxide as a catalyst. The result is a mixture of methyl esters of the fatty acids (biodiesel).

i. The value of the stoichiometric ratio $\frac{\text{number of moles of methanol}}{\text{number of moles of POP}}$ is

Sol. 3 or 3:1

ii. Calculate the volume, in litres, of methanol (density = 0.79 g mL^{-1}) required to react completely with 10.0 kg of the triglyceride POP (Mr = 833) to produce glycerol and the mixture of methyl esters.
Sol.
n(POP)=10.0x103/833 =12.0 mol
$n(CH_3OH) = 3 \times 12.0 = 36.0$ mol
$m(CH_3OH) = 36.0 \times 32.0$
= 1.15x103 g
$V(CH_3OH) = m(CH_3OH)/ d(CH_3OH)$
= 1.15x103 g/ 0.79 g mL^{-1}
= 1.46x103 ml
= 1.5 L (range accepted 1.46–1.5)
b. Cervonic acid is a polyunsaturated fatty acid found in fish oil. The number of carbon-carbon double bonds in a molecule of cervonic acid can be determined by titration with iodine, I_2, solution. An addition reaction takes place between the double bonds in cervonic acid and iodine. 20.00 mL of 0.300 M I_2 solution reacted exactly with 0.328 g of cervonic acid. The molar mass of cervonic acid is 328.0 g mol^{-1}.
i. Calculate the number of double bonds in a molecule of cervonic acid.
Sol. $n(I2) = 0.300 \times 20.00x10^{-3}$
$= 6.00x10^{-3}$* mol
n(cervonic acid) = 0.328 / 328
= $1.00x10^{-3}$* mol
Ratio $n(I_2)$ / n(cervonic acid) = 6 / 1
Hence 6 (C=C) double bonds.
There are 22 carbon atoms in a molecule of cervonic acid.
ii. What is the formula of cervonic acid?
Sol. $C_{22}H_{32}O_2$ or $C_21H_{31}COOH$

Q109. The following diagram is a simplified representation of a section of DNA**.**



The main types of bonds at X and Y are:

	X	Y
a.	ionic bonds	hydrogen bonds
b.	covalent bonds	dispersion forces
c.	dispersion forces	ionic bonds
d.	covalent bonds	hydrogen bonds

Q110. In a double-stranded DNA sample, adenine constitutes 16% of the total number of bases. The percentage of guanine content in the double strand is:
a. 16%
b. 34%
c. 42%
d. 68%

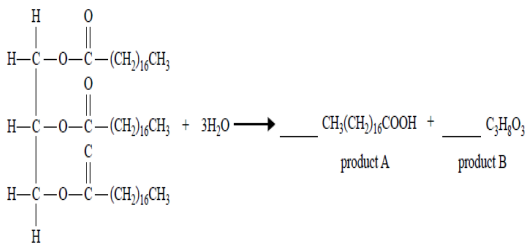
Q111. Consider the following statements about the structure of proteins.
I. The primary structure of a protein is determined by the sequence of amino acid residues.
II. The secondary structure of a protein is the result of hydrogen bonding between –NH and –CO groups.
III. The tertiary structure of a protein involves bonding between the side chains on the amino acid residues.
Of these statements
a. only I and III are true.
b. only I and II are true.
c. only II and III are true.
d. I, II and III are all true.
Sol. d. The primary, secondary and tertiary structures were accurately described in statements I, II and III respectively. The choice of option **a** suggested that many students were not aware that the hydrogen bonding in the secondary structure that occurs between peptide, –CONH–, groups, in the secondary structure of proteins is between the H atom on peptide group and the O atom on a peptide group further along the chain.

Q112. Which one of the following amino acids is likely to be most polar in an aqueous solution at pH 7?
a. glutamic acid
b. glycine
c. leucine
d. valine
Sol. a. All amino acids contain the $-NH_2$ and –COOH functional groups. Overall polarity therefore depends on the polarity of the side chains. Of the amino acids listed, only glutamic acid (option **a**) has a polar group(–COOH) in its side chain. Students could have checked this in the Data Book.

Q113. Enzymes play an important role in biochemical reactions. Consider the following statements relating to enzyme-catalysed reactions.

I. The shapes of the substrate and the active site of the enzyme are complementary.
II. When enzymes are denatured, the shape and structure of the active sites are **not** altered.
III. The substrate forms bonds with the active site of the enzyme of these statements:
a. only I is true.
b. only III is true.
c. only I and III are true.
d. I, II and III are all true.

Q114. Triglycerides are an important source of energy in the body. During digestion, triglycerides are broken down in the small intestine by the enzyme lipase. An incomplete chemical equation that shows the hydrolysis of a triglyceride is shown below.



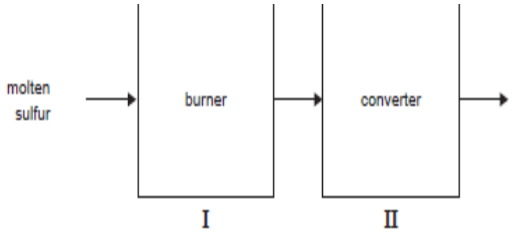
i. In the spaces provided above, balance the equation by adding appropriate coefficients for product A and product B**.**
Sol.
Either of:
• 3 $CH_3(CH_2)16COOH$ + 1 $C_3H_8O_3$
• 3 $CH_3(CH_2)16COOH$ + 2 $C_3H_8O_3$
(that is, no coefficient for glycerol).

The presence of an extra C in the structure of the triglyceride meant that there was a valid argument for only two $CH_3(CH_2)16COOH$, which was also accepted.
ii. Name the fatty acid that is produced by the hydrolysis of this triglyceride.
Sol. Either of:
• stearic acid
• octadecanoic acid.
iii. The fatty acid produced in the above reaction is completely oxidised to produce carbon dioxide and water.
Write a balanced equation for the oxidation reaction.
Sol. $CH_3(CH_2)16COOH + 26O_2 \rightarrow 18CO_2 + 18H_2O$
$C_{17}H_{35}COOH$ and $C_{18}H_{36}O_2$ are also acceptable formulas for stearic acid.

CHAPTER FOUR
Industrial Chemistry
الكيمياء الصناعية

Tests & Answers

Q1. Sulfuric acid can be produced from mined sulfur via the Contact Process. The first two stages in the industrial production of sulfuric acid by this process are represented below.



a. Give a reason why, in stage I, the molten sulfur is sprayed into the burner rather than being allowed to flow through it.

Sol. Spraying the molten sulphur produces droplets which provide a greater surface area* for contact with O_2 and hence speed up the reaction.

b. A conflict is involved in choosing the best temperature to be used in stage II, where the reaction is

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

i. Describe the nature of the convict and explain how the convict is resolved.

Sol. Because the forward reaction is exothermic, the yield of SO_3 is greater at lower temperatures. However, the rate of reaction is faster at higher temperatures.

This rate/ yield conflict is resolved by using a temperature which provides a balance (compromise) between the conflicting effects.

or the combination of a moderate temperature and a catalyst gives a good yield at a good rate.

ii. Would increasing the pressure of the reacting mixture in the converter affect the amount of SO_3 produced in stage II? Explain your answer.

Sol. The amount of SO_3 will increased as the equilibrium responds to the pressure increase by moving to the side with fewer particles or to decrease pressure or to compensate for pressure increase.

The 'rate/ yield' conflict is a common aspect in questions relating to the production of sulphuric acid. Many responses showed a good understanding of the conflict and its resolution

c. Sulfuric acid is a diprotic acid. The first ionization reaction of sulfuric acid is complete while its second ionization is that of a weak acid. Give chemical equations for both the first and second ionization reactions of sulfuric acid.

Sol.

H_2SO_4 (l) + H_2O (l) → HSO_4^-(aq) + H_3O^+(aq)*

$HSO4^-$(aq) + H_2O (l) ⇌ SO_4^{2-}(aq) + H_3O^+(aq)*

or

H_2SO_4 (l) → H+ (aq) + HSO^{4-}(aq)

HSO^{4-}(aq) ⇌ H+ (aq) + SO_4^{2-}(aq)

d. Give one major industrial use of sulfuric acid.

Sol. Some of the accepted answers are listed below:

- Production of fertilizers such as superphosphate
- Electrolyte in car batteries
- Metallurgy
- Drug manufacture (sulfonating agent).

Q2. Which one of the following fuels is the most sustainable?

a. biodiesel.

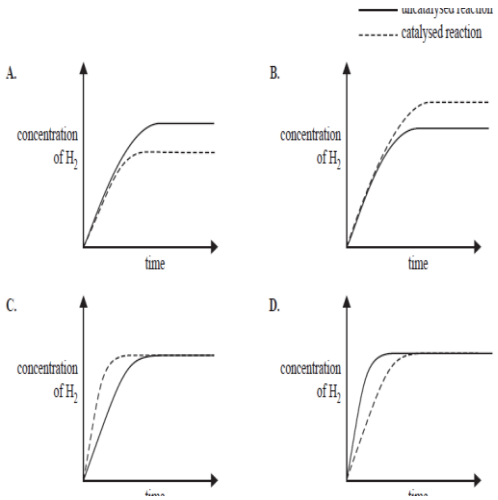
b. uranium.

c. brown coal.

d. natural gas.

Q3. In trials, the reaction is carried out with and without a catalyst in the sealed container. All other conditions are unchanged. The change in hydrogen concentration with time between an uncatalysed and a

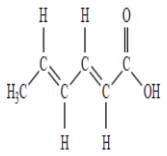
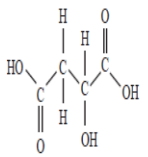
catalysed reaction is represented by a graph. Which graph is correct?



Sol. A catalyst increases the rate of reaction; hence the graph for the catalysed reaction is initially steeper. Acatalyst has no effect on the yield/position of equilibrium, so both graphs level off at the same concentration of H_2.

Q4. Fuel cells have a number of applications that offer advantages over conventional methods of electricity generation.
Which one of the following is not a feature of modern fuel cells?
a. They generate very little noise.
b. They are a cheap source of electricity.
c. They enable electricity to be generated on site.
d. They have the potential to reduce emissions of carbon dioxide into the atmosphere.
Sol. b. At this stage, fuels cell are not a cheap source of electricity, therefore option **b** was correct.
Fuel cells are quiet because they do not involve combustion but rather a quiet chemical to electrical energy conversion. Most fuel cells are hydrogen-oxygen fuel cells in which the only product is water. So the use of a hydrogen-oxygen fuel cell as an energy source instead of the combustion of a carbon based fuel will reduce emissions of carbon dioxide.

Q5. The following weak acids are used in the food industry.

Acid	Common use	Formula	Structure	K_a values
sorbic	preservative	$C_6H_8O_2$		1.73×10^{-5}
malic	low-calorie fruit drinks	$C_4H_6O_5$		3.98×10^{-4} 8.91×10^{-6}

a. What does the term 'weak acid' mean?
Sol. A weak acid (any one of)
• does not completely ionize in water.
• Only partially ionizes (dissociates) in water.
• does not easily donate protons in water.
Many students defined a weak acid as having a higher pH than a strong acid. This would only apply in aqueous solutions, of the same concentration, of both acids. A 0.0001 M solution of hydrochloric acid, a strong acid, has a higher pH (4.0) than a 1 M solution of ethanoic acid, a weak acid, (2.4).
Statements such as 'a weak acid does not completely ionize' without mentioning water (or an aqueous solution of the acid) were too vague, given that in the presence of a stoichiometric quantity of a strong base, a weak acid may be expected to fully ionize; for example, the determination of the ethanoic acid content of vinegar by titration with

NaOH(aq). Students should also be aware that an aqueous solution of a weak acid is more ionised at lower concentration.

b. i. Why are two K_a values listed for malic acid?

Sol. Because malic acid (any one of)
- is a diprotic acid.
- is able to donate two protons (H^+)
- contains two carboxyl groups.
- undergoes two-stage ionization.

Most students did not relate the two K_a values to the ability to donate two protons–that is, that the acid is diprotic. Given that students should be aware that the carboxyl group in carboxylic acids is the source of their acidity, more responses were expected to refer to the presence of two carboxyl groups on malic acid molecules. Some students incorrectly related the ability to donate two protons to the presence of –OH and –COOH groups in the molecule rather than two –COOH groups.

The equation related to the first K_a value of malic acid is:

$HOOCCH_2CH(OH)COOH(aq) + H_2O(l) \rightleftharpoons HOOCCH_2CH(OH)COO^-(aq) + H_3O^+(aq)$

ii. Write an appropriate chemical equation that relates to the second Ka of malic acid.

$HOOCCH_2CH(OH)COO^-(aq) + H_2O(l) \rightleftharpoons {}^-OOCCH_2CH(OH)COO^-(aq) + H_3O^+(aq)$

$C_4H_5O_5^-(aq) + H_2O(l) \rightleftharpoons C_4H_4O_5^{2-}(aq) + H_3O^+(aq)$

Some students who recognised the intent of the question did not provide an 'appropriate' chemical equation. Many students recognised that the second K_a value referred to the 'other' carboxyl group but provided an equation for the ionisation of that group on the malic acid molecule rather than the ion formed in the equation for the first K_a value. Others wrote an equilibrium law equation, which was often accurate, for the second ionization; however, the question clearly asked for a chemical equation.

When writing equations for equilibrium reactions, students must remember to include equilibrium arrows

c. Sorbic acid, $CH_3(CH)_4COOH$, has antimicrobial properties that are used to inhibit yeast and mould growth. However, its solubility is very low. The more soluble potassium sorbate is used instead. The antimicrobial activity of sorbic acid is retained because equilibrium exists according to the equation:

$CH_3(CH)_4COO^-(aq) + H_2O(l) \rightleftharpoons$
Sorbet ion.
$CH_3(CH)_4COOH(aq) + OH^-(aq)$
sorbic acid

How would the addition of a small amount of 1.0 M hydrochloric acid affect the concentration of sorbic acid in solution? Justify your answer in terms of equilibrium principles.

Sol. The concentration of sorbic acid would increased because the added HCl reacts with $OH^-(aq)$/ reduces the $[OH^-]$, thus causing the reaction (position of equilibrium) to shift to the right to partially oppose the change.

Although there were many excellent responses to this questionuestion, overall it was not handled as well as might have been expected. While the sorbate/ sorbic acid equilibrium may be unfamiliar to students, it was a relatively fundamental application of Le Chatelier's principle.

Some students argued that the added acid reacted with $OH^-(aq)$ to produce H_2O and the increased concentration of water was the reason the equilibrium shifted to the right. However, the concentration of water in an aqueous solution is effectively constant. Other students suggested the

given equilibrium shifted to the right because the added acid reacted with the sorbate ion. This is not consistent with Le Chatelier's principle. There may be an argument for reaction of the sorbate ion with added acid, but only as a competing equilibrium to the one provided.
Arguments for a decrease in sorbic acid concentration were unexpectedly common, suggesting that many students considered that adding the strong acid, HCl(aq), would have the same effect as adding more sorbic acid.

d. Calculate the percentage dissociation of sorbic acid when the pH = 4.76.

Sol. The long way:
$CH_3(CH)_4COOH(Aq) \rightleftharpoons CH_3(CH)_4COO^-(aq) + H_3O^+(aq)$
$pH=4.76 \rightarrow [H_3O^+]=10^{-4}.76= 1.738\times10^{-5}M = [CH_3(CH)_4COO^-]aq$
$Ka[CH_3(CH)_4COO^-]^2=$
$[CH_3(CH)_4COO^-(aq)] =$
$1.73\times10^{-5}=(1.73\times10^{-5})^2+[CH_3(CH)_4COOH]$
$or1.73\times10^{-5}=$
$(10^{-4.76})^2 + [CH_3(CH)_4COOH]$
$[CH_3(CH)_4COOH]_{aq}=(10^{-4.76})^2+ 1.73\times10^{-5} =1.738\times10^{-5}M$
$Initial[CH_3(CH)_4COOH]= [CH_3(CH)_4COOH]_{aq}+[CH_3(CH)_4COO^-]_{aq}=1.738\times10^{-5} +1.746\times10^{-5}=3.38\times10^{-5}$ M
$\%dissociation=\{[CH_3(CH)_4COOH]_{aq}+[CH_3(CH)_4COO^-]Initia\times100\}=(1.738\times10^{-5} +3.38\times10^{-5}) \times100=50\%$

The more intuitive way:
$CH_3(CH)_4COOH_{(aq)} + H_2O(l)\ CH_3(CH)_4COO^-(aq) + H_3O^+_{(aq)}$
$pH = 4.76 \times [H_3O^+] = 10^{-4.76}$
$K_a = [CH_3(CH)_4COO^-][H_3O^+] \div [CH_3(CH)_4COOH_{(aq)}]$
$1.73 \times 10^{-5} = [CH_3(CH)_4COO^-] \times 10^{-4.76} \div$
$[CH_3(CH)_4COOH] = [CH_3(CH)_4COO^-] \div$
$[CH_3(CH)_4COOH]$ **or**
$[CH_3(CH)_4COO^-]$ at equilibrium =
$[CH_3(CH)_4COOH]$ at equilibrium
$[CH_3(CH)_4COOH]$ at equilibrium =
$[CH_3(CH)_4COOH]$ initially –
$[CH_3(CH)_4COO^-]$ at equilibrium
$[CH3(CH)4COOH]$ initially =
$[CH_3(CH)_4COOH]$ at equilibrium +
$[CH_3(CH)_4COO^-]$ at equilibrium
$= 2 \times [CH_3(CH)_4COOH]$ at equilibrium
Hence 50% of the sorbic acid is dissociated.

Q6. Circle the industrial chemical that you have studied in detail this semester. Ammonia, ethane, nitric acid, sulfuric acid.

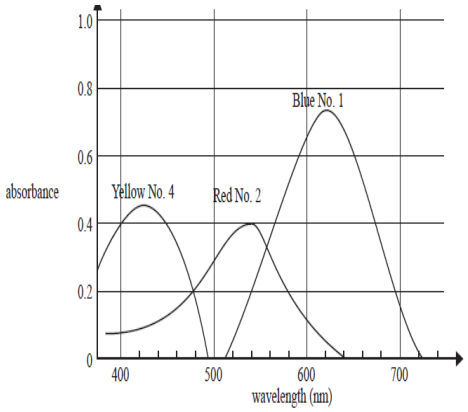
a. State one application of your selected chemical that is useful to society.

Sol. The 'application' of the selected chemical required the identification of a 'use' of the chemical rather just stating a chemical property of the chemical.
Students should think about their responses; for example, the application of sulfuric acid 'in fertilisers' is incorrect and is a significantly different response to 'in the production of fertilisers'.
Strict environmental guidelines are attached to the industrial production of your selected chemical.

b. i. State one undesirable effect that 4 chemical has on the environment

ii. Outline one procedure that would be appropriate to avoid this damage to the environment during the production of your selected chemical.

Q7. The graph shows the absorption spectra of three food dyes: Blue No. 1, Red No. 2 and Yellow No. 4.
Which one of the following is the best wavelength to determine the concentration of Red No. 2 dye in a solution containing a mixture of all three dyes?



a. 430 nm
b. 500 nm
c. 540 nm
d. 620 nm

Sol. The best wavelength to use is one where Red No. 2 dye absorbs strongly but no other dye in the mixture does, i.e. 500 nm. According to the absorption spectra provided, Red No. 2 absorbs most strongly at 540 nm. However, because Blue No.1 dye also absorbs significantly at 540 nm, it is not the best wavelength to use.

Q8. a. Biodiesel is an alternative to standard diesel fuel. Biodiesel is made from biological ingredients instead of petroleum.
Biodiesel is usually made from plant oils or animal fats through a series of chemical reactions. In one process a common triglyceride in palm oil, known as POP, is reacted with methanol in the presence of potassium hydroxide as a catalyst. The result is a mixture of methyl esters of the fatty acids (biodiesel).
i. The value of the stoichiometric ratio number of moles of methanol number of moles of POP is?
Sol. 3 or 3:1. This question required students to recall that during the production of biodiesel, three fatty acid molecules from each molecule of the triglyceride are converted to methyl ester molecules. Hence for one mole of POP, 3 moles of methanol were required.
ii. Calculate the volume, in liters, of methanol (density=0.79 gmL^{-1}) required to react completely with 10.0 kg of the triglyceride POP (Mr = 833) to produce glycerol and the mixture of methyl esters.
Sol.
$n(POP) = 10.0x10^3/833 = 12.0$ mol
$n(CH_3OH) = 3x12.0 = 36.0$ mol
$m(CH_3OH)=36.0x32.0=1.15x10^3$g
$V(CH_3OH)=m(CH_3OH)/d(CH_3OH)$
$=1.15x10^3 g/0.79gmL^{-1}=1.46x10^3$ ml
= 1.5* L (range accepted 1.46–1.5)

b. Cervonic acid is a polyunsaturated fatty acid found in fish oil. The number of carbon-carbon double bonds in a molecule of cervonic acid can be determined by titration with iodine, I_2 solution. An addition reaction takes place between the double bonds in cervonic acid and iodine.
20.00 mL of 0.300 M I_2 solution reacted exactly with 0.328g of cervonic acid. The molar mass of cervonic acid is 328.0g mol^{-1}.
i. Calculate the number of double bonds in a molecule of cervonic acid.
Sol. $n(I_2)=0.300x20.00x10^{-3} = 6.00x10^{-3}$ mol
$n(\text{cervonic acid}) = 0.328 / 328 = 1.00x10^{-3}$ mol
Ratio n(I2) / n(cervonic acid) = 6 / 1
Hence 6 (C=C) double bonds.
There were some quite intuitive approaches to this question. Some students calculated the n(cernovic acid) and then determined what its molar mass would be if the I_2: cernovic acid mole ratio was 1:1. They then used the ratio of the actual molar mass $328gmol^{-1}$ to the calculated molar mass to deduce the number of C=C double bonds.
Some students also deduced that since there are 22 C atoms in cernovic acid,

if it was saturated ($C_{22}H_{44}O_2$ or $C_{21}H_{43}COOH$) its molar mass would be 340 g mol^{-1}. Since the actual molar mass is 12 less, then each cernovic acid molecule has 12 fewer H atoms than a saturated fatty acid with 22 C, indicating the presence of 6 C=C double bonds.
Some students interpreted the lead-in to the question to mean the 'total' number of double bonds, including the C=O double bond in the carboxyl. Seven double bonds was also an acceptable answer.

There are 22 carbon atoms in a molecule of cervonic acid.

ii. What is the formula of cervonic acid?

Sol. $C_{22}H_{32}O_2$ or $C_{21}H_{31}COOH$

It was surprising that many students who correctly calculated the number of C=C double bonds in Q6 bi. did not effectively combine that with the information that there are 22 carbon atoms in a molecule of cernovic acid to deduce the formula of cernovic acid, based on the principle that for each C=C double bond, a cernovic acid molecule contains 2 fewer H atoms than a saturated fatty acid with 22C atoms ($C_{22}H_{44}O_2$).

Q10. The boiling points of several alkanols are provided in the following table.

Alkanol	methanol	ethanol	propan-1-ol	butan-1-ol	pentan-1-ol
Boiling point (°C)	64.5	78.3	97.2	117.2	138.0

A mixture of two of these alkanols is to be separated in an experiment using fractional distillation. The mixture is placed into the distillation apparatus at room temperature and then gently heated. The first fraction is collected at 97.2 °C.

a. i. Identify one alkanol that could **not** be present in this mixture.

Sol. Methanol or ethanol

Responses to this question suggested two distinct interpretations of the 'mixture'. Students who identified methanol or ethanol interpreted the question as intended, i.e. the mixture of alkanols added to the distillation flask. Many students stated that butan-1-ol (or pentanol-1-ol) could not be present, presumably thinking of the mixture as the 'fraction' collected at 97.2°C in a fractionating tower.

ii. By specifically referring to this experiment, explain why the alkanol identified in **part i.** could not be present.

Sol. Any of:

• if methanol (ethanol) had been present in the mixture it would have condensed as the first fraction at 64.5°C (78.3°C)
• the boiling temperature of methanol (ethanol) is below 97.2°C.
• methanol (ethanol) has boiled off before the first fraction is collected.

Most students who identified methanol or ethanol in question **9ai**. provided an appropriate response to this question.

b. Provide one reason why the distillation flask should not be heated using a bunsen burner.

Sol. Flammability of alkanol vapours or risk of fire or explosion. The difficulty of controlling temperature using a Bunsen burner was also accepted.

The emphasis in this question was on why a Bunsen burner should not be used. While just over 50 per cent of students received the mark this was more a reflection of mention of or reference to 'temperature control' rather than common recognition of the risk factor.

c. Butane and propan-1-ol have similar molar masses. The boiling point of butane is –138.4°C and that

of propan-1-ol is 97.2°C. Explain, in terms of intermolecular forces, the difference between the boiling points of these two compounds.

Sol. The three marks for this question were awarded for:

• Correctly describing the bonding (dispersion force attraction) between butane molecules

• Correctly describing the bonding (hydrogen bonding) between propan-1-ol molecules

• indication that the higher boiling point of propan-1-ol is because the hydrogen bonding between propan-1-ol molecules is stronger than the dispersion forces bonding between butane molecules.

Some responses showed good understanding of bonding and included points such as the relative polarity of butane and 1-propanol molecules, and the role of the –OH group in hydrogen bonding between 1-propanol molecules. However,

overall performance on this question suggested that many students were perhaps not expecting a 'bonding'-related question .

While the boiling point of butane as stated in the question, -138.4(C), is its melting temperature (the correct boiling temperature is -0.5(C), this did not affect student performance.

Common errors included:

• reading the data as butane having the higher boiling point.

• relating the boiling point to the bonds within the molecules.

• describing the hydrogen bonding in propan-1-ol as the bond between O and H in the hydroxyl group.

• referring to hydrogen bonding between propan-1-ol and water.

There was clear evidence that many students were not familiar with, or were confused by, the term 'intermolecular'.

Q11. The best description of the effect of a catalyst on a chemical reaction is that it

a. lowers the activation energy of the forward reaction without changing the activation energy of the reverse reaction.

b. lowers the activation energy of the forward reaction and raises the activation energy of the reverse reaction.

c. lowers the activation energy of both forward and reverse reactions by the same amount.

d. lowers the activation energy of the reverse reaction without changing the activation energy of the forward reaction.

Q12. Water and chlorine, each at 1 atm pressure, are placed in a closed container at 375 K. The following reaction occurs.

$2H_2O(g) + 2Cl_2(g) \rightleftharpoons 4HCl(g) + O_2(g)$, $K = 5\times10^{-4}$ at 375 K

Which one of the following will be correct at equilibrium at this temperature?

a. $2[O_2] > [Cl_2]$

b. $2[Cl_2] > [HCl]$

c. $2[HCl] = [Cl_2]$

d. $[O_2] = 4[HCl]$

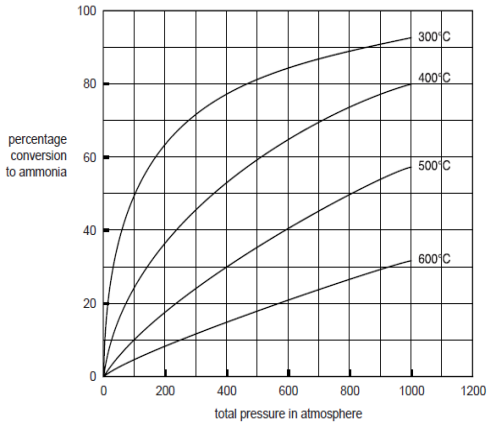
Sol. Given the small K and the fairly high concentrations of the reactants, it should have been evident that there would only be low concentrations of product at equilibrium. This should have eliminated A and C immediately.

But D was a trap for many – since 4 mole of HCl was produced for every mole of O_2 produced it should have been clear that the HCl concentration was four times higher than the O_2 concentration, i.e. $4[O_2] = [HCl]$. The stoichiometric equation was quite a trap.

Q13. Sulfur compounds are often present in crude oil.
If a sample of crude oil containing 1% sulfur was burnt in air, which of the following compounds would be produced in the smallest amount in the flame?
a. SO_3
b. SO_2
c. H_2O
d. CO_2
Sol. a. From student knowledge of the preparation of sulfuric acid, it should have been clear that the production of SO_3 from SO_2 is not favored by high temperatures (as in a flame). In any event, it is very well known that SO_2 is a common pollutant arising from the burning of coal with a high sulfur content.

Q14. Concentrated H_2SO_4 is often used in the laboratory as a dehydrating agent for gases. For which one of the following gases would this method not be suitable?
a. O_2
b. N_2
c. NH_3
d. CO_2
Sol. c. A large number of students thought that N_2 could not be successfully dried by sulfuric acid. This seemed odd, particularly with ammonia sitting there beneath it.

Q15. Ammonia is prepared industrially from hydrogen and nitrogen in the presence of a suitable catalyst according to the equation:
$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$
The graph below shows the variation of the equilibrium yield of ammonia with pressure at different temperatures.



a. A particular industrial plant uses a pressure of 300 atm and a temperature of 500°C**.** From the graph, determine the percentage yield of ammonia under these conditions.
Sol. 24–1%.
b. State Le Chatelier's principle
Sol. A system at equilibrium will shift so as to minimise the effects of any change in external conditions imposed on it.
c. Deduce from the graph whether the production of ammonia from hydrogen and nitrogen is an exothermic or an endothermic reaction. Explain your reasoning.
Sol. Raising the temperature has reduced the proportion of ammonia at equilibrium, therefore the reaction as given is exothermic.
d. Temperatures less than 400°C are not used for this industrial reaction even though such temperatures give a greater equilibrium yield of ammonia. Give a possible reason why this is so.
Sol. Reaction rate may be too slow at lower temperatures.

Q16. Esters are common components of artficial flavours. An ester, known to contain only the elements carbon, hydrogen and oxygen, was isolated and its composition analysed.
a. To determine the empirical formula of the ester, 1.02 g of the ester was burnt completely in excess oxygen.

The only products formed were 2.20 g of carbon dioxide and 0.90 g of water vapour. Calculate the

i. mass of carbon in 1.02g of the compound.

Sol. mol of CO_2 = 2.20/44 = 0.050; mass of C =0.050x12= 0.60 g (= 0.05 mol C).

ii. mass of hydrogen in 1.02 g of the compound.

Sol.

mol of H_2O = 0.90/18 = 0.050; mass of H = 2 x 0.05 x 1 = 0.10 g (= 0.10 mol H).

iii. mass of oxygen in 1.02 g of the compound.

Sol. mass of O = 1.02 - 0.60 - 0.10 = 0.32 g.

Having often got i and ii correct, many students then failed to see that oxygen had to be calculated by difference. This is a good point to emphasis in solving this type of Q.

iv. empirical formula of the compound.

Sol.

No. of mole of O = 0.32/16 = 0.020.

Empirical formula: C (0.050) : H (0.10) : O (0.02) = $C_5H_{10}O_2$.

b. Another sample of the compound was used to determine its molar mass. It was found that 51.0 g of the vaporised compound occupied the same volume as 16.0 g of oxygen gas at the same temperature and pressure. Calculate the molar mass of the compound in g mol^{-1}.

Sol. 16.0 g O_2 is 0.50 mol of O_2, thus 51.0 g of the unknown compound will be 0.50 mol. The molar mass of the compound is 51.0x2 = 102 g mol^{-1}.

c. Using your answers to parts **a.** and **b.**, determine the molecular formula of the compound.

Sol. $C_5H_{10}O_2$.

d. Given that the compound is an ester, give a possible structural formula for the compound.

Sol. Any one of:

$HCOOCH_2CH_2CH_2CH_3$;
$CH_3COOCH_2CH_2CH3$;
$CH_3CH_2COOCH_2\ CH_3$;
$CH_3CH_2CH_2COOCH_3$.

Having failed to find the correct response in **c**, students could still gain a mark by identifying a correct structure for an ester. Students should always be reminded that they are never penalised for 'consequential' errors when they continue on in a complex problem. Quite a few students picked up marks for giving the correct structure of an ester.

Q17. Petrol and ethene are both obtained from crude oil.

a. Name the process by which petrol is obtained from crude oil.

Sol. Fractional distillation.

b. i. Name the process by which ethene is obtained from the hydrocarbons extracted from crude oil.

Sol. Cracking.

ii. Write a chemical equation for the production of ethene from this process, using octane, C8H18, as the hydrocarbon.

Sol. C_8H_{18} (g) → C_2H_4 (g) + C_6H_{14} (g) (or equivalent).

c. A chemistry book describes the properties of ethene as being

• unsaturated
• a flammable gas
• able to participate in addition reactions

i. What is meant by unsaturated?

Sol. Having a double bond.

ii. Write a balanced equation to show the burning of ethene in a large excess of air.

Sol. C_2H_4 (g) + $3O_2$ (g) → $2CO_2$ (g) + $2H_2O$ (g).

iii. Write a chemical equation to show ethene undergoing an addition reaction.

Sol. C_2H_4 (g) + H_2 (g) → C_2H_6 (g) (or equivalent with H2 replaced with H_2O, HCl, Cl_2, etc).

Q18. The rate of decomposition of hydrogen peroxide is increased by the presence of a catalyst. The catalyst:
a. increases the equilibrium constant for the reaction.
b. provides a reaction pathway with a lower activation energy.
c. provides a reaction pathway with a greater activation energy.
d. increases the average kinetic energy of the hydrogen peroxide molecules.
Sol. b.
A catalyst speeds up the rate of reaction by decreasing the activation energy.

Q19. a. The concentration of carbon dioxide (CO_2) in the Earth's atmosphere has been increasing steadily since the mid nineteenth century. This is due mainly to the increased burning of fossil fuels (principally natural gas, petroleum and coal) since that time.
i. Name one factor, other than the heat of combustion, that should be considered when selecting a fuel for a particular purpose.
Sol. Any one of cost, energy content, convenience of state (gas, liquid, solid), safety, emission properties.
ii. The burning of fossil fuels is associated with other undesirable emissions besides CO_2. Give two other undesirable atmospheric pollutants directly or indirectly caused by the burning of fossil fuels.
Sol.
Any two of CO, SO_2, NO_x, PAN, particulates, SO_3, O_3, H_2SO_4.
b. Other non-fossil fuel alternatives include nuclear, solar, wind, tidal and hydro energy.
Choose any two of the following non-fossil fuels alternatives.
nuclear, solar, wind, tidal, hydro
For each one, identify one advantage (other than the non-emission of CO_2) and one disadvantage in relation to its suitability as a substitute for the current uses of fossil fuels.

Non-fossil fuel alternative	Advantage (other than the non-emission of CO_2)	Disadvantage
1 _____	_____ _____ _____	_____ _____ _____
2 _____	_____ _____ _____	_____ _____ _____

Sol. For two advantages and two disadvantages from following list. (Fusion power is not acceptable for 'nuclear' option).
Common advantages and disadvantages used by students in answering 5b were 'expensive' for a disadvantage and 'cheap' for an advantage. Students had to be more specific and be able to distinguish between, say, 'running cost' for 'cheap' (for say solar and wind), and, for example, 'solar cells' for 'expensive'. Clearly it should not have been hard to do well on this question but many students had not apparently even thought about these issues, even though they would all be aware of the contents of the study design.

nuclear	• can provide major energy source • high energy per unit mass	• radioactive waste • earthquake danger • terrorist danger
solar	• widely available • no pollutant emissions • renewable • low running costs	• difficult to store • not always available • needs large catchment area • high cost of solar cells • low efficiency of solar cells
wind	• readily available • no pollutant emissions • renewable • low running costs	• difficult to store • unsightly • noisy • not always available • needs large catchment area • limited energy available
tidal	• no pollutant emissions • renewable • low running costs	• difficult to store • limited energy available • few useable sites available
hydro	• readily stored • no pollutant emissions • low running costs	• limited energy available • unsightly • deleterious effects on ecosystems

c. As an alternative to using fossil fuels, some countries are now relying significantly on nuclear fission for electricity production, the major fuel used being 235U.

i. What is meant by the term 'nuclear fission'?

Sol. Atomic nucleus (or 'atom') is divided (either spontaneously or by collision)
into two smaller nuclei (or 'atoms').

ii. What is the source of the energy released when 235U undergoes fission?

Sol. Any one of: nuclear (binding) energy, mass loss (i.e. $E = mc^2$).

Q20. An isolated research station is to be staffed by a small group of scientists for 13 weeks. Part of the exercise is to test the effectiveness of liquid ethanol (CH_3CH_2OH) as a source of fuel under these conditions. It is planned to use two different methods of generating energy from the ethanol.

a. Some of the ethanol is to be directly burnt for heating and cooking, using the reaction
$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$; $\Delta H = -1370$ kJ mol^{-1}
The average need for heating and cooking over the 13-week period is 800 MJ per week. Calculate the total mass of ethanol needed to satisfy the heating and cooking requirements of the research station.
1 MJ = 103 kJ

Sol. Total energy needed = $13 \times 800 \times 10^6 = 1.04 \times 10^{10}$ J,
CH_3CH_2OH used = $(1.04 \times 10^{10} / 1370 \times 10^3) = 7591$ mol,
mass of ethanol = $7591 \times 46 = 349\,200$ g = 349 kg.

b. Some ethanol may also be used for electric power for lighting, refrigeration, computing and other electronic equipment. This can be provided by a fuel cell with an acidic electrolyte, whose cell reaction is identical to the equation given above.
In the fuel cell the cathode reaction is
$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
The voltage across the fuel cell is 1.15 V.

i. Give the half reaction occurring at the anode where the ethanol is oxidised in the fuel cell.

Sol.
$CH_3CH_2OH(aq) + 3H_2O(l) \rightarrow 2CO_2(g) + 12H^+(aq) + 12e^-$.

ii. Calculate the electrical energy provided per mole of ethanol consumed in the fuel cell.

Sol. Energy provided = $1.15 \times (12 \times 96500) = 1.33 \times 10^6$ J (1.33 MJ).

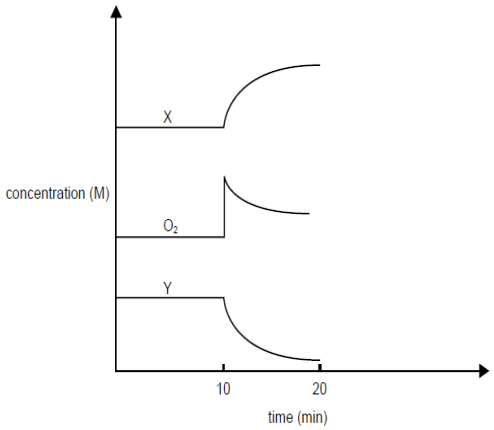
c. An alternative way of generating electricity from ethanol is to use it as the fuel for an internal combustion engine driving a generator.
Suggest one important reason why the fuel cell would be better than the generator for this purpose.

Sol. One of: more efficient; less pollution.

Q21. Ethanol can be manufactured by the reaction between ethene and water. This is represented by the equation:
$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ $\Delta H = -46$ kJ mol^{-1}
Which conditions would produce the highest percentage yield of ethanol at equilibrium?
a. low pressure and low temperature
b. high pressure and low temperature
c. low pressure and high temperature
d. high pressure and high temperature
Sol. b. The forward reaction is exothermic hence is favoured by low temperature. The forward reaction produces fewer particles hence is favoured by high pressure.

Q22. Catalytic cracking of alkanes is carried out by passing the hydrocarbon vapour over a heated catalyst in the absence of air. Which of the following is not a possible product of the catalytic cracking of hexane?
a. propene
b. methane
c. hydrogen
d. carbon dioxide
Sol. d. Cracking of alkanes can produce alkenes, smaller alkanes and hydrogen.

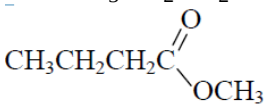
Q23. Part of the contact process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation:
$2SO_2(g) + O_2(g)$ $2SO_3(g)$ $\Delta H = -192$ kJ mol^{-1}
As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was initially at 450^{o}C**.** The container had a fixed volume and was thermally well insulated.
Concentrations during a following experiment are shown on the diagram below.



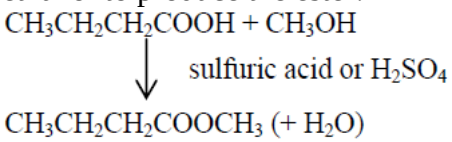
Sol. Some O_2 was added to the container.
b. Which components of the equilibrium mixture are represented by X and Y?
X = ?, Y =?
Sol. X – SO_3, Y – SO_2
c. Give explanations for the changes in concentration that occur in X, Y and O_2 between 10 and 20 minutes.
Sol. Upon addition of O_2, the position of equilibrium moves to the right (there is a net forward reaction), hence the amount of SO_3 (or X) will increase and the amounts of SO_2 (or Y) will decrease and O_2 will decrease (or net increase).
d. Would the temperature of the mixture increase, decrease or remain the same between 10 and 20 minutes? Explain your reasoning.
Sol. The temperature will increase because the forward reaction is exothermic

Q24. Esters are the basis of many naturally occurring odours and are therefore widely used in the creation of artificial flavours. Methyl butanoate is a component of the smell of pineapple. A manufacturer decides

to test the use of some of this compound in an ice-cream mix.
Chromium trioxide is an oxidising agent that can convert a simple alcohol to the corresponding carboxylic acid.
a. Give a simple structure for the ester methyl butanoate.
Sol. $CH_3CH_2CH_2COOCH_3$, or



b. Using 1-butanol and methanol as starting materials give chemical equations showing the steps in the preparation of methyl butanoate. Give the name of any catalyst used.
Sol. 1-butanol is converted to butanoic acid:
$CH_3CH_2CH_2CH_2OH \rightarrow$
$CH_3CH_2CH_2COOH$
Or $C_4H_9OH \rightarrow C_3H_7COOH$
Butanoic acid is reacted with methanol to produce the ester:



Q25. **a.** A natural gas-fired power station generates electricity by reacting gaseous methane (CH4) with oxygen.
List, in order, the energy conversions that take place in the power station during this process.
Sol. Chemical → heat/thermal → mechanical/ gas expansion/ generator rotation/ kinetic → electrical
b. Less electricity is generated by burning methane in a gas power station than if the same amount of methane were used in a fuel cell.
i. Give one reason for this difference.
Sol. More energy lost in greater than one-stage process.

ii. State one factor that limits the widespread applications of fuel cells to generate electricity.
Sol. Higher cost of fuel cells.

Q26. The industrial production of sulfuric acid can be described as a four-stage process beginning with the burning of raw sulfur with oxygen.
a. Stage 1 The burning of sulfur
Give the equation for the burning of sulfur in oxygen.
Sol. $S(l) + O_2(g) \rightarrow SO_2(g)$
b. Stage 2 The oxidation of sulfur from the +4 to the +6 oxidation state
i. Give the equation for this reaction.
Sol. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

ii. What goes wrong in the industrial process if the temperature for this stage of the process is too high, and why?
Sol. Yield of SO_3 decreases* because the forward reaction is exothermic*.

iii. What goes wrong in the industrial process if the temperature for this stage of the process is too low, and why?
Sol. Rate of reaction decreases* / is too low.
c. Stage 3 the conversion of S in the +6 oxidation state from a gaseous to a liquid form by reacting the +6 form of the gas with a suitable solvent**.**
i. Give the chemical reaction for this process.
Sol. $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

ii. Explain why water is not used as the solvent for this process.
Sol. an acid fog (or mist) is created when SO_3 is added to water under these conditions.
d. Stage 4 The production of liquid sulfuric acid
Give the chemical reaction for this process.
Sol. $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

Q27. Nuclear energy is often proposed as an alternative to fossil-fuel energy sources. Power stations based on nuclear fission are widely used in some parts of Europe, however there are no nuclear fusion reactors in use. Nuclear fusion is not currently used in preference to nuclear fission because:

a. it is a source of greenhouse gas emissions.
b. it uses very rare metals as an energy source.
c. it is difficult to dispose of its waste products.
d. its technology is still not sufficiently developed.

Sol. d. its technology is still not sufficiently developed.
Nuclear fusion reactors are yet to be developed, so they could not, even in principle, replace existing fission reactors.

Q28-29. The oxidation of methane (natural gas) can be used to produce electricity in a gas-fired power station. Methane can also be oxidised to produce electricity in a fuel cell. The overall equation for the oxidation of methane is:
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\Delta H = -900$ kJ mol^{-1}

28. In a gas-fired power station, the energy available from the above reaction is used to convert water in a boiler from liquid water to steam,
$H_2O(l) \rightarrow H_2O(g)$
$\Delta H = +44.0$ kJ mol^{-1}
The maximum mass of water, in grams, that could be converted from liquid water to steam by the complete oxidation of one mole of methane is

a. 20.5
b. 61.8
c. 184
d. 368

Sol. d. One mol of CH_4 produces 900 kJ of heat. This will vaporise (900/44) = 20.5 mol of H_2O. The mass of H_2O vaporised equals:
20.5 mol x 18gmol^{-1} = 368 g.
Twenty-five per cent of students gave response a, which was the mole of water vaporised.

Q29. In a fuel cell based on the oxidation of methane, the equation for the anode half reaction is:
$CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$
The corresponding equation for the half reaction at the cathode is

a. $2H_2O(l) + 4e^- \rightarrow 4H^+(aq) + O_2(g)$
b. $4H^+(aq) + O_2(g) \rightarrow 2H_2O(l)$
c. $2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e^-$
d. $4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$

Sol. d. The cell reaction for the fuel cell is given as $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.
Subtracting the given anode half reaction from this and simplifying gives $4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$

Q30. Sulfur dioxide and oxygen are mixed to form sulfur trioxide according to:
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
Which one of the following best describes the effect of adding the catalyst V_2O_5 to the mixture?

	Equilibrium yield	Reaction rate
A.	increases	increases
B.	no change	increases
C.	no change	no change
D.	increases	no change

Sol. b. A catalyst increases the rate of reaction, hence gets the reaction to equilibrium faster, and it has no effect on the equilibrium yield.

Q31. a. Coke, which is essentially pure carbon, is widely used as a fuel. Its complete combustion can be represented by the following equation.

$C(s) + O_2(g) \rightarrow CO_2(g)$

$\Delta H = .393$ kJ mol.1

However, under certain conditions, the combustion is incomplete and the following reaction also occurs.

$2C(s) + O_2(g) \rightarrow 2CO(g)$ $\Delta H = .232$ kJ mol.1

Calculate the energy, in kJ, released when 2.00 tonne (1 tonne = 106 gram) of coke is reacted with oxygen if 80% of the coke is oxidised to carbon dioxide and the remaining 20% is oxidised to carbon monoxide.

Sol.

1.6×106 g C $\rightarrow CO_2$* $= 1.33 \times 10^5$ mol* $\rightarrow 1.33 \times 10^5 \times 393 = 5.24 \times 107$ kJ*

0.40×106 g $C \rightarrow CO = 0.33 \times 10^5$ mol $* \rightarrow 3.33 \times 10^3 \times 2322 \rightarrow 0.39 \times 107$ kJ

Total $= 5.63 \times 107$ kJ*

b. Carbon is also a reactant in nuclear fusion reactions in some stars. One such reaction can be represented by the following equation.

$$^{12}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + \text{energy}$$

For a given amount of carbon, significantly more energy is released in nuclear fusion reactions than in chemical reactions.

i. What is the source of the energy released in this nuclear fusion reaction?

Sol. mass loss/ nuclear binding energy/ nuclear energy

ii. Why is nuclear fusion not currently used as an energy source in our society?

Sol. It is not yet practical.

c. Consider the following list of forms of energy.

Chemical electrical mechanical nuclear solar thermal

In a coal-fired power station, the energy released from the combustion of coal undergoes several energy conversions before electricity is generated.

i. Using the forms of energy listed above, complete the energy conversions that occur in the following stages of a coal-fired power station. (The same form of energy may be used more than once.)

- Coal is oxidised to generate steam _____ energy to _____ energy.
- Steam is used to drive a turbine _____ energy to _____ energy.
-The turbine drives a generator _____energy to _____ energy.

Sol.

chemical	thermal
thermal	mechanical
mechanical	electrical

ii. The amount of electrical energy obtained in a coal-fired power station is generally less than half of the available energy in the coal. What happens to the rest of the energy released when the coal is burnt?

Sol. It becomes waste heat.

Q32. Petroleum is a complex mixture of hydrocarbons. The hydrocarbons are mainly alkanes of various carbon chain lengths.

a. Write the name and molecular formula of an alkane which has nine carbon atoms.

Name

Molecular formula

Sol. Nonane, C_9H_{20}

b. Alkanes with short carbon chains boil at lower temperatures than long chain alkanes. Explain, in terms of bonding, why this is so.

Sol. Shorter chain (smaller) alkanes have weaker bonding/dispersion forces between the molecules.

c. Briefly describe the fractional distillation process that is used for rending petroleum. You may use a fully labeled sketch to answer this question.

Sol. Acceptable points included the following.

• The temperature decreases up the tower/there is a temperature gradient in the tower.

• Lighter (lower boiling temperature) fractions are collected near the top of the tower and heavier (higher boiling temperature) fractions near the bottom.

• Crude oil is separated into fractions. Each fraction consists of molecules within a specific mass range, with similar boiling temperatures.

• Fractions condense on strategically placed trays. Trays contain bubble caps which force the vapour to travel through condensed liquid.

• A mixture of vapour and liquid from heated crude oil is added near the bottom of the tower.

• The compounds in the vapour rise up until they condense at temperatures below their boiling temperatures.

d. Another process in petroleum refining involves cracking. Some of the products of the cracking process are unsaturated hydrocarbons.

i. When the gas propane (C_3H_8) is cracked, several different products can be obtained. Write the formulas for four likely products of this process.

Sol. Acceptable responses included

• C_3H_6 / $CH_3CH{=}CH_2$

• H_2

• C_2H_4 / $CH_2{=}CH_2$

• CH_4

• C_2H_2

• C_3H_4

ii. Ethene is an example of an unsaturated hydrocarbon. Write equations for two chemical reactions in which ethene acts as a reactant.

Reaction 1

Reaction 2

Sol. Acceptable responses included the following:

- $CH_2{=}CH_2(g) + H_2(g) \rightarrow CH_3CH_3(g)$ *or* $C_2H_4 + H_2 \rightarrow C_2H_6$
- $CH_2{=}CH_2(g) + Br_2(g) \rightarrow CH_2BrCH_2Br(g)$ *or* $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ (or with Cl_2, I_2, or F_2 instead of Br_2)
- $CH_2{=}CH_2(g) + HCl(g) \rightarrow CH_3CH_2Cl(g)$ *or* $C_2H_4 + HCl \rightarrow C_2H_5Cl$ (or with HF, HI, or HBr instead of HCC)
- $CH_2{=}CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g)$ *or* $C_2H_4 + H_2O \rightarrow C_2H_6O$
- $nCH_2{=}CH_2 \rightarrow (CH_2{-}CH_2)_n$ *or* $nC_2H_4 \rightarrow (C_2H_4)_n$
- $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
- $C_2H_4(g) + 2O_2(g) \rightarrow 2CO(g) + 2H_2O(g)$

Q33. One of the steps involved in the industrial preparation of sulfuric acid is the oxidation of sulfur dioxide to sulfur trioxide according to the equation: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

a. Give the name or formula for the catalyst that is most widely used for this reaction.

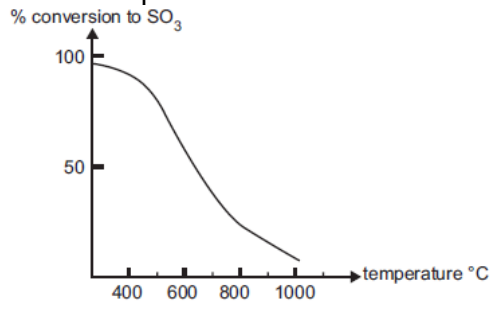
Sol. Either of:

• vanadium pentoxide

• vanadium (V) oxide

• V_2O_5.

b. The graph below shows the percentage conversion of sulfur dioxide to sulfur trioxide at equilibrium at 1 atm pressure and various temperatures.



There is almost complete conversion of sulfur dioxide to sulfur trioxide at 300°C. However, this reaction is

performed at a higher temperature of approximately 450°C in industry. Why?

Sol. Either of:

• at 300° the rate of reaction is too slow

• at 450° a good yield is obtained but with a faster rate of reaction.

c. Explain why

i. high pressures would increase the equilibrium yield of sulfur trioxide in this reaction.

Sol. Le Chatelier's principle suggests that higher pressures will cause the equilibrium to adjust by moving to lower the pressure by favouring the side with fewer particles/moles so the amount of SO_3 present at equilibrium is greater.

ii. atmospheric pressure is **usually** used in industry, even though high pressures increase the equilibrium yield of sulfur trioxide in this reaction.

Sol. The yield is very good/ economical at low pressures so the expense of high pressures is not necessary.

d. A chemical reaction that involves sulfuric acid occurs in each of the following situations. Write a balanced chemical equation for each reaction, showing the states of all reactants and products.

i. Dilute sulfuric acid is added to sodium carbonate solution.

Sol.

• $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + CO_2(g \text{ or } aq) + H_2O(l)$

• $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2CO_3(aq)$

• $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g \text{ or } aq) + H_2O(l)$

• $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2CO_3(aq)$

• $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow NaHSO_4(aq) + NaHCO_3(aq)$

• $H^+(aq) + CO_3^{2-}(aq) \rightarrow HCO_3^-(aq)$

ii. Sulfur trioxide gas is bubbled through concentrated sulfuric acid.

Sol. $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

iii. A piece of zinc metal is added to 6 M sulfuric acid. Zinc ions are formed as well as an oxide of sulfur in which sulfur exhibits an oxidation state of +4.

• $Zn(s) + SO_4^{2-}(aq) + 4H^+(aq) \rightarrow Zn^{2+}(aq) + SO_2(g) + 2H_2O(l)$

• $Zn(s) + H_2SO_4(aq) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + SO_2(g) + 2H_2O(l)$

• $Zn(s) + 2H_2SO_4(aq) \rightarrow ZnSO_4(aq) + SO_2(g) + 2H_2O(l)$

Q34. Which one of the following is **not** an important energy conversion in a coal-Þ red power station?

a. chemical energy of coal → thermal energy of steam

b. thermal energy of steam → mechanical energy of turbine

c. mechanical energy of turbine → chemical energy of steam

d. mechanical energy of turbine → electrical energy from generator

Q35. Sources of energy other than fossil fuels are increasingly being used by power companies to generate electricity for domestic use.

Which one of the following energy sources is not available in Australia for domestic purposes?

a. wind power

b. nuclear fusion

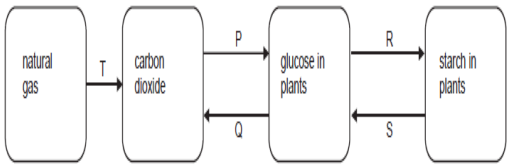
c. solar energy

d. hydroelectricity

Q36. Natural gas can be burnt in a power station to provide electrical

energy. Alternatively, natural gas can be fed into a fuel cell for electricity generation.
At the present time, which one of the following best compares the efficiency and cost of generating electrical energy by these two methods in a city like Melbourne?
Efficiency of fuel cell…. cost per k_j of electricity from fuel cell**:**
a. higher lower
b. higher higher
c. lower lower
d. lower higher

Q 37-38 A simplified section of the carbon cycle is shown below.

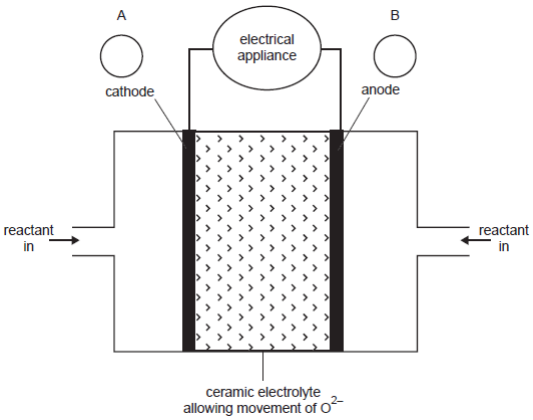


Q37. Carbon atoms are oxidised in reaction(s)
a. Q only.
b. S and Q only.
c. Q and T only.
d. Q, R and T only.
Sol. c. The oxidation of natural gas (methane) in process T and glucose in process Q both involved a change in the oxidation state of carbon.

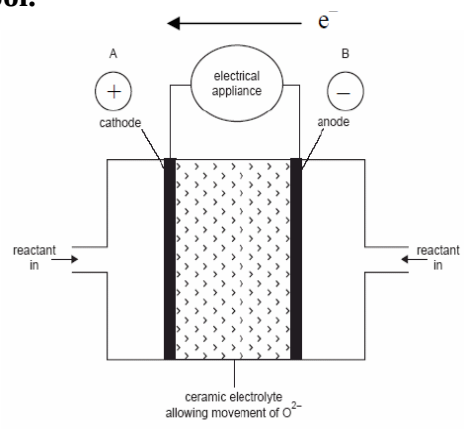
Q38. Reactions in which water is a product are
a. P and R.
b. Q and S.
c. P, S and T.
d. Q, R and T.

Q39. An Internet site reporting the latest developments in fuel cell technology describes a cell that uses a solid ceramic material as the electrolyte and hydrogen gas and oxygen gas as the reactants.
Key features of this cell are:
- Water is the only product from the cell reaction
- The ceramic material allows the movement of oxide ions (O_2)
- The reaction at the anode is $H_2(g) + O_2$ (in ceramic) $\rightarrow H_2O(l) + 2e$.
- operation at very high temperatures of over 1000°C means that precious metal catalysts are not required.

A representation of the cell providing electricity for an appliance is shown in the diagram below.



a. What distinguishes a fuel cell from a galvanic cell such as a dry cell or lead-acid battery?
Sol. Reactants are delivered continuously. This should have been a simple recall question.
b. On the diagram above
i. in circles A and B, indicate the polarity of the cathode and anode
Sol.



ii. show, by using an arrow, the direction of electron blow in the external circuit.

Sol.

Electrons travel from right to left in an external circuit (see above). This is a galvanic cell operating as a fuel cell and electrons will flow from the anode to the cathode in the external circuit.

c. Write an equation for each of the following reactions. You are not required to show states in these two equations.

i. the overall cell reaction

Sol. $2H_2 + O_2 \rightarrow 2H_2O(l)$

ii. the reaction at the cathode

Sol. $O_2 + 4e^- \rightarrow 2O^{2-}$

d. A ceramic fuel cell delivers a current of 0.500 A for 10.0 minutes at a potential of 0.600 volts.

i. How much electrical energy, in joules, would be provided by the cell?

Sol. Energy = 0.500 × 10 × 60 × 0.600 = 180

ii. Calculate the charge, in coulomb, produced by the cell.

Sol.

iii. If this particular cell operated at 60.0% efficiency, what amount of hydrogen gas (H_2), in mole, would be consumed by the fuel cell?

Sol.

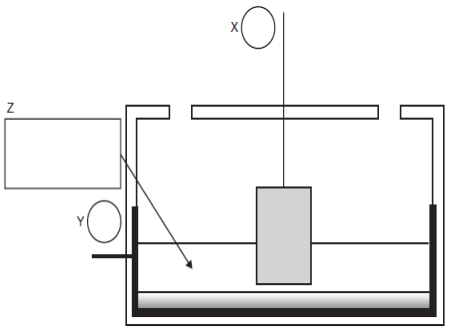
$$300C \text{ uses } \frac{300}{96500}$$

$$= 3.108 \times 10^{-3} \text{ mol of electrons}$$

$$= \frac{3.108^*}{2} \times 10^{-3} \text{ mol of } H_2$$

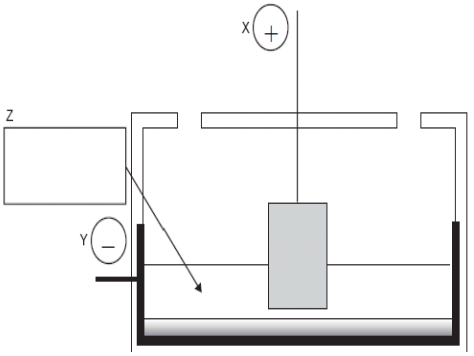
$$\text{At efficiency of 60\% we then have } \frac{3.108}{2} \times 10^{-3} \times \frac{100^*}{60} = 2.59 \times 10^{-3}$$

Q40. The sampled diagram below shows the Hall Cell that is used for the industrial production of aluminum.



a. In circles X and Y in the diagram, show the polarity of the electrodes.

Sol.



b. In the Hall Cell, the electrolyte consists of alumina mixed with another compound. In box Z, write the name or the formula of this compound.

Sol. cryolite or cryolyte or Na_3AlF_6

c. Write a half equation for the reaction that occurs at the:

i. anode

Sol. $C + 2O^{2-} \rightarrow CO_2 + 4e^- + OR$ $_2O^{2-} \rightarrow O_2 + 4e^-$

ii. cathode.

Sol. $Al^{3+} + 3e^- \rightarrow Al$

d. Suppose the electrolyte was replaced with an aqueous solution of Al $(NO_3)3$ at 25°C**.** Write an equation for the half reaction that would occur at the cathode.

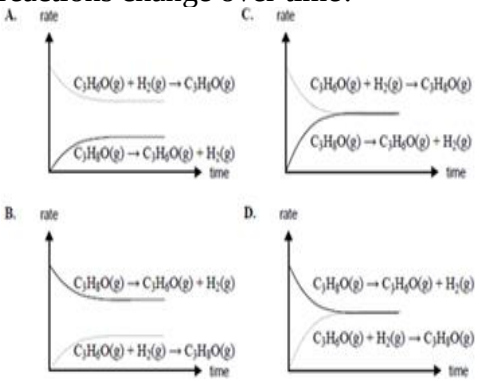
Sol. $2H_2O + 2e– \rightarrow H_2 + 2OH^-$

or $2H^+ + 2e \rightarrow H_2$

Q41-42 Propanone (C_3H_6O) can be made from 2-propanol using a copper-zinc catalyst.
$C_3H_8O(g)$ $C_3H6O(g) + H_2(g)$;
$\Delta H = 0.54$ kJ mol.1

Q41. At equilibrium at a particular temperature, 10% of the 2-propanol is converted to propanone.
In order to increase the percentage yield of propanone at equilibrium, you should
a. lower the temperature and lower the pressure.
b. lower the temperature and raise the pressure.
c. raise the temperature and lower the pressure.
d. raise the temperature and raise the pressure.
Sol. a. Since the forward reaction is exothermic ($\Delta H < 0$), the yield of propanone would increase at a lower temperature. With more particles on the product side, the yield of propanone would be increased by a change in pressure that would force the position of equilibrium to move to the side with more particles, i.e. by a decrease in pressure.

Q42. When 2-propanol reacts to form an equilibrium mixture with propanone and hydrogen, which one of the following best represents how the rates of the forward and back reactions change over time?



Sol. d. As the reaction $C_3H_8O(g) \rightarrow C_3H_6O(g) + H_2(g)$ proceeds, its rate decreases due to the decreasing concentration/partial pressure of C_3H_8O. Simultaneously, as the concentrations/partial pressures of $C_3H_6O(g)$ and $H_2(g)$ increase, the rate of the reaction $C_3H_6O(g) + H_2(g) \rightarrow C_3H_8O(g)$ increases. When the two reactions are occurring at the same rate equilibrium has been established.

Q43. Paraffin oil contains a mixture of high molecular mass alkanes. A gaseous mixture of ethene and other low molecular mass alkanes and alkenes can be produced in the laboratory by heating paraffin oil in the presence of alumina.
a. i. What is the general name given to this process?
Sol. cracking (or thermal/ steam/ catalytic cracking).
ii. Suggest the likely function of the alumina.
Sol. It acts as a catalyst (or increases reaction rate, etc.).
b. If one of the components of paraffin oil is $C_{17}H_{36}$, write a balanced equation in which this component forms ethene and only one other product.
Sol.
$C_{17}H_{36}(g\ /l) \rightarrow C_{15}H_{32}(g/l) + C_2H_4(g)$
$C_{17}H_{36} \rightarrow C_{17-2n}H_{36-4n} + nC_2H_4$
e.g. $C_{17}H_{36} \rightarrow C_7H_{16} + 5C_2H_4$
c. A chemist collects three samples of ethene and performs the following reactions. Write balanced equations for each one.
i. addition of bromine (Br_2)
Sol.
$C_2H_4(g) + Br_2(g) \rightarrow C_2H_4Br_2(g)$ or $CH_2{=}CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$
ii. complete combustion
Sol.
$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

iii. heated with steam and a catalyst at 300°C

Sol.

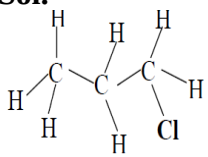
$C_2H_4(g) + H_2O(g) \rightarrow C_2H_6O(g)$ or $CH_2=CH_2 + H_2O \rightarrow CH_3CH_2OH$

d. A low molecular mass alkane was extracted from a gas sample obtained by this method. The following sequence of chemical reactions was then performed using this alkane.

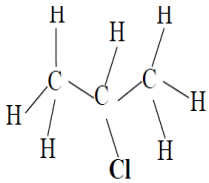
- The alkane was allowed to react with chlorine in the presence of ultraviolet light. Two compounds, A and B, were formed, each of molar mass 78.5 g mol^{-1}.
- One of these two compounds was isolated and allowed to react with potassium hydroxide solution. The product of this reaction was heated with acidified potassium dichromate solution to form C, an acidic compound.

i. Draw the structural formulas of compounds A and B in the boxes below, showing all bonds present in the molecules. Give the systematic name of each compound.

Sol.



1-chloropropane



2-chloropropane

Since A and B have the same molar mass, they are most likely to be structural isomers.

Alkanes react with Cl_2 to form chloroalkanes.

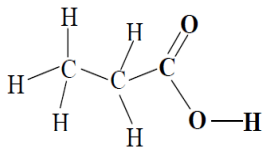
M (chloroalkanes) = 78.5 g mol^{-1} → Mr (chloroalkanes) = 78.5.

Since Ar (Cl) = 35.5, each chloroalkane molecule contains one Cl atom.

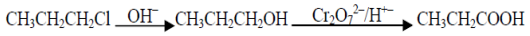
The hydrocarbon component of each molecule has Mr = 43, hence the two compounds formed are chloropropanes.

ii. Draw the structural formula of compound C in the box below, showing all bonds present in the molecule. Give the systematic name of the compound.

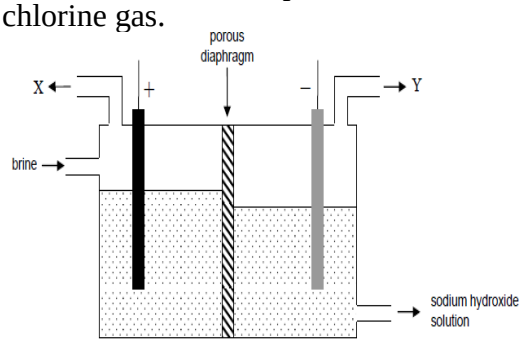
Sol.



propanoic acid



Q44-46. The diagram below represents a diaphragm cell used for the commercial production of chlorine gas.



Q44. The gases labelled X and Y are X Y

a. chlorine oxygen

b. oxygen chlorine

c. chlorine hydrogen

d. hydrogen chlorine

Q45. One function of the porous diaphragm in the cell is to

a. act as a catalyst to increase the rate of the reaction.

b. allow movement of ions between the cell compartments.

c. prevent sodium ions from entering the solution near the anode.

d. prevent the electrolyte from making contact with the gases produced.

Q46. A highly concentrated salt solution, called brine, is used as the electrolyte in this cell.
The main reason that a highly concentrated, rather than a dilute, solution is used is in order to
a. allow an electric current to pass through the cell.
b. produce chlorine gas, in preference to oxygen gas.
c. allow sodium hydroxide to be separated from the salt by crystallisation.
d. create non-standard conditions that ensure hydrogen gas production.

Q47. During the production of electricity in a coal-fired power station, energy is present in the following forms.
I mechanical energy of turbine
II chemical energy of coal and oxygen
III thermal energy of steam
The amount of energy in each of these forms that take part in the generation of a fixed quantity of electricity is, from lowest to highest:
a. III, I, II
b. I, II, III
c. I, III, II
d. II, III, I

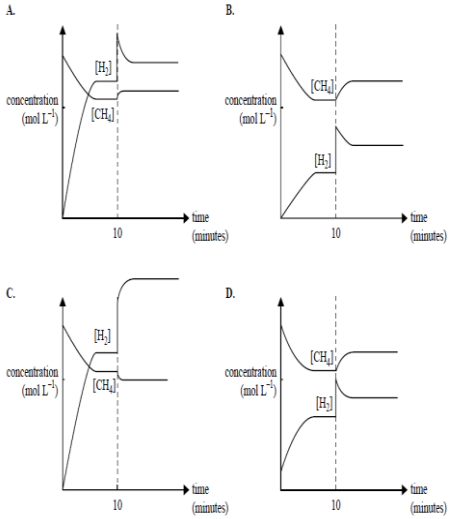
Q48-50 The following gaseous equilibrium is established at high temperatures in the presence of a finely divided nickel (Ni) catalyst.
$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$; $\Delta H = +206$ kJ mol^{-1}

Q48. A particular reaction is carried out using equal amounts of $CH_4(g)$ and $H_2O(g)$.
Which one of the following sets of changes in conditions would lead to the greatest increase in the proportion of the reactants converted to products? Volume of reaction vessel Temperature
a. increased increased
b. increased decreased
c. decreased increased
d. decreased decreased
Sol. a. More particles on the product side suggests that increased conversion of reactants to products will be favoured by decreased pressure/ increased volume. Since the forward reaction is endothermic it is favoured by a temperature increase.

Q49. This reaction occurs at a measurable rate only when the finely divided catalyst is present.
This catalyst increases the reaction rate because
a. it strongly attracts the reaction products, driving the reaction to the right.
b. the reactants can become attached to its surface where they can meet and undergo reaction.
c. it provides energy to the reactants when their molecules bounce off it, increasing the proportion of molecules
in the gas state with the required activation energy.
d. it increases the equilibrium constant of the reaction, causing an increase in the proportion of products at equilibrium.
Sol. b. Solid catalysts decrease the activation energy for a reaction by providing a surface onto which reactant molecules are adsorbed and from which product molecules are desorbed. A 'finely divided' catalyst provides a greater surface area.

Q50. Equal amounts of $CH_4(g)$ and $H_2O(g)$ are added to a reaction vessel

and allowed to react. After 10 minutes, equilibrium has been reached. At that time, some H_2 is added to the mixture and equilibrium is reestablished.
Which one of the following graphs best represents the changes in the amounts of CH_4 and H_2 in the reaction mixture?



Sol. a.

Q51. The numerical value of heat of combustion of 1-propanol in kJ g^{-1} is:
a. 33.60
b. 2016
c. 3.360 × 104
d. 1.210 × 105
Sol. a. Heat of combustion = 2016 kJ mol^{-1} =2016/60.0 kJg^{-1} =33.6 kJ g^{-1}

Q52. Fuel cells are being developed that use fuels other than hydrogen as their energy sources. The table below shows four potential fuels and their reactions in the fuel cell. (For simplicity, symbols of state have been omitted from these reaction equations.)

Fuel		Reaction in the fuel cell
methanol	CH_3OH	$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$
ethanol	C_2H_5OH	$C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$
ethane	C_2H_6	$C_2H_6 + 4H_2O \rightarrow 2CO_2 + 14H^+ + 14e^-$
ethane-1, 2-diol	$C_2H_4(OH)_2$	$C_2H_4(OH)_2 + 2H_2O \rightarrow 2CO_2 + 10H^+ + 10e^-$

Which one of the fuels would produce the greatest amount of CO_2 per coulomb of electrical charge generated?
a. methanol
b. ethanol
c. ethane
d. ethane-1, 2-diol
Sol. d. The number of mole of electrons is proportional to the electric charge, so each reaction produces the same n(e^-) per coulomb of electric charge (i.e. 1/96500 mol e^-).

Q53. The following chemicals are produced on an industrial scale in Australia. Ammonia ethane nitric acid sulfuric acid
a. Choose one only of these chemicals and circle its name in the left-hand column of the table below. In the right-hand column, next to the chemical that you have chosen, circle all substances that can be used as raw materials in its production.

ammonia	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
ethene	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
nitric acid	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
sulfuric acid	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2

Sol.

ammonia	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
ethene	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
nitric acid	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2
sulfuric acid	H_2 N_2 O_2 CO_2 C_6H_{14} C_8H_{18} FeS_2 NH_3 SiO_2

As the table suggests, a variety of combinations were accepted. Sulfuric acid was by far the most popular choice, but a large proportion of students who selected it did not circle FeS_2 and missed out on the mark.

b. Write an equation for a reaction, in the industrial production of the chemical you have chosen, that is carried out above room temperature.

Sol. Fundamentally, any balanced equation describing a reaction involved in the production of the chemical was accepted.

c. Describe one way in which waste heat from the production of the chemical you have chosen is reused to reduce energy costs.

Sol. The mark was awarded for any common sense use of waste heat, including preheating reactants, generating electricity, heating water to raise steam.

d. Name one useful product formed from the chemical you have chosen.

Sol. The range of possibilities in this question depended on the chemical chosen. Some of the options included (but were not limited to):

- NH_3 – ammonium nitrate, ammonium sulfate, urea
- HNO_3 – ammonium nitrate, potassium nitrate
- $C2H_4$ – ethanol, chloroethane, polyethylene
- H_2SO_4 – ammonium sulfate, superphosphate, hydrogen, sodium sulfate, oleum.

If the substance identified is 'formed from the chemical' (interpreted as having components of the chemical in its structure) it was accepted.

Q54. Since the start of the industrial age, most of the energy used by humans has come from the burning of coal and oil. In that time the amount of CO_2 in the air has increased from approximately 0.42% by mass to 0.58% by mass.

a. Assume that the total mass of the earth's atmosphere is 5.15×1018 kg. Calculate the additional mass of CO_2, in kg, that has been added to the earth's atmosphere since the start of the industrial age.

Sol. $m(CO_2) = [(0.58 – 0.42) / 100] \times 5.15\times10^{18} = 8.2\times10^{15}$***** kg

b. If half of this additional CO_2 has come from the burning of coal, calculate the total amount of energy, in kJ, that has been produced by burning all this coal, given that

$C(s) + O_2(g) \rightarrow CO_2(g)$;

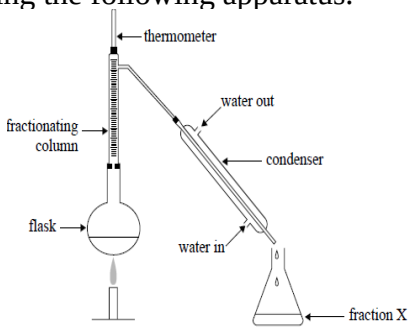
$\Delta H = –394$ kJ mol^{-1}

For the purposes of this calculation, assume that coal is pure carbon.

Sol. $n(CO_2) = 4.1\times10^{15}\times10^3 / 44$***** $= 9.4\times10^{16}$ mol

Energy produced = $9.4\times10^{16} \times 394 = 3.7\times10^{19}$ (kJ)

Q55. In a laboratory experiment, a mixture of alkanes was separated into components by fractional distillation using the following apparatus.



The first fraction collected is fraction X, then fraction Y then fraction Z. From this information we can deduce that

a. fraction Y is more volatile than Z.

b. fraction Y has a higher molar mass than Z.

c. fraction X has a higher boiling point than Y and Z.

d. fraction Z has stronger covalent bonds in its molecules than X and Y.

Sol. a.

The first fraction collected in fractional distillation contains the smallest molecules in the mixture.

Molecule size, molar mass and boiling point all increase in the order X < Y < Z. Volatility decreases in the order X > Y > Z (that is, Y is more volatile than Z). Fraction Z has the largest molecules and the strongest dispersion forces between its molecules, and hence the highest boiling temperature.

Q56. In many countries, ethanol is present in petrol as a renewable fuel additive to reduce dependence on fossil fuels.

a. Write a chemical equation for the combustion of ethanol in excess oxygen.

Sol.

$$C_2H_6O(l \text{ or } g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g \text{ or } l)$$

Ethanol is fully miscible with water. It is also fully miscible with petrol (a mixture of hydrocarbons).

b. Give chemical reasons why ethanol can mix with both water and petrol.

Sol. Both or:

- the polar –OH end forms (hydrogen) bonds with water
- the non-polar $-CH_2CH_3$ end mixes with petrol.

Ethanol can be produced by fermentation of glucose.

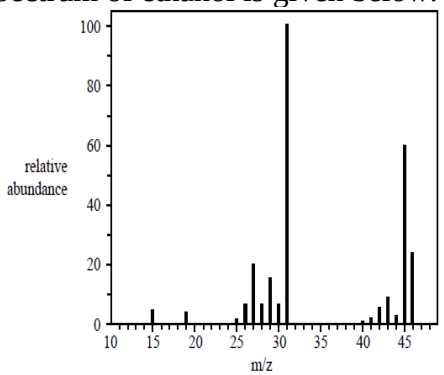
c. i. Write a chemical equation for the fermentation of glucose to produce ethanol.

Sol.

$$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$$

ii. Explain why ethanol produced by fermentation is referred to as a 'biochemical fuel'.

Sol. Because it is produced fro, a biological source/ biomass. Ghicose is produced by plants. The mass spectrum of ethanol is given below.

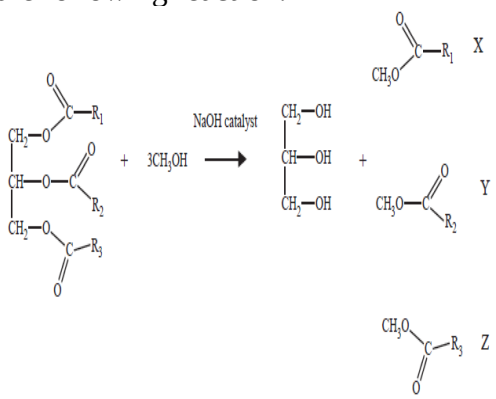


d. What fragment must have been lost from the molecular ion to account for the high peak at m/z 45?

Sol. H m or H

Q57. A product derived from palm tree oil is used as an alternative fuel in diesel engines.

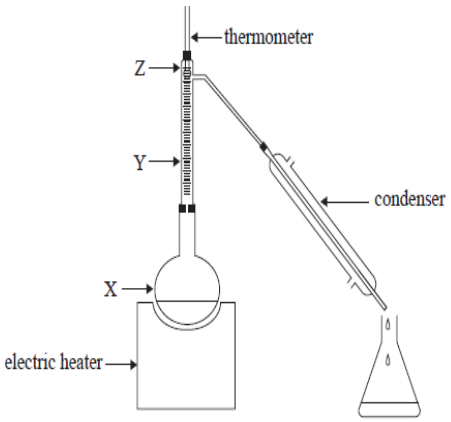
Palm oil is converted to biodiesel by the following reaction.



Glycerol is separated from the reaction mixture. The mixture of the compounds labelled X, Y and Z is used as palm oil biodiesel.

The term that best describes the mixture of compounds in palm oil biodiesel is:
a. methyl esters.
b. carbohydrates.
c. carboxylic acids.
d. monoglycerides.

Q58. A liquid mixture of 50% ethanol and 50% water was distilled in the apparatus shown above. The boiling point of ethanol is 78°C and that of water is 100°C**.**



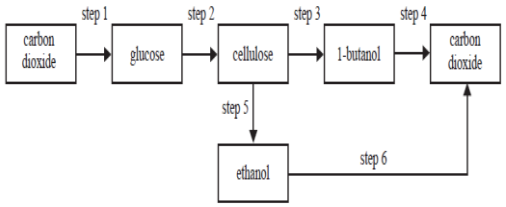
As the mixture was heated the temperature shown by the thermometer initially rose but then remained constant at 78°C for some time. Which one of the following statements about percentage of ethanol in the vapours shown at points X, Y and Z, when the temperature is at a constant 78°C, is true?
a. The percentage of ethanol in the vapours at X is equal to 50%.
b. The percentages of ethanol in the vapours increase in order at positions X, Y and Z.
c. The percentages of ethanol in the vapours at Y and Z are equal but greater than at X.
d. The percentages of ethanol in the vapours at X, Y and Z are equal but greater than 50%.

Sol. b. The temperature of the vapour mixture decreases as it moves up the column. Hence, as the vapour rises up it, the relative amount of ethanol increases (and the amount of water vapour decreases). Therefore the percentage of ethanol present is greatest at Z and lowest at X, that is, it increases in order from X to Y to Z.

Q59. Myrcene is a naturally occurring compound found in the leaves of bay trees. It is known to be a polyunsaturated hydrocarbon. It can react with hydrogen to produce a saturated hydrocarbon. In a laboratory investigation, a 1.00 g sample of pure myrcene fully reacted with exactly 510 mL of hydrogen gas measured at 20.0°C and 105.0 kPa. In this reaction, myrcene was converted to a saturated alkane with a molecular formula $C_{10}H_{22}$.
a. What type of reaction has occurred between the myrcene and hydrogen?
Sol. Addition/ hydrogenation/redox
b. Calculate the amount, in moles, of hydrogen reacting.
Sol.
n(H_2) = pV / RT = 105.0 x 0.510 / (8.31 x [20.0 +273]) = 0.0220* (mol)
c. Calculate the mass of $C_{10}H_{22}$ produced in the reaction.
Sol. m($C_{10}H_{22}$)= m(myrcene) + m(H_2)
m(H_2) = 0.0220 x 2.0 * = 0.044 g
m($C_{10}H_{22}$) = 1.00 + 0.0440 = 1.04 g*
d. Determine the number of double bonds in each molecule of myrcene.
Sol. n($C_{10}H_{22}$) =1.044/142 =7.35x10^{-3} mol = n(myrcene)
Equation for reaction is:
myrcene + **x**H_2 → $C_{10}H_{22}$
n(H_2) / n(myrcene) = x / 1
0.0220 / 0.0735 = x, 3 = x

Q60. Research is being conducted into the development of new biofuels. It is known that a type of bacteria,

clostridium acetobutylcium, converts cellulose to butanol.
The following diagram represents a series of steps (which may involve multiple reactions) for the formation and combustion of the biofuels, ethanol and 1-butanol.



a. Identify **one** step that represents an overall reduction reaction.

Sol.
Step 1/ (Step 3/Step 5**)**
While the conversion of CO_2 to glucose is perhaps the obvious 'reduction' step – perhaps deduced from the fact that in the reverse process (respiration) glucose is oxidised to CO_2 – Steps 3 and 5 were also accepted as the production of alcohols by fermentation does involve reduction.
b. Write a balanced equation for step 4 where, in a single reaction, 1-butanol reacts to form carbon dioxide as one of the products.
Sol. $C_4H_{10}O(g \text{ or } l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$*
$CH_3CH_2CH_2CH_2OH(g \text{ or } l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$
Glucose can combine with fructose to form the disaccharide, sucrose.
Sucrose (molar mass 342 g mol^{-1}) is highly soluble in water. However, 1-butanol, a muchsmaller molecule (molar mass 74 g mol^{-1}), is much less soluble in water.
c. Explain, in terms of the structure of these two molecules, why this is the case.
Sol. Sucrose has more hydroxyl (-OH) functional groups on each molecule*/a greater number of polar groups and so can form more hydrogen bonds with water.
Consider the following two observations about sucrose.
I Dry sucrose can be mixed with the enzyme sucrase and no significant change will occur
II Sucrose rapidly breaks down into its monosaccharides when a small amount of sucrase is added to a solution of sucrose at room temperature.
d. Why does the breakdown of sucrose require the presence of both water and sucrase?
Sol. H_2O is required for the (hydrolysis) reaction and sucrase catalyses the reaction.

Q61. The following table contains information about three experiments. In each experiment 0.10 mol of an alkane is burned completely and all the energy released is used to heat 1.00 L of water which was initially at 20°C**.**

experiment	alkane	molecular formula
I	butane	C_4H_{10}
II	pentane	C_5H_{12}
III	hexane	C_6H_{14}

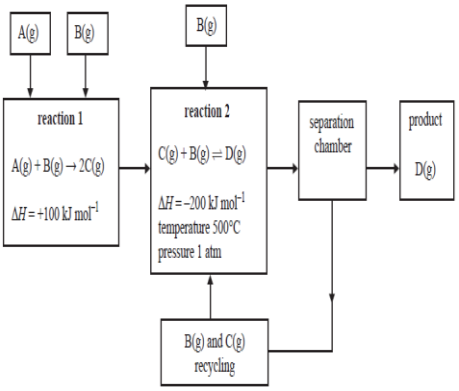
In which experiment(s) will the water be heated to its boiling temperature?
a. III only
b. II and III only
c. I and II only
d. I, II and III
Sol. Energy required to heat water to its boiling temperature is determined using the specific heat of water. This was given in the data book.
$E = 4.18 \text{ J } g^{-1} \text{ °C}^{-1} \text{ x } m(H_2O) \text{ x } \Delta T$
Using the density of water, also given in the data book, 1.00
L of water has a mass of $1.00x10^3$g.
$E = 4.18x1.00x10^3 \text{ x } (100 – 20)$

= 3.34 x 105 J = 334 kJ.
From Table of the data book it could be deduced that
0.10 mol C_4H_{10} → 287 kJ
0.10 mol C_5H_{12} → 351 kJ
0.10 mol C_6H_{14} → 416 kJ
Hence, both 0.10 mol C_5H_{12} and 0.10 mol C_6H_{14} release enough energy to heat the water to its boiling temperature if all of the energy released is transferred to the water.

Q62. Most of Victoria's electricity is generated by burning fossil fuels such as coal and natural gas. Alternative methods of generating electricity are currently being developed.
e. Biochemical fuels are an alternative fuel for generating electricity.
i. Name one biochemical fuel, other than methyl palmitate, and the raw material used in its production.
Biochemical fuel……
Raw material used in its production.. .
Sol. Acceptable responses included:
• ethanol* – from plant material*, for example, sugar cane, corn, bagasse or biomass
• methane/biogas – from plant and animal waste
• biodiesel – from plant and animal fats, algae
• methanol/ wood gas – from wood, sawmill offcuts, biomass.
ii. Identify **one** disadvantage or limitation of the use of this biochemical fuel for the large-scale generation of electricity.
Sol. Acceptable responses included:
• use of land normally used for crops (food production)
• clearing forests
• availability of water.
f. Some countries rely on nuclear fission for the large-scale production of electricity.
i. State one advantage of using nuclear fission.
Sol.
Acceptable responses included:
• large amounts of energy released from a small mass [of nuclear fuel (uranium)]
• high energy density of nuclear fuel
• limited greenhouse gas emissions.
ii. State one disadvantage of using nuclear fission.
Sol. Acceptable responses included:
• disposal of radioactive waste*.
• potential use in nuclear weapons/ terrorism.

Q63. A classroom experiment was set up to simulate the industrial extraction of zinc metal from an aqueous solution of zinc ions by electrolysis. In this experiment 150 mL of 1.00 M $ZnSO_4$ solution was electrolysed at 25°C using inert carbon electrodes.
a. Write a half-equation for the oxidation reaction.
Sol. $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$
b. A mass of 0.900 g of zinc is produced in 30.0 minutes.
Calculate the electric current, in A, supplied to the cell during the electrolysis. Express your answer to an appropriate number of significant figures.
Sol. n(Zn) = 0.900 / 65.4 = 0.01376 mol
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$
$n(e^-) = 2 \times 0.01376 = 0.02752$ mol
Q = 0.02752 x 96500***** = 2656 C
I = Q / t
= 2656 / (30.0x60) = 1.48 A***** - 3 sig figs*****

Q64. A particular industrial process involves the following steps.



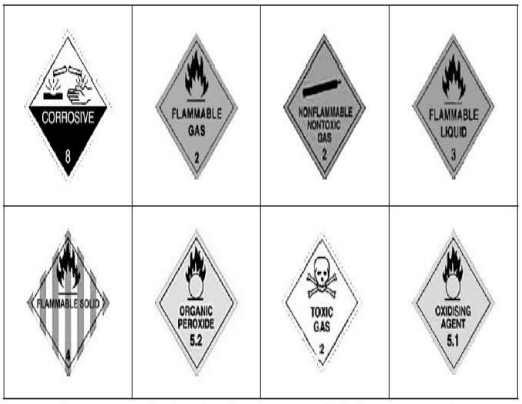
a. It is possible to alter the temperature and pressure at which reaction 2 occurs.
In the table below, indicate what effect the following changes to temperature and pressure would have on the **rate**, **equilibrium yield** and value of the **equilibrium constant**, **K**, for reaction 2.

	Would the rate of reaction 2 become **higher**, lower or **remain unchanged**?	Would the **equilibrium yield** of reaction 2 become **higher**, lower or **remain unchanged**?	Would the value of the **equilibrium constant**, *K*, of reaction 2 become **higher**, lower or **remain unchanged**?
The temperature of reaction 2 is lowered to 150°C.			
The pressure of reaction 2 is increased to 5 atm by pumping more B(g) and C(g) into the reaction vessel, at constant temperature.			

Sol.

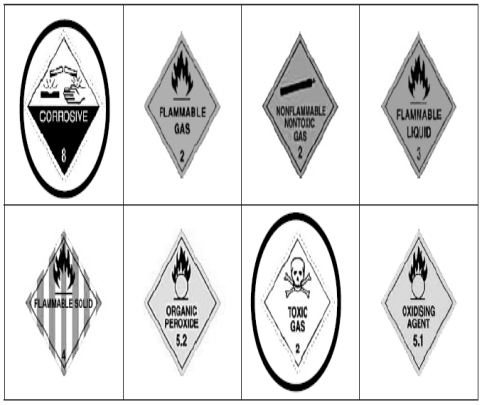
	Would the rate of reaction 2 become **higher**, lower or remain **unchanged**?	Would the **equilibrium yield** of reaction 2 become **higher**, lower or **remain unchanged**?	Would the value of the **equilibrium constant**, *K*, of reaction 2 become **higher**, lower or remain **unchanged**?
The temperature of reaction 2 is lowered to 150°C.	lower*	higher*	higher*
The pressure of reaction 2 is increased to 5 atm by pumping more B(g) and C(g) into the reaction vessel, at constant temperature.	higher*	higher*	unchanged*

b. Heat energy is released by reaction 2. Describe how the heat energy could be used within this industrial process.
Sol. Acceptable responses included:
• provide energy for reaction 1
• increase the rate and/ or yield of reaction 1
• heat the incoming reactants
• generate electricity.
c. During this semester you have studied the production of one of the following chemicals.
Circle the chemical you have studied in detail this semester. ammonia ethene sulfuric acid nitric acid.
i. Describe one waste management strategy, other than recycling heat, employed in the industrial production of your selected chemical.
Sol. Acceptable responses included:
• recycling unreacted N_2 and H_2
• Monitoring/using by-products associated with H_2 production.
ii. The following table includes a selection of HAZCHEM labels used to identify dangerous goods.



Circle one label that could be used to identify the hazardous nature of your selected chemical.

Sol.



iii. State two uses of your selected chemical.

Use 1

Use 2

Sol. Acceptable responses included:

• as a fertiliser

• in the production of fertilisers, for example, NH_4NO_3

• production of nitric acid

•production of ammonium compounds

• industrial refrigeration

• manufacture of pharmaceuticals/ vitamins

• production of nylon and other polymers

• in cleaning products.

Q65. a. The most common method for the industrial production of hydrogen is the steam reforming process, which requires high temperature, high pressure and a Ni catalyst. The equation for this reaction is:

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

$\Delta H = +207 \text{ kJ mol}^{-1}$

i. Write an equilibrium expression for the steam reforming reaction.

Sol. One of:

• $K = [CO][H_2]^3/[CH_4][H_2O]$

• $[CO][H_2]^3/[CH_4][H_2O]$.

As all the reactants and products are in the gaseous phase, water is not a solvent and must be included in the equilibrium expression. The most common errors made by students were leaving H_2O out of the equilibrium expression or having an incorrect power on the $[H_2]$.

ii. Le Chatelier's principle indicates that equilibrium yield for the reaction above is favoured by low pressure.

Suggest one reason why high pressure is used in the industrial process described above.

Sol. One of:

• the rate of reaction is too slow at low pressure

• to increase the rate of reaction

• to prevent air from entering the system

• to move reactants through faster.

At 1500 °C the concentrations of the gases in a particular equilibrium mixture were found to be:

$[CH_4] = 0.400$ M, $[CO] = 0.300$ M, $[H_2O] = 0.068$ M

$K = 5.67$ M_2 at 1500 °C for the reaction.

iii. Calculate the molar concentration of H2 in the equilibrium mixture.

Sol. $5.67 = [CO][H_2]^3 / [CH_4][H_2O]$

$= 0.300 \times [H_2]^3 / (0.400 \times 0.068)$

$5.67 \times (0.400 \times 0.068)$

$= 0.300 \times [H_2]^3$

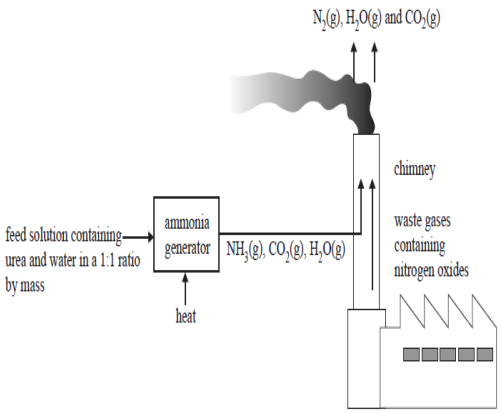
$[H_2]^3 = 5.67 \times (0.400 \times 0.068) / 0.300$

= 0.514
$[H_2] = (0.514)^{1/2}$ or (0.514)1/3 = 0.80 (0.801) **(**M)
This question was well handled, with the most common errors associated with finding the cube root.
b. Methane can be obtained from natural gas deposits or as a biochemical fuel from biomass.
i. Which of these sources of methane would be considered more sustainable? Explain your answer.
Sol. Biochemical fuel (biomass) is more sustainable because natural gas is non-renewable (biomass is renewable).
Most students were well aware of the link between sustainability of energy sources and renewability. Those who were not aware of the link generally focused on methane as a 'natural' source or on relative CO_2 emissions. A number of students interpreted the word 'sustainable' as meaning 'abundant', focusing on the size of natural gas reserves.
ii. Energy density may be defined as the amount of energy released per gram of fuel. Use molar enthalpy of combustion data to calculate the energy density of hydrogen gas in kJ g^{-1}.
Sol. 1.4 x 10^2 kJ g^{-1} (143)
This question was not well done by students. Although H_2 was given as the chemical formula of hydrogen in the molar enthalpy of combustion data (table 13 in the Data Book), many students did not recognise that 286 kJ mol^{-1} indicates 286 kJ of energy is released from 2.0 g H_2.

Both hydrogen and methane can be burned to produce heat energy.
iii. Calculate the volume of hydrogen gas in L, at SLC, that produces the same amount of energy as 2.0 L of methane gas at SL**c.**
Sol. $n(CH_4)$ = 2.0/24.5
= 0.0816 mol
Energy released by CH_4 = 0.0816 x 889 = 72.6 kJ
$n(H_2)$ = 72.6/286 = 0.254 mol
$V(H_2)$ = 0.254 x 24.5 = 6.2 (L)
Alternatively
Since $n(H_2)$ x $\Delta Hc(H2)$ = $n(CH_4)$ x $\Delta Hc(CH_4)$
and both gases are at the same temperature and pressure
$V(H_2)x\ \Delta Hc(H_2)=V(CH_4)x\ \Delta Hc(CH_4)$
$V(H_2) = V(CH_4)$ x $\Delta Hc(CH_4)/\Delta Hc(H_2)$ = 2.0 x 889/286 = 6.2 (L)

Q66. Many industrial processes create waste products such as chimney gases. These gases may contain serious atmospheric pollutants, such as oxides of nitrogen (for example, NO and NO_2). One way to remove these nitrogen oxides is to treat the chimney gases with ammonia. This treatment converts the oxides of nitrogen in the chimney gases to nitrogen and water. These are then released into the atmosphere.
a. i. Determine the coefficients that correctly balance the equation for this reaction. Write your answers in the spaces provided.
…..NO(g) +…… NH_3(g) → …..N_2(g) + …..H_2O(g)
Sol. Acceptable responses included:
• $6NO(g) + 4NH_3(g) \rightarrow 5N_2(g) + 6H_2O(g)$
• $3NO(g) + 2NH_3(g) \rightarrow 2.5N_2(g) + 3H_2O(g)$.
It is important to adjust the amount of ammonia mixing with the chimney gases to give the correct mole ratio of ammonia to nitrogen (II) oxide, NO.
ii. Explain the effect on the composition of the gases released into the atmosphere if the amount of ammonia
was too low……
too high……

Sol. Too low – unreacted NO will also be released into the atmosphere (less N_2/H_2O is produced)
Too high – unreacted NH_3 will also be released into the atmosphere
b. The ammonia can be produced on-site in industrial plants using small-scale ammonia generators. The ammonia is produced by reacting urea with water. A simplified diagram of such a plant is provided below.

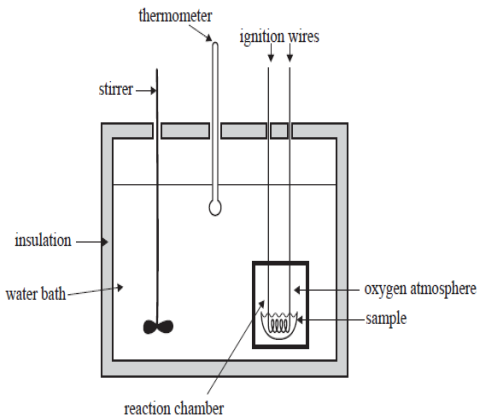


The chemical reaction occurring in the ammonia generator is:
$(NH_2)_2CO(aq) + H_2O(l) \rightleftharpoons 2NH3(aq) + CO_2(aq)$ ΔH + ve
In a particular generator a 1:1 mass ratio of urea and water is used.
i. Which reactant is in excess?
Sol. H_2O (water)
Urea has a larger molar mass than water, so for equal masses of both reactants, the mole amount of H2O is higher and, since the reactants combine in a 1:1 mole ratio, it will be in excess.
ii. Give one reason why an excess of one reactant is used in this chemical reaction.
Sol. Acceptable responses included:
• to increase the amount of the other, more expensive, reactant consumed
• to increase the yield of NH_3.
• to push the position of equilibrium further to the right.

Changing the temperature of the reaction mixture in the ammonia generator can control the amount of ammonia gas produced.
iii. Explain the effect of increasing the temperature on the amount of ammonia formed in the generator.
Sol. The amount of NH_3 produced increases because the forward reaction is endothermic.
The table gives some of the properties of ammonia and urea**.**

	ammonia	urea
Physical state at room temperature	gas	solid
Chemical reactivity	high	low
Toxicity	high	low
Flammability	low	low

c. Give one advantage, other than cost, of producing ammonia on-site by this method rather than having large quantities of ammonia delivered from a plant at another location.
Sol. Onsite production eliminates the risks associated with the transport (handling) of NH_3 (due to it is being a gas/ toxic/ chemically reactive).
It is much easier to store urea (solid) than ammonia (gas) or it is safer and easier to transport (handle) urea because it is a solid.
Q67. Below is a diagram of a bomb calorimeter which can be used to determine the enthalpy changes in combustion reactions.
The sample is placed in the reaction chamber or 'bomb' which has a volume of 50.0 cm^3. The chamber is then sealed and pure oxygen is pumped into the bomb to a pressure of 25 atm. The reaction chamber is then placed into the water bath.



Solid benzoic acid, C6H5COOH, is commonly used to calibrate bomb calorimeters. 1 mol of benzoic acid releases 3227 kJ of heat energy when completely combusted.

a. Write a thermochemical equation for the complete combustion of benzoic acid, including a ΔH value.

Sol. Either of:

• $2C_6H_5COOH(s \text{ or } l) + 15O_2(g) \rightarrow 14CO_2(g) + 6H_2O(g)$ $\Delta H = -6454$ (kJ mol^{-1})

• $C_7H_6O_2(s \text{ or } l) + 7.5O_2(g) \rightarrow 7CO_2(g) + 3H_2O(g)$; $\Delta H = -3227$ (kJ mol^{-1}).

b. A 1.025 g sample of benzoic acid was placed into the bomb. Pure oxygen was also pumped into the bomb to a pressure of 25 atm. The complete combustion of the benzoic acid created a 2.17°C temperature rise in the surrounding water bath. The molar mass of benzoic acid is 122.0 g mol^{-1}.

i. Why must the oxygen be pumped into the bomb at high pressure?

Sol. Acceptable responses included:

• to ensure there is sufficient O_2 for complete reaction of the benzoic acid

• to provide an excess of oxygen.

ii. Calculate the calibration factor for the bomb calorimeter. Express your answer to the correct number of significant figures and include appropriate units.

Sol. $n(C_7H_6O_2) = 1.025 / 122.0$
$= 8.402 \times 10^{-3}$ (mol)

Energy released $= 8.402 \times 10^{-3} \times 3227$
$= 27.11$ (kJ)

Calibration factor $= 27.11/2.17$
$= 12.5$ kJ $°C^{-1}$ (1.25×10^4 J $°C^{-1}$)

iii. Would the value of the calibration factor be higher, lower or the same if the calibration was conducted on this calorimeter without its insulation? Explain.

Sol. Higher calibration factor and (either of):

• no insulation will cause a smaller temperature change during calibration

• more energy is needed to raise the temperature (by 1°C) because of loss to the environment.

Q68. During this semester you have studied the production of one of the following chemicals.

Circle the chemical you have studied this semester.

Ammonia ethene sulfuric acid nitric acid

a. A catalyst plays an important part in the production of your selected chemical.

i. Write a balanced equation for a chemical reaction where a catalyst is used. (If you have studied the production of ammonia do not include the steam reforming reaction in your answer.)

Sol. Ammonia: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Ethene: Any correctly balanced cracking equation in which C_2H_4 is a product was acceptable; for example,
$C_4H_{10}(g) \rightleftharpoons CH_2{=}CH_2(g) + C_2H_6(g)$

Sulfuric acid:$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Nitric acid:$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$

This question assessed a fundamental aspect of the production of the

particular chemicals and students were expected to be well aware of the key catalyst-linked equation in each process. Students who had studied ethene and explained that since thermal cracking does not involve the use of a catalyst an equation could not be written were awarded the mark.

ii. Name the catalyst.

Sol. Ammonia: iron or iron oxides
Ethene: zeolites or 'no catalyst'
Sulfuric acid: vanadium pentoxide or vanadium (V) oxide
Nitric acid: platinum/rhodium

iii. Explain how a catalyst increases the rate of a chemical reaction at a given temperature.

Sol. A catalyst lowers the activation energy by providing an alternative reaction pathway.

b. Chemical laboratories and production plants carry out risk assessments on the procedures involving chemicals they use or produce.

i. Identify one specific chemical hazard associated with the handling of your selected chemical.

Sol. Acceptable responses for chemical hazards included:
• ammonia: toxic gas, corrosive.
• ethene: explosive mixture with air, toxic gas.
• sulfuric acid: corrosive, strong oxidant, strong acid, dehydrating agent, toxic vapours.
• nitric acid: corrosive, strong oxidant, strong acid, toxic vapours.

ii. Identify one risk to humans of exposure to the chemical hazard you identified.

Sol. Acceptable responses, linked to a chemical hazard in 5bi., included:
• ammonia: severe respiratory irritant; liquid NH_3 may cause burns
• ethene: severe burns from explosion; asphyxiation
• sulfuric acid: severe burns; respiratory irritation
• nitric acid: severe burns; respiratory irritation.

iii. Give one action that can be taken to reduce the risk of human exposure to the chemical hazard you identified.

Sol. Acceptable responses included:
• appropriate protective clothing and equipment (where particular items relevant to the hazard are specified); for example, safety goggles/face shield, gloves, breathing apparatus
• spill-management strategies.
• workers well practiced in emergency and first aid procedures.
• fire prevention and firefighting strategies (ethene)…….

Q69. When the battery is discharging the:

A. H^+ concentration decreases resulting in a higher pH.
B. H^+ concentration increases resulting in a higher pH.
C. H^+ concentration decreases resulting in a lower pH.
D. H^+ concentration increases resulting in a lower pH.

Sol. a. Discharging is a spontaneous reaction where the oxidant is in the half-equation with the higher E^o value. When the half-equations are arranged in order of decreasing E^o values, i.e.
$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$ $E^o = +1.69$ V
$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO4^{2-}(aq)$ $E^o = -0.36$ V
it can be deduced that the reduction of strongest oxidant, PbO2(s), is accompanied by a decrease in $[H^+]$ and so the pH increases.

Q70. When the lead-acid battery is recharging the energy transformation occurring is:

A. chemical → electrical + heat.
B. kinetic → chemical + electrical + heat.
C. electrical → chemical + heat.
D. electrical → light + kinetic + heat.

Sol. c. During recharging, electrical energy is converted into chemical energy and the passage of electrical current through the external circuit also generates some heat energy.

Q71. A desalination plant produces 200 gigalitres (GL) of fresh water each year. The maximum level of boron permitted in desalinated water is 0.5ppm (0.5mg L^{-1}). The maximum mass, in kilograms, of boron that is permitted in one year's production of desalinated water is:

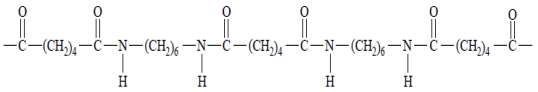
a. 9.26×10^3
b. 1.0×10^5
c. 1.08×10^6
d. 1.0×10^8

Sol. b. V(water) produced = 200×10^9 L .
m(B) permitted = 0.5 mg $L^{-1} \times 200 \times 109$ L
= 100×10^9 mg
= $100 \times 10^9 \div 10^3$ g
= 100×10^6 g
= $100 \times 10^6 \div 10^3$ kg
= 1×10^5 kg

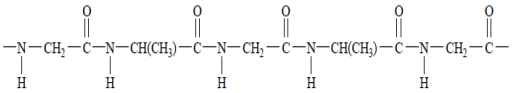
Option **c** resulted from adding an incorrect and irrelevant step – multiplying the m (B) as calculated in kilograms by the molar mass of B (10.8).

Option **d** was consistent with a unit manipulation error – either not, or incorrectly, converting milligrams to grams and/or grams to kilograms.

Q72. Sections of the primary structure of nylon and the primary structure of a protein are shown below.

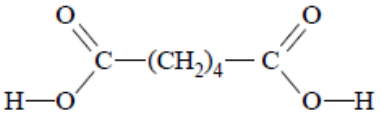


nylon



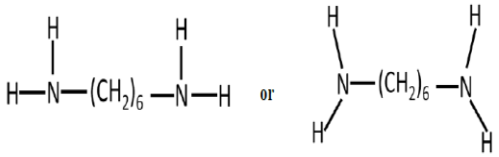
protein

Nylon is composed of two monomers. The structure of one of the monomers is provided below.



a. Draw the structure of the other monomer.

Sol.



The structures represented above were consistent with the style given on the exam for the structure of the other monomer. Other structures correctly showing all bonds were also acceptable.

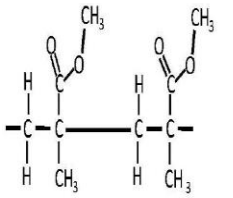
b. Name the functional groups that link the monomers in:
nylon……
protein……..

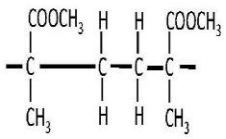
Sol.
• nylon: amide
• protein: amide or peptide

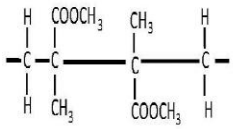
The functional groups that link the monomers are the functional groups that have formed as a result of the monomers linking together.

c. Look carefully at the functional group that links monomers in protein and nylon. The functional groups that connect the protein monomers are oriented in the same direction. The functional groups that link the nylon

monomers are oriented in opposing directions.
Explain why the functional groups that link the monomers in protein are oriented differently from the functional groups that link the monomers in nylon. Make appropriate reference to the structures of nylon and protein monomers in your answer
Sol. The monomers from which the protein is produced all contain both the amino (NH_2) and carboxyl (COOH) functional groups, and reaction between different functional groups on adjacent monomers always produces the sequence CONH.
The monomers from which nylon is produced have either two amino (NH_2) or two carboxyl (COOH) functional groups. Reaction between the different functional groups on adjacent monomers alternately produces CONH and NHCO.
d. Perspex (polymethyl methacrylate) is a clear, colourless polymer used for optical applications. The structural formula of the only monomer used in the synthesis of perspex, methyl methacrylate, is shown below.
Sol. Acceptable representations of the section of the polymer included the three shown below.







Q73. A solvent has the following risk statement printed on its label. 'Inhalation of fumes may cause dizziness'. To minimise the risk associated with the effects of exposure when using this solvent, a student should.
a. use gloves.
b. wear a laboratory coat.
c. keep the solvent away from flames.
d. use the solvent in a well-ventilated area.

Q74. Which one of the following fuels is the most sustainable?
a. biodiesel
b. uranium
c. brown coal
d. natural gas

Q75–77. The following reaction is used in some industries to produce hydrogen.
$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$
$\Delta H = -41 \text{ kJ mol}^{-1}$

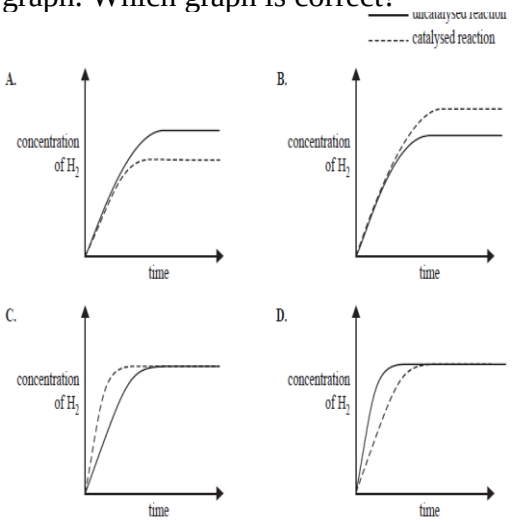
Q75. Carbon monoxide, water vapour, carbon dioxide and hydrogen were pumped into a sealed container that was maintained at a constant temperature of 200 °C**.** After 30 seconds, the concentration of gases in the sealed container was found to be [CO] = 0.1 M, $[H_2O]$ = 0.1 M, $[H_2]$ = 2.0 M, $[CO_2]$ = 2.0 M.
The equilibrium constant at 200 °C for the above reaction is K = 210.
Which one of the following statements about the relative rates of the forward reaction and the reverse reaction at 30 seconds is true?
a. The rate of the forward reaction is greater than the rate of the reverse reaction.
b. The rate of the forward reaction is equal to the rate of the reverse reaction.
c. The rate of the forward reaction is less than the rate of the reverse reaction.
d. There is insufficient information to allow a statement to be made about

the relative rates of the forward and reverse reactions.

Sol. c. At 30 seconds, CF (Q) = $[CO_2][H_2] \div [CO][H_2O]$
$= 2.0 \times 2.0 \div \{0.1 \times 0.1\} = 400$
Since CF (Q) is greater than K (210), the system is moving to decrease the concentration fraction and reach equilibrium. Hence, the amounts of products must be decreasing and the amounts of reactants increasing. This means the reverse reaction is favoured and this requires that the rate of the forward reaction is less than the rate of the reverse reaction.

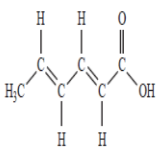
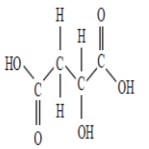
Q76. The reaction between carbon monoxide and water vapour is carried out in a sealed container. The equilibrium yield of hydrogen will be increased by
a. an increase in pressure at constant temperature.
b. a decrease in temperature.
c. the addition of an inert gas at constant temperature.
d. the use of a suitable catalyst at constant temperature.
Sol. b. Since the forward reaction is exothermic, the yield of hydrogen would increase as the temperature decreases; that is, the system responds to the temperature decrease by moving in the direction of the energy-releasing reaction.
An increase in pressure (option **a**) would have no effect on the equilibrium position, or yield of H2, because the equilibrium has the same number of particles on both sides and cannot shift to oppose the pressure increase.

Q77. In trials, the reaction is carried out with and without a catalyst in the sealed container. All other conditions are unchanged. The change in hydrogen concentration with time between an uncatalysed and a catalysed reaction is represented by a graph. Which graph is correct?



Sol. c. A catalyst increases the rate of reaction; hence the graph for the catalysed reaction is initially steeper. A catalyst has no effect on the yield/position of equilibrium, so both graphs level off at the same concentration of H_2.

Q78. The following weak acids are used in the food industry.

Acid	Common use	Formula	Structure	K_a values
sorbic	preservative	$C_6H_8O_2$		1.73×10^{-5}
malic	low-calorie fruit drinks	$C_4H_6O_5$		3.98×10^{-4} 8.91×10^{-6}

a. What does the term 'weak acid' mean?
Sol. A weak acid (any one of)
• does not completely ionise in water
• only partially ionises (dissociates) in water

• does not easily donate protons in water.

b. i. Why are two K_a values listed for malic acid?

Sol. Because malic acid (any one of)
• is a diprotic acid
• is able to donate two protons (H^+)
• contains two carboxyl groups
• undergoes two-stage ionisation.

The equation related to the first K_a value of malic acid is
$HOOCCH_2CH(OH)COOH(aq) + H_2O(l) \rightleftharpoons HOOCCH2CH(OH)COO^-(aq) + H_3O^+(aq)$

ii. Write an appropriate chemical equation that relates to the second Ka of malic acid.

Sol.
$HOOCCH_2CH(OH)COO^-(aq) + H_2O(l) \rightleftharpoons {}^-OOCCH2CH(OH)COO^-(aq) + H_3O^+(aq)$
$C_4H_5O_5^-(aq) + H_2O(l) \leftrightarrow C_4H_4O_5^{2-}(aq) + H3O^+(aq)$

c. Sorbic acid, $CH_3(CH)_4COOH$, has antimicrobial properties that are used to inhibit yeast and mould growth. However, its solubility is very low. The more soluble potassium sorbate is used instead. The antimicrobial activity of sorbic acid is retained because an equilibrium exists according to the equation
$CH_3(CH)_4COO^-(aq) + H_2O(l) \rightleftharpoons CH_3(CH)_4COOH(aq) + OH^-(aq)$
sorbate ion sorbic acid
How would the addition of a small amount of 1.0 M hydrochloric acid affect the concentration of sorbic acid in solution? Justify your answer in terms of equilibrium principles.

Sol.
The concentration of sorbic acid would increase because the added HCl reacts with $OH^-(aq)$/ reduces the $[OH^-]$, thus causing the reaction (position of equilibrium) to shift to the right to partially oppose the change.

d. Calculate the percentage dissociation of sorbic acid when the pH = 4.76.

Sol.
$CH_3(CH)_4COOH(aq) + H_2O(l) \rightleftharpoons CH_3(CH)_4COO^-(aq) + H_3O+(aq)$
$pH = 4.76 \rightarrow [H_3O+] = 10^{-4.76} = 1.738 \times 10^{-5}$ M
$= [CH_3(CH)_4COO^-]eq$
$K_a = [CH_3(CH)_4COO^-]^2 \div [CH_3(CH)_4COOH(aq)]$
$1.73 \times 10^{-5} = (1.73 \times 10^{-5})^2 \div [CH_3(CH)_4COOH]$
or 1.73×10^{-5}
$= (10–4.76)^2 \div [CH_3(CH)_4COOH]$

$[CH_3(CH)_4COOH]eq = (10^{-4.76})^2 \div 1.73 \times 10^{-5}$
$= 1.746 \times 10^{-5}$ M

Initial $[CH_3(CH)_4COOH] = [CH_3(CH)_4COO^-]eq + [CH_3(CH)_4COOH]eq$
$= 1.738 \times 10^{-5} + 1.746 \times 10^{-5}$
$= 3.48 \times 10^{-5}$ M

% dissociation = $\{[CH_3(CH)4COO–]eq \div [CH_3(CH)4COOH]initially\} \times 100$
$= (1.738 \times 10^{-5} \div 3.48 \times 10^{-3}) \times 100$
= 50% (49.9%)

Q79. Circle the industrial chemical that you have studied in detail this semester. Ammonia ethane nitric acid sulfuric acid.

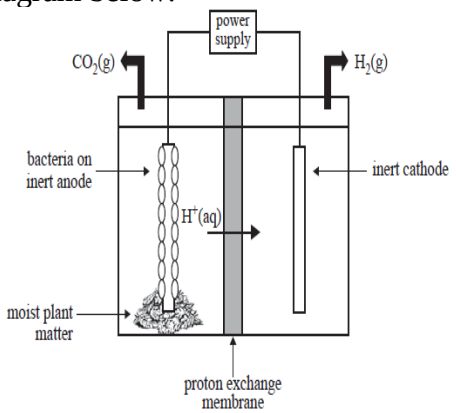
a. State one application of your selected chemical that is useful to society.

Sol. The 'application' of the selected chemical required the identification of a 'use' of the chemical rather just stating a chemical property of the chemical.
Strict environmental guidelines are attached to the industrial production of your selected chemical.

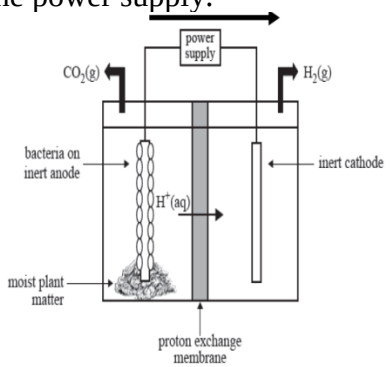
b. Outline one procedure that would be appropriate to avoid this damage to

the environment during the production of your selected chemical.
Sol. While the majority of students were able to identify an 'undesirable effect' on the environment in part i., some of those students did not effectively link their response to part ii. to this effect.

Q80. Hydrogen gas is an energy source. Researchers are investigating the production of hydrogen gas in a microbial electrolysis cell.
The cell is made up of an anode half-cell and a cathode half-cell. The half-cells are separated by a proton exchange membrane, as shown in the diagram below.



A number of reactions take place in the cell, resulting in the production of hydrogen. These reactions are summarized below.
Anode half-cell
• The anode half-cell contains moist plant matter and electrochemically active bacteria that live on an inert anode.
• The gaseous mixture that is present in the half-cell does not contain oxygen.
• The moist plant matter ferments to produce ethanoic acid (CH_3COOH). Bacteria on the anode consume the ethanoic acid and release hydrogen ions, electrons and carbon dioxide gas. A small voltage is then applied to reduce the H^+ ions.
Cathode half-cell
• The cathode half-cell contains an inert cathode.
• The gaseous mixture that is present in the half-cell does not contain oxygen.
• The released hydrogen ions and electrons react to form hydrogen gas, as shown in the equation below.
$2H^+(aq) + 2e^- \rightarrow H_2(g)$
a. Ethanoic acid is converted to carbon dioxide gas and H+ ions at the anode.
Write an equation for this reaction.
Sol. $CH_3COOH(aq) + 2H_2O(l) \rightarrow 2CO_2(g) + 8H^+(aq) + 8e^-$
There was significant diversity in the responses to this question, mostly associated with balancing. The initial step in developing the half-equation, balancing the C atoms, was commonly missed.
b. On the diagram above, use one arrow to indicate the direction of electron flow in the cell when an external voltage is supplied to the cell by the power supply.



Students were expected to show that the electrons move from left to right (from the site of oxidation to the site of reduction) and in the external circuit. The most common errors showed electrons moving through the proton exchange membrane or in the wrong direction.

c. Hydrogen gas is not produced at the cathode if oxygen is present in the half-cell.
Write a balanced half-equation to show the product that would be produced at the cathode if oxygen were present in the half-cell.
Sol. $O_2(g)+4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
d. Describe one difference between an electrolysis cell and a traditional fuel cell.
Sol. Acceptable responses included
• in a fuel cell, chemical energy is converted into electrical energy; in an electrolysis cell, electrical energy is converted to chemical energy
• in a fuel cell, the reaction produces electrical energy; in an electrolysis cell, electrical energy drives the reaction
• a fuel cell is not connected to an external power supply
• cathode/anode polarity is different in the two cells.

Q81. Decisions about clean energy with reduced carbon dioxide emissions will have an impact on electricity generation from brown coal. However, there will be a much smaller impact on the use of black coal for electricity generation.
The following table compares the energy and carbon content of three different coal samples.

	Percentage carbon* by mass	Energy content (kJ g^{-1})
Black coal	93	36.0
Brown coal (dried)	66	28.0
Brown coal (wet – as mined)	40	5.0

*Coal is not a pure substance and the composition of samples will vary even within one mine.
From the data in this table, it can be deduced that the complete combustion of 1 tonne of black coal will generate 3.6×10^7 kJ of energy.

a. i. Calculate the mass, in tonne, of wet brown coal that is required to generate 3.6×10^7 kJ of energy.
Sol. m(coal) = energy released ÷ energy per gram
$= 3.6 \times 10^7$ kJ ÷ 5.0 kJ g^{-1}
$= 7.2 \times 10^6$ g = 7.2 tonne
ii. Calculate the mass, in tonne, of carbon dioxide that is produced from the complete combustion of this mass of wet brown coal.
Sol. m(C) = 0.40 × 7.2 (only 40% of the sample is C) =2.88 tonne= 2.88×10^6 g

$n(CO_2) = n(C) = 2.88 \times 10^6 \div 12.0 = 2.4 \times 10^5$ mol

$m(CO_2) = 2.4 \times 105 \times 44.0 = 1.1 \times 10^7$ g = 11 tonne

b. What are the most likely reasons for the energy content of wet brown coal being so much lower than the energy content of dried brown coal? Justify your answer.
Sol. Wet brown coal has a lower carbon content. Some of the energy released from the combustion of the carbon content is used to vaporise water in the coal – that is, not all of the energy available from the combustion of the carbon content is released during combustion of the coal.

Q82. Which of the following odors does the ester, methyl salicylate, produce? Is the odor that of:
a. cinnamon
b. avocado
c. orange
d. oil of wintergreen

Q83. Vegetable oil is made into margarine through:
a. halogenation
b. partial hydrogenation
a. methylation

a. oxidation

Q84. Crude oil is separated into its components by:
a. chemical reaction
b. simple distillation
c. fractional distillation
d. settling

Q85. Glycerine and what other substance are made by heating animal fats or vegetable oils with sodium hydroxide?
Sol. Soap

Q86. Which liquid has the highest vapor pressure at 25 °C?
a. butane, C_4H_{10}
b. glycerol, $C_3H_5(OH)_3$
c. octane, C_8H_{18}
d. propanol, C_3H_7OH

Q87. A catalyst speeds up a chemical reaction by:
a. shifting the equilibrium.
b. increasing the activation energy.
d. decreasing the reaction enthalpy.
d. providing an alternate reaction pathway.

Q88. A large polyethene molecule is found to have a relative molecular mass of 4.0×104.
The number of carbon atoms in this molecule would be closest to:
a. 1500
b. 2900
c. 3300
d. 1.8 × 1027
Sol. b. c and **d** were both common incorrect responses. In **c**, students divided the 40 000 relative molecular mass by 12 (for **c)** rather than 14 (for CH_2). In d, the number of atoms in a mole was given– not the number in a molecule (an example of not reading the equation carefully enough).

CHAPTER FIVE
Organic Chemistry
الكيمياء العضوية

Tests & Answers

Q1. The reaction between 2-bromo-2-methylpropane and hydroxide ions occurs in two steps.

step 1 $(CH_3)_3CBr(aq) \rightarrow (CH_3)_3C^+(aq) + Br^-(aq)$

step 2 $(CH_3)_3C+ (aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq)$

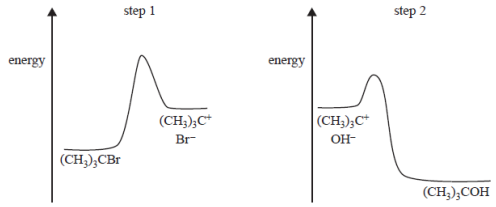
a. Write an equation that represents the overall reaction between 2-bromo-2- methylpropane and hydroxide ions.

Sol.

$(CH_3)_3CBr(aq) + OH^-(aq) \rightarrow (CH_3)_3COH(aq) + Br^-(aq)$

Some students who did not receive the mark for this equation simply wrote down all of the species shown on both sides of the step 1 and step 2 equations and did not provide a simplified equation.

The energy profile diagrams for step 1 and step 2 are shown below. Both are drawn to the same scale.



b. i. Which step involves an endothermic reaction? Provide a reason for your answer.

Sol. Step 1, because the energy (enthalp**c.** of the products, [$(CH_3)_3C+$, Br–], is higher than that of the reactant $(CH_3)_3CBr$.

Students were expected to refer to the information provided on the profile rather than just the learned definition of endothermic reaction. The reason that 'energy is absorbed' in an endothermic reaction is because the enthalpy of the products is higher than the enthalpy of the reactants.

Some good responses linked the profile information to relative energies required for bond breaking and released in bond formation. However, although the argument that an endothermic reaction is one for which the activation energy is greater than the magnitude of the ΔH is an accurate description, it is not a distinguishing factor as it can also apply to some exothermic reactions.

The reaction at step 1 occurs at a different rate to the reaction at step 2.

ii. Which step is slower? Justify your answer.

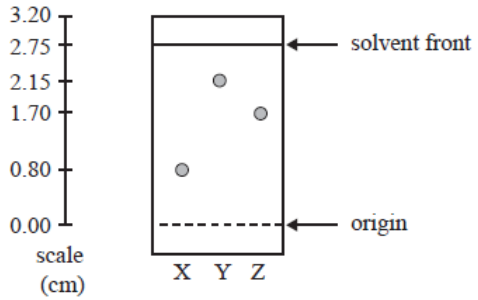
Sol. Step 1, because it has the higher activation energy or because a smaller proportion of the collisions between reactant particles will result in reaction.

Some students overlooked the clear difference in activation energy for the two reactions. Many students assumed that the horizontal axis was 'time' and endeavored, incorrectly, to relate reaction rate to the horizontal distance between the reactants and the products. The point of an energy profile is to show the relative energies (enthalpies) of reactants and product. A detailed energy profile will have a meaningful vertical scale but not a horizontal scale.

Some students mistakenly believed that because a reaction is endothermic it must occur at a slower rate. Students should be aware that the terms 'exothermic' and 'endothermic' do not provide an indication of reaction rate.

Q2. Consider the following TLC plate of compounds X, Y and Z developed using a suitable mobile phase on a polar stationary phase.

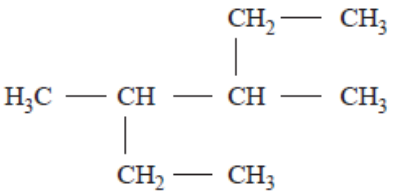
The Rf value of the most polar component in this TLC separation is:



a. 0.29
b. 0.62
c. 0.78
d. 0.80

Sol. The most polar substance will be most strongly attracted to the polar stationary phase, and hence will move least along the stationary phase and will have the lowest R_f value.
$R_f = 0.80 / 2.75 = 0.29$
Students who chose option **c** may have assumed that the species being referred to was the one least attracted to the stationary phase. This suggests the need for better understanding of the link between the principles of chromatography and bonding.

Q3. What is the correct systematic name for the following compound?



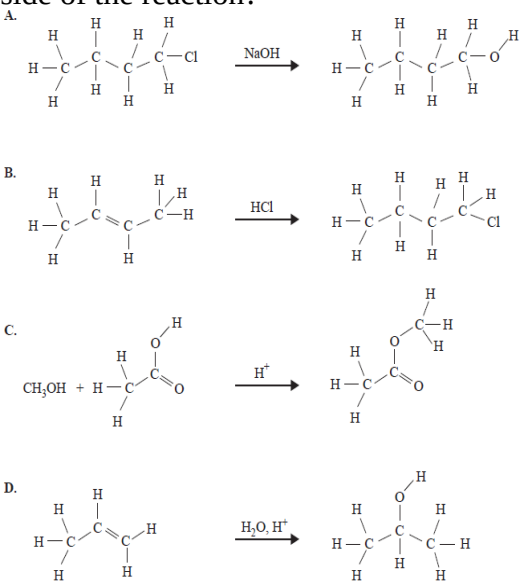
a. 2-ethyl-3-methylpentane
b. 3-methyl-4-ethylpentane
c. 3, 4-dimethylhexane
d. 2, 3-diethylbutane

Q4. For which one of the following molecular formulas is there only one possible structure?
a. C_2HCl_3
b. $C_2H_4Cl_2$
c. $C_2H_2Cl_2$
d. C_4H_9OH

Q5. An organic compound reacts with both dilute hydrochloric acid and dilute sodium hydroxide solution. The compound could be
a. C_3H_7Cl
b. $C_3H_7NH_2$
c. C_4H_9COOH
d. H_2NCH_2COOH

Sol. H_2NCH_2COOH will react with both dilute HCl(aq) and dilute NaOH(aq) because the amino group, NH_2, is basic and the carboxyl group, COOH, is acidic.
This equation was less well done than might have been expected. Students should be aware that amino acids have both basic and acidic character.

Q6. Which one of the following organic reactions does not result in the product shown on the right-hand side of the reaction?



All the reactions represented, albeit incorrectly in option **b**, should have been familiar to students.
Option **b** was incorrect because when HCl reacts with an unsaturated hydrocarbon the H and Cl add at opposite ends of the C=C double bond.

Some students may have been drawn to option **c** because the other product of the reaction, H_2O, was not shown.

Q7. The following are incomplete and unbalanced equations representing three types of chemical reactions that involve glucose. In reactions 1 and 3, product A is the same compound. In reactions 2 and 3, product B is the same compound.

reaction 1 $C_6H_{12}O_6(aq) \rightarrow C_2H_5OH(aq)$ + product A

reaction 2 $C_6H_{12}O_6(aq) \rightarrow C_{12}H_{22}O_{11}(aq)$ + product B

reaction 3 $C_6H_{12}O_6(aq) \rightarrow$ product A + product B

Which one of the following correctly names reaction 3 and identifies product A and product B?

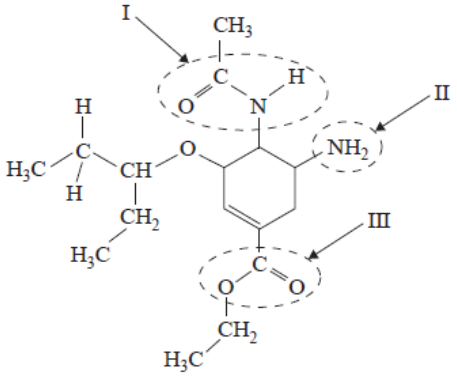
	Reaction 3	Product A	Product B
A.	fermentation	water	carbon dioxide
B.	fermentation	carbon dioxide	water
C.	combustion	water	carbon dioxide
D.	combustion	carbon dioxide	water

Sol. Reaction 1 represented fermentation and product A was CO_2. Reaction 2 represented a condensation reaction in which a disaccharide is produced from a monosaccharide. Product B was H_2O. Since one reactant in reaction C was $C_6H_{12}O_6(aq)$, and the products were CO_2 and H_2O, it is perhaps most readily recognised as respiration $C_6H_{12}O6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$.

Respiration and combustion reactions are very similar; the main difference in the combustion equation being that $C_6H_{12}O_6$ would normally be shown as $C_6H_{12}O_6(s)$. Because it occurs at a low temperature, respiration may be referred to as 'slow' combustion.

The popularity of option **b** suggested that many students were relatively unfamiliar with fermentation, a process which would generally be covered when discussing the production of the biofuel ethanol.

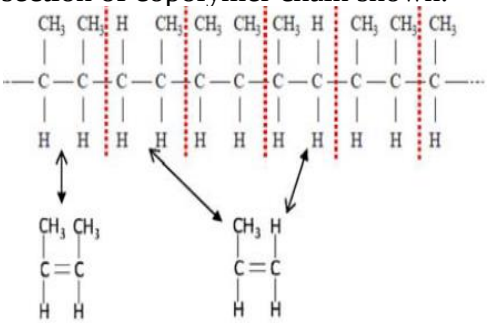
Q8. The structure of Tamiflu, an antifludrug, is shown below.



The names of the functional groups labelled I, II and III are:

	I	II	III
A.	amide	amino	carboxylic acid
B.	amino	amide	ester
C.	amide	amino	ester
D.	amino	amide	carboxylic acid

Sol. To identify the two alkenes/ monomers it was necessary to identify the 'repeating' units in the section of copolymer chain shown.

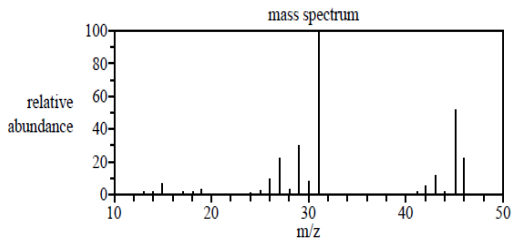


This suggests the copolymer was formed by reaction between but-2-ene, $CH_3CH=CHCH_3$ and propene, $CH_3CH=CH_2$.

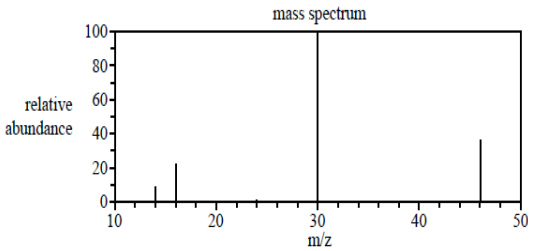
Q9. The molecules ethanol and nitrogen dioxide have the same molar

mass ($M=46 g.mol^{-1}$). They can be easily distinguished by mass spectrometry. The mass spectra of the two molecules are shown below.

Spectrum A



Spectrum B



a. Write an equation showing how either an ethanol molecule or a nitrogen dioxide molecule becomes ionised in the mass spectrometer.

Sol. Any of:

- $CH_3CH_2OH(g) + e^- \rightarrow [CH_3CH_2OH] + (g) + 2e^-$
- $CH_3CH_2OH(g) \rightarrow CH_3CH_2OH+(g) + e^-$
- $C_2H_6O(g) \rightarrow [C_2H_6O]+(g) + e^-$
- $NO_2(g) + e^- \rightarrow [NO_2]+(g) + 2e^-$
- $NO_2(g) \rightarrow NO_2+(g) + 2e^-$.

This equation was not well answered. Many students struggled to provide an appropriate balanced equation, particularly with respect to the correct location of the electron(s). The differences between 'ionisation' and 'fragmentation' in mass spectroscopy should be made clear to students. Of significant concern was the use of (aq) as the state for the species included in the equation.

b. Which mass spectrum cannot be that of nitrogen dioxide? What evidence does the mass spectrum provide to support your answer?

Sol. Either of:

- Spectrum A
- Peaks at m/e = 45 **(**or 31 or 29 or 27) will not result from fragmentation of NO_2 or NO_2, since molecules with only three atoms cannot produce as many fragmentation peaks.

Students argued successfully from both the ethanol and nitrogen dioxide perspectives. Identification of specific peaks, for example, 31–CH_2OH^+, 30–NO^+ was a component of many correct responses.

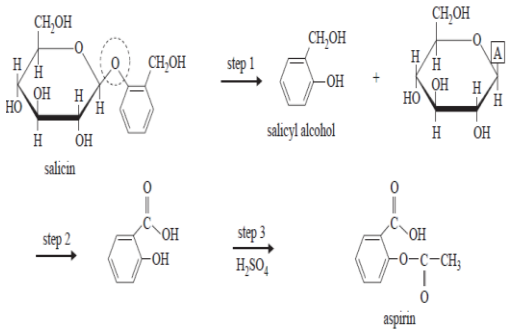
Students should be reminded that when associating peaks with the 'loss of H' during fragmentation, it is H atoms thatare lost, not H^+ ions.

c. What is the formula of the species that produces the peak seen at m/z 30 in spectrum B?

Sol. $[NO]^+$ or NO^+ or NOn^+

Students did not perform as well as expected on this equation**.** Some students referred to species from spectrum A rather than spectrum B, or incorrect, or lack of, charge.

Q10. Since ancient times, the bark of willow trees has been used for pain relief. In the 19th century, chemists isolated the active compound, salicin, from the bark. This was eventually converted into aspirin, which is now a widely used drug. The reaction scheme below shows the steps used to carry out the conversion.



a. What type of linkage is circled in the structure of salicin?

Sol. ether or glycosidic linkage

The most common error was identifying the linkage as an ester linkage.

b. In step 1, salicyl alcohol and another compound is produced.

i. What group of biomolecules does this other compound belong to?

Sol. Any of:

• monosaccharides
• carbohydrates
• sugars
• hexoses.

The most common error on this equation was identifying the compound rather than the 'group of biomolecules' to which it belongs. Polysaccharides was an unexpectedly common and incorrect answer.

ii. The structure of this other compound is not complete. Write the formula of the atom or group of atoms represented by A in the reaction scheme above.

Sol. OH or ₋OH

Students need to be aware of the difference between a hydroxyl group ₋OH, and an hydroxide ion OH^-.

c. Step 2 involves the conversion of salicyl alcohol into salicylic acid.

i. What type of reaction is step 2?

Sol. oxidation or redox

The reaction involves the conversion of $–CH_2OH$ on salicyl alcohol to –COOH, which students should recognise as being consistent with the oxidation of a primary alcohol to a carboxylic acid.

Some students identified the process as a condensation reaction, suggesting that there is a need for clarification of the distinction between condensation reactions (such as between alcohols and acids where water is a product) and the broader range of reactions in which water is a product; for example, combustion or the overall reaction between acidified dichromate and a primary alcohol.

ii. Suggest a suitable reagent to carry out the reaction

Sol.

• $Cr_2O_7^{2-}(aq)$, $Cr_2O_7^{2-}(aq)/H^+(aq)$, acidified dichromate or potassium dichromate
• $MnO_4^-(aq)$, $MnO_4^-(aq)/H^+(aq)$, acidified permanganate or potassium permanganate
• $O_2(g)$ or oxygen

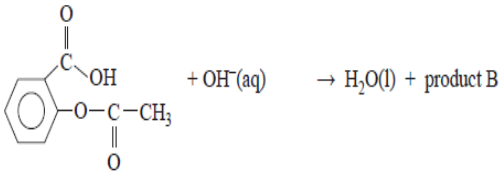
Overall performance on this equation suggested that students were familiar with the reagents generally used in the oxidation of primary alcohols. However, many responses were inaccurate. Students are reminded that accuracy in chemical formulas is essential. The variety of incorrect representations of the dichromate ion suggests that this point needs to be strongly emphasised. Charge on ions is not an optional extra.

d. Step 3 requires sulfuric acid catalyst and another reagent. Name this reagent.

Sol. ethanoic acid or ethanoic anhydride Step 3 involved the conversion of salicylic acid to aspirin. This reaction is specifically covered in the study, and the preparation of aspirin is a common practical exercise, so stronger student performance on this equation might have been expected.

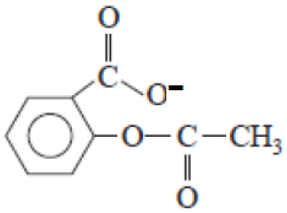
While there was some leniency in the marking, in that correct chemical formulas were accepted instead of the name, students must not presume this will always be the case when the 'name' of substance is asked for. 'Acetic' was an acceptable alternative for 'ethanoic'.

e. Aspirin reacts with a strong base according to the equation



Draw the structure of product B.

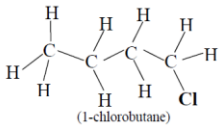
Sol.

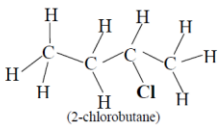


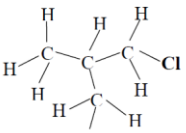
Most students identified that the carboxyl group on aspirin loses H+ in the reaction. However, many omitted the (-) charge on the final structure. A number of students, perhaps having used the 2009 paper for practice, showed a structure for sodium salicylate. This was not accepted as it was not consistent with the equation as given in the equation**.**

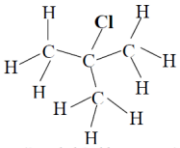
Q11. a. Draw full structural formulas for all possible structural isomers of C_4H_9Cl

Sol.


(1-chlorobutane)


(2-chlorobutane)


(2-methyl-1-chloropropane)


(2-methyl-2-chloropropane)

This equation was generally well done, although some students struggled to identify a 'fourth' isomer. Repetition of 2-chlorobutane or 2-methyl-1-chloropropane was relatively common.

b. 1-chlorobutane can be hydrolysed to 1-butanol. 1-butanol can then be oxidised to a carboxylic acid of empirical formula $C_4H_8O_2$.

i. Give the name or formula of a suitable laboratory oxidising agent for the reaction of 1-butanol to a carboxylic acid.

Sol. Any of:

- potassium dichromate
- acidified potassium dichromate
- $K_2Cr_2O_7$
- Cr_2O_{72-}.

There were occasional mentions of acidified potassium permanganate, $KMnO_4$, or O_2 in the presence of a silver catalyst, which were also accepted.

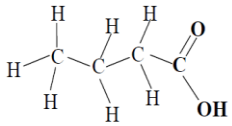
ii. Give the systematic name for the carboxylic acid.

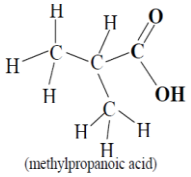
Sol. Butanoic acid

A common answer was 1-butanoic acid. While this was accepted, it should be emphasised to students that since 2-butanoic acid does not exist, the 1- is not necessary in the systematic name.

c. Draw full structural formulas of all carboxylic acids with the empirical formula $C_4H_8O_2$.

Sol.


(butanoic acid)


(methylpropanoic acid)

The number of students who did not score on this equation was surprisingly high given that the key knowledge in the Industrial Chemistry Area of Study is so specific: structural isomers of compounds containing one chloro, hydroxy or carboxyl functional group (up to four-carbon compounds).

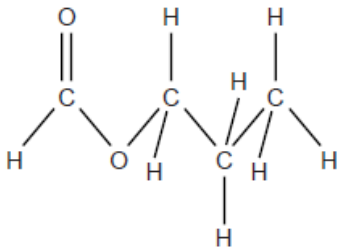
d. Using systematic nomenclature, name the compounds represented by the following formulas.

i. $CH_3CH_2COOCH_3$

Sol. Methyl propanoate

ii.
$CH_2OHCH_2CH_2CH_2CH_2CH_2CH_2CH_3$
Sol. 1-octanol
iii. $CH_3CH_2CH_2CHClCH_3$
Sol. 2-chloropentane

Q12. A compound associated with the smell or flavour of raspberries has the structure



To synthesise this compound in the laboratory you would react
a. methanol and propanoic acid.
b. methanol and butanoic acid.
c. 1-propanol and methanoic acid.
d. 1-butanol and methanoic acid.

Q13. When two mole of an organic compound is burnt in oxygen, eight mole of carbon dioxide gas is formed. In a second test, when a few drops of bromine are added to the compound and shaken, the bromine rapidly decolorizes. The formula of the compound could be:
a. C_4H_8
b. C_4H_{10}
c. C_8H_{16}
d. C_8H_{18}

Q14. Gaseous propane reacts with chlorine in the presence of ultraviolet light.
a. Name the type of reaction that occurs.
Sol. Substitution (or chlorination, oxidation).
b. What is the function of the light?
Sol. Catalyst.
This was the best response given what was required by the equation**.** The light dissociates the Cl_2 and the resultant Cl atoms then abstract an H atom from the alkane giving HCl and an alkyl free radical. The free radical then pulls a Cl atom off another Cl_2 molecule and generates another Cl atom and so on; however, that is all beyond what is required so the simple response 'catalyst' was accepted.
c. Other than various chlorinated hydrocarbons, what other compound is formed in this reaction?
Sol. HCI
d. One of the possible products has the chemical formula C_3H_7Cl. Draw the structural formulas of all the possible isomers of C3H7Cl and give the name of one of them.
Sol. $CH_3CH_2CH_2Cl$; $CH_3CHCl.CH_3$; 1- or 2-chloropropane as appropriate.
This was extremely well done.

Q15. Consider the reaction:
$CH_3CH = CHCH_3 + Br_2 \rightarrow Z$
Z would be represented by
a. $CH_3CHBrCHBrCH_3$
b. $CH_2BrCH_2CHBrCH_3$
c. $CH_3CHBrCH_2CH_2Br$
d. $CH_2BrCH_2CH_2CH_2Br$
Sol. a. $CH_3CH=CHCH_3 + Br_2 \rightarrow CH_3CHBrCHBrCH_3$

Q16. Consider the reaction
$CH_3CH = CHCH_3 + H_2O \rightarrow X$
$X + CH_3COOH \rightarrow Y$
The structure of Y would be

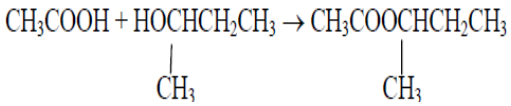
A. $CH_3CH_2\underset{\displaystyle CH_3}{\underset{|}{C}}HCOOCH_3$

B. $CH_3COOCH\underset{\displaystyle CH_3}{\underset{|}{C}}HCH_3$

C. $CH_3CH_2CH_2COOCH_3$

D. $CH_3OOCH_2CH_2CH_2CH_3$

Sol. $CH_3CH=CHCH_3 + H_2O \rightarrow CH_3CH_2CHOHCH_3$
2-butene is converted into 2-butanol
2-butanol then reacts with ethanoic acid to produce an ester



Q17. The compound that is a structural isomer of CH_3CH_2COOH is
a. $HCOOCH_2CH_3$
b. $CH_3CH_2CH_2OH$
c. $CH_3COOCH_2CH_3$
d. $CH_3CHOHCH_2OH$
Sol. a. The only alternative with the same molecular formula, i.e. $C_3H_6O_2$ was $HCOOCH_2CH_3$

Q18. How many hydrogen atoms are there in a molecule of 3-nonanol?
a. 9
b. 19
c. 20
d. 21

Sol. C: 3-nonanol → 9 C atoms with –OH on carbon number 3.
$CH_3CH_2CH_2CH_2CH_2CH_2CHOHCH_2CH_3$ → 20 H atoms

Q19. The number of structural isomers with the formula C_4H_9Cl is:
a. 1
b. 2
c. 3
d. 4
Sol. d. 4 structural isomers
$CH_3CH_2CH2CH2Cl$, 1-chlorobutane
$CH_3CH_2CHClCH_3$, 2-chlorobutane
$(CH_3)_2CHCH_2Cl$, 2-methyl-1-chloropropane
$(CH_3)_3CHCl$, 2-methyl-2-chloropropane

Q20. A sample of hydrocarbon contains 81.8% carbon by mass. The empirical formula of the compound would be:
a. CH_2
b. CH_3
c. C_2H_5
d. C_3H_8

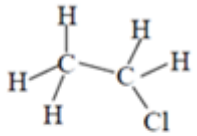
mass ratio 81.8 g : 18.2 g
mole ratio 81.8/12.0 : 18.2/1.0
6.82:18.2
simplest ratio 6.82/6.82 : 18.2/6.82
1 : 2.67
1 : 22/3
1 : 8/3
3 : 8
Empirical Formula C_3H_8

Q21. Concentrated sulfuric acid reacts with glucose. One of the chemical reactions that can occur may be represented as:
$C_6H_{12}O_6(s) + 6H_2SO_4(l) \rightarrow 6C(s) + 6H_3O^+(aq) + 6HSO_4^-(aq)$
This reaction is best described as being
a. dehydration only.
b. acid-base and redox only.
c. dehydration and acid-base only.
d. dehydration, acid-base and redox.
Sol. c. $C_6H_{12}O_6$ is clearly dehydrated to C when reacting with sulfuric acid. H_2SO_4 acts as an acid in donating a proton to H2O to produce H3O+ and HSO4

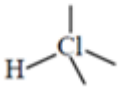
Q22. A 2L sample of a gaseous hydrocarbon is burnt in excess oxygen. The only products of the reaction are 8 L of $CO_2(g)$ and 10 L of $H_2O(g)$, all at 100ºC and 1 atm pressure. The formula of the hydrocarbon is
a. CH
b. C_2H_4
c. C_4H_{10}
d. C_8H_{10}
Sol. Since all gases are measured at the same temperature and pressure, the volumes of CxHy, CO_2 and H_2O are in the same ratio as the mole ratio.
$CxHy \rightarrow CO_2 + H_2O$
2 L 8 L 10 L
2 mol 8 mol 10 mol
1 mol 4 mol 5 mol
So 1 mol CxHy → 4 mol CO_2 (4 mol C. and 5 mol H_2O (10 mol H)

Molecular formula is C_4H_{10}

Q23. a. Give the systematic names of the following organic compounds.
i. $CH_3CHOHCH_3$
Sol. 1. 2-propanol or propan-2-ol
ii. HCOOH
Sol. 1. methanoic acid
iii. $CH_3CH_2CHClCH_3$
Sol. 1. 2-chlorobutane
iv. $CH_3CH_2COOCH_2CH_3$
Sol. 1. ethyl propanoate
b. Complete the following chemical equation by giving relevant structural formulas in the boxes provided:
$C_2H_6 + Cl_2 \rightarrow$
Sol.



or CH_3CH_2Cl;



or HCl or H — Cl

Q24. Experiments were carried out on several different cracking reactions of butane (semi-structural formula of butane is $CH_3CH_2CH_2CH_3$). The following series of different possible reactions of butane were observed under a variety of different conditions.
$CH_3CH_2CH_2CH_3 \rightarrow V + W$
$CH_3CH_2CH_2CH_3 \rightarrow X + W$
$CH_3CH_2CH_2CH_3 \rightarrow Y + Z$
Molecules V, W, X, Y and Z were further investigated and the following three items of information were obtained.
$V + Cl_2 \rightarrow CH_3CHClCHClCH_3$
X has the same molecular formula as V but has a different structure
$Y + H_2O \rightarrow CH_3CH_2CH_2OH$
On the basis of all the information provided, give the semi-structural formulas of each of the following molecules.
i. V
Sol. $CH_3CH=CHCH_3$ or $CH_3CHCHCH_3$ or $CH_3(CH)_2CH_3$
ii. W
Sol. H_2
iii. X
Sol. $CH_3CH_2CH=CH_2$ [CH_2=CH CH_2 CH_3] or $CH_3CH_2CHCH_2$ or $(CH_3)_2C=CH_2$ or $(CH_3)_2CCH_2$
iv. Y
Sol. $CH_3CH=CH_2$ [$CH_2=CHCH_3$] or CH_3CHCH_2
v. Z
Sol. CH_4

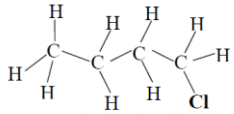
Q25. Give the chemical formula for
i. A nitrogen-containing compound that is the end waste product of the digestion of proteins.
Sol. H_2NCONH_2 or $CO(NH_2)2$, etc.
ii. The carboxyl functional group
Sol. COOH
iii. An oxide from period 3 that reacts with NaOH but not with HCl
Sol. any one of SiO_2, P_2O_3, P_2O_5, SO_2, SO_3, Cl_2O, Cl_2O_7
iv. A compound that is always a reactant in a hydrolysis reaction
Sol. H_2O

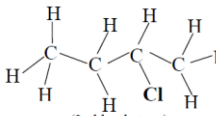
Q26. 0.10 mole of C_4H_9OH reacts completely with molecular oxygen, O2. The number of mole of oxygen molecules used is:
a. 0.50
b. 0.55
c. 0.60
d. 0.65
Sol. c. 0.60
The products of the combustion of C_4H_9OH are CO_2 and H_2O.
$C_4H_9OH \rightarrow 4CO_2 + 5H_2O$
1 'O' on the reactant side; 13 'O' on the product side
12 'O' i.e. 6 O_2 required on the reactant side
$C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$

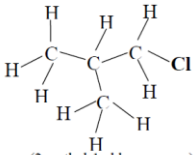
So, 0.10 mol C_4H_9OH reacts with 0.60 mol O_2 (option **c**).This equation proved more challenging than might have been expected.

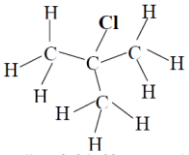
Q27. An organic compound is known to contain only carbon, hydrogen and oxygen. The compound contains, by mass, 39.1% of carbon and 8.7% of hydrogen. The number of carbon atoms in the empirical formula is:
a. 1
b. 2
c. 3
d. 4
Sol. c. Assume a 100 g sample
m**c.** = 39.1 g; m(H) = 8.7 g; m(O) = 100 – (39.1+8.7) = 52.2 g
C : H : O
mass ratio 39.1 : 8.7 : 52.2
mole ratio 39.1/12.0 : 8.7/1.0 : 52.2/16.0
3.26 : 8.7 : 3.26
simplest ratio 3.26/3.26 : 8.7/3.26 : 3.26/3.26
1 : 2.67 : 1
1 : 22/3 : 1
1 : 8/3 : 1
3 : 8 : 3
Empirical formula $C_3H_8O_3$

Q28. a. Draw full structural formulas for all possible structural isomers of C_4H_9Cl.
Sol.

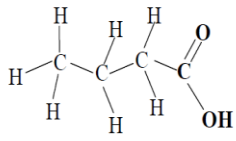

(1-chlorobutane)

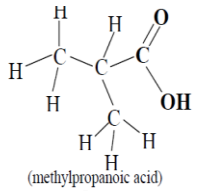

(2-chlorobutane)


(2-methyl-1-chloropropane)


(2-methyl-2-chloropropane)

b. 1-chlorobutane can be hydrolysed to 1-butanol. 1-butanol can then be oxidised to a carboxylic acid of empirical formula $C_4H_8O_2$.
i. Give the name or formula of a suitable laboratory oxidising agent for the reaction of 1-butanol to a carboxylic acid.
Sol. Any of:
• potassium dichromate
• acidified potassium dichromate
• $K_2Cr_2O_7$
• Cr_2O_7
There were occasional mentions of acidified potassium permanganate, $KMnO_4$, or O_2 in the presence of a silver catalyst, which were also accepted.
ii. Give the systematic name for the carboxylic acid.
Sol. Butanoic acid
c. Draw full structural formulas of all carboxylic acids with the empirical formula $C_4H_8O_2$.
Sol.


(butanoic acid)


(methylpropanoic acid)

d. Using systematic nomenclature, name the compounds represented by the following formulas.
i. $CH_3CH_2COOCH_3$
Sol. Methyl propanoate
ii. $CH_2OHCH_2CH_2CH_2CH_2CH_2$ CH_2 CH_3
Sol. 1-octanol
iii. $CH_3CH_2CH_2CHClCH_3$
Sol. 2-chloropentane

Q29. Consider the molecule $CH_3CH_2CH_2CH_2CHClCH_2CH_3$. The systematic name of this molecule is
a. 5-chloroheptane.
b. 3-chloroheptane.
c. 5-chlorooctane.
d. 3-chlorooctane.
Q30. The raspberry-F avoured food additive, butyl methanoate, can be

prepared from $CH_3CH_2CH_2CH_2OH$ using
a. an addition reaction with HCOOH.
b. an addition reaction with CH_3COOH.
c. a condensation reaction with HCOOH.
d. a condensation reaction with CH_3COOH.
Sol. c. Butyl methanoate, $HCOOCH_2CH_2CH_2CH_3$, is produced by reaction between 1-butanol ($CH_3CH_2CH_2CH_2OH$) and methanoic acid (HCOOH).

Q31. The number of structural isomers that are carboxylic acids with the formula $C_4H_8O_2$ is:
a. 1
b. 2
c. 3
d. 4
Sol. b. There are two (alternative **b**) carboxylic acids with molecular formula $C_4H_8O_2$,
$CH_3CH_2CH_2COOH$ – butanoicacid
$(CH_3)_2CHCOOH$ – methylpropanoic acid.

Q32. Two chemical reactions occur as follows.
$CH_2{=}CH\ CH_2CH_2CH_3 + X \rightarrow$ 2-chloropentane
2-chloropentane + sodium hydroxide solution → Y
X and Y are given by

	X	Y
A.	Cl_2	$CH_3CH_2CH_2CHOHCH_3$
B.	HCl	$CH_3CH_2CH_2CHOHCH_3$
C.	Cl_2	$CH_3CH_2CH_2CH_2CH_2OH$
D.	HCl	$CH_3CH_2CH_2CH_2CH_2OH$

Sol. b.
$CH_2 = CHCH_2CH_2CH_3 + HCl \rightarrow CH_3CHClCH_2CH_2CH_3$
$CH_3CHClCH_2CH_2CH_3 + OH^- \rightarrow CH_3CHOHCH_2CH_2CH_3 + Cl^-$
2-chloropentane 2-pentanol

Q33. A student was given four colourless liquids that were labelled A, B, C and D. They were known to be ethanol, ethanoic acid, pentane and hexene, but the exact identity of each liquid was unknown.
The student tested the properties of each liquid and obtained the following results.

	A	B	C	D
Solubility in water	insoluble	soluble	soluble	insoluble
Addition of red-coloured bromine (Br_2) solution	colour disappears	no immediate reaction	no immediate reaction	no immediate reaction
Addition of sodium carbonate (Na_2CO_3) powder	no reaction	gas evolved	no reaction	no reaction

Identify each of the liquids by completing the table below.

	Name of liquid
A	
B	
C	
D	

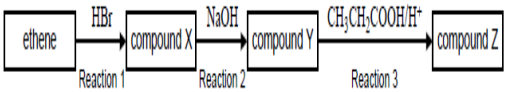
Sol.

	Name of liquid
A	hexene
B	ethanoic acid
C	ethanol
D	pentane

Q34. Which of the following statements would apply to compounds that belong to the same homologous series?
I they have similar physical properties
II they have similar chemical properties

III they contain the same functional group
IV they have the same molecular formula but different structures
a. III only
b. IV only
c. II and III only
d. I, II, III and IV
Sol. c. Since all members of an homologous series contain the same functional group (statement III) they will have similar chemical properties (statement II). However, since successive members of an homologous series differ by CH_2, they have different physical properties (e.g. boiling temperature) and different molecular formulae, therefore statements I and IV are incorrect.

Q35-36 Ethene can be converted into other carbon-containing compounds using the reagents shown in the following blow chart.



Q35. Compounds X, Y and Z are, respectively:
a. bromoethane, ethanol, propyl ethanoate.
b. bromoethane, ethanol, ethyl propanoate.
c. bromoethene, ethanoic acid, ethyl propanoate.
d. bromoethene, ethene hydroxide, propyl ethanoate.
Sol. b.

1. $CH_2{=}CH_2 \xrightarrow{HBr} CH_3CH_2Br$ (bromoethane) – addition reaction
2. $CH_3CH_2Br \xrightarrow{OH^-} CH_3CH_2OH$ (ethanol) – substitution reaction
3. $CH_3CH_2COOH + CH_3CH_2OH \rightarrow CH_3CH_2COOCH_2CH_3 + H_2O$ (ethyl propanoate)

This is a condensation reaction

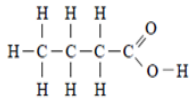
Q36. Reactions 1, 2 and 3 can be described as, respectively
a. addition, addition, neutralisation.
b. addition, substitution, condensation.
c. substitution, neutralisation, oxidation.
d. substitution, substitution, condensation.

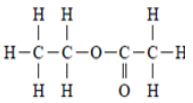
Q37. How many structural isomers, each containing a double bond, have the molecular formula C_5H_{10}?
a. 3
b. 4
c. 5
d. 6
Sol. c. Structural isomers refer to compounds which have the same molecular formulae but different structural formulae, i.e. atom connectivities. Options for C_5H_{10} are:
$CH_3CH_2CH_2CH{=}CH_2$: 1–pentene
$CH_3CH_2CH{=}CHCH_3$: 2–pentene
$CH_3CH_2C(CH_3){=}CH_2$: 2–methyl–1–butene
$(CH_3)_2CHCH{=}CH_2$: 3–methyl–1–butene
$(CH_3)_2C{=}CHCH_3$: 2–methyl–2–butene
Therefore, there are five structural isomers containing a double bond.

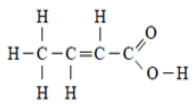
Q38. A student was given the task of identifying a liquid organic compound that contains only carbon, hydrogen and oxygen. The following tests were carried out

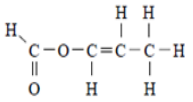
	Procedure	Result
Test 1	Some brown $Br_2(aq)$ was added to a sample of the compound.	A reaction occurred and a colourless product formed.
Test 2	Some $Na_2CO_3(s)$ was added to a sample of the compound.	A reaction occurred and a colourless gas was evolved.

Based on the above test results, the compound could be:

A. 

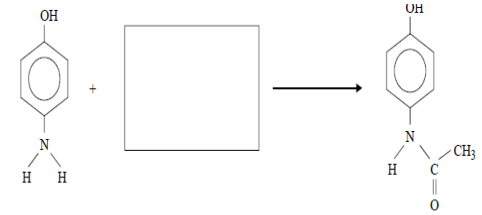
C. 

B. 

D. 

Sol. b. $Br_2(aq)$ will react across a C=C double bond in an addition reaction. Na_2CO_3 will react with an acid, in this case a carboxyl functional group.

Q39. Paracetamol is a commonly used painkiller. The equation below shows one method of preparing paracetamol.

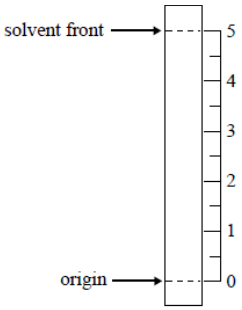


4-aminophenol paracetamol

a. In the box provided in the equation above, give the formula of a possible reagent that can be used in this synthesis.

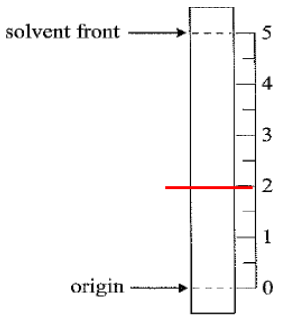
Sol. Either of:
CH_3COOH/ $C_2H_4O_2$/ structural formula of ethanoic acid
$CH_3CO.O.COCH_3/C_4H_6O_3$/ structural formula of acetic anhydride.

b. A student uses thin layer chromatography (TL**c.** to analyse the products of this preparation of paracetamol.
For the stationary and mobile phases used for this analysis, the R_f of paracetamol is 0.4.
i. On the diagram of a TLC plate below, use a horizontal line to mark the spot where paracetamol would appear in such an analysis.

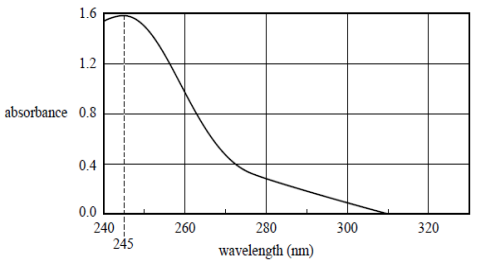


ii. 4-aminophenol adsorbs less strongly than paracetamol onto the stationary phase of this TLC plate. Predict whether the Rf value of 4-aminophenol in this analysis is greater or smaller than that of paracetamol, giving a reason for your choice.

Sol.



The UV-visible absorption spectrum of a solution of paracetamol is shown below. The concentration of paracetamol in the solution is 15.1 μg mL^{-1}.



The absorbance of another solution of paracetamol is measured under the same conditions and, at 245 nm, the absorbance is 0.96.

c. What is the concentration, in μg mL^{-1}, of the paracetamol in this other solution?

Sol. 9.1 ($\mu g\ mL^{-1}$)

Q40 A mixture contains several different organic liquids all of which boil at temperatures greater than 50°C**.** The compounds present in the mixture are separated. Three of the compounds, compounds X, Y and Z, are analysed as follows.

Compound X is vaporised. At a temperature of 120°C and a pressure of 115 kPa, a 0.376 g sample of the vapour occupies 124 mL.

a. Calculate the molar mass, in g mol^{-1}, of compound X.

Sol.

$$n = \frac{pV}{RT}$$
$$= \frac{115 \times 0.124}{8.31 \times 393}$$
$$= 4.37 \times 10^{-3} * \text{ mol}$$

$$M = \frac{m}{n}$$
$$= \frac{0.376}{4.37 \times 10^{-3}}$$
$$= 86.1 * \ (\text{g mol}^{-1})$$

Compound Y is an alkanol of molecular formula of $C_4H_{10}O$.

b. i. In the boxes below, draw the structural formulas, showing all bonds, of the four possible alkanols with a molecular formula of $C_4H_{10}O$.

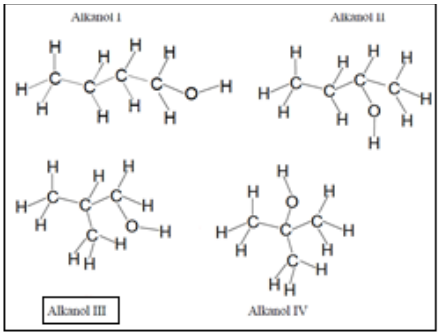
Alkanol I	Alkanol II
Alkanol III	Alkanol IV

Compound Y shows 3 lines in the ^{13}C NMR spectrum and undergoes reaction with $Cr_2O_7^{2-}(aq)$ in acid to produce a carboxylic acid.

ii. What evidence about the structure of Y can be gained from this information?

Evidence from 13C NMR spectrum

Sol.



ii. What evidence about the structure of Y can be gained from this information?

Evidence from 13C NMR spectrum

Sol. 13C NMR. The number of different carbon environments (three) could be methylpropan–1–ol

Evidence from reaction with Cr_2O_7 2–(aq) in acid solution

Sol. Reaction with Cr_2O7^{2-}/H^+ the compound must be a primary alkanol with ^-OH on C^{-1}

iii. Based on the above evidence, identify compound Y by:

• circling the structural formula in **part i.** that corresponds to compound Y

• Writing below the systematic name of compound Y.

Sol. Structure

as circled in part i. above

Name

methylpropan–1–ol

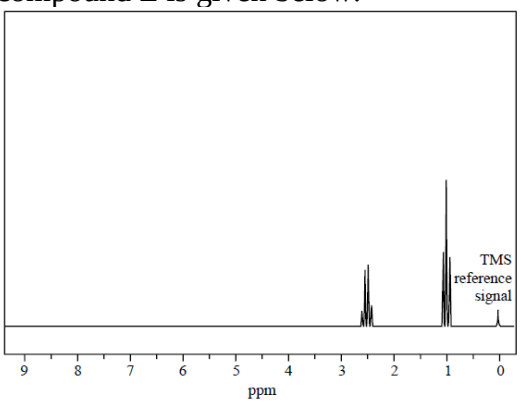
methyl–1–propanol

2–methyl–1–propanol

This equation was generally well done. The main concerns were:

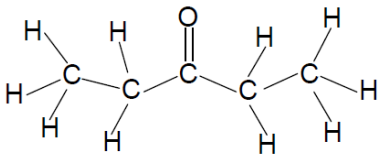
repetition of structures in part i. not drawing out the O–H link in part i.

responses to the evidence from the reaction with $Cr_2O_7^{2-}(aq)/H^+(aq)$ not being specific about the location of the ^-OH group or type of alkanol.
Compound Z has the molecular formula $C_5H_{10}O$ and shows a strong band in the infrared spectrum at about 1700 cm^{-1}. The 1H NMR spectrum of compound Z is given below.



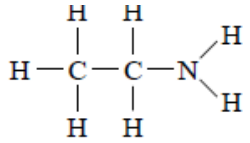
c. i. What information about the structure of Z can be deduced from the above spectral data? From IR data
Sol. IR data +C=O is present, carbonyl group From 1H NMR
Sol.
- two different hydrogen environments
- splitting patterns quartet and triplet → CH_3CH_2 is present
-6 H in one environment, 4 H in a different environment.

ii. Draw a structure for compound Z that is consistent with the spectral data.
Sol. $CH_3CH_2COCH_2CH_3$ or



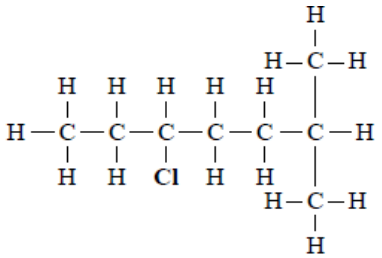
Q41. a. Give a systematic name for each of the following compounds.
Sol.

i.



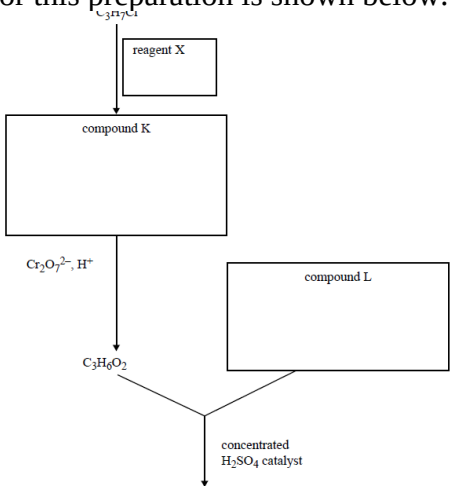
Sol. Any of:
- aminoethane.
- ethylamine.
- ethanamine

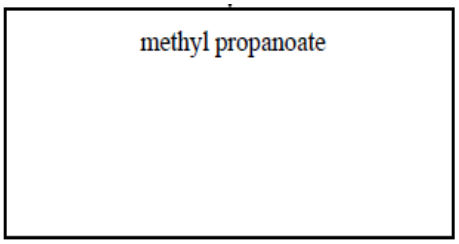
ii.



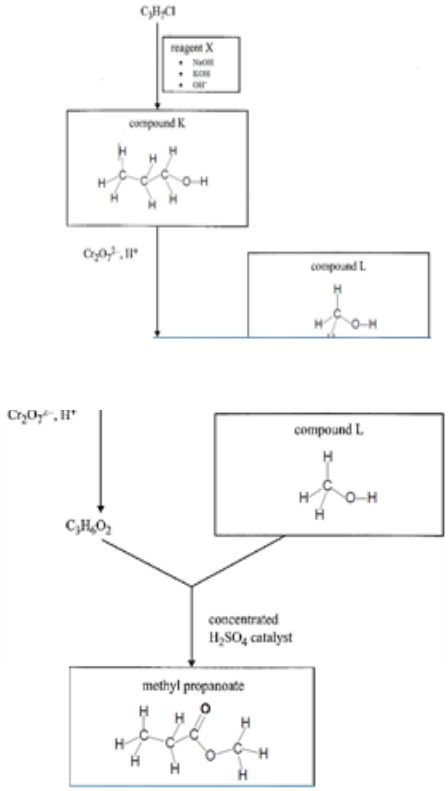
Sol. Either of:
- 5–chloro–2–methylheptane
- 3–chloro–6–methylheptane.

The ester methyl propanoate has a characteristic fruityodour and has been isolated from many fruits including pineapple. A sample of this ester is to be prepared in the laboratory.
A partly completed reaction pathway for this preparation is shown below.

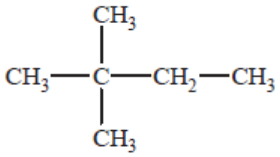




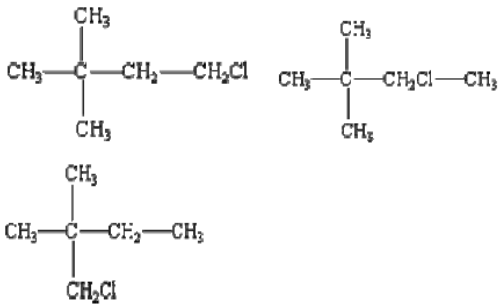
b. i. In the appropriate box, write a structural formula, showing all bonds, for methyl propionate.
ii. In the appropriate boxes, write structural formulas, showing all bonds, for compounds K and L.
iii. In the appropriate box, write the formula of reagent X
Sol.



Q42. In a particular chlorination reaction, a single hydrogen atom of 2,2-dimethylbutane, C_6H_{14}, is replaced by one chlorine atom. More than one compound of formula C6H13Cl will be formed. A structure of 2, 2-dimethylbutane is provided below.

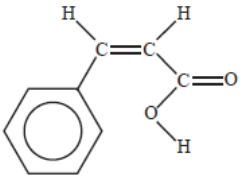


The number of different compounds that could be formed in this monosubstitution reaction is:
a. 2
b. 3
c. 4
d. 5
Sol. As the words 'different compounds' could be interpreted in two ways, two answers were accepted for this question**.** The first sentence of the question**.** referred to 'compound of formula $C_6H_{13}Cl$'. 2,2-dimethylbutane can react with Cl_2 to produce 3 different monochloro compounds.



1-chloro-3, 3-dimethylbutane; 2-chloro-3, 3- dimethylbutane; 1-chloro-2, 2-dimethylbutane. However, each substitution reaction also produces hydrogen chloride, HCl, so a total of 4 different compounds will be formed.

Q43. Cinnamic acid is an organic substance that partly contributes to the flavour of oil of cinnamon. A structure of cinnamic acid is given below.



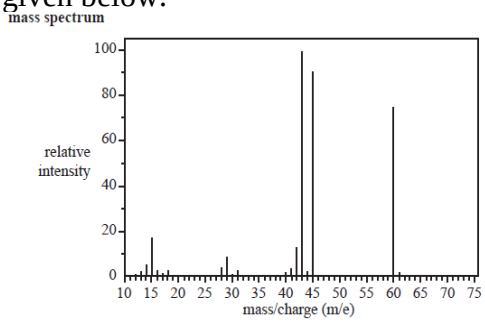
Which of the following reagents would you expect to react with cinnamic acid under the conditions given below?

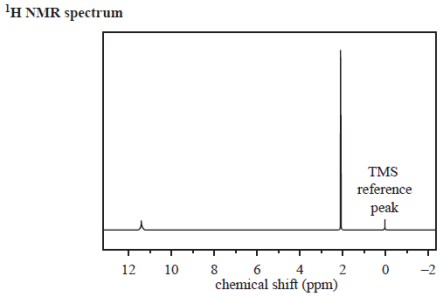
CH_2CH_2 $Br_2(aq)$at CH_3OH and catalyst room temperature H_2SO_4 catalyst

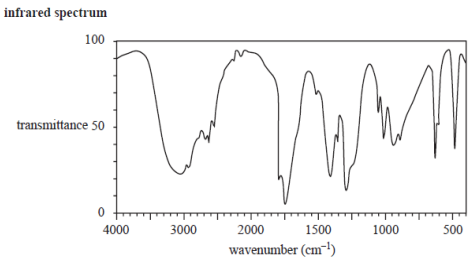
a. Yes Yes Yes
b. Yes No Yes
c. No Yes Yes
d. No Yes No

Sol. a. Cinnamic acid contains a C=C double bond and may be expected to partake in similar chemical reactions to ethene $CH_2=CH_2$. Like ethene it can be involved in addition polymerisation and might be expected to react with ethene to form a copolymer. Cinnamic acid will undergo an addition reaction with Br_2. As cinnamic acid has a carboxyl –COOH group, it will react with methanol to produce the ester methyl cinnamate.

Q44. The structure of an organic molecule, with empirical formula CH_2O, is determined using spectroscopic techniques. The mass spectrum, infrared spectrum and 1H NMR spectrum for this molecule are given below.







Use the information provided by these spectra to answer the following

Q45.

a. What is the molecular formula of this molecule?

Sol. $C_2H_4O_2$

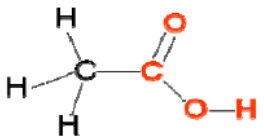
Students should know the differences between molecular and semi-structural formulae

b. How many different proton environments are there in this molecule?

Sol. 2 different environments

c. Draw the structure of the unknown molecule, clearly showing all bonds.

Sol.



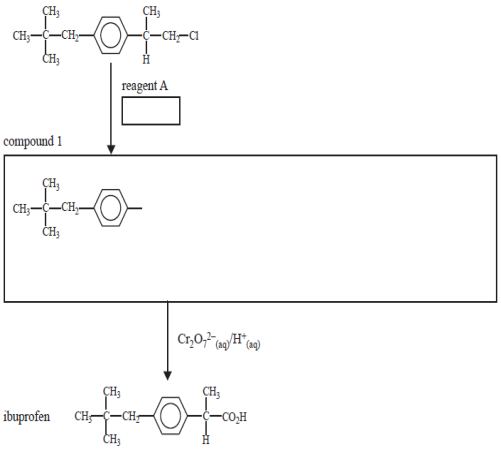
d. Explain how the structure of the compound you have drawn in part **c.** is consistent with its IR spectrum.

Sol. Broad peak at 2500-3300 (cm^{-1}) indicates O-H (acid)* bond.

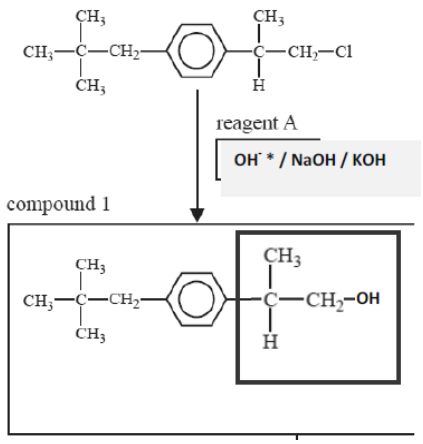
e. Name the compound you have drawn in part **c.**

Sol. In Section B, students' overall performance was the best on equation 5. The majority of students were clearly comfortable with the interpretation of mass, NMR and IR spectra and linking together the information to deduce a molecular structure.

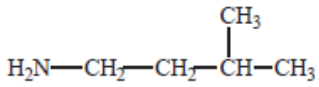
Q46. a. A partially completed reaction pathway for the synthesis of the painkiller ibuprofen is given below.



i. In the appropriate box, write the formula for reagent **a.**
ii. In the appropriate box, complete the structure for compound 1.
Sol. i. and **ii.**

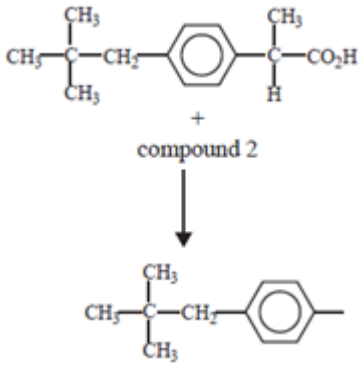


iii. Write a balanced half-equation for the reduction of dichromate ions to Cr^{3+} ions in an aqueous acid solution.
Cr_2O_7
$2\text{-(aq)} + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$*
b. Ibuprofen reacts with compound 2 which has the semi-structural formula shown below.

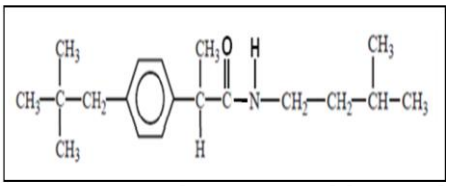


compound 2

i. Give the systematic name of compound 2.
Sol. 3-methylbutan-1-amine/3-methyl-1-butanamine/3-methylbutylamine
ii. Complete the following structure of the compound formed between ibuprofen and compound 2.

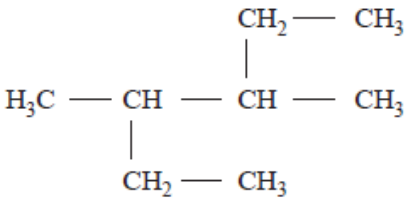


Sol.



CO-NH was also acceptable in the structure.

Q47. What is the correct systematic name for the following compound?

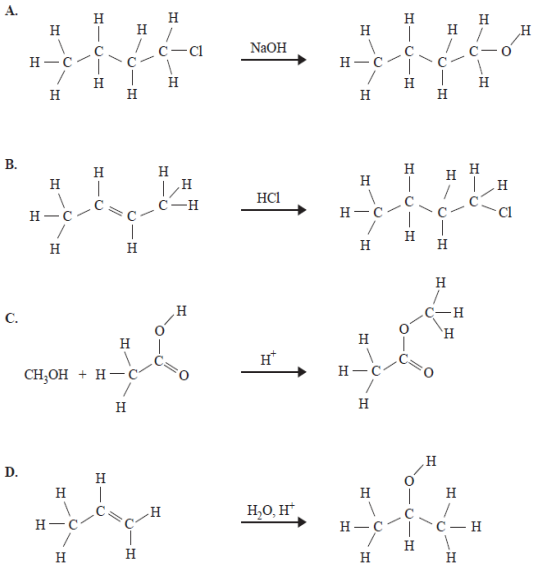


a. 2-ethyl-3-methylpentane
b. 3-methyl-4-ethylpentane
c. 3,4-dimethylhexane
d. 2,3-diethylbutane

Q48: For which one of the following molecular formulas is there only one possible structure?
a. C_2HCl_3
b. $C_2H_4Cl_2$
c. $C_2H_2Cl_2$
d. C_4H_9OH

Q49. An organic compound reacts with both dilute hydrochloric acid and dilute sodium hydroxide solution. The compound could be:
a. C_3H_7Cl
b. $C_3H_7NH_2$
c. C_4H_9COOH
d. H_2NCH_2COOH
Sol. d. H_2NCH_2COOH will react with both dilute HCl(aq) and dilute NaOH(aq) because the amino group, NH_2, is basic and the carboxyl group, COOH, is acidic.

Q50. Which one of the following organic reactions does **not** result in the product shown on the right-hand side of the reaction?



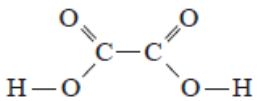
Sol. b. All the reactions represented, albeit incorrectly in option **b**, should have been familiar to students. Option **b** was incorrect because when HCl reacts with an unsaturated hydrocarbon the H and Cl add at opposite ends of the C=C double bond.

Q51. The following are incomplete and unbalanced equations representing three types of chemical reactions that involve glucose. In reactions 1 and 3, product A is the same compound. In reactions 2 and 3, product B is the same compound.
reaction 1 $C_6H_{12}O_6(aq) \rightarrow C_2H_5OH(aq)$ + product A
reaction 2 $C_6H_{12}O_6(aq) \rightarrow C_{12}H_{22}O_{11}(aq)$ + product B
reaction 3 $C_6H_{12}O_6(aq) \rightarrow$ product A + product B
Which one of the following correctly names reaction 3 and identifies product A and product B?

	Reaction 3	Product A	Product B
A.	fermentation	water	carbon dioxide
B.	fermentation	carbon dioxide	water
C.	combustion	water	carbon dioxide
D.	combustion	carbon dioxide	water

Sol. d. Reaction 1 represented fermentation and product A was CO_2. Reaction 2 represented a condensation reaction in which a disaccharide is produced from a monosaccharide. Product B was H_2O. Since one reactant in reaction C was $C_6H_{12}O_6(aq)$, and the products were CO_2 and H_2O, it is perhaps most readily recognised as respiration:
$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$.
Respiration and combustion reactions are very similar; the main difference in the combustion equation being that $C_6H_{12}O_6$ would normally be shown as $C_6H_{12}O_6(s)$. Because it occurs at a low temperature, respiration may be referred to as 'slow' combustion.

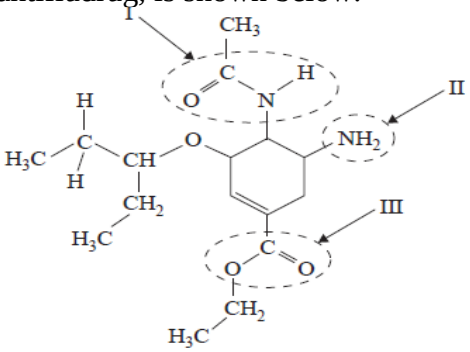
Q52: The structure of oxalic acid is shown below.



A 25.0 mL solution of oxalic acid reacts completely with 15.0 mL of 2.50 M NaOH.
The concentration of the oxalic acid solution is
a. 0.667 M
b. 0.750 M
c. 1.33 M
d. 1.50 M
Sol. b. When oxalic acid HOOCCOOH reacts completely with a strong base it acts as a diprotic acid, according to the equation:

$HOOCCOOH(aq) + 2NaOH(aq) \rightarrow NaOOCCOONa(aq) + H_2O(l)$
$n(\text{oxalic acid}) = ½ \times n(NaOH) = ½ \times 2.50 \times 15.0 \times 10^{-3} = 0.01875$ mol
$c(\text{oxalic acid}) = 0.01875 \text{ mol} / 25.0 \times 10^{-3}$ L = 0.750 M

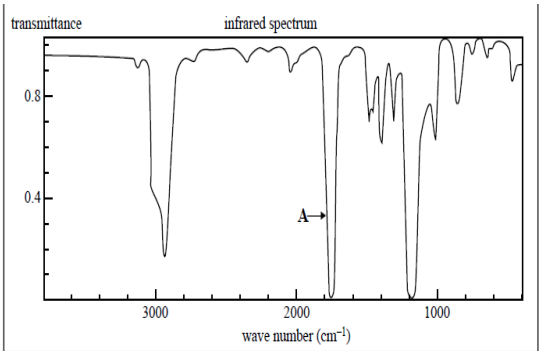
Q53. The structure of Tamiflu, an antifludrug, is shown below.

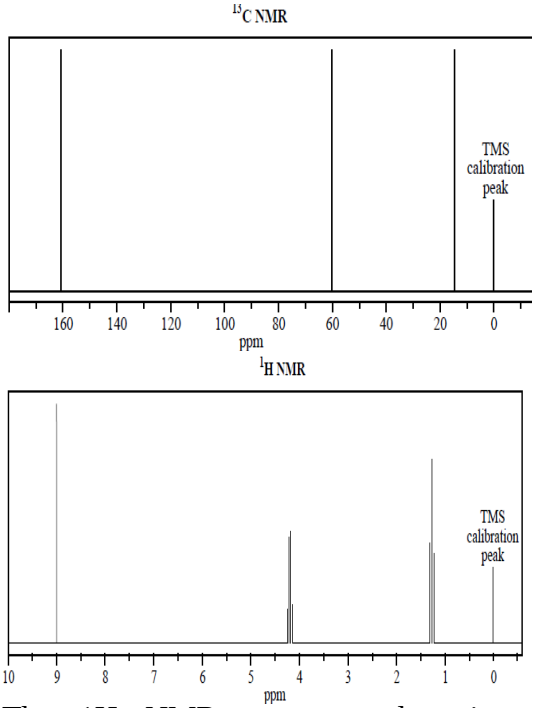


The names of the functional groups labelled I, II and III are:

	I	II	III
A.	amide	amino	carboxylic acid
B.	amino	amide	ester
C.	amide	amino	ester
D.	amino	amide	carboxylic acid

Sol. c.
Q54. The molecular formula of an unknown compound, X, is $C_3H_6O_2$.
The infrared 13C NMR and 1H NMR spectra of this compound are shown below.



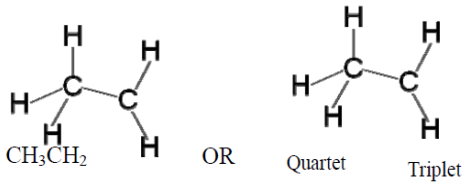


The 1H NMR spectrum data is summarised in the following table.

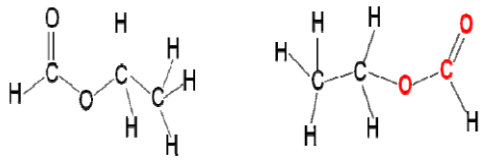
Chemical shift (ppm)	Relative peak area	Peak splitting
1.3	3	triplet (3)
4.2	2	quartet (4)
9.0	1	singlet (1)

a. Using the **Infrared absorption data** of the Data Book, identify the atoms and the bonds between them that are associated with the absorption labelled A on the infrared spectrum.
Sol. Either of:
• C=O
• Carbon, oxygen with double covalent bond.
b. How many different carbon environments are present in compound X?
Sol. Three
c. How many different hydrogen environments are present in compound X?
Sol. Three

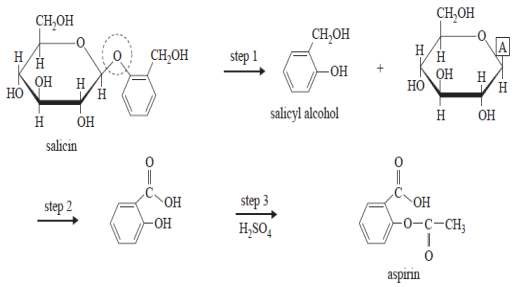
d. i. The signal at 1.3 ppm is split into a triplet. What is the number of equivalent protons bonded to the adjacent carbon atom?
Sol. Two
ii. Draw the grouping of atoms that would give rise to the triplet and quartet splitting patterns.
Sol.



e. A chemical test showed that compound X does not react with a base. Propose a structure for compound X that is consistent with all the evidence provided.
Sol.

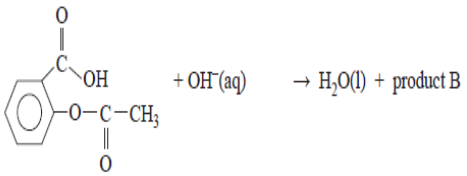


Q55. Since ancient times, the bark of willow trees has been used for pain relief. In the 19th century, chemists isolated the active compound, salicin, from the bark. This was eventually converted into aspirin, which is now a widely used drug.
The reaction scheme below shows the steps used to carry out the conversion.

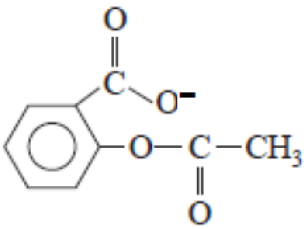


a. What type of linkage is circled in the structure of salicin?
Sol. ether or glycosidic linkage

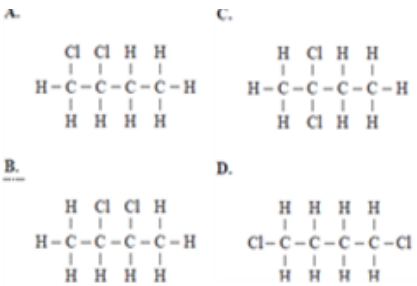
b. In step 1, salicyl alcohol and another compound is produced.
i. What group of biomolecules does this other compound belong to?
Sol. Any of:
• monosaccharides
• carbohydrates
• sugars
• hexoses.
ii. The structure of this other compound is not complete. Write the formula of the atom or group of atoms represented by A in the reaction scheme above.
Sol. OH or –OH
c. Step 2 involves the conversion of salicyl alcohol into salicylic acid.
i. What type of reaction is step 2?
Sol. oxidation or redox
ii. Suggest a suitable reagent to carry out the reaction.
Sol.
• Cr_2O_7
2-(aq), Cr_2O_7
2-(aq)/H+(aq), acidified dichromate or potassium dichromate
• MnO_4-(aq), MnO_4-(aq)/ H^+(aq), acidified permanganate or potassium permanganate
• O_2(g) or oxygen
d. Step 3 requires sulfuric acid catalyst and another reagent. Name this reagent.
Sol. ethanoic acid or ethanoic anhydride
e. Aspirin reacts with a strong base according to the equation



Draw the structure of product **b.**

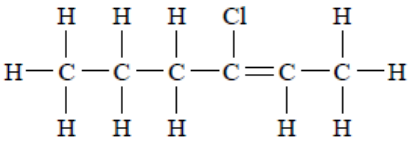


Q56. The structure of the product that is formed from the addation reaction between but-2-ene and chlorine, cl2, is:



Q57. The triple bond between the carbon atoms causes acetylene, C_2H_2, to have which of the following shapes?
a. trigonal planar (pron: try-gon-al)
b. linear
c. tetrahedral
d. trigonal bipyramidal

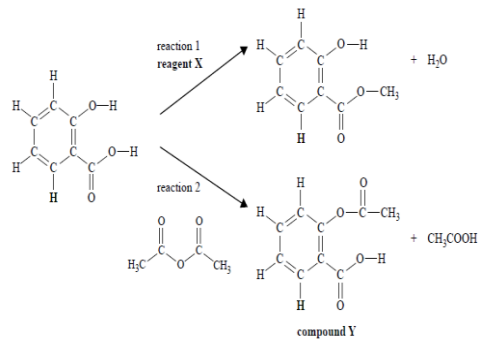
Q58. The correct systematic name for the compound shown above is:



a. 2-chlorohex-2-ene
b. 3-chlorohex-2-ene
c. 3-chlorohex-3-ene
d. 4-chlorohex-5-ene

Q59. The number of structural isomers of C4H9Cl is:
a. 2
b. 3
c. 4
d. 5
Sol. c.
1-chlorobutane, $CH_3CH_2CH_2CH_2Cl$
2-chlorobutane, $CH_3CH_2CHClCH_3$
1-chloro-2-methylpropane, $(CH_3)_2CHCH_2Cl$
2-chloro-2-methylpropane, $(CH_3)_3CCl$

Q60. In the laboratory, salicylic acid can be used to produce two different compounds as shown in the diagram below. These compounds are key components of pharmaceutical products.

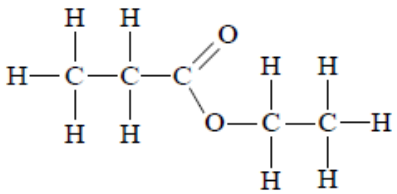


Which one of the following correctly identifies reagent X and compound Y?

	reagent X	compound Y
A.	methanol	methyl salicylate
B.	methanoic acid	methyl salicylate
C.	methanoic acid	acetylsalicylic acid (aspirin)
D.	methanol	acetylsalicylic acid (aspirin)

Sol. d. In reaction 1, salicylic acid was converted to the ester methyl salicylate by reaction with methanol (reagent X). In reaction 2, salicylic acid was converted to acetylsalicylic acid (aspirin) (compound **c.** by reaction with ethanoic anhydride.

Q61–62.



Q61. Which one of the following is the correct systematic name of this compound?
a. ethyl propanoate
b. ethyl ethanoate
c. propyl ethanoate
d. propyl pentanoate

Q62. The species that produces the molecular ion peak in the mass spectrum of this compound is
a. $[CH_3CH_2COOCH_2CH_3]+$
b. $[CH_3CH_2COOCH_2CH_3]_2+$
c. $[CH_3CH_2COOCH_2CH_3]–$
d. $CH_3CH_2COOCH_2CH_3$

Q63. 2.1g of an alkene that contains only one double bond per molecule reacted completely with 8.0 g of bromine, Br_2. The molar mass of bromine, Br_2, is 160 g mol^{-1}.
Which one of the following is the molecular formula of the alkene?
a. C_5H_{10}
b. C_4H_8
c. C_3H_6
d. C_2H_4
Sol. c. Since each molecule contains only one C=C
n(alkene) = n(Br_2)
= 8.0 ÷ 160.0 = 0.050 mol

M(alkene) = 2.1 g ÷ 0.050 mol
= 42 g mol^{-1}

Q64. a. Give the systematic names of the alkanol and the carboxylic acid that are required to synthesise propyl propanoate

Sol. Both of:

- propan-1-ol or 1-propanol
- propanoic acid.

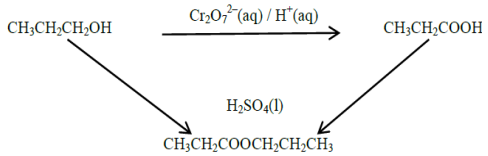
b. Write a balanced chemical equation for the synthesis of propyl propanoate. Use the semi-structural formula for the reactants and products.

Sol.

$CH_3CH_2CH_2OH(l)$ + $CH_3CH_2COOH(l)$ → $CH_3CH_2COOCH_2CH_2CH_3(l)$ + $H_2O(l)$

c. Describe the steps that are required to prepare a sample of pure propyl propanoate using only a pure sample of the alkanol as the starting reagent. Include any reagents that are used in the synthesis. An annotated flow chart may be used in your answer.

Sol.



The pure sample is collected by fractional distillation.

d. Identify one method that could be used to verify that the substance produced is pure propyl propanoate. Explain how this method would indicate that the product is pure propyl propanoate.

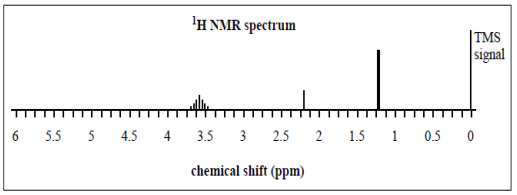
Sol. Acceptable responses included the following.

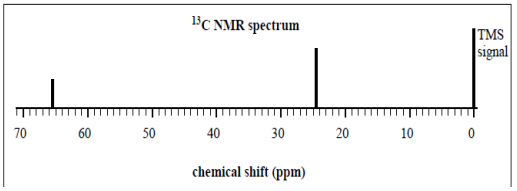
IR spectroscopy	Either of: • run an IR spectrum of the compound and compare it with the IR spectrum of pure propyl propanoate • pure propyl propanoate will not produce a broad absorption peak at 2500–3330 cm^{-1} (O–H acid), or 3200–3350 cm^{-1} (O–H alcohol).
Boiling temperature	Determine the boiling temperature of the collected ester and compare it with the known boiling temperature of pure propyl propanoate from data sources.
Chromatography	Either of: • run a spectrum (HPLC, GC or TLC) of the collected ester and check for the number of peaks or spots. A single peak or spot suggests the sample is pure • compare a chromatogram of the collected ester with a chromatogram of a pure sample obtained under the same conditions.
UV-visible spectroscopy	Run an absorption spectrum of the ester and compare it with the UV-visible absorption spectrum of pure propyl propanoate.

Q65. An organic chemist found a bottle in the laboratory that was labelled 'organic cleaning fluid, C_3H_8O'. She decided to test the liquid. The chemist obtained the following data about the compound in the cleaning fluid: the 1H NMR and 13C NMR spectra, and the infrared spectrum.

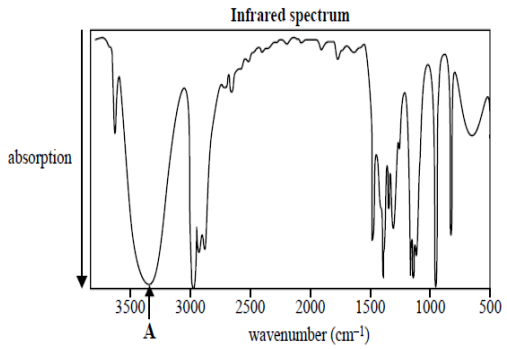
The 1H NMR data is summarised in the table below.

Chemical shift (ppm)	Relative peak area	Peak splitting
1.2	6	doublet (2)
2.2	1	singlet (1)
3.6	1	septet (7)

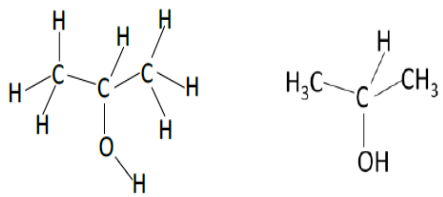




a. i. How many different carbon environments are present in the compound?
Sol. Two
ii. How many different hydrogen environments are present in the compound?
Sol. Three
iii. In the 1H NMR spectrum, the signal at 3.6 ppm is split into a septet (7 peaks). What is the number of equivalent protons that are bonded to the adjacent carbon atom(s)?
Sol. Six

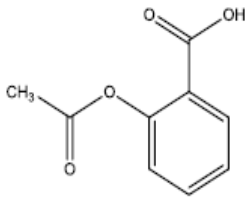


b. Using the Infrared absorption data of the Data Book, identify the atoms that are associated with the absorption labelled A on the infrared spectrum.
Sol. O and H
c. Draw a structure of the compound in the cleaning fluid that is consistent with the NMR and IR data.
Sol.



Q66. Aspirin has the structure formula below. Which functional group does this molecule contain?

I acid II alcohol III ester IV ether



(A) I and III (B) II and III
(C) II and IV (D) I, II, III and IV

Sol. a.

Q67. The triple bond between the carbon atoms causes acetylene, C2H2, to have which of the following shapes?
a. trigonal planar (pron: try-gon-al)
b. Linear
c. Tetrahedral
d. trigonal bipyramidal

Q68. Azo (pron: A-zo) Compounds characteristically are compounds containing the group:
a. C_2
b. N_2
c. O_2
d. C_{l2}

Q69. A compound which contains two ring structures having one common carbon atom is known as a:
a. spiro-compound
b. nonpolar compound
c. interstitial compound
d. inner compound

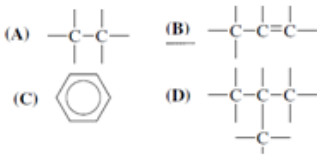
Q70. How many atoms of oxygen are in a glucose molecule?
a. 2

b. 6
c. 10
d. 12

Q71. An alcohol is related to an ester as hydroxide compound is related to:
a. an acid
b. a ketone
c. an ether
d. a salt

Q72. What is the name given to the non-superimposable mirror image forms of chiral compounds?
a. cis-trans
b. enantiomers
c. functional isomers
d. diasteriomers

Q73. Which structure formula represents a mono-unsaturated aliphatic hydrocarbon?



Q74. How many different alcohols (not including optical isomers) have the molecular formula $C_4H_{10}O$?
a. 2
b. 3
c. 4
d. 5

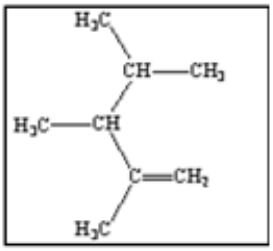
Q75. The compounds C_3H_8, CH_3CH_2OH, and CH_3OCH_3 have very similar molar masses. When they are arranged in order of increasing strength of their intermolecular forces, what is the correct order?
a. C_3H_8, CH_3OCH_3, CH_3CH_2OH
b. CH_3CH_2OH, CH_3OCH_3, $C3H8$
c. CH_3OCH_3, C_3H_8, CH_3CH_2OH
d. CH_3CH_2OH, C_3H_8, CH_3OCH_3

Q76. Which formula can be used to represent an alkynes?
a. C_nH_{2n-2}
b. C_nH_{2n}
c. C_nH_{2n+2}
d. C_nH_{2n+4}

Q77. How many different structural isomers exist fordichloropropane, $C_3H_6Cl_2$?
a. 4
b. 5
c. 6
d. some other number

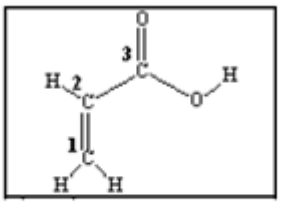
Q78. A reaction in which a carboxylic acid reacts with an alcohol to form an organic compound and water is called:
a. esterification
b. hydrolysis
c. neutralization
d. saponification

Q79. What is the name for compound with the structure?



a. 2-isopropy1-1-butene
b. 2,3-dimethy1-2-hexene
c. 2-methy1-3isopropy1-1-butene
d. 2,3,4-trimethy1-1-putene

Q80. What is the hybridization of carbon atoms 1, 2 and 3 respectively in the structure?



(A) sp^3, sp, sp^2 (B) sp^2, sp, sp^2
(C) sp^3, sp^2, sp^2 (D) sp^2, sp^2, sp^2

Q81. How many isomers exist for dibromobenzene ($C_6H_4Br_2$)?
a. One
b. two
c. three
d. four

Q82). Which can exist as geometric isomers?
a. 1,1-dichloroethane
b. 1,1-dichloroethene
c. 1,2-dichloroethane
d. 1,2-dichloroethene

Q83. Which family of compounds is used most frequently as flavoring agents?
a. acids
b. alkenes
c. esters
d. ethers

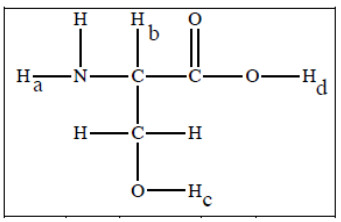
Q84. How many different compounds have the formula C_3H_8O?
a. one
b. two
c. three
d. four

Q85. The conversion of glucose to ethanol is represented:
$xC_6H_{12}O_6 + y\ C_2H_5OH + z\ CO_2$
What are the coefficients x, y, z, respectively, in the balanced equation?
a. 1, 2, 2
b. 1, 3, 3
c. 1, 1, 4
d. 2, 4, 2

Q86. Which term describes the formation of acetic acid from ethyl alcohol?
a. addition
b. esterification
c. neutralization
d. oxidation

Q87. How many structural isomers have the formula C_5H_{12}?
a. 2
b. 3
c. 4
d. 5

Q88. Which hydrogen is the most acidic in the molecule shown:



a. H_a
b. H_b
c. H_c
d. H_d

Q89. The gentle oxidation of ethanol, CH_3CH_2OH, produces:
a. ethanal, CH_3CHO.

b. ethanoic acid, CH_3CO_2H.
c. carbon monoxide, CO.
d. carbon dioxide, CO_2.

Q90. An alcohol is related to an ester as a hydroxide compound is related to:
a. an acid
b. a ketone
c. an ether
d. a salt

Q91. What is the name given to the non-superimposable mirror image forms of chiral compounds?
a. cis-trans
b. enantiomers
c. functional isomers
d. diasteriomers

CHAPTER SIX
Inorganic & Nuclear Chemistry
الكيمياء اللاعضوية والنووية

Tests & Answers

Q1. Which compound is probably most polar of the following?
a. boron trichloride
b. oxygen difluoride
c. silicon tetrafluoride
d. selenium difluoride

Q2. If the formula for potassium chlorate is $KClO_3$ and the formula for magnesium fluoride is MgF_2, then what is the formula for magnesium chlorate?
a. $MgClO_3$
b. Mg_2ClO_3
c. $Mg(ClO_3)_2$
d. $Mg_2(ClO3)_3$

Q3. Which chemical equation represents this reaction?
A Bronsted-Lowry acid-base reaction
a. $2\,KClO_3(s) \rightarrow 2\,KCl(s) + 3\,O_2(g)$
b. $Zn(s) + Cu^{2}+(aq) \rightarrow Zn^{2}+(aq) + Cu(s)$
c. $Co^{3}+(aq) + 6\,NH^{3}(aq) \rightarrow [Co(NH^{3})_6{}^{3}+](aq)$
d. $H_2O+(aq) + NH_3(aq) \rightarrow H_2O(l) + NH_4+(aq)$

Q4. Which chemical equation represents this reaction?
diproportioration reaction
a. $2\,KClO_3(s) \rightarrow 2\,KCl(s) + 3\,O_2(g)$
b. $Zn(s) + Cu^{2}+(aq) \rightarrow Zn^{2}+(aq) + Cu(s)$
c. $Co^{3}+(aq) + 6\,NH^{3}(aq) \rightarrow [Co(NH^{3})_6{}^{3}+](aq)$
d. $H_2O+(aq) + NH_3(aq) \rightarrow H_2O(l) + NH_4+(aq)$

Q5. Which chemical equation represents this reaction?
A combustion reaction and oxidation
a. $2\,KClO_3(s) \rightarrow 2\,KCl(s) + 3\,O_2(g)$
b. $Zn(s) + Cu^{2}+(aq) \rightarrow Zn^{2}+(aq) + Cu(s)$
c. $Co^{3}+(aq) + 6\,NH^{3}(aq) \rightarrow [Co(NH^{3})_6{}^{3}+](aq)$
d. $H_2O+(aq) + NH_3(aq) \rightarrow H_2O(l) + NH_4+(aq)$
E. $2\,C_8H_{18}(l) + 25\,O_2(g) \rightarrow 16\,CO_2(g)\ 18\,H_2O(g)$

Q6. The attractions between atoms within a molecule of NH_3 are best characterized as:
a. hydrogen bonds
b. ionic bonds
c. polar covalent bonds
d. London (dispersion) forces
E. ion-dipole forces

Q7. Which of the following represents the number of moles of an ideal gas in a 2.0 L container at 3.0 atm and 450 K?
a. $\frac{(3.0)(450)}{(0.0821)(2.0)}$ mol
b. $\frac{(3.0)(2.0)}{(0.0821)(450)}$ mol
c. $\frac{(450)(2.0)}{(0.0821)(3.0)}$ mol
d. $\frac{(0.0821)(450)}{(3.0)(2.0)}$ mol
E. $\frac{(0.0821)(2.0)}{(3.0)(450)}$ mol

Q8. Which of the following would be the most suitable analytical technique to determine the ratio of 235U to 238U in a sample of uranium metal?
a. mass spectroscopy.
b. gas liquid chromatography.
c. atomic absorption spectroscopy.
d. nuclear magnetic resonance spectroscopy.
Sol. Isotopes are separated and quantified by mass spectroscopy. The popularity of option **c** suggested that some students did not distinguish between the use of atomic absorption spectroscopy to determine the amount of a specific metallic element in a sample, and the use of mass spectroscopy to determine the

amounts of different isotopes of an element.

Q9. Some carbon dioxide is to be generated by reacting 50 g of calcium carbonate with a Solution of hydrochloric acid.

$CaCO_3+2HCl \rightarrow CO_2+CaCl_2+H_2O$

Which of the following actions is least likely to lead to an increase in the rate of formation of carbon dioxide?

a. grinding the calcium carbonate to a fine powder

b. raising the temperature

c. raising the atmospheric pressure

d. raising the concentration of hydrochloric acid

Q10. In which one of the following would the position of the equilibrium **not** be affected by a volume change at constant temperature?

a. $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$

b. $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$

c. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

d. $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$

Q11. When concentrated sulfuric acid is poured onto **Sol**id sodium bromide, the liquid turns brown as bromine is produced. In this reaction the sulfuric acid is acting as:

a. an oxidant.

b. a reductant.

c. a dehydrating agent.

d. a strong acid.

Q12. 5.00g of nitrogen is completely converted into an oxide of nitrogen. The mass of the oxide formed is 19.3 g. The empirical formula of the oxide would be

a. NO

b. N_2O_3

c. NO_2

d. N_2O_5

Q13. The transition metal vanadium exists in a range of different oxidation states. Two vanadium species are VO^{2+} and VO_4^{3-}.

The oxidation states of vanadium in these two species are, respectively,

a. +4 and +5

b. +4 and +8

c. +6 and +5

d. +6 and +8

This elicited the highest correct response rate for any multiple-choice Q– one that was not thought to be a particularly easy one. Students are well able to calculate oxidation numbers.

Q14. The electron configuration of an **ion** with its electrons in an excited state is

a. $1s^2 2s^2 2p^1$ (atomic number: 5)

b. $1s^2 2s^2 2p^3 3s^1$ (atomic number: 8)

c. $1s^2 2s^2 2p^5 3s^1$ (atomic number: 8)

d. $1s^2 2s^2 2p^6$ (atomic number: 9)

Q15. As you move down the elements of Group 1 of the periodic table, the first ionisation energy:

a. decreases and the electronegativity decreases.

b. decreases and the electronegativity increases.

c. increases and the electronegativity decreases.

d. increases and the electronegativity increases

Q16. In comparison with Group 1 metals, transition metals in the same period as Group 1 metals tend to
a. be harder and have a smaller atomic radius.
b. have a higher melting temperature and a larger atomic radius.
c. be more easily oxidised and display variable oxidation states.
d. have lower ionisation energy and are more likely to form complex

Q17. The mass of an atomic nucleus other than 1H is:
a. equal to the sum of the masses of its individual protons and neutrons.
b. slightly less than the sum of the masses of its individual protons and neutrons.
c. slightly greater than the sum of the masses of its individual protons and neutrons.
d. sometimes greater, sometimes smaller, than the sum of the masses of its individual protons and neutrons, depending on the binding energy of the nucleus.

Q18. An ion with a charge of positive two, and the same electron configuration as the chloride ion, is:
a. phosphide ion.
b. sulfide ion.
c. magnesium ion.
d. calcium ion.

Q19. Use the periodic table to write the chemical symbols for the following elements.
a. The element that forms a–2 ion with the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$
Sol. S1b1c1d1e1f
b. An element from period two that forms a basic oxide.
Sol. Na or Mg
c. The element from period two with the largest atomic radius.
Sol. Na
d. An element from period four that can form complex ions.
Sol. anything from Ca to Ga inclusive
e. The most electronegative element in group VII.
Sol. F
f. The first transition series element that forms a +3 ion with a half-filled d sub-shell.
Sol. Fe

Q20. a. In the periodic table the atomic mass of elements usually increases as the atomic number increases. However, there are exceptions to this general rule.
For example, tellurium, with atomic number of 52, has a relative atomic mass of 127.6 whereas iodine, with atomic number 53, has a relative atomic mass of 126.6.
How is it possible for the element with a smaller atomic number to have the greater relative atomic mass?
Sol. An element with fewer protons (lower atomic number) can have a higher relative atomic mass if it has more neutrons in its isotopes. An essentially correct explanation scored the full 2 marks. Many students who appeared to have the general idea were unable to formulate it unambiguously, e.g. 'because of the proton to neutron ratio tellurium has a greater number of neutrons'–a

response that is on the right track but is worth only one mark. A student giving this response may well have understood the point, but did the student mean 'more neutrons than protons'? or 'more neutrons than iodine'? Students need practice in constructing clear written responses and responses need to be unambiguous.

b. One section of the modern periodic table contains elements known as transition metals.

i. Why does a series of transition metals have 10 elements?

Sol. A transition series is formed by the progressive filling of a d subshell which has 10 electrons.

ii. Some transition elements exhibit different oxidation states in different compounds.

Choose one particular transition element. Give the formulas for two different compounds where this transition element shows different oxidation states.

Compound 1

Compound 2

Sol. e.g. $FeCl_2$ and $FeCl_3$. No marks for ions rather than compounds. Many students suggested ions rather that molecules; others chose to combine a potentially correct molecule with the ion or molecule of another transition metal. Many students seemed to think that they had to produce something a bit unusual–whereas all that was needed was something simple, e.g. MnO and MnO_2 or $CrCl_2$ and $CrCl_3$.

Q21. The oxidation number of Cl in $HClO_4$ is:

a. +7

b. +5

c. +3

d. –1

Sol. **a.** H(+1)Cl B.O(-2)4 → +1 + x + 4(-2) = 0 → x = +7

Q22. In the periodic table, which electronic subshells are progressively filled in the second transition series, the actinides and the lanthanides?

	2nd transition series	actinides	lanthanides
A.	3d	4f	5f
B.	4d	5f	4f
C.	4d	6d	5d
D.	5d	5f	4f

Q23. The origin of the Sun's energy is the conversion of hydrogen to helium: ^{4}1H → ^{4}He

The relative isotopic mass of 4He is 4.00260. However, the sum of the relative isotopic masses of four 1H is 4.03130. This mass difference is:

a. a measure of the energy absorbed when four 1H are converted to one ^{4}He.

b. due to the loss of two electrons when four 1H are converted to one 4He.

c. a measure of the energy released when four 1H are converted to one 4He.

d. equal to the mass of the two positrons produced when four 1H are converted to one 4He.

Q24. Consider the oxides from the third period, Na_2O, MgO, Al_2O_3,

P_4O_{10} and SO_3. Identify correctly their properties.

	Na_2O	MgO	Al_2O_3	P_4O_{10}	SO_3
A.	acidic oxide	acidic oxide	amphoteric oxide	basic oxide	basic oxide
B.	basic oxide	basic oxide	basic oxide	acidic oxide	acidic oxide
C.	basic oxide	basic oxide	amphoteric oxide	acidic oxide	acidic oxide
D.	basic oxide	basic oxide	amphoteric oxide	amphoteric oxide	amphoteric oxide

Q25. The transition metal scandium forms the ion Sc^{3+} in water. The electronic configuration of Sc3+ is

A. $1s^22s^22p^63s^23p^63d^44s^2$
B. $1s^22s^22p^63s^23p^63d^14s^2$
C. $1s^22s^22p^63s^23p^44s^2$
D. $1s^22s^22p^63s^23p^6$

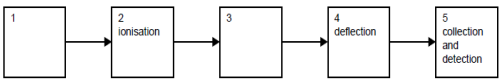
Q26. An element X has the following properties:
• it is a good reductant.
• it reacts readily with water to produce molecular hydrogen and a Solution containing a colourless ion, X^{2+}.
• it is naturally strongly radioactive.
Which of the following is most likely to be element X?
a. Ra
b. Cs
c. Ca
d. Po

Q27. Mendeleev published his version of the periodic table in 1869. Which one of the following statements about Mendeleev's periodic table is not correct?
a. There were many gaps in the table.
b. Each element had an atomic weight greater than the one before it.
c. The table was used to predict the existence of some then unknown elements.
d. The elements were arranged into vertical groups of elements with similar chemical properties.

Q28. In which of the following sets are all the compounds likely to be coloured?

A. $KClO_4$, $FeCl_2$, NH_4VO_3
B. $Ca_3(PO_4)_2$, NH_4VO_3, $MgBr_2$
C. $FeCl_2$, $NiCl_2$, K_2CrO_4
D. $KClO_4$, $MgBr_2$, $Ca_3(PO_4)_2$

Q29. The element antimony (Sb. has at least 29 known isotopes. Only two of these are stable isotopes that occur naturally; the other 27 isotopes are radioactive and have been made artificially. The stable isotopes are Sb (relative isotopic mass = 120.9038) and Sb (relative isotopic mass = 122.9041). The relative atomic mass of naturally occurring antimony of 121.75 has been determined using mass spectrometry.
a. The flow chart below represents the sequence of operations in a mass spectrometer. Three of the stages are labelled.



i. What operations occur in stages 1 and 3?
stage 1
stage 3
Sol. Introduction/ vaporisation of Sb sample; acceleration of ions.
ii. How is ionisation achieved in stage 2?

Sol. Electron bombardment

iii. How is deflection achieved in stage 4?

Magnetic and/or electric field

b. What information can be obtained from a mass spectrometer about naturally occurring antimony?

Sol. The relative masses and the relative abundance of each isotope; OR number of isotopes and relative atomic mass

c. From the data given, calculate the percentage abundance of each of the stable isotopes of naturally occurring antimony.

Sol. 122.9041x + (1 – b)120.9038 = 121.75; 2.0002x = 0.8462; x = 0.423, 1 – x = 0.577 thus (123Sb = 42.3% and 121Sb = 57.7%)

d. Give the symbol and charge of the most common antimony ion that would be detected using mass spectrometry.

Sol. $^{121}Sb+$ (also accept 121Sb2+ and $^{121}Sb^{3+}$ but NOT negatively charged ions).

e. How many neutrons are there in the nucleus of the Sb isotope?

Sol. 70

f. Two of the radioactive isotopes of antimony are:

- $^{125}_{51}Sb$ which decays by emission of a beta particle (an electron) and
- $^{117}_{51}Sb$ Which decays by positron emission (a positive electron).

Give the symbol of the atoms produced from the decay process of each of the given radioactive isotopes:

i. $^{125}_{51}Sb \rightarrow$

Sol. Te

ii. $^{117}_{51}Sb \rightarrow$

Sol. Sn (for interchanging the atoms)

Q30. a. Cobalt is one of the three metals in the first transition series that is ferromagnetic (magnetic). Give the name or symbol of one of the other two ferromagnetic metals in the first transition series.

Sol. Fe or Ni or (Fe + Ni)

b. Cobalt can form the complex ion $Co(NH_3)_6^{3+}$ in the presence of ammonia.

i. Sketch the structure for $Co(NH_3)_6^{3+}$.

Sol. The usual structure (3+ must be either on the Co or outside brackets).

ii. Name the type of bonding that exists.

- between Co^{3+} ion and the NH_3 molecules.
- within the NH_3 molecule.

Sol. Coordination co-NH_3bond.

c. Suggest a reason why NH_3 might bond more firmly to Co^{3+} than to Co^{2+}.

Sol. Higher charge on Co^{3+}

d. Part of the electrochemical series is given below and should be used to answer the following equations.

	half reaction	$E^\ominus$ value in volt
1	$Co(H_2O)_6^{3+}(aq) + e^- \rightarrow Co(H_2O)_6^{2+}(aq)$	1.81
2	$O_{2(g)} + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	1.23
3	$Co(NH_3)_6^{3+}(aq) + e^- \rightarrow Co(NH_3)_6^{2+}(aq)$	0.10
4	$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
5	$Co(H_2O)_6^{2+}(aq) + 2e^- \rightarrow Co(s) + 6H_2O(l)$	–0.28
6	$Co(NH_3)_6^{2+}(aq) + 2e^- \rightarrow Co(s) + 6NH_3(aq)$	–0.43
7	$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83

i. Select two of the above half reactions which together indicate that, in aqueous Solution, NH_3 bonds to Co^{3+} rather than to Co^{2+}.

1 and 3 (also accept 2 and 3).

ii. Explain, using the above data, why aqueous Solutions containing $Co(H_2O)_6^{3+}(aq)$ might be too unstable to be conveniently used in the laboratory.

Sol. $Co(H_2O)_6^{3+}$ will react with water (higher Eo).

Q31. Consider the reaction

$MnO_2(s) + 4HCl(aq) \rightarrow Cl_2(g) + 2H_2O(l) + MnCl_2(aq)$

The atoms whose oxidation numbers change during this reaction are:

a. Mn

b. Mn and Cl

c. Mn, Cl and O

d. Mn, Cl, O and H

Sol. b.

$\overset{+4}{Mn}\overset{-2}{O_2}(s) + 4\overset{+1}{H}\overset{-1}{Cl}(aq) \rightarrow \overset{0}{Cl_2}(g) + 2\overset{+1}{H_2}\overset{-2}{O}(l) + \overset{+2}{Mn}\overset{-1}{Cl_2}(aq)$

Oxidation number of Mn decreases from +4 to +2.

Oxidation number of Cl increases from –1 to 0.

Q32. Which of the following could **not** be a product of the reduction of sulfuric acid when it acts as an oxidant?

a. S

b. H_2S

c. SO_2

d. $H_2S_2O_7$

Sol. When sulfuric acid acts as an oxidant it causes oxidation and is itself reduced.

Consequently the oxidation number of S must decrease from +6.

Oxidation numbers of sulfur in the alternatives.

S(0); H_2S - H(+1)2S(-2); SO_2 -S(+4)O(-2)2; $H_2SO_4^-$ H(+1)2S (+6)2O(-2)7

Q33. The number of neutrons in an atom of 131I is:

a. 53

b. 78

c. 131

d. 184

Sol. c. Mass number (131) - Atomic number (53) = 78.

Q34. In the electrolytic production of aluminium metal from alumina (Al_2O_3), the alumina is dissolved in cryolite (Na_3A1F_6). The anodes and cathodes are made of carbon. The electrode reactions may be represented by:

$C + 2O^{2-} \rightarrow CO_2 + 4^{e-}$

$Al^{3+} + 3e^- \rightarrow Al$

The net reaction for this electrolysis process is

a. $2Al_2O_3 \rightarrow 4Al + 3O_2$

b. $Al_3^+ + C + 2O_2^- \rightarrow Al + CO_2$

c. $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

d. $4Al_3+ + 6O^{2-} + O_2 + C \rightarrow 2Al_2O_3 + CO_2$

Sol. c. Combining the half reactions to eliminate the electrons gives:

$4Al_3^+ + 6O_2^- + 3C \rightarrow 4Al + 3CO_2$

The only response that this can correspond to is:

$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

Q35. The energy (kJ mol^{-1}) required to remove the first five electrons from an atom of element X is shown in the table.

Electron number	1	2	3	4	5
Energy	495	4560	6910	9550	13420

Element X is most likely to be located in the periodic table in group
a. I
b. II
c. III
d. IV
Sol. a. The first electron removed needs only about one tenth of that needed to remove the second electron; the ratios for first, second, third, etc. go
1 : 9.2 : 13.9 : 19.3 : 27.1. It is reasonable to conclude that the first electron is alone in an outer shell and the atom must be from Group I (or 1).

Q36. The isotope 35S is radioactive and decays by emitting a beta particle (an electron) to form an isotope of a different element.
During the decay process which of the following occurs?
Sol.

	Mass number	Atomic number	Nuclear charge
A.	decreases	decreases	decreases
B.	remains unchanged	decreases	increases
C.	increases	increases	remains unchanged
D.	remains unchanged	increases	increases

Sol. d. Since an electron is emitted by the nucleus, the mass number must remain unchanged. Because a negative charge is removed from the nucleus, the nuclear charge must increase by one unit and hence the atomic number must increase by one unit. Thirty-six per cent of students chose response **b**, correctly identifying that the mass number must remain unchanged but becoming confused about the need for both the atomic number and the nuclear charge to increase.

Q37. The elements in Group IV of the periodic table become more metallic in character down the group. This trend is best explained by the:
a. core charge decreasing.
b. atomic size increasing.
c. ionisation energy increasing.
d. number of outer shell electrons decreasing.
Sol. d. An increasing atomic size will lead to a decreasing first ionization energy and hence an increasing metallic character. Note that the core charge must remain constant within a group **a.** Outer shell ionization energies will decrease down a group **c.** and the number of outer shell electrons remains constant within a group **d.**

Q38. The electron configurations of four elements are listed.
The electron configuration of the element least likely to act as a reductant is:
a. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$
b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
c. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$
d. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$
Sol. b. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
The $-s^2p^5$ outer shell configuration indicated an atom in group VII. It will therefore be a strong oxidant (it was chlorine). **a.** is a group III atom (Al) or transition metal (Fe and Zn); these are all metals and will have reducing rather than oxidising properties.

Q39. Which of the following compounds of manganese can be reduced to form the other three?
a. MnO
b. MnO_2
c. $KMnO_4$
d. K_2MnO_4
Sol. c. $KMnO_4$
The oxidation numbers of manganese in the possible responses are:
a. +2, **b.** +4, **c.** +7 and **d.** +6.
The equation asked for the compound with the highest oxidation number of Mn.

Q40. The formula of an amphoteric oxide formed by a third period element is:
a. Na_2O
b. Al_2O_3
c. P_4O_{10}
d. Cl_2O_7
Sol. b. Al_2O_3This was straight recall.

Q41. Naturally occurring copper exists as two isotopes, 63Cu and 65Cu. The relative atomic mass of copper is 63.6.
The ratio of 63Cu to 65Cu in natural copper is approximately
a. 63 : 65
b. 1 : 1
c. 1 : 3
d. 3 : 1
Sol. d. Many students probably solved this by inspection. The atomic mass is closer to 63 than to 65 so there must be more of 63Cu than of 65Cu. More precisely, 63.6 = 63x + 65(1 – b**)**. Solving this equation leads to x = 0.7 and a 63Cu: 65Cu ratio of 2.3:1. Clearly that response 3:1 is the closest correct response.

v. The element whose ion of charge +3 has an electron configuration of $1s^22s^22p^63s^23p^63d^5$
Sol. Fe

Q42. Some atoms of element X in a discharge tube are found to have the electron configuration $1s^22s^22p^44s^1$.
a. Give the name, or the chemical symbol, of element X.
Sol. F or fluorine (the common spelling error, 'flourine', was also accepted)**.**
b. If the electron configuration changed from $1s^22s^22p^44s^1$ to $1s^22s^22p^43s^1$, would the process be exothermic or endothermic? Explain your reasoning.
Sol. Exothermic. e- moves from higher (or 4s level/subshell) to lower (or 3s level/subshell) E level.
c. Write the ground state electron configuration for atoms of element X.
Sol. 1s22s22p5

Q43. **a.** By referring to their electron configurations, explain why metals in the first transition series of the periodic table typically have several different oxidation states while Group II metals have only one.
Sol. For transition metals, energies of 3d and 4s subshells are close, so electrons can be more readily lost from both/either 4s and/or 3d subshells. For Group II metals, the d (or equivalent) subshell is not close so only two outer electrons can be lost.
To get two marks both transition metals and Group II metals had to be mentioned. For examples, V^{+5}, V^{+3} V^{+2}, Cr^{+2}, Cr^{+3}, Mn^{+2} , Mn^{+3}.

b. Predict the trend in the following properties of the second period elements, moving from lithium to fluorine, giving an explanation in support of each prediction.

Property	Increases or decreases?	Explanation for predicted trend
Atomic size		
Electronegativity		

Sol.

Property	Increases or decreases?	Explanation for predicted trend
Atomic size	decreases	Increasing the core charge (nuclear charge), outer electrons are pulled closer to nucleus (emphasis on the effect of the core charge on size).
Electronegativity	increases	Increasing the core charge (nuclear charge), greater pull/attraction on outer shell electrons (emphasis on core charge on electron attracting power).

c. There is also a general trend in first ionisation energy both across periods and down groups of the periodic table.

i. What is meant by the term ionisation energy?

Sol. The energy required to remove an electron (not electrons).

ii. Given that the atomic size of potassium is greater than that of sodium, explain why the first ionisation energy of sodium is greater than that of potassium.

Sol. The outermost electron in potassium is further from the nucleus than the outer shell electron in sodium and so weaker attraction (the electron is more easily removed.

Q44. Sodium hydride (NaH) reacts with water as follows.

$NaH(s) + H_2O(l) \rightarrow Na+(aq) + OH.(aq) + H_2(g)$

This reaction should be classif ed as

a. acid-base but not redox.

b. redox but not acid-base.

c. both acid-base and redox.

d. neither redox nor acid-base.

Sol. **c.** Applying oxidation numbers shows that this is a redox reaction:

$\overset{+1\ -1}{NaH(s)} + \overset{+1\ -2}{H_2O(l)} \rightarrow \overset{+1}{Na+(aq)} + \overset{-2\ +1}{OH-(aq)} + \overset{0}{H_2(g)}$

The oxidation number of H decreases from +1 in H_2O to 0 in H_2.

The oxidation number of H increases from –1 in H- (NaH) to 0 in H_2.

H- reduces H_2O to H_2, and is itself oxidised to H_2.

H_2O oxidises H- to H_2, and is itself reduced to H_2.

This can also be verified by half-equations.

Reduction: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH$

Oxidation: $2H-(aq) \rightarrow H_2(g) + 2e$

The ionic equation shows that the reaction is also an acid-base reaction:

$H^-(aq) + H_2O(l) \rightarrow OH-(aq) + H_2(g)$

H_2O is the acid. It donates H^+, to the base H^-, and forms OH^-.

H^- is the base. It accepts H^+, from the acid H_2O, and forms H_2.

Over one-third of the students were able to identify the reaction as a redox reaction but not as an acid-base reaction.

Q45. In the following four substances, $H_2S_2O_7$, N_2O_5, HIO_3, Cl_2O7, the atom with the highest oxidation number is
a. I
b. S
c. N
d. Cl
Sol. d. Applying an oxidation number of -2 for O and +1 for H:
$H_2S_2O_7$: $2(+1) + 2x + 7(-2) = 0 \rightarrow 2x = 12 \rightarrow x = +6$
The oxidation number of S is +6
N_2O_5: $2x + 5(-2) = 0 \rightarrow 2x = 10 \rightarrow x = +5$
The oxidation number of N is +5
HIO_3: $+1 + x + 3(-2) \rightarrow x = +5$
The oxidation number of I is +5
Cl_2O_7: $2x + 7(-2) = 0 \rightarrow 2x = 14 \rightarrow x = +7$
The oxidation number of Cl is +7.

Q46. Which one of the following would be predicted to spontaneously oxidise aqueous iodide ions but not aqueous chloride ions?
a. $Au^+(aq)$
b. $Sn^{2+}(aq)$
c. $Fe^{2+}(aq)$
d. $Br_2(aq)$
Sol.a. lies above the chlorine-chloride pair in the electrochemical series.

Q47. Element X has an atomic radius that is smaller than that of sulfur. In chemical reactions, element X commonly forms an ion that has the same electron conf guration as the Sc^{3+} ion. Element X could be:
a. oxygen.
b. chlorine.
c. argon.
d. potassium.

Q48. In which one of the following sets of chromium-containing compounds do the chromium atoms all have the same oxidation number?
a. Cr_2O_3 $K_2Cr_2O_7$ Na_2CrO_4
b. $CrCl_2$ Cr_2O_3 K_2 Cr_2O_7
c. Cr_2O_3 $CrCl_3$ $Cr(NO_3)_3$
d. Na_2CrO_4 CrO_3 $Cr(NO_3)_3$
Sol. c. In response **c**, the chromium atom has a+3 oxidation state in all three substances. The order of oxidation states in the other three choices is: a: +3, +6, +6. b: +2, +3, +6. d: +6, +6, +3.

Q49. Sodium and chlorine are both in Period 3. You would expect sodium to have.
a. the lower ionisation energy and the lower electronegativity.
b. the higher ionisation energy and the lower electronegativity.
c. the lower ionisation energy and the higher electronegativity.
d. the higher ionisation energy and the higher electronegativity.

Q50. The noble gases (helium to radon) have an outer shell electron configuration of:
a. s^2
b. s^2p^6
c. either s^2 or s^2p^6
d. either s^2p^6 or $s^2p^6d^{10}$

Q51. Potassium has a radioactive isotope, 40K. One of the ways this isotope disintegrates leads to the emission of abeta particle (an electron) by the 40K nucleus. The

new nucleus produced by this disintegration is:
a. 40K+
b. 41K
c. 40Ar
d. 40Ca

Sol. d. The equation clearly referred to a nuclear reaction so, given that the nuclear reaction involves the potassium nucleus, the correct result could not possibly be anything involving K – yet 30% of students chose K+ as the answer. The loss of an electron by the nucleus must have raised its atomic number by one unit to the adjacent calcium (from 19 to 20), hence response **d** is correct.

Q52. Consider the following three compounds which contain complex ions that involve iron:
I $[Fe(NH_3)6]Cl_3$
II $K_3[FeCl_6]$
III $K_4[FeCl_6]$
The oxidation state of the iron in each of these compounds is

	I	II	III
a.	+3	-3	-.2
b.	+3	+3	+2
c.	+6	+6	+6
d.	+3	-.3	-.4

Q53. Which one of the following is least likely to act as a ligand with Fe^{3+} ions?
a. F.
b. CN.
c. H_2O
d. NH_4^+
Sol. d. While F^-, CN^- and H_2O should all be reasonably familiar as ligands, NH_4^+ cannot act as a ligand at all because there are no electron pairs available for bonding and the ion has no dipole.

Q54. From the following list of elements:
Li Be B C N O F
Na Mg Al Si P S Cl
give the symbol or name for
a. the most electronegative element
Sol. F (or F_2)
b. the element that commonly forms an ion which has an electron configuration of $1s^2 2s^2 2p^6$ and a -2 charge
Sol. O or (O_2)
c. an element that forms an amphoteric oxide.
Sol. either Al or Be.
d. an element X that forms oxides with the formula XO and XO_2.
Sol. either C, N, Si, or S.
e. an element that is found in proteins but not in carbohydrates.
Sol. either N or S.

Q55. Magnesium has three naturally occurring isotopes. Their relative abundances and masses are given in the table below.

	Percentage abundance	Relative isotopic mass
^{24}Mg	78.99	23.985
^{25}Mg	10.00	24.986
^{26}Mg	11.01	25.983

a. The abundances and relative isotopic masses have been determined experimentally. What instrument is commonly used to obtain this information?
Sol. A mass spectrometer (mass spectrometry and mass spectrograph were also accepted**.**

b. Using the information above, show how the relative atomic mass of magnesium can be determined.
Calculate your answer to an appropriate number of significant figures.
Sol. (0.7899 × 23.985) + (0.1000 × 24.986) + (0.1101 × 25.983) = 24.3051
c. Calcium is in the same group of the periodic table as magnesium.
i. Explain why Mendeleev would have placed these two elements in the same vertical group.
Sol. They have similar chemical properties.
ii. The electronegativity of magnesium (1.31) is greater than that of calcium (1.00). Give a brief explanation for this difference.
Sol. The size of the calcium atom is greater than that of magnesium; hence electrons are less strongly attracted.
iii. Write the electron configuration, in terms of shells and subshells, for the calcium atom.
Sol. $1s^2 2s^2 p^6 3s^2 p^6 4s^2$
iv. Write the electron configuration, in terms of shells and subshells, for the Ca^{2+} ion.
Sol. $1s^2 2s^2 p^6 3s^2 p^6$
v. The radius of the calcium atom is 1.97 × 10.10 m.
The radius of the Ca^{2+} ion is 9.9 × 10.11 m.
Explain why the calcium atom is significantly larger than the Ca^{2+} ion.
Sol. Students had to provide some indication/ implication that calcium has an extra occupied shell, or an explanation of the same 'nuclear' charge acting on more electrons in the calcium atom. The 'extra shell' argument should have been obvious, but many students struggled with explanations that referred to 'core charge', often attempting to give a core charge to the Ca^{2+} ion. The concept of core charge is not always well understood or well applied.

Q56. Give concise explanations for each of the following
b. Hydrogen gas is bubbled through a Solution of 1.0 M Fe^{3+}(aq) ions. On the basis of the electrochemical series, a redox reaction is predicted to occur. In practice, no reaction occurs at room temperature.
Sol. The reaction is too slow or the electrochemical series gives no indication of reaction rate.
c. The oxidation state of iron, in its compounds, is normally either +2 or +3, whereas that of calcium, in its compounds, is +2 only.
Sol. Iron is a transition metal which can lose electrons from both 4s and 3d subshells. Calcium can only lose electrons from the 4s subshell.

Q57. Give balanced equations for the following reactions.
a. The complete oxidation of glucose ($C_6H_{12}O_6$) in plant and animal cells.
Sol. $C_6H_{12}O_6(aq) + 6O_2(g \text{ or } aq) \rightarrow 6CO_2(g \text{ or } aq) + 6H_2O(l \text{ or } g)$
b. The formation of helium by nuclear reaction in the sun.
Sol. $4\,{}^1_1H \rightarrow {}^4_2He + 2\,{}^0_1e$
c. The reaction between ammonia and sulfuric acid to form ammonium sulfate fertilizer.

Sol. $2NH_3 + H_2SO_4 \rightarrow (NH_4)2SO_4$
d. The reaction of an oxide of sulfur with aqueous sodium hydroxide.
Sol. $2NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$
- $2OH^- + SO_2 \rightarrow SO_3^{2-} + H_2O$
- $NaOH + SO_2 \rightarrow NaHSO_3$
- $OH^- + SO_2 \rightarrow HSO_3^-$
- $2NaOH + SO_3 \rightarrow Na_2SO_4 + H_2O$
- $2OH^- + SO_3 \rightarrow SO_4^{2-} + H_2O$
- $OH^- + SO_3 \rightarrow HSO_4^-$
- $NaOH + SO_3 \rightarrow NaHSO_4$

Q58. The equation for a reaction that occurs during the extraction of iron from iron ore is:
$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$
During this reaction the oxidation number of iron changes from
a. +3 to 0, and CO is the reductant.
b. +6 to 0, and CO is the reductant.
c. +3 to 0, and CO is the oxidant.
d. +6 to 0, and CO is the oxidant.

$\overset{+3\ -2}{Fe_2O_3(s)} + \overset{+2-2}{3CO(g)} \rightarrow \overset{0}{2Fe(l)} + \overset{+4-2}{3CO_2(g)}$

Fe_2O_3 is reduced to Fe by CO; therefore, CO is the reduct

Q59. The passage of 0.019 faradays of electricity through a molten chromium compound yields 0.50 g of chromium metal.
The oxidation number of chromium in the compound is likely to be
a. +2
b. +3
c. +4
d. +6.
Sol. a. 0.019 Faraday equals 0.019 mol of electrons. 0.50 g of Cr equals 0.50/52= 0.0096 mol. Thus each mole of Cr must have provided 2 mol of electrons so that the oxidation number was +2 (option **a**).

Q60. Which one of the following alternatives lists the atoms of aluminum, calcium, sulfur and chlorine in order of increasing electronegativity?
a. (lowest) Al, S, Cl, Ca (highest)
b. (lowest) Ca, Al, S, Cl (highest)
c. (lowest) Cl, S, Al, Ca (highest)
d. (lowest) S, Ca, Al, Cl (highest)

Q61. Which one of the following alternatives lists the atoms of chlorine, fluorine, magnesium and potassium in order
of increasing atomic radius?
a. (smallest) K, Mg, Cl, F (largest)
b. (smallest) F, Mg, Cl, K (largest)
c. (smallest) K, F, Mg, Cl (largest)
d. (smallest) F, Cl, Mg, K (largest)
Sol. d. Atomic radius increases initially down the halide group and then continues to increase from right to left across the third period from Cl to Mg and then to finally increase further as we go from group 2 to group 1, period four.

Q62. Which one of the following alternatives lists the atoms of chlorine, magnesium, neon and phosphorus in order of increasing f rst ionisation energy?
a. (smallest) Mg, P, Cl, Ne (largest)
b. (smallest) Ne, Cl, P, Mg (largest)
c. (smallest) Cl, Mg, Ne, P (largest)
d. (smallest) P, Mg, Cl, Ne (largest)
Sol. a. The first ionisation energy increases from left to right across the third period and then increases further

as we go up the inert gas group from period 3 to period 2.

Q63. When Dimitri Mendeleev developed the periodic table he left gaps for as yet undiscovered elements. On the basis of the position of these gaps and in relation to these undiscovered elements, Mendeleev was able to predict
a. their electron configurations.
b. the occurrence of their isotopes.
c. many of their physical properties.
d. their atomic numbers and mass numbers.
Sol. c. Some students were distracted by the mention of atomic numbers and mass numbers and chose option **d**, failing to remember that the concepts of atomic number and mass number were unknown at the time of Mendeleev.

Q64. When the oxide Cl_2O_7 is added to water a reaction takes place which is not a redox process. The product(s) of the reaction could be
a. $HClO_4$
b. HOC1
c. Cl_2 and O_2
d. HCl and O_2
Sol. a. Many students chose option **d**, which, at first glance, may have looked correct since HCl and O_2 can be formed from a balanced reaction between Cl_2O_7 and H_2O. However, the item specifically provides the information that the reaction is not a redox reaction, and $HClO_4$ is the only product suggested in which neither Cl not O suffer a change of oxidation state.

Q65. a. In 1804 the atomic theory of John Dalton was first published. Two of the ideas expressed in his theory are listed below. How does our current understanding of atomic theory differ from each of these two ideas?
i. All matter is composed of tiny, indivisible particles called atoms.
Sol. Atoms are not indivisible or contain nucleus and electrons or undergo fission or radioactive decay.
ii. Atoms of the same element are identical in every respect.
Sol. Atoms of the same element may have different masses or isotopes exist or they can have different numbers of neutrons.
b. In 1913 the Danish physicist Niels Bohr proposed a theory to explain the emission spectrum of hydrogen. His theory stated that
- the electron in the hydrogen atom circled the nucleus in certain fixed orbits
- each orbit was of a certain energy level
- orbits closer to the nucleus were of lower energy than those further away.
i. How does this theory explain that the emission spectrum of hydrogen consists of a set number of discrete lines?
Sol. Emission lines represent the energy difference between two different electron energy levels as an electron moves between two orbits; emission results when an electron drops from a high energy level (orbit) to a lower energy level.
ii. State one way in which our present understanding of the electron

structure of atoms in general differs from that proposed by Bohr for the hydrogen atom.

Sol. Existence of subshell or orbitals occupying a 'region of space'.

Q66. A uranium nucleus can undergo nuclear fission when bombarded with a neutron. In one such fission reaction, two neutrons are released and two different new nuclei form. One is a zirconium nucleus, $_{40}^{97}Zr$, and the other is a nucleus of element X, as shown in following equation.

$$_{0}^{1}n + {}_{92}^{235}U \rightarrow X + {}_{40}^{97}Zr + 2{}_{0}^{1}n$$

a. How many neutrons are present in a nucleus of $_{92}^{235}U$?

Sol. 143

b. To which section of the periodic table does uranium belong?

Sol. actinides or f-block or f-subshell

c. What is the

i. chemical symbol for element X

Sol. Te

ii. mass number of the above isotope of element X?

Sol. 137

d. Zirconium, Zr, is placed in the second series of transition elements. Given that the properties of the elements in the second transition series are similar to those in the first transition series, predict two properties of the element zirconium.

Sol. Any two of:

- metallic
- good conductor
- dense
- high melting temperature
- variable oxidation state
- coloured salts
- forms complex ions.

Q67. a. The following information refers to the isotopes of copper and was collected by using a mass spectrometer.

Isotope	Relative isotopic mass
^{63}Cu	62.93
^{65}Cu	64.93

Given that the relative atomic mass of copper is 63.54, calculate the percentage abundance of the $_{63}Cu$ isotope.

Sol.

let x = abundance of ^{63}Cu

Then for $\frac{62.93x + 64.93(100 - x)}{100} * = 63.54; x = 69.5*$

b. i. The atomic number of nickel is 28. Write the electron configuration, in terms of shells and subshells, of the nickel atom in its ground state.

Sol.

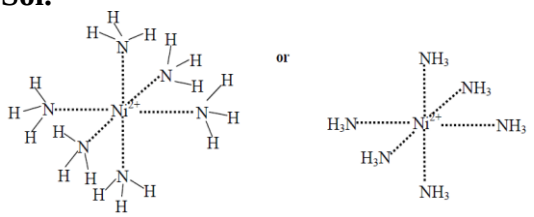
$1s^2 2s^2 p^6 3s^2 p^6 4s^2 3d^8$ **or** $1s^2 2s^2 p^6 3s^2 p^6 d^8 4s^2$

ii. Write the electron configuration, in terms of shells and subshells, of the nickel (II) ion in its ground state.

Sol. $1s^2 2s^2 p^6 3s^2 p^6 d^8$

iii. The nickel (II) ion forms a complex ion with six molecules of ammonia (NH_3). Sketch the structure of this complex ion, clearly showing the position and the orientation of the ammonia molecules around the Ni^{2+} ion.

Sol.



c. Nickel and copper are both found in the first transition series of the periodic table. Explain why there are exactly 10 elements in each of the series of transition metals.
Sol. Due to systematic filling of a d-subshell.

Q68. Different quantities of nitrogen oxide (NO) are listed below.
Which one contains the least number of molecules?
a. 6 × 102 L at 273 K and 1 atm
b. 6 × 1023 molecules
c. 6 × 102 g
d. 6 mol
Sol. b. The least number of molecules of NO corresponds with the least n(NO).

$$\text{Option A: } n(\text{NO}) = \frac{V}{V_m(\text{STP})} = \frac{6\times10^2}{22.4} = 27 \text{ mol}$$

$$\text{Option B: } n(\text{NO}) = 1 \text{ mol}$$

$$\text{Option C: } n(\text{NO}) = \frac{m}{M} = \frac{6\times10^2}{30.0} = 20 \text{ mol}$$

$$\text{Option D: } n(\text{NO}) = 6 \text{ mol}$$

Q69. When 2.54 g of Solid iodine reacts with excess chlorine and the unreacted chlorine is evaporated, 4.67 g of a yellow product remains. The empirical formula of the product is
a. ICl_2
b. ICl_3
c. ICl_4
d. ICl_5
Sol. b. The empirical formula reflects the mole ratio n(I) : n(Cl)

$$m(\text{I}) = 2.54 \text{ g} \rightarrow n(\text{I}) = \frac{2.54}{126.9}$$
$$= 2.00 \times 10^{-2} \text{ mol}$$
$$m(\text{Cl}) = m(\text{product}) - m(\text{I})$$
$$= 4.67 - 2.54$$
$$= 2.13 \text{ g}$$
$$n(\text{Cl}) = \frac{2.13}{35.5}$$
$$= 6.00 \times 10^{-2} \text{ mol}$$
$$\text{Ratio } n(\text{I}) : n(\text{Cl}) = 2.00 \times 10^{-2} : 6.00 \times 10^{-2}$$
$$= 2 : 6$$
$$= 1 : 3$$

Hence, the empirical formula is ICl_3

Q70. Which one of the following is **least** likely to be a product of a redox reaction between sulfuric acid and zinc metal?
a. H_2
b. H_2S
c. SO_2
d. SO_3
Sol. d. In a redox reaction between zinc metal and sulfuric acid, zinc metal would be the reductant (and be oxidised. and sulfuric acid would be the source of the oxidant (which will be reduced.
In dilute sulfuric acid, the oxidant is $H^+(aq)$, which is reduced to H_2 according to $2H^+(aq) + 2e^- \rightarrow H_2(g)$. In concentrated sulfuric acid the oxidant is $H_2SO_4(l)$. When H_2SO_4 is reacting as an oxidant, and hence being reduced, the oxidation number of sulfur, which is +6, must decrease. The oxidation numbers of sulfur in the suggested products are $H_2S^-(-2)$; SO_2^- (+4); SO_3^- (+6). Hence SO_3 is unlikely to be a product of the reaction.

Q71. Two bottles, I and II, have the same volume and are at the same temperature.
Bottle I contains 10 g of argon gas only.
Bottle II contains 10 g of neon gas only.
Compared to bottle I, the number of atoms and pressure in bottle II would be number of atoms pressure:
a. equal the same
b. equal higher
c. approximately double the same
d. approximately double higher
Sol. d. For the same volume of different gases, at the same temperature, the pressure exerted by each gas depends on the number of moles present in the sample.

$$n(\text{Ar}) = \frac{m\ (\text{Ar})}{M\ (\text{Ar})} = \frac{10}{39.9} = 0.2506\ \text{mol}$$

$$n(\text{Ne}) = \frac{m\ (\text{Ne})}{M(\text{Ne})} = \frac{10}{20.1} = 0.498\ \text{mol}$$

The number of Ne atoms present in bottle II is approximately double the number of Ar atoms present in bottle I, so the pressure in bottle II is higher than the pressure in bottle I.

Q72. Sulfur dioxide (SO_2) is a chemical of major industrial significance.
a. SO_2 gas can be produced in a reaction between concentrated sulfuric acid and nickel metal. A Solution containing Ni_2^+ ions is also formed.
Write balanced equations for the
i. oxidation reaction
Sol. $Ni \rightarrow Ni_2^+ + 2e^-$
ii. reduction reaction
Sol. $SO4^{2-} + 4H^+ + 2e^- \rightarrow SO_2 + 2H_2O$
$H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$
iii. overall reaction, showing the states of all reactants and products.
Sol.
$Ni(s) + SO4^{2-}(aq) + 4H^+(aq) \rightarrow Ni^{2+}(aq) + SO_2(g/aq) + 2H_2O(l)$
$Ni(s) + H_2SO_4(aq) + 2H+(aq) \rightarrow Ni^{2+}(aq) + SO_2(g/aq) + 2H_2O(l)$
b. SO_2 can also be produced in a chemical reaction between zinc sulf te (ZnSO3) and hydrochloric acid according to the equation
$ZnSO_3(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + SO_2(g) + H_2O(l)$
Is this reaction also a redox reaction? Explain your answer.
Sol. No; there is no change in oxidation numbers (or nothing is oxidised or reduced)**.**
c. The SO_2 produced as a by-product of the extraction of lead from its ore can cause serious pollution. In order to avoid releasing the SO_2 into the atmosphere it is often collected and used to produce chemicals of industrial importance. Give the formula of such a chemical.
Sol. Any one of:
H_2SO_4
SO_3
$H_2S_2O_7$
$(NH_4)_2SO_4$
d. The following pairs of statements refer to the reaction of $SO_2(g)$ with $O_2(g)$ in the presence of vanadium (V) oxide. Each statement contains one or more missing words.
Circle the most appropriate words beside each statement.

i.

Statements	Circle the most appropriate words		
1. The product of this reaction is _____.	oleum	sulfuric acid	sulfur trioxide
2. At constant temperature, the chemical energy of the product is _____ the chemical energy of the reactants.	equal to	more than	less than

Sol. 1. The product of this reaction is sulfur trioxide.
2. At constant temperature, the chemical energy of the product is less than the chemical energy of the reactants.

ii.

1. The equilibrium yield of product is _____ as temperature decreases at constant pressure.	unchanged	increased	decreased
2. The equilibrium yield of product is _____ as pressure increases at constant temperature.	unchanged	increased	decreased

Sol. 1. The equilibrium yield of product is increased as temperature decreases at constant pressure.
2. The equilibrium yield of product is increased as pressure increases at constant temperature.

iii.

1. The reaction rate is _____ as the temperature increases at constant pressure.	unchanged	increased	decreased
2. The activation energy of the reaction is _____ by the presence of vanadium (V) oxide.	unchanged	increased	decreased

Sol. 1. The reaction rate is increased as the temperature increased at constant pressure.
2. The activation energy of the reaction is decreased by the presence of vanadium (V) oxide.

Q73. In which one of the following compounds does the transition metal display the lowest oxidation state?
a. CrO_3
b. Cu_2S
c. $MnCl_2$
d. $K_2Cr_2O_7$

Q74. Consider the following nuclear reaction that takes place in stars.

$$^{8}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C$$

Which of the following statements about this change is/ are correct?
I The reaction is endothermic.
II The mass of the $_6{}^{12}C$ nucleus is greater than the combined masses of the reactants.
a. I only
b. II only
c. both I and II
d. neither I nor II

Q75. Some information about the element rhenium (Re) is given in the table below.

Isotope	Relative isotopic mass
^{185}Re	185.0
^{187}Re	187.0

Given that the relative atomic mass of Re is 186.2, the percentage abundance of ^{187}Re is closest to
a. 40
b. 50
c. 60
d. 70

Q76. A Solution prepared by stirring $Na_2O(s)$ in water undergoes an acid-base reaction with a Solution prepared from $SO_3(g)$ and water.

Which one of the following salts could be isolated from the reaction mixture?

a. Na_2S

b. $NaHSO_3$

c. Na_2SO_3

d. Na_2SO_4

Sol. d. The poor response to this item indicated unfamiliarity with the reactions of alkali metal oxides with water.

Q77. Which one of the following alternatives contains molecules and ions that are all likely to form a complex ion with a transition metal cation?

a. Cl., F., CN., H^+

b. NH_3, Cl., F., H_2O

c. Na^+, CN., F., H2O

d. CH_4, Cl., NH_3, H_2O

Q78. Predict which one of the following compounds would be coloured.

a. $BaSO_4$

b. $AlPO_4$

c. $KClO_4$

d. $NaMnO_4$

Q79. Refer to the periodic table in the data sheet when answering this equation. Identify each of the following elements on the basis of the properties listed in the table below. Write its chemical symbol in the appropriate box in the third column.

	Property	Chemical symbol of the element
i.	The element which forms an ion with electron configuration of $1s^2 2s^2 2p^6$ and a charge of 2+	
ii.	The third member of the actinides	
iii.	A period 3 element which forms an ionic oxide that reacts with both acids and bases	
iv.	In the ground state, atoms of this element have electrons in 2 shells and the first four ionisation energies are 0.80, 2.43, 3.66 and 25.02 MJ mol^{-1}	
v.	An element that is more electronegative than chlorine and its atoms have an outer-shell configuration of s^2p^4	
vi.	An element which is more metallic than germanium (Z = 32), has a higher first ionisation energy than bismuth (Z = 83) and atoms with an outer-shell configuration of s^2p^2	

Sol.

	Property	Chemical symbol of the element
i.	The element which forms an ion with electron configuration of $1s^2 2s^2 2p^6$ and a charge of 2+	Mg (or magnesium)
ii.	The third member of the actinides	U (or uranium) [Pa]
iii.	A period element which forms an ionic oxide that reacts with both acids and bases	Al (or aluminium)
iv.	In the ground state, atoms of this element have electrons in 2 shells and the first four ionisation energies are 0.80, 2.43, 3.66 and 25.02 MJ mol^{-1}	B (or boron)
v.	An element that is more electronegative than chlorine and its atoms have an outer-shell configuration of s^2p^4	O (or oxygen)
vi.	An element which is more metallic than germanium (Z = 32), has a higher first ionisation energy than bismuth (Z = 83) and atoms with an outer-shell configuration of s^2p^2	Sn (or tin)

Q80. The work of many scientists has contributed to an understanding of atomic structure. As a result of their work, previously unknown elements have been discovered and the search for new elements continues today.

a. Dimitri Mendeleev (1834.1907) is usually given much of the credit for systematically arranging the elements into a periodic table. Briefly describe two important features of the table he created.

Sol. Any two of the following (or their equivalent):

• elements arranged in order of increasing atomic mass

• similar chemical properties arranged in vertical groups
• gaps left in table allowing for missing elements
• properties of missing elements predicted.

b. The discovery of element 113 was claimed by teams of Russian and American scientists in February 2004. Following international conventions, it has initially been given the name ununtrium and the symbol Uut, before a permanent name and symbol are given to it. Uut undergoes rapid radioactive decay but atoms of Uut have been identified with a mass number of 283 and also with a mass number of 284.

i. Name an instrument that could be used to determine the mass numbers of different isotopes of an element.

Sol. Mass spectrometer ('spectrograph' was also accepted).

ii. State the number of subatomic particles in an uncharged Uut atom of mass number 284.

protons __ electrons__ neutrons __

Sol.

• protons: 113
• electrons: 113
• neutrons: 171

iii. In what group and period is Uut located in the periodic table?

Group _____ period _____

Sol.

• group III (or 13)
• period 7

iv. Give the symbol of the element that is expected to be most similar to Uut in chemical properties.

Sol. Tl (Thallium)

v. In terms of atomic structure, explain why the atomic radius of Uut is predicted to be smaller than that of Fr (Z = 87).

Sol. The core charge increases across the period.

vi. In terms of atomic structure, explain why the first ionisation energy of Uut is predicted to be smaller than that of Al (Z = 13).

Sol. The outer electrons are further away from core charge.

vii. Atoms of Uut with a mass number of 283 undergo radioactive decay into two particles, one of which is an α-particle (a helium nucleus). Write a balanced equation for this nuclear reaction.

Sol.

$$^{283}Uut_{113} \rightarrow {}^{4}He_{2} + {}^{279}Rg_{111}$$

Q81. The arrangements of electrons in atoms and ions are often written in simplified form, known as .condensed electron configurations. For example, the condensed electron configuration of beryllium is written as: $[He]2s^2$ where [He] stands for the electron configuration of helium (1s2), which is the noble gas element previous to beryllium in the periodic table.

a. Write condensed electron configurations for the following atoms and ions.

i. C

Sol.

$[He]2s^22p^2$
$[He]2s^2p^2$ was also accepted

ii. Fe

Sol.

$[Ar]3d^64s^2$

$[Ar]4s^2 3d^6$ was also accepted.

iii. Fe^{3+}

Sol. $[Ar]3d^5$

The condensed method of representing the electronic structures was clearly not familiar to students. Even though the example demonstrating the method was given, it was not copied very well.

b. State the group and period of the periodic table where an element with the electron configuration $[Kr]\ 4d^{10}5s^2 5p^4$ is found.

group _____ period _____

Sol.

•group VI (or 16)

• period 5

Q82. When comparing the electrolysis of molten NaF and that of a 1.0 M aqueous Solution of NaF, which one of the following statements is correct?

a. The product at the anodes is the same in both cells and the product at the cathodes is the same in both cells.

b. The product at the anodes is the same in both cells but the products at the cathodes are different.

c. The product at the cathodes is the same in both cells but the products at the anodes are different.

d. The products at the cathodes of the cells are different and also the products at the anodes are different.

Sol. d. In NaF(l) the oxidant, Na^+ is reduced to Na at the cathode and the reductant, F-, is oxidised to F_2 at the anode. In NaF(aq) the strongest oxidant, H_2O, is reduced to H_2 at the cathode and the strongest reductant, H_2O, is oxidised to O_2 at the cathode.

Skill in using the electrochemical series to identify the strongest oxidant and strongest reductant needs to be emphasised.

Q83. The following reactions occur spontaneously as written.

$2Cr^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + Co(s)$

$Co(s) + Pb^{2+}(aq) \rightarrow Co^{2+}(aq) + Pb(s)$

$Fe(s) + 2Cr^{3+}(aq) \rightarrow Fe^{2+}(aq) + 2Cr^{2+}(aq)$

Using this information, predict which one of the following pairs of reactants will react spontaneously.

a. $Co(s) + Fe^{2+}(aq)$

b. $Cr^{2+}(aq) + Fe^{2+}(aq)$

c. $Cr^{2+}(aq) + Pb^{2+}(aq)$

d. $Pb(s) + Co^{2+}(aq)$

Sol. c. Three of the oxidant/ reductant pairs are on the electrochemical series.

$Pb^{2+} + 2e^- \rightarrow Pb$

$Co^{2+} + 2e^- \rightarrow Co$

$Fe^{2+} + 2e^- \rightarrow Fe$

The location of the Cr^{3+}/ Cr^{2+} pair is deduced from reactions 1 and 3.

Cr_3+ is a weaker oxidant than Co_2+ but a stronger oxidant than Fe_2+.

Hence the order in terms of decreasing oxidant strength is:

$Pb^{2+} + 2e^- \rightarrow Pb$

$Co^{2+} + 2e^- \rightarrow Co$

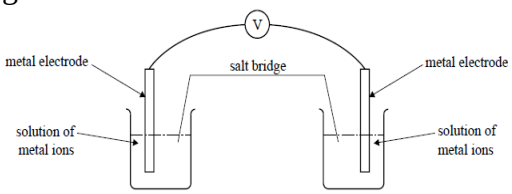
$Cr^{3+} + e^- \rightarrow Cr^{2+}$

$Fe^{2+} + 2e^- \rightarrow Fe$

For a spontaneous reaction the oxidant must be above the reductant in the electrochemical series.

Q84. Four half cells are constructed as follows.

Half cell I: an electrode of metal P in a 1.0 M Solution of $P^+(aq)$ ions.
Half cell II: an electrode of metal equation in a 1.0 M Solution of $Q^+(aq)$ ions.
Half cell III: an electrode of metal R in a 1.0 M Solution of $R^+(aq)$ ions.
Half cell IV: an electrode of Cu(s) metal in a 1.0 M Solution of $Cu^{2+}(aq)$ ions.
The half cells are connected in pairs, as shown below, to form a series of galvanic cells.



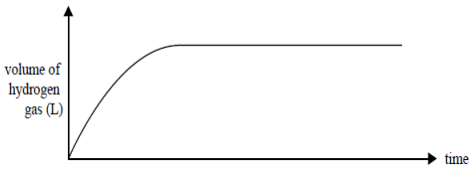
For each cell, the polarity of the electrodes and the voltage generated are recorded.

Half cells used	Positive electrode	Negative electrode	Voltage (V)
I and IV	P	Cu	0.46
II and IV	Cu	Q	0.57
III and IV	Cu	R	1.10
II and III	Q	R	0.53

Which one of the following alternatives lists the metals in order of increasing strength as reductants?
a. R, Q, Cu, P
b. Cu, P, Q, R
c. P, Cu, R, Q
d. P, Cu, Q, R
Sol. d. In a galvanic cell the reductant is oxidised; oxidation occurs at the anode; the anode is the negative electrode. In each cell the stronger reductant is at the negative electrode. According to the data relative reductant strengths are:
I and IV Cu > P; II and IV Q> Cu; III and IV R > Cu; II and III R > Q
Hence, the order of increasing reductant strength is P < Cu < Q< R.

Q85. Which one of the following, under standard conditions, can not be predicted from the electrochemical series?
a. $Fe^{2+}(aq)$ is a stronger reductant than $Br^-(aq)$.
b. $Fe^{2+}(aq)$ is a stronger oxidant than $Zn^{2+}(aq)$.
c. $Sn^{2+}(aq)$ reacts faster with $Ag^+(aq)$ than with $Cu^{2+}(aq)$.
d. The equilibrium constant for the reaction between $Sn^{2+}(aq)$ and $Cu^{2+}(aq)$ is greater than the equilibrium constant for the reaction between $Sn^{2+}(aq)$ and $Zn^{2+}(aq)$.

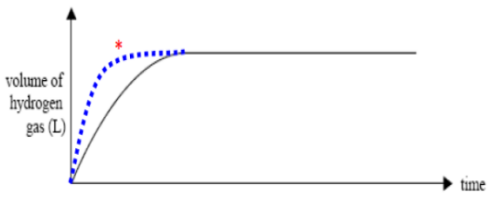
Q86. A 2.0 g piece of magnesium ribbon was added to a known volume of 2.0 M hydrochloric acid. The volume of hydrogen gas produced during the reaction was measured and recorded. The graph below shows the result of this experiment.



a. Write an equation for the reaction between magnesium and hydrochloric acid.
Sol.
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ or
$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$
b. In a second experiment, 2.0 g of magnesium powder was added to the same volume of 2.0 M hydrochloric acid as used in the first experiment.

On the axes above, sketch the expected graph of volume of hydrogen against time for this second experiment. Give an explanation for the shape of your graph.

Sol.



Powdered Mg has a greater surface area so the reaction occurs faster**.**

Q87. When Solid sodium hydride, NaH, is added to water, the hydride ion reacts according to the following equation.

$H^-(aq) + H_2O(l) \rightarrow OH^-(aq) + H_2(g)$

This reaction can be classified as

a. acid-base only.
b. oxidation-reduction only.
c. both acid-base and oxidation-reduction.
d. neither acid-base nor oxidation-reduction.

Sol. c.

$H^-(aq) + H_2O(l) \rightarrow OH^-(aq) + H_2(g)$

This is an acid-base reaction because $H^-(aq)$ accepts a proton (forming $H_2(g)$) and $H_2O(l)$ donates a proton (forming $OH^-(aq)$).

It is also a redox reaction because the oxidation number of H increases (from -1 in H^- to 0 in H_2) and also decreases (from +1 in H_2O to 0 in H_2).

Q88. Which of the following four elements has the largest atomic radius? Is it:

a. strontium
b. francium
c. calcium
d. bromine

Q89. $Ca(BrO_3)_2$ (read: C- a, left parenthesis, B - r - O - subscript 3, right parenthesis, subscript 2) is called:

a. calcium bromate
b. calcium bromite
c. calcium dibromite
d. calcium bromide

Q90. Name the person who developed a table of elements which revealed regularities in elemental properties?

Sol. Dmitri Mendeleev

Q91. Who was the first American chemist to receive a Nobel Prize? He was selected in 1914 for his precise determination of atomic weights.

a. Edward Frankland
b. Theodore Richards
c. John Bardeen
d. Paul Dirac

Q92. All alloys contain this element if they are amalgam. The element is:

a. iron
b. mercury
c. gold
d. platinum

Q93. Which of the following elements would form an acid oxide with the formula XO_2 and an acidic compound with hydrogen with the formula XH_2?

a. Sodium

b. Magnesium
c. Aluminum
d. Sulfur

Q94. Which of the following would have the largest THIR ionization energy? Is it:
a. Boron
b. Carbon
c. Nitrogen
d. Magnesium

Q95. It is believed that carbon-14 in nature is slowly generated by the action of:
a. protons on carbon-12
b. electrons on hydrogen
c. cosmic rays on boron
d. neutrons on nitrogen

Q96. In the filling of electron orbitals for the element sulfur, which has 16 electrons, the number of electrons in the 3p orbitals is:
a. 3
b. 4
c. 6
d. 0

Q97. Marie Curie shared the 1911 Nobel Prize in chemistry with two fellow chemists. Name them.
Sol. Pierre Curie and (A. Henri) Becquerel.

Q98. Which of the following metals melts in your hand?
a. gallium
b. cesium
c. sodium
d. magnesium

Q99. The structure of an ammonia molecule can best be described as:
a. linear
b. tetrahedral
c. pyramidal
d. triagonal planar

Q100. Which bond has the LEAST ionic character?
a. H – F
b. Li - F
c. Li - Br
d. F - F

Q101. The type of crystal lattice exemplified in a diamo is:
a. ionic crystal
b. covalent network crystal
c. metallic crystal
d. covalent molecular crystal

Q102. A colorless Solution is known to contain one of these ions. Which ion is present if adding dilute HCl produces a white precipitate that dissolves when the Solution is warmed?
a. Ag^{+}
b. Cu^{2+}
c. Hg_2^{2+}
d. Pb^{2+}

Q103. Analysis of a compound known to contain only Mg, P, and O gives this analysis. 21.8% Mg 27.7% P 50.3% O. What is its empirical formula?
a. $MgPO_2$
b. $MgPO_3$
c. $Mg_2P_2O_7$
d. $Mg_3P_2O_8$

Q104. Which characteristic is most useful for determining that a substance is a metal?
a. conductivity
b. hardness
c. melting point
d. X-ray pattern

Q105. Which element has an outer electron configuration of s2p4?
a. Ca
b. Cr
c. Ge
d. Se

Q106. Which set contains only covalently bonded molecules?
a. BCl_3, $SiCl_4$, PCl_3
b. NH_4Br, N_2H_4, HBr
c. I_2, H_2S, NaI
d. Al, O_3, As_4

Q107. What is the arrangement in space of the hybrid orbitals of an atom with sp2 hybridization?
a. linear
b. bent
c. pyramidal
d. trigonal planar

Q108. Lead(II) fluoride (PbF_2), lead(II) chloride ($PbCl_2$), lead(II) bromide ($PbBr_2$), and lead(II) iodide (PbI_2) are all slightly soluble in water. Which lead salt will increase in Solubility when its saturated Solution is acidified?
a. PbF_2
b. $PbCl_2$
c. $PbBr_2$
d. PbI_2

Q109. Which bond is expected to be the least polar?
a. O–F
b. P–F
c. Si–N
d. B–Cl

Q110. The nitrite ion, NO_2^-, may be represented by two major resonance forms. The lengths of the nitrogen-to-oxygen bonds in this ion are expected to be:
a. the same as the length of nitrogen-to-oxygen double bonds.
b. the same as the length of nitrogen-to-oxygen triple bonds.
c. between the lengths of a nitrogen-to-oxygen single bond and a nitrogen-to-oxygen double bond.
d. between the lengths of a nitrogen-to-oxygen double bond and a nitrogen-to-oxygen triple bond.

Q111. Which statement about silicon is false?
a. It is a met alloid.
b. It behaves as a semiconductor when pure.
c. It is extremely rare in the earth's crust.
d. It has a smaller atomic radius than aluminum

Q112. For which substance is the oxidation number of vanadium the same as that in the VO_3^- ion?
a. VN
b. VCl_3
c. $VOSO_4$
d. VF_5

Q113. In which species does the central atom obey the octet rule?
a. XeF_4
b. SF_4
c. SiF_4
d. ClF_4^-

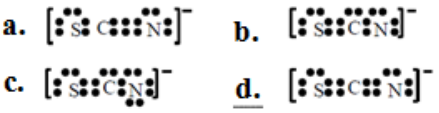
Q114. How many orbitals contain one or more electrons in an isolated ground state iron atom (Z = 26)?
a. 13
b. 14
c. 15
d. 16

Q115. The H–O–H bond angles in H_3O^+ are approximately 107°. The orbitals used by oxygen in these bonds are best described as
a. p orbitals.
b. sp hybrid orbitals.
c. sp^2 hybrid orbitals.
d. sp^3 hybrid orbitals.

Q116. According to the Aufbau principle, which is the sequential order of filling subshells in a ground state atom?
a. $3s^3p^3d$
b. $3p^4s^3d$
c. $3d^4s^4p$
d. $4p^4d^4f$

Q117. Which has the highest ionization energy for the removal of the second electron?
a. F
b. Ne
c. Na
d. Mg

Q118. Which Lweis dot structure is the best represemtation of the bonding in the thiocyanate, SCN^-?



Q119. What bonds are present is H-C=CH?
a. 5 sigma
b. 4 sigma and 1 pi
c. 2 sigma and 3 pi
d. 3 sigma and 2 pi

Q120. How many valence electrons are in the pyrophosphate ion, P_2O7^{4-}?
a. 48
b. 52
c. 54
d. 56

Q121. Which species is polar?
a. CO_2
b. SO_2
c. SO_3
d. O_2

Q122. Evidence for the electron arrangement in atoms has been obtained primarily from the study of:
a. isotopes.
b. radioactivity.
c. stoichiometry.
d. atomic spectra.

Q123.
Which statement about the radii of atoms and their ions is correct?
a. Cations are smaller than their atoms, anions are larger.

b. Cations and anions are both smaller than their atoms.
c. Cations and anions are both larger than their atoms.
d. Cations are larger than their atoms, anions are smaller.

Q124. Which type of radioactive decay produces a daughter nucleus with a higher atomic number?
a. α
b. $\beta-$
c. γ
d. β^+

Q125. In which species is the central atom NOT surrounded by exactly 8 valence electrons?
a. BF_4^-
b. NCl_3
c. PCl_4^+
d. SF_4

Q126. All of these are characteristics of MOST ionic compounds in the solid phase EXCEPT:
a. high electrical conductivity
b. high melting point
c. solubility in water
d. insolubility in organic Solvents

Q127. What is the oxidation number of Ti in the compound $Na_2Ti_3O_7$?
a. –2
b. +4
c. +6
d. +12

Q128. Which is the electron configuration for an Fe(III) ion in its ground state?
a. [Ar] $3d_5$
b. [Ar] $3d^6$
c. [Ar] $4s^2 3d^3$
d. [Ar] $4s^2 3d^6$

Q129. In which species does the central atom have one or more lone pairs of valence electrons?
a. $AlCl_4^-$
b. CO_2
c. PCl_4^+
d. SO_2

Q130. Which substance has both covalent and ionic bonds?
a. $NH_4Br(s)$
b. KI(s)
c. $CH_2Cl_2(l)$
d. $SiF_4(g)$

Q131. Which salt is colorless?
a. $KMnO_4$
b. $BaSO_4$
c. Na_2CrO_4
d. $CoCl_2$

Q132. What is the geometry of the fluorine atoms around the boron atom in BF_4^-?
a. planar
b. see-saw
c. tetrahedral
d. triangular pyramidal

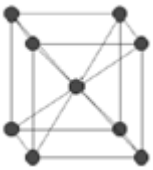
Q133. What is the ground state electron configuration of a 27Co atom in the gas phase?
a. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$
b. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$
c. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^1$
d. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$

Q134. Which molecule is least stable?
a. OF_2
b. OF_4
c. SF_2
d. SF_4

Q135. In which choice are the molecules listed in order of increasing bond angle?
a. H_2O, CH_4, NH_3
b. CH_4, NH_3, H_2O
c. H_2O, NH_3, CH_4
d. NH_3, CH_4, H_2O

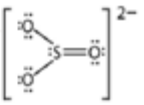
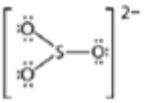
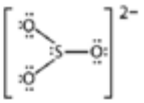
Q136. How many orbitals have the quantum numbers: n = 4, l = 3, ml = 0
a. 7
b. 3
c. 1
d. 0

Q137. Metallic sodium has a body-contained cubic unit cell. How many atoms are contained in one unit cell?



a. 1
b. 2
c. 5
d. 9

Q138. Which Lweis dot structure is a valid represemtation of the sulfite, $[SO_3^{2-}]$?

a. 
b. 
c. 
d. 

Q139. To whom is the discovery of the nuclear atom attributed?
a. Neils Bohr
b. Louis deBroglie
c. Robert Millikan
d. Ernest Rutherford

Q140. The ion $^{55}Mn^{2+}$ contains which combination of protons, neutrons and elections?

	protons	neutrons	electrons
A	25	30	23
B	25	55	23
C	27	30	25
D	30	25	28

a. A **b.** B **c.** C **d.** D

Q141. Which bond is strongest?
a. C=C
b. C=N
c. C=O
d. C=S

Q142. What is the relationship between the two species show in figure?

a. geometric isomers
b. enantiomers
c. resonance forms
d. structural isomers

Q143. Chemical crossword – inorganic chemistry. Letters A, B, D

ect. stands for unknown inorganic compounds, which react as shown in table. Formulas for all organic compounds are known.

• Compound A contains transition metal and transition metal content is approximately 72% (by mass)

• Solutions of compounds U, N, Ģ are strongly basic. There are no information about Solutions of other compounds.

• Solutions of compounds O and N colors gas flame yellow, while compounds U and Ō colors flame purple red.

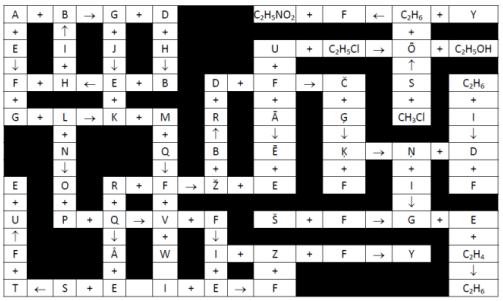
• Water Solutions of compounds V, P and L are blue.

• Substances E, G, H, M, R, S, Ā contain only one chemical element.

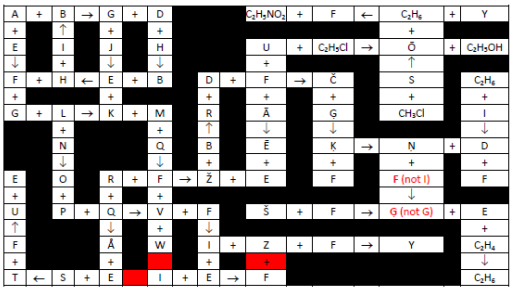
• Three transition metals are mentioned in this crossword.

• Equations in crossword are not balanced.

Write chemical formulas for all compounds abbreviated with letters.



Sol.



A – Fe_3O_4 or other oxide which contains 72% metal, Mn_3O_4, Rh_2O_5, CaO – is not accepted wrong chemistry.

B – CO

D – CO_2

E – H_2

F – H_2O

G – Fe

H – C

I – O_2

J – HCl

K – $FeCl_2$

L – $CuCl_2$

M – Cu

N- NaOH

O – NaCl

P – $Cu(OH)_2$

Q– H_2SO_4

R – Zn or other metal

S – Li or other alkali metal

T – LiH or other alkali metal

U – LiOH or other alkali metal

V – $CuSO_4$

W – SO_2

Z – NO_2

Y – HNO_3

Š – CaH_2, Ca accepted

Ž – ZnO

Ā – Al

Č – H_2CO_3

Ē – $Li[Al(OH)_4]$

Ģ – $Ca(OH)_2$

Ķ – $CaCO_3$
Ņ – CaO
Ō – LiCl or other metal
Å – $ZnSO_4$

Q144. An example of a chemical property is:
a. density
b. mass
c. acidity
d. Solubility

Q145. Which of the following is not one of Dalton's laws?
a. Atoms are indestructible.
b. Atoms of the same element have isotopes with different masses.
c. Atoms of different elements have different chemical and physical properties.
d. All of these are examples of Dalton's laws.

Q146. Bohr's model of the atom was able to accurately explain:
a. Why spectral lines appear when atoms are heated.
b. The energies of the spectral lines for each element.
c. Why electrons travel in circular orbits around the nucleus.
d. none of the above answers is correct.

Q147. True or false: All isotopes are radioactive.
a. True
b. False

Q148. Mass spectrometers separate isotopes of different elements based on their:
a. mass
b. electric charge
c. mass divided by electric charge
d. none of these

Q149 Which of the following is true of the distance of an electron from the nucleus of a 1H atom?
a. It is 1 amu.
b. It remains constant over time.
c. It's distance at any given time can only be predicted by looking at a "wavefunction".
d. It is impossible to say where an electron will be at any given time.

Q150. Orbitals hold:
a. A maximum of one electron each
b. A maximum of two electrons each
c. A number of electrons that depends on the energy level.
d. A number of electrons that depends on the type of orbital.

Q151. Which of the following is not an allowed value for the angular momentum quantum
number of an atom?
a. -1
b. 0
c. +1
d. more than one of the above is disallowed

Q152. The magnetic quantum number of an orbital defines:
a. The energy level of the orbital
b. The shape of the orbital
c. The spatial orientation of the orbital
d. The spin of the electrons in the orbital

Q153. Which of the following typically has a low melting point?
a. metals
b. nonmetals
c. metalloids
d. transition metals

Q154. The difference between a "family" and a "group" in the periodic table is that:
a. Families are columns and groups are rows.
b. Families are rows and groups are columns.
c. Families determine the energy level of an element and groups determine their
properties.
d. None of the above is true.

Q155. What section of the periodic table is a very strong oxidizer?
a. alkali metals
b. lanthanides
c. halogens
d. none of these answers is correct.

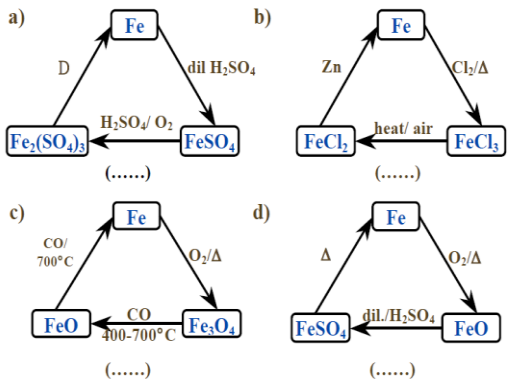
Q156. Which element has the largest atomic radius?
a. fluorine
b. carbon
c. tin
d. iodine

Q157. The shielding effect explains why:
a. the electronegativity of fluorine is greater than that of bromine.
b. the electronegativity of fluorine is greater than that of boron.
c. the electronegativity of fluorine is smaller than that of gallium.
d. none of these answers is correct.

Q158. Hydrates are defined as:
a. compounds with water molecules attached to them.
b. compounds that have had their water molecules removed
c. compounds that have been heated to high temperatures
d. none of these answers is correct.

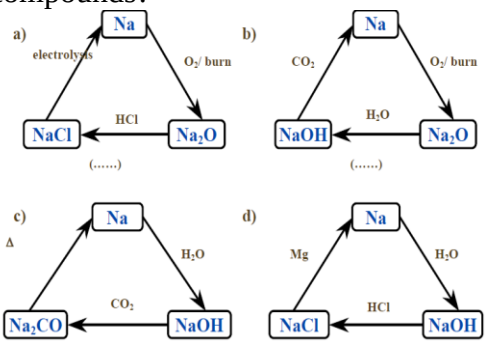
Q159. Why do covalent compounds usually have lower melting and boiling points than ionic compounds?
a. No bonds need to be broken to melt a covalent compound.
b. The intermolecular forces in ionic compounds are weaker than those in covalent compounds.
c. Covalent molecules have higher electron affinities than ionic molecules.
d. None of the above is correct.

Q160. Which systemic diagram represents the correct chemical relations between iron and its compounds?



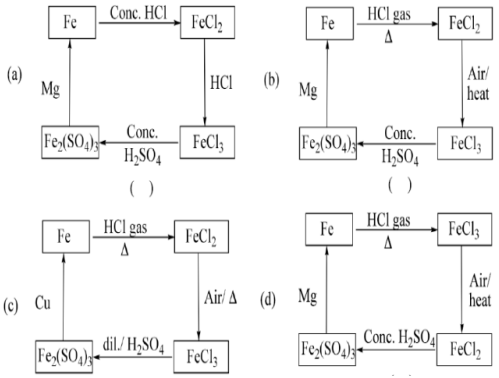
Sol. c.

Q161. Which systemic diagram represents the correct chemical relations between sodium and its compounds?



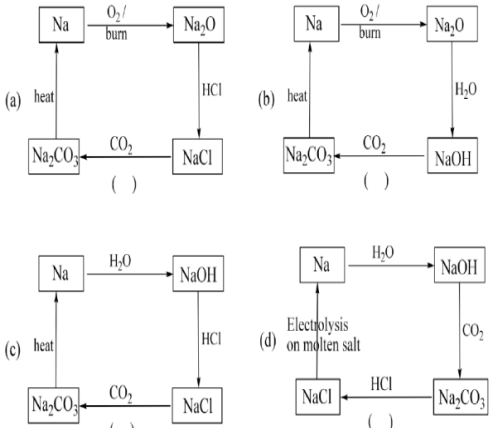
Sol. a.

Q162. Which systemic diagram represents the correct chemical relations between iron and its compounds?



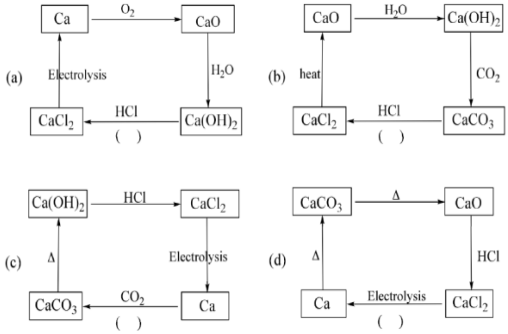
Sol. b.

Q163. Which systemic diagram represents the correct chemical relations between sodium and its compounds?



Sol. d.

Q164. Which systemic diagram represents the correct chemical relations between calcium and its compounds?



Sol. a.

CHAPTER SEVEN
Analytical Chemistry
الكيمياء التحليلية

Tests & Answer

Q1. The following are analytical instruments.
- gas-liquid chromatograph
- UV-visible spectrophotometer
- atomic absorption spectrophotometer
- Two features that are common to all three of these instruments are

a. detector and recorder.
b. light source and detector.
c. monochromator and recorder.
d. light source and liquid sample

Sol. a. Chromatographs and spectrophotometers all have a 'detector' and a 'recorder', so option **a** was the correct solution**.** Light sources and monochromators are components of spectrophotometers only.

Q2. A mixture extracted from honey contains two different sugars. The most appropriate way of separating these sugars would be with the use of
a. high-performance liquid chromatography.
b. atomic absorption spectroscopy.
c. UV-visible spectrophotometry.
d. flame tests.

Sol. a. of the techniques listed, only chromatography (option **a**) can be used to separate components of the mixture. Since sugars are heat sensitive, and likely thermally decompose in a GC, HPLC is the most appropriate technique.

Q3. Deuterium (symbol D) is an isotope of hydrogen. Water made from deuterium has the symbol D_2O and has similar properties to normal water. D_2O ionises according to the equilibrium

$D_2O \rightarrow D^+ + OD$**.**
$Kd = [D^+]\,[OD] = 1.82 \times 10^{-16}$ M2 at 25°C**.**
In a neutral solution of pure D_2O at 25°C the concentration of D+, in mole per litre, is
a. 1.00×10^{-7}
b. 1.35×10^{-8}
c. 0.91×10^{-16}
d. 1.82×10^{-16}

Sol. b. $[D^+][OD^-] = 1.82 \times 10^{-16}$
In a neutral solution; $[D^+] = [OD^-]$
So $[D^+]^2 = 1.82 \times 10^{-16} \rightarrow [D^+] = \sqrt{(1.82 \times 10^{-16})1.35 \times 10^{-8}}$ mol L^{-1}
Students who chose option **a** probably did not see past $Kw = 10^{-14}$ at 25°C**.** The popularity of option **c** suggests that, although students understood that $[D^+] = [OD-]$, many struggled with the mathematical operation required to get to the $[D^+]$ and divided by 2 rather than taking the square root.

Q4. 0.10 mole of C_4H_9OH reacts completely with molecular oxygen, O_2. The number of mole of oxygen molecules used is:
a. 0.50
b. 0.55
c. 0.60
d. 0.65

Sol. c. The products of combustion of C_4H_9OH are CO_2 and H_2O.
$C_4H_9OH \rightarrow 4CO_2 + 5H_2O$
1 'O' on the reactant side; 13 'O' on the product side 12 'O' i.e. $6O_2$ required on the reactant side.
$C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
So, 0.10 mol C_4H_9OH reacts with 0.60 mol O_2 (option **c**).

Q5. 50.00 mL of a 0.020 M solution of $Ba(OH)_2$ is added to 50.00 mL of a 0.060 M solution of HNO_3. The hydrogen ion concentration in the resultant solution, in mole per liter, is:

a. 0.010
b. 0.020
c. 0.030
d. 0.040

Sol. a.

$Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(l)$

50.00 mL 50.00 mL

0.020 M 0.060 M

Initially (mol) 1.0×10^{-3} 3.0×10^{-3}

Reacting (mol) 1.0×10^{-3} 2.0×10^{-3}

Finally (mol) - 1.0×10^{-3}

$n(H^+)$ in resultant solution = $n(HNO_3)$ in excess

$=1.0 \times 10^{-3}$ mol (in 100mL of solution)

$[H^+]$ in resultant solution = 1.0×10^{-3} mol / 0.10 L = 0.010 mol L^{-1}

Alternatively:

$n(H+)$ initially = $n(HNO_3)$

= 0.0030 mol

$n(OH^-)$ initially = 2 x $n[Ba(OH)_2]$

= 2 x 0.0010 = 0.0020 mol

Since the reaction is $OH^-(aq) + H+(aq) \rightarrow H_2O(l)$

$n(H^+)$ in resultant solution = 0.0030 – 0.0020 = 0.0010 mol

$[H^+]$ in resultant solution = 1.0×10^{-3} mol / 0.10 L = 0.010 mol L^{-1}

When provided with the amounts of both reactants, a recommended starting point is to identify the limiting (or excess) reactant. Also, when working the concentration of a species after mixing two solutions, students should divide by the total volume. This was a similar equation to equation 10 on the 2004 examination. Given that 'division by total volume' was emphasised in the 2004.

Assessment Report, the popularity of option **b** may also have been due to students not establishing the correct mole ratio for the reaction between $Ba(OH)_2$ and HNO_3. Assuming a 1:1 mole ratio leads to the calculation of 2.0×10^{-3} mol HNO_3 in excess, and a $[H^+]$ of 0.020 M.

Q6. Sodium hydride (NaH) reacts with water as follows.

$NaH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq) + H_2(g)$

This reaction should be classified as

a. acid-base but not redox.
b. redox but not acid-base.
c. both acid-base and redox.
d. neither redox nor acid-base.

Sol. Applying oxidation numbers shows that this is a redox reaction:

+1 -1 +1 -2 +1 -2 +1 0

$NaH(s) + H_2O(l) \rightarrow Na^+(aq) + OH^-(aq) + H_2(g)$

The oxidation number of H decreases from +1 in H2O to 0 in H_2.

The oxidation number of H increases from –1 in H^- (NaH) to 0 in H_2.

H- reduces H_2O to H_2, and is itself oxidised to H_2.

H_2O oxidises H- to H_2, and is itself reduced to H_2.

This can also be verified by half-equations.

Reduction: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$ oxidation:

$2H^-(aq) \rightarrow H_2(g) + 2e$

The ionic equation shows that the reaction is also an acid-base reaction:

$H^-(aq) + H_2O(l) \rightarrow OH^-(aq) + H_2(g)$
H_2O is the acid. It donates H+, to the base H^-, and forms OH^-.
H- is the base. It accepts H+, from the acid H_2O, and forms H_2.

Q.7-8. The amount of calcium carbonate ($CaCO_3$; molar mass = 100.1 g mol.1) in the ore dolomite can be determined by gravimetric analysis. The dolomite sample is dissolved in acid and the calcium ions (Ca^{2+}) present are precipitated as calcium oxalate (CaC_2O_4; molar mass = 128.1 g mol.1). The calcium oxalate is filtered, dried and strongly heated to form calcium oxide (CaO; molar mass =56.1g mol.1).

Q7. In one analysis the mass of dolomite used was 3.72 g. The mass of calcium oxide formed was found to be 1.24 g. The percentage of calcium carbonate in the dolomite sample is closest to:
a. 26.9
b. 33.3
c. 56.0
d. 59.5
Sol. $n(CaCO_3)$ in dolomite = n(CaO) produced = 1.24 g / 56.1 g mol^{-1}
= 0.0221 mol
$m(CaCO_3)$ in dolomite = 0.0221 mol x 100.1 g mol^{-1} = 2.21 g
% $CaCO_3$ in dolomite = [$m(CaCO_3)$ / m(dolomite)] x 100
=(2.21/ 3.72) x100=59.5% (option **d**)
The popularity of option **b** suggests that many students simply divided the mass of CaO by the mass of dolomite. This may have been because students focused on the data in the actual equation without integrating it with the information that preceded the equation.

Q8. Two possible sources of error in this analysis are:
I. The precipitate of calcium oxalate is not rinsed with water after being filtered.
II. The calcium oxide is not heated to constant mass.
Which of these two errors, if any, would lead to a result that is too high?
a. I only
b. II only
c. both I and II
d. neither I nor II
Sol. If the CaO precipitate is not rinsed with water, acid soluble components of the ore may be trapped in and collected with the precipitate, hence increasing the total mass of the precipitate. If the precipitate is not heated to constant mass, some water will remain and the weighed mass of the precipitate will be higher than the mass of CaO.
In both instances the calculated $m(CaCO_3)$ will be higher and the calculated percentage $CaCO_3$ in the dolomite will be higher, so option **c** was the correct Sol.
Students should be able to deduce the effect of 'not fully drying the precipitate' on the calculated percentage, by mass, of $CaCO_3$ in the sample. The popularity of option **b** suggests that the impact of not rinsing the precipitate with water was more challenging

Q9. Hydrogen and chlorine react according to the equation

$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

3 mole of H_2 and 2 mole of Cl_2 are placed in a vessel and sealed. When reaction is complete the vessel will contain

a. 5 mole of HCl
b. 6 mole of HCl and 1 mole of Cl_2
c. 4 mole of HCl and 1 mole of Cl_2
d. 4 mole of HCl and 1 mole of H_2

Sol. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

Initially (mol) 3 2

Reacting (mol)2 2 → 4

Finally (mol) 1 - 4

When reaction is complete, 1 mol of H_2 and 4 mol of HCl are present (option **d**).

When given the amounts of both reactants, it is essential that a check for 'excess' reactant is carried out. The molar amounts of reactants reacting will always be in the ratio indicated by the equation.

Q10. An organic compound is known to contain only carbon, hydrogen and oxygen. The compound contains, by mass, 39.1% of carbon and 8.7% of hydrogen. The number of carbon atoms in the empirical formula is

a. 1
b. 2
c. 3
d. 4

Sol. Assume a 100 g sample

m**c.** = 39.1 g; m(H) = 8.7 g; m(O) = 100 – (39.1+8.7) = 52.2 g

C : H : O

mass ratio 39.1 : 8.7 : 52.2

mole ratio 39.1/12.0 : 8.7/1.0 : 52.2/16.0

3.26 : 8.7 : 3.26

simplest ratio 3.26/3.26 : 8.7/3.26 : 3.26/3.26

1 : 2.67 : 1

1 : 22/3 : 1

1 : 8/3 : 1

3 : 8 : 3

Empirical formula $C_3H_8O_3$

This was a straightforward empirical formula calculation; however, the fact that 1 in 5 students chose option **a** suggests that in the empirical formula calculation 2.67 was rounded off to 3 to give the ratio 1:3:1.

Students should be discouraged from such severe rounding off in empirical formula calculations.

Q11. A solution of sodium hydroxide (NaOH) has a pH of 10.

10 mL of this solution is mixed with 990 mL of water. The pH of the diluted solution is closest to:

a. 8
b. 9
c. 11
d. 12

Sol. The solution of NaOH(aq) is basic, so dilution is a decrease in the $[OH^-]$.

pH 10 → $[H_3O^+] = 10^{-10}$

Assuming the solution is at 25°C; $[H_3O^+][OH^-]$

$[OH^-] = 10^{-14} / 10^{-10} = 10^{-4}$ M

Volume is increased by a factor of 100 (from 10 mL to 1000 mL).

Concentration is therefore decreased by a factor of 100.

$[OH^-] = 10^{-4} / 100 = 10^{-6}$ M

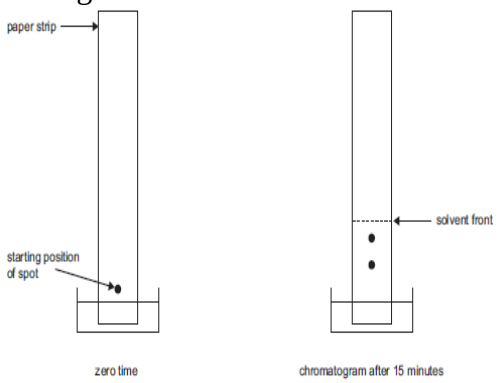
$[H_3O^+] = 10^{-14} / 10^{-6} = 10^{-8}$ M
pH = 8 (option **a**).
The popularity of option **d** suggests that students applied the principle that a tenfold decrease in concentration of H^3O^+ causes a 1 unit increase in pH. However, the solution – $NaOH(aq)^-$ was basic, not acidic, so d is an illogical

Sol. If the pH increases it suggests that a more dilute solution of NaOH(aq) is more strongly basic, i.e. has a higher concentration of OH^- (aq).
For a base, if the concentration decreases by a factor of 10, the pH decreases by 1 unit. For an acid, if the concentration decreases by a factor of 10, the pH increases by 1 unit. Since $[H_3O^+][OH^-]=10^{-14}$ at 25°C, if the $[OH^-]$ decreases, due to dilution, then the $[H_3O^+]$ must increase and
the pH decrease.

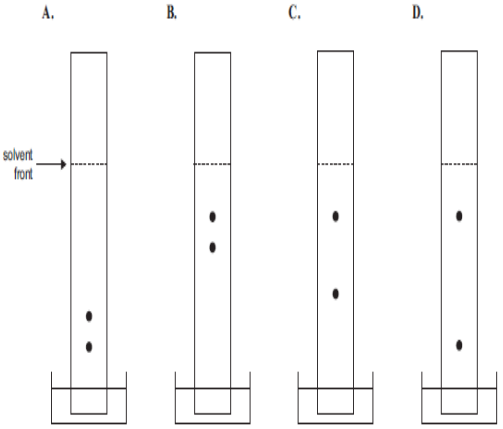
Q12. 20.0 mL of 0.10 M hydrochloric acid (HCl) reacts with 20.0 mL of 0.30 M potassium hydroxide (KOH) solution. The concentration of potassium ions in the resultant solution, in mole per litre, is:
a. 0.10
b. 0.15
c. 0.20
d. 0.3

Sol. $HCl(aq) + KOH(aq) \rightarrow KCl(aq) + H_2O(l)$; $K^+(aq)$ is a spectator ion
$KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$
$n(K^+) = n(KOH) = 0.30 \times 20.0 \times 10^{-3} = 6.0 \times 10^{-3}$ mol
Total volume = 40.0 mL
$c(K^+) = 6.0 \times 10^{-3} / 40.0 \times 10^{-3} = 0.15$ mol L^{-1} (option **b**).

Q13. Some students used paper chromatography to separate the pigments in purple ink. They set up a chromatogram and after 15 minutes the colours had separated as shown in the diagram.



Which one of the following diagrams is most likely to indicate the appearance of the chromatogram after a further 30 minutes?

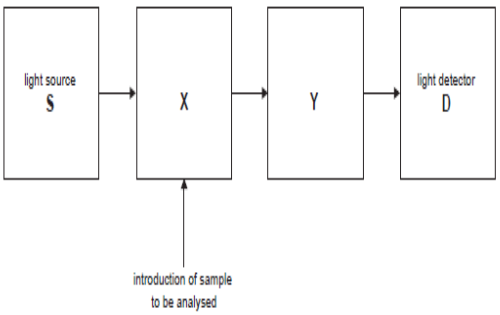


Sol. During the further 30 minutes, the two pigments and the solvent front would each move approximately twice the distance that they had moved from the origin in the first 15 minutes. So, after a further 30

minutes, the chromatogram would show the pigments having moved approximately three times as far as they moved in the first 15 minutes. Both pigments would have moved further and would be further apart. Only option **c** is consistent with this outcome.

This equation emphasised the importance of being able to interpret and apply given information/data.

Q14. An analyst determines the concentration of calcium ions in a city.s water supply using Atomic Absorption Spectroscopy (AAS) as the analytical tool. A simplified diagram of an AA spectrophotometer is shown below.



a. What particular characteristic is needed by the lamp providing the light source S?

Sol. Any of:

−the lamp must emit wavelengths of light that will be absorbed by Ca atoms

−the lamp must emit an emission spectrum of calcium

−the lamp must emit wavelengths absorbed by the element being analysed

−it must be a Ca lamp.

The characteristics of lamps used in AAS should be emphasised by teachers in the study of the instrument.

b. A sample of water from the water supply is introduced into X for analysis. What happens to the Ca^{2+} ions introduced into X? Explain your solution**.** Two marks were awarded if the response included two of the following three points:

−The sample is dehydrated in the flame and the Ca^{2+} ions are converted to an atomic vapour**.**

−Ca atoms absorb some of the wavelengths of light coming from the lamp.

−Electrons in Ca atoms are excited to higher energy levels by the light.

In AAS the flame dehydrates the ions in the solution, forming anhydrous salts. These salts are then dissociated into atoms. It is the Ca atoms which absorb the light from the calcium lamp.

Many students referred to electrons being excited to higher energy levels due to the heat of the flame. This was generally combined with the emission of light as electrons returned to lower energy levels. Such responses suggested that many students were well aware of the impact of spraying a sample into a flame as part of a flame test, but that they could not distinguish between the functions of the flame and the light in atomic absorption spectroscopy.

c. What happens to the light in Y?

Sol. A particular wavelength/ emission line/ colour is selected by the monochromator.

An implication of wavelength separation was required here. A significant number of students identified the involvement of the monochromator, but did not then explain what happens to the light as it passes through the monochromator.

d. The intensity of the light arriving in D is recorded. What additional experiments does the analyst carry outso that he can convert the light intensity recording into an actual concentration of Ca^{2+}?

Sol. The instrument is calibrated by measuring the absorbances of a series of $Ca^{2+}(aq)$ standards.

Many students mentioned a 'calibration curve' with little or no reference to how the curve is established experimentally.

This emphasises the importance of **Sol.** ing the equation which is asked, in this case: 'What additional experiment**s** does the analyst carry out…?'

e. In a particular measurement the concentration of $Ca^{2+}(aq)$ was 0.025 ppm (part per million). A concentration of 1 ppm is the same as a concentration of 1x10.6 mg L.1. Calculate the concentration of $Ca^{2+}(aq)$ in water supply in mol L.1.

Sol. As a result of an error on the exam, either 1 mg L^{-1} or $1x10^{-6}$mg L^{-1} was accepted for ppm.

$$0.025\ ppm \rightarrow 0.025\ mg\ L^{-1} \rightarrow 2.5 \times 10^{-5}\ g\ L^{-1} \rightarrow \frac{2.5 \times 10^{-5}}{40.1\ mol\ L^{-1}} = 6.2 \times 10^{-7}\ mol\ L^{-1}$$

$$0.025\ ppm \rightarrow 0.025 \times 10^{-6}\ mg\ L^{-1} \rightarrow 2.5 \times 10^{-11}\ g\ L^{-1} \rightarrow \frac{2.5 \times 10^{-11}}{40.1\ mol\ L^{-1}} = 6.2 \times 10^{-13}\ mol\ L^{-1}$$

The overall performance on this equation indicates that the use of mg, and particularly converting mg to mol, continues to prove challenging for many chemistry students.

Q14. For quality control, a chemist analyses the vitamin C (molecular formula $C_6H_8O_6$) content of a new brand of fruit juice. The reaction used is an oxidation-reduction reaction in which I_3^- is the oxidant and vitamin C is the reductant.The reaction is:

$$C_6H_8O_6(aq) + I_3^-(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 3I^-(aq)$$

The half reaction for the condiation of $I^-(aq)$ to $I_3^-(aq)$ is:

$$I_3^-(aq) + 2e^- \rightarrow 3I^-(aq)$$

a. Give the half reaction for the oxidation of vitamin**c.**

Sol. $C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2e^-$

The most common error on this equation was incorrectly locating the electrons. Students are advised to always check that half-equations are balanced for charge as well as atoms.

b. A 20.00 mL sample of the fruit juice was made up to 250.0 mL with pure water in a volumetric pask.

25.00 mL aliquots of the diluted fruit juice were then placed in a conical flask and titrated with a solution in

which $[I_3^-]=2.00\times10^{-4}$M. An average liter of 15.65 mL was obtained.

i. Calculate the amount of I_3^-. present in the average liter, in mole.

Sol. $n(I_3^-) = 2.00 \times 10^{-4} \times 15.65 \times 10^{-3} = 3.13 \times 10^{-6}$ mol

ii. Calculate the amount of vitamin C present in each 25.00 mL aliquot, in mole.

Sol. $n(C_6H_8O_6)$ in 25.00 mL diluted fruit juice = $n(I_3^-) = 3.13 \times 10^{-6}$ mol

iii. Calculate the concentration of vitamin C in the original (undiluted) sample of fruit juice in mole per liter

Sol.

$$n(C_6H_8O_6) \text{ in undiluted fruit juice} = \frac{3.13\times10^{-6}}{25} \times 250 = 3.13 \times 10^{-5}* \text{ mol}$$

$$c(C_6H_8O_6) = \frac{3.13\times10^{-5}}{20\times10^{-3}} = 1.57 \times 10^{-3}* \text{ mol L}^{-1}$$

Alternatively:

$$c(C_6H_8O_6) \text{ in diluted juice} = \frac{3.13\times10^{-6}}{25.0\times10^{-3}} = 1.25 \times 10^{-4}* \text{ mol L}^{-1}$$

$$c(C_6H_8O_6) \text{ in original sample} = 1.25\times10^{-4} \times \frac{250}{20} = 1.57 \times 10^{-3}* \text{ mol L}^{-1}$$

Significant figures were checked on this equation. Acceptable solutions included 1.565×10^{-3} and 1.6×10^{-3}, which was consistent with past practice of allowing one more or one less than the actual number of significant figures.

c. During the analysis the chemist rinsed, but did not dry, each item of glassware. She had available for use: pure water, the original fruit juice, the diluted fruit juice and the standard I_3^- solution. For each item listed below, name the liquid that should be used to rinse it by placing a tick in the appropriate box.

	pure water	original fruit juice	diluted juice	standard I_3^- solution
i. 20.00 mL pipette				
ii. 250.0 mL volumetric flask				
iii. 25.00 mL pipette				
iv. conical flask				

Sol.

	pure water	original fruit juice	diluted juice	standard I_3^- solution
i. 20 mL pipette		✓		
ii. 250 mL volumetric flask	✓			
iii. 25 mL pipette			✓	
iv. conical flask	✓			

Students generally knew the rinsing procedures associated with titration.

Q15. Ethanoic acid (CH_3COOH) is a weak acid in water.

a. Write an equation showing the ionisation of ethanoic acid in water.

Sol. $CH_3COOH(aq) + H2O(l) \leftrightarrow CH_3COO^-(aq) + H_3O^+(aq)$, or $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$

b. A 0.100 M solution of ethanoic acid in water at 25°C has a pH of 2.88.

i. Calculate the hydrogen ion concentration in a 0.100 M solution of ethanoic acid.

Sol. $[H^+] = 10^{-2}.88 = 1.32 \times 10^{-3}$ M

ii. Calculate the acidity constant of ethanoic acid at 25°C.

Sol.

$$Ka = \frac{[CH3COO^-][H^+]}{[CH3COOH]}$$

$$= \frac{[H^+]^2}{[CH3OOH]}$$

$$= \frac{(1.32 \times 10^{-3})^2}{0.100} * \quad or \quad \frac{(1.32 \times 10^{-3})^2}{0.100 - 0.00132}$$

$$= 1.74 \times 10^{-5} * \quad or \; 1.77 \times 10^{-5}$$

A significant number of students used the concentration of CH_3COOH, rather than the pH, to determine the $[H^+]$. When asked to calculate the $[H^+]$, $1.32x10^{-3}$M is more appropriate solution. than 10^{-2}.88. If students incorrectly calculated $[H^+]$ in part i. but used this value correctly in part ii, they received both marks for ii.

Calculations associated with acidity constants continue to prove challenging for significant proportion of students.

c. At 25°C, methanoic acid (HCOOH) has an acidity constant that is approximately ten times greater than the acidity constant of ethanoic acid.

i. Comparing two 0.10 M solutions of methanoic and ethanoic acids, which solution would have the higher pH? Give a simple qualitative explanation for your solution.

Sol. Ethanoic acid, because:

- lower Ka → weaker acid, hence less ionisation
- fewer H+ ions in solution
- $[H^+]$ is lower → higher pH.

ii. Equal volumes of both solutions were titrated against a 0.10 M solution of NaOH. Which of the solutions, if either, would require the greater volume of the NaOH solution for complete neutralisation? Explain your conclusion.

Sol.

- They would both require the same amount of NaOH.
- The n(NaOH) required depends on the n(acid) present. Both acids are monoprotic and there are equal numbers of moles of both acids present.

Providing a qualitative explanation of why ethanoic acid had the higher pH challenged most students. In part ii. Most solutions related the required volume of NaOH to acid strength rather than to concentration.

Most students probably encounter stoichiometry equation s related to the analysis of the ethanoic acid content of vinegar by titration with NaOH(aq); some useful links might be made with this equation.

d. Write the equilibrium expression for the following equation:

$$H_{2(g)} + I_{2(g)} \Leftrightarrow 2HI_{(g)}$$

If K is calculated to have a value of 2.5 for the reaction above, what is the value of the equilibrium constant for the following reaction?

$$4HI_{(g)} \Leftrightarrow 2H_{2(g)} + 2I_{2(g)}$$

Explanation

The equilibrium constant expression for the reaction is

$$K = \frac{[HI]^2}{[H_2][I_2]}$$

The reaction has been doubled and reversed, so the new K is the reciprocal of the old K squared (since the reaction coefficients are doubled):

$$K' = \frac{1}{2.5^2} = 0.16$$

Q16. Pure water at 100 °C has a pH of 6.14. This is because:

a. the self-ionisation of water is endothermic.

b. pH measurements at this temperature are unreliable.

c. pH measurements are affected by the bubbles of hydrogen gas that form in boiling water.

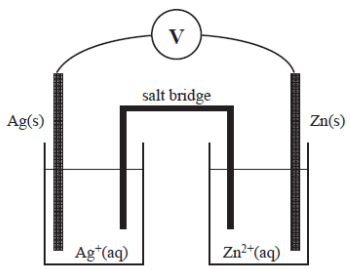
d. the concentration of H_3O^+ ions is not equal to the concentration of OH^- ions at this temperature.

At 25 °C the pH of pure water is 7. At 100 °C the pH of pure water is 6.14, implying a higher $[H_3O^+]$ than at 25 °C. This higher $[H_3O^+]$ at the higher temperature is consistent with the endothermic nature of the self-ionisation of water.

$2H_2O(l)$ $H_3O^+(aq) + OH^-(aq)$

Option **d** was suprisingly popular; students should be aware that the pH of water is temperature dependent, and 'pure' water is always neutral and hence the $[H^3O^+]$ is equal to $[OH^-]$.

Q17–18. A galvanic cell set up under standard conditions is shown below.



Q17. Which one of the following is correct? As the cell discharges

	electrons would flow from the	in the salt bridge
A.	zinc electrode to the silver electrode.	anions migrate to the Ag^+/Ag half-cell.
B.	silver electrode to the zinc electrode.	cations migrate to the Zn^{2+}/Zn half-cell.
C.	silver electrode to the zinc electrode.	cations migrate to the Ag^+/Ag half-cell.
D.	zinc electrode to the silver electrode.	anions migrate to the Zn^{2+}/Zn half-cell.

Sol. According to electrochemical series,

$Ag+(aq) + e– \rightleftharpoons Ag(s)$ $E° = 0.80$ V

$Zn^{2+}(aq) + 2e– \rightleftharpoons Zn(s)$ $E° = –0.76$ V

The strongest oxidant, $Ag^+(aq)$, will react with the strongest reductant, Zn(s).

Anode (–): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Cathode (+): $Ag^+(aq) + e^- \rightarrow Ag(s)$

Electrons flow from the site of oxidation (anode) to the site of reduction (cathode) – that is, from the Zn electrode to the Ag electrode. Anions migrate towards the anode, Zn^{2+}/Zn half-cell. Cations migrate towards the cathode, Ag+/Ag half-cell. This equation assessed basic understanding of the fundamental principles of operation of galvanic cells.

Q18. In this cell

a. $Ag^+(aq)$ is reduced and the Zn(s) is oxidised.

b. Ag(s) is oxidised and the $Zn^{2+}(aq)$ is reduced.

c. Ag(s) is reduced and the $Zn^{2+}(aq)$ is oxidised.

d. $Ag^+(aq)$ is oxidised and the Zn(s) is reduced.

Sol.
The strongest oxidant, $Ag^+(aq)$, is reduced at the cathode; the strongest reductant, Zn(s) is oxidised at the anode.
Anode (–): $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
Cathode (+): $Ag^+(aq) + e^- \rightarrow Ag(s)$

Q19. The cathode in this cell and the maximum voltage produced by this cell, under standard conditions, are respectively:
a. Ag and 0.16 V
b. Ag and 1.56 V
c. Zn and 0.16 V
d. Zn and 1.56 V
Sol. d. The predicted voltage, under standard conditions is:
E=E° (half-cell containing the oxidant) – E° (half-cell containing the reductant)
= 0.80 – (–0.76) = 1.56 V

Q20. Condiseder the following equilibrium expression:

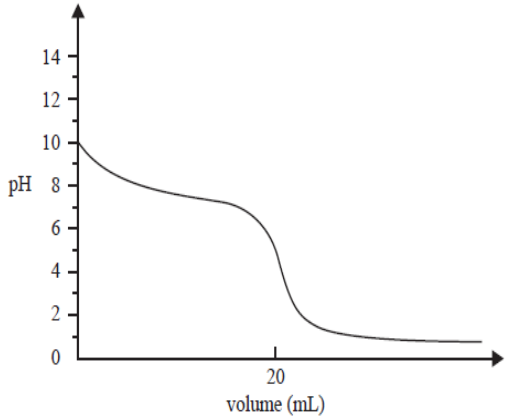
$$K = \frac{[L][M]^4}{[J]^6[K]}$$

The equation of the forwad recation for this equilibrium expression is:
a. $6J+K \rightleftharpoons L+4M$
b. $L+M_4 \rightleftharpoons J_6+K$
c. $J_6+K \rightleftharpoons L+M_4$
d. $L+4M \rightleftharpoons 6J+K$

Q21. $R(g)^{+2}\ T(g) \rightleftharpoons 2\ X(g) + Z(g)$
The reaction mixture represented above is at equilibrium at 298 K. The value of the equilibrium constant for the reaction is 16 at 298 K. If R(g), X(g) and Z(g) each have an equilibrium concentration of 2.0 M, what is the equilibrium concentration of T(g)?
a. 0.25
b. 0.50
c. 2.0
d. 4.0
e. 8.0

Q22. What is the pH of a solution made by diluting 1.00 mL of 0.10 M HCl with enough distilled water to make 1.00 L of solution?
a. 1.0
b. 2.0
c. 3.0
d. 4.0
e. 7.0

Q23-24. The following titration curve was obtained by measuring the pH in a reaction flask during an acid-base titration.



Q23. The graph represents the change in pH in the reaction flask when
a. a weak acid is added to a strong base.
b. a weak base is added to a strong acid.
c. a strong acid is added to a weak base.

d. a strong base is added to a weak acid.

Sol. The starting pH of 10 is indicative of a weak base. The drop in pH to 1 would be due to titration with a strong acid; therefore, a strong acid was added to a weak base.

Q24. Which one of the following is a suitable indicator for use in this titration?

a. phenol red.

b. thymol blue.

c. phenolphthalein.

d. bromophenol blue.

Sol. The titration curve suggests that the endpoint is around pH 4. Of the indicators listed, only bromophenol blue (3.0–4.6) would be suitable for identifying the endpoint.

Q25. A sample of the insecticide dichlorodiphenyltrichloroethane (DDT), $C_{14}H_9Cl_5$, was found to contain 0.120 g of carbon. What mass of chlorine was present in the sample?

a. 0.127 g

b. 0.355 g

c. 0.994 g

d. 1.01 g

Sol. **nc.** $=0.120/12.0=1.00\times10^{-2}$ mol

$n(C_{14}H_9Cl_5) = 1.00\times10^{-2} / 14$

$n(Cl) = 5 \times 1.00\times10^{-2} / 14$

$= 3.57\times10^{-3}$ mol

$m(Cl)=3.57\times10^{-3}\times35.5= 0.127$ g

Option **b** was consistent with not using the Cl:C ratio implied in the chemical formula of DDT.

Q26. When 1.0 mole of Cu_3FeS_3 and 1.0 mole of O_2 are mixed and allowed to react according to equation

$2Cu_3FeS_3(s) + 7O_2(g) \rightarrow 6Cu(s) + 2FeO(s) + 6SO_2(g)$

a. no reagent is in excess.

b. 5 mole of O_2 is in excess.

c. 5/7 mole of Cu_3FeS_3 is in excess.

d. 2/7 mole of Cu_3FeS_3 is in excess

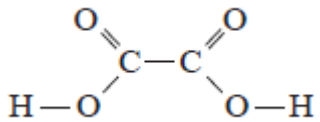
Sol.

	$2Cu_3FeS_2$	$+ 7O_2$	$\rightarrow 6Cu$	$+ 2FeO$	$+ 6SO_2$	
Initial	1.0	1.0				mol
Reacting	$^2/_7$	$1.0 \rightarrow$	$^6/_7$	$^2/_7$	$^6/_7$	mol
Final	$^5/_7$	-	$^6/_7$	$^2/_7$	$^6/_7$	mol

Hence, 5/7 mol Cu_3FeS_2 is in excess.

Overall performance on this equation indicated that many students found the 2:7 mole ratio of Cu_3FeS_2 to O_2 difficult to handle. Since the equation indicated that 2 mol Cu_3FeS_2 reacts with 7 mol O_2, then for each 1 mol O_2 reacting, 2/7 mol Cu_3FeS_2 will react. Students who selected option dprobably realised this but did not follow through to calculate the amount of Cu_3FeS_2 in excess. The popularity of option **b** suggested that the equation was not interpreted effectively by a significant number of students.

Q27. The structure of oxalic acid is shown below.



A 25.0 mL solution of oxalic acid reacts completely with 15.0 mL of 2.50 M NaOH. The concentration of the oxalic acid solution is:

a. 0.667 M

b. 0.750 M

c. 1.33 M
d. 1.50 M
Sol. When oxalic acid HOOCCOOH reacts completely with a strong base it acts as a diprotic acid, according to the equation HOOCCOOH(aq) + 2NaOH(aq) → NaOOCCOONa(aq) + H_2O(l)
n(oxalic acid) = ½ x n(NaOH)
= ½ x 2.50 x $15.0x10^{-3}$
= 0.01875 mol
c(oxalic acid) = 0.01875 mol / $25.0x10^{-3}$ L = 0.750 M
The fact that most students selected option **d** suggests that they simply assumed a 1:1 mole ratio between oxalic acid and NaOH, did not take note of the supplied structure of oxalic acid and so did not recognise the significance of the two carboxyl groups.

Q28. The amount of iron in a newly developed, heat-resistant aluminium alloy is to be determined.
An 80.50 g sample of alloy is dissolved in concentrated hydrochloric acid and the iron atoms are converted to Fe^{2+}(aq) ions.
This solution is accurately transferred to a 250.0 mL volumetric flask and made up to the mark. 20.00 mL aliquots of this solution are then titrated against a standard 0.0400 M potassium permanganate solution.
$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$
Four titrations were carried out and the volumes of potassium permanganate solution used were recorded in the table below.

Titration number	1	2	3	4
Volume of $KMnO_4$ (mL)	22.03	20.25	21.97	21.99

a. Write a balanced half-equation, including states, for the conversion of MnO_4^- ions, in an acidic solution, to Mn^{2+} ions.
Sol. Either of:
• MnO_4
-(aq) + 8H+(aq) + $5e^-$ → Mn^{2+}(aq) + $4H_2O$(l)
• MnO_4^-
(aq) + $8H_3O$ +(aq) + $5e^-$ → Mn^{2+}(aq) + $12H_2O$(l).
b. Calculate the average volume, in mL, of the concordant liters of the potassium permanganate solution.
Sol.
(22.03 + 21.97 + 21.99)/3 = 22.00 mL
A number of students who identified the three concordant liters did not access the mark because they truncated the average (21.997) to 21.99. A significant proportion of students simply averaged all four liters, not recognising that 20.25 was not concordant with the other three liters.
c. Use your solution**.** to part **b** to calculate the amount, in mol, of MnO^{4-}(aq) ions used in this titration.
solution**.**
$n(MnO^{4-}) = 0.0400 \times 22.00x10^{-3}$
$= 8.80x10^{-4}$* (mol) or 0.000880
Consequential marks were applied throughout this equation. The mark for this equation was awarded if the solution to equation 1b. was correctly converted to the number of mol.
There was a significant number of errors associated with not converting

the volume to mL, and not expressing the solution to the correct number of decimal places.

d. Calculate the amount, in mol, of $Fe^{2+}(aq)$ ions present in the 250.0 mL volumetric flask.

Sol. $n(Fe^{2+})$ in 20 mL aliquot = 5 x $n(MnO_4^-)$

= 5 x 8.80×10^{-4} = 4.40×10^{-3} (mol)

$n(Fe2+)$ in 250 mL flask = 4.40×10^{-3} x (250/20) = 5.50×10^{-2} (mol)

The marks were awarded for accurately multiplying the solution to equation 1c. by 5 and by (250/20). Some students used their liter value rather the 20.00 mL aliquot in determining the amount present in the 250 mL volumetric flask.

e. Calculate the percentage, by mass, of iron in the 80.50 g sample of alloy.

Sol.

$n(Fe)$ in 80.50 g alloy = 5.50×10^{-2} (mol)

$m(Fe)$ in 80.50 g alloy = 5.50×10^{-2} x 55.9 = 3.07 (g)

% Fe in alloy = (3.07 / 80.50) x 100

= 3.82 % (3.81)

The most common error was not expressing the solution to the required 3 significant figures. Students should also be reminded to use the molar masses as supplied (as relative atomic masses) in the Data Book.

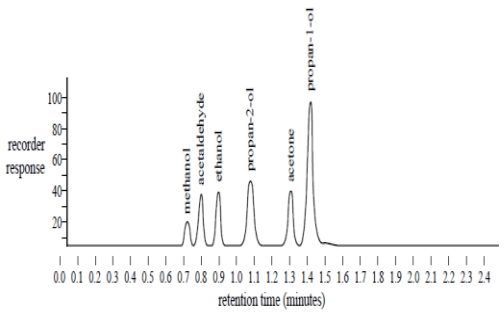
Many students who incorrectl solutioned equation. 1b. still obtained full consequential marks for equation s 1c., 1d. and 1e. A common final solution was 3.74 %, consistent with using all four liters in 1b.

Students should be reminded that severe rounding of data in early parts of a equation, for example, 0.0009 for 0.00088 in equation 1c., can have a significant impact on the accuracy of their final solution**.**

Students should be aware of the difference between 'truncating' and 'rounding off' an solution**.** In equation 1a. correctly rounding off 21.997 to 4 significant figures gives the solution **.** as 22.00, not 21.99.

Q29. A forensic chemist wants to test the accuracy of a gas chromatograph that is to be used for the analysis of blood alcohol content.

A blood sample may contain a number of volatile chemicals that can interfere with the identification and measurement of ethanol in the blood. A sample containing a mixture of ethanol and several other volatile chemicals was injected into the gas chromatograph. The following chromatogram was obtained.

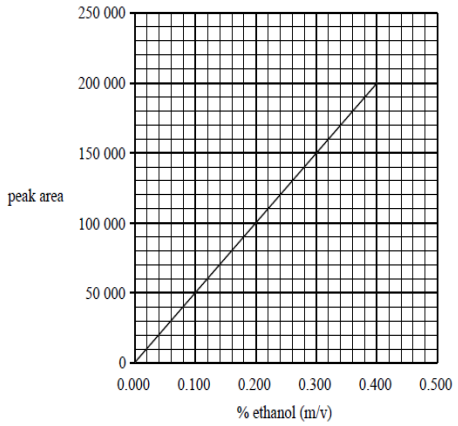


a. The forensic chemist claims that the presence of these volatile chemicals would not affect the qualitative analysis of ethanol.

i. What evidence is presented in the chromatogram to support this claim?

Sol. While these equations were generally well handled, some students did not distinguish between the two parts and provided a similar response

to both. Some gave a detailed description of 'how' the chromatogram could be used to determine the percentage of alcohol in the blood rather than why the peak at 0.9 was measured.
Acceptable responses included:
• ethanol has a unique retention time/peak.
• each chemical produces a distinct peak on the chromatogram.
ii. To determine the percentage of alcohol in a blood sample only the peak at a retention time of 0.9 minutes is measured. Explain why.
Sol. Acceptable responses included:
• the analysis is to determine the amount of ethanol in blood
• 0.9 is the retention time of ethanol, the alcohol in blood which is analysed.
The following calibration graph was constructed using simulated standard blood alcohol samples ranging in concentration from 0.000% to 0.400% m/v ethanol. Each standard was run through the chromatography column and the area under the peak produced at a retention time of 0.9 minutes was measured.
The blood alcohol content of a car driver was determined using this chromatographic technique.
b. Determine the percentage (m/v) of alcohol in the driver's blood if the peak area at a retention time of 0.9 minutes was found to be 110 000.
Sol. 0.220(%)



Q30. 1g of each of the following substances is dissolved in 1 L of water. In which one would the pH of the resultant solution be closest to 7?
a. H_2SO_4
b. NH_3
c. $NaHSO_4$
d. NaCl

Q31. 0.010 mol of chloral hydrate, $CCl_3CH(OH)_2$, is dissolved in a pure organic solvent. The resulting solution is made up to one litre exactly. In this solvent, the chloral hydrate dissociates to chloral, CCl3CHO, and water. The chemical reaction for the process is:
$CCl_3CH(OH)_2$(in solution)↔ CCl_3CHO(in solution) + H_2O(in solution).
When the reaction has reached equilibrium the concentration of water in the solution is measured to be 0.0020 M. The equilibrium constant for the reaction at this temperature would be:
a. 4.0×10^{-4}
b. 5.0×10^{-4}
c. 0.20
d. 0.25

Sol. Students selecting A, made the mistake of omitting to note that, when the0.010 mol of $CCl_3CH(OH)_2$ dissociated to give 0.002 mol of each of two products, then there would be only 0.008 mol of $CCl_3CH(OH)_2$ left.

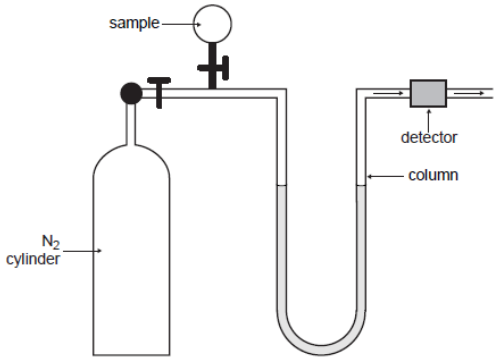
Q32. Given the equilibrium,
$A_2(g) + 4C(g) \rightleftharpoons 2AC_2(g)$, $K_1 = 4.8$
It follows that, for the reaction,
$AC_2(g) \rightleftharpoons A_2(g) + 2C(g)$, $K_2 =$ **X**
X would be:
a. 1/4.8
b. 2.4
c. 1/2.4
d. $1/\sqrt{4.8}$
Sol. The frequency of responses for b and c suggested that many students wanted to halve the equilibrium constant rather than take its square root.

Q33. An aqueous solution of copper sulfate is a clear blue colour. The concentration of this solution is to be measured using UV-visible spectroscopy. An aqueous copper sulfate solution will
a. absorb mainly red light and therefore allow red light to pass through the solution.
b. absorb mainly red light and therefore allow blue light to pass through the solution.
c. absorb mainly blue light and therefore allow red light to pass through the solution.
d. absorb mainly blue light and therefore allow blue light to pass through the solution.

Q34. 100 mL of an 0.0100 M aqueous solution of calcium hydroxide will absorb carbon dioxide according to the equation:
$Ca(OH)_2(aq) + 2CO_2(g) \rightarrow Ca(HCO_3)_2(aq)$
The maximum volume, in mL, at STP of CO_2 that could be absorbed by the solution is
a. 22.4
b. 44.8
c. 224
d. 448

Q35. In pure water at 5°C the hydroxide ion concentration is measured to be 4.0×10^{-8} M.
The Kw and pH of pure water at this temperature will be, respectively:
a. 1.0×10^{-14} and 7.0
b. $1.0 \times 10^{-1}4$ and 6.6
c. 1.6×10^{-15} and 7.0
d. 1.6×10^{-15} and 7.4
Sol. Many still find this difficult. The high frequency of the incorrect response B is attributed to students believing that Kw is always 10^{-14} whatever the temperature. The important point to see here is that $[H^+]$ and $[OH^-]$ in pure water must always be the same, whatever the temperature.

Q36. The diagram below represents a gas chromatograph.



a. Clearly identify, on the diagram, the mobile and stationary phases in the gas chromatograph shown and explain how gas chromatography is able to separate the components of a gaseous mixture.

Sol. Mobile phase → N_2 (or equivalent indication). Stationary phase → shaded part of U-tube.

Components of mixture are adsorbed to differing extents by stationary phase so rate of movement through the tube is determined by the extent of adsorption.

b. A pure substance was suspected of being the high molecular weight anabolic steroid Stanozolol. A sample of this substance was dissolved in a suitable pure solvent and injected into a gas chromatograph. How many peaks would you expect to see in the resulting chromatogram? Justify your result.

Sol. Solvent, Stanozolol.

When a student responded 'only one peak' and then asserted that there was only onesubstance present, 1 mark was awarded.

c. If a sample of pure Stanozolol were available, how could it be used in the gas chromatograph to confirm the identity of the suspect sample?

Sol. Mix suspect sample with pure Stanozolol and then verify that only one peak is obtained (or, compare retention times). Surprisingly a significant number of students had the idea that this was somehow related to mass spectrometry and suggested that there were 'many peaks because the molar mass is so large'.

Q37. Boric acid (H_3BO_3) is a weak acid. Its conjugate base, the borate ion, exists in water as $B(OH)_4^-$. A solution of pure sodium borate, $NaB(OH)_4$, is prepared in water at 25°C. The borate ion dissociates according to the equation

$B(OH)_4^-(aq) \leftrightarrow OH^-(aq) + H_3BO_3(aq)$

a. Give an expression for the equilibrium constant for the reaction above.

Sol. $K = [OH^-][H_3BO_3]/[BOH)_4^-]$.

b. At equilibrium in a particular solution of $NaB(OH)_4$, concentration of $B(OH)_4$ is exactly 0.100 M and the pH is 11.11.

i. Calculate the hydrogen ion and hydroxide ion concentrations in the solution.

Sol.

$[H+] = 10^{-11}.11 = 7.76 \times 10^{-12}$ M;

$[OH-]=10^{-14}/7.76x10^{-12}=1.29x10^{-3}$M

ii. Hence give the H_3BO_3 concentration in the solution

Sol. $[H_3BO_3] = [OH^-] = 1.29 \times 10^{-3}$ M.

c. The equilibrium constant for the dissociation of boric acid is given by

$$K_a = \frac{[H^+][B(OH)_4^-]}{[H_3BO_3]}$$

Use the data from part **b.** to calculate the value of the Ka of boric acid.
Sol. $K_a = (7.76 \times 10^{-12} \times 0.100)/1.29 \times 10^{-3} = 6.01 \times 10^{-10}$.

Q38. Some students were set the task of determining the concentration of acetic acid in a particular brand of vinegar. An outline of the method they used is given below.
1. A burette is filled with a standard solution of sodium hydroxide.
2. The vinegar is diluted by a factor of 10 in a volumetric flask. A pipette is used to transfer 20.00 mL of diluted vinegar to a conical flask and a few drops of phenolphthalein indicator is added.
3. The diluted vinegar is titrated with the base. Titrations are repeated until three concordant results are obtained.
The equation for the reaction is
$NaOH(aq) + CH_3COOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$
a. The volumetric flask, the burette, the pipette and the conical flask are all rinsed before they are used. Indicate which solution should be used to finally rinse each of these pieces of glassware by ticking your responses in the appropriate boxes below.
Sol.

glassware used	rinse with water	rinse with diluted vinegar solution	rinse with NaOH solution
volumetric flask	✓		
burette			✓
20.00 ml pipette		✓	
conical flask	✓		

b. Why is the vinegar diluted before titrating?
Sol. So as not to use too large a volume of the NaOH solution (or to use and obtain a reasonably sized liter).
c. Explain why titrations are repeated until three concordant results are obtained.
Sol. To minimise the error (or to ensure reliability).
d. One student's results are given below. The data shown in the student's laboratory book was
concentration of NaOH(aq) = 0.11 M
volume of undiluted vinegar = 10.00 ml , total volume of diluted vinegar = 100.00 mL. volume of diluted vinegar used in each titration = 20.00 mL.
Average liter of NaOH = 15.35 mL
Based on these results, calculate the concentration, in mol L^{-1}, of acetic acid in the undiluted vinegar solution.
Sol. Concentration of titrated vinegar = $(0.11 \times 15.35)/20.00 = 0.0844$ M. Since the initial dilution of vinegar is 10, giving the concentration of undiluted vinegar is 0.84 M. The final result needed to be given to exactly two significant figures.

Q39. 5L volumes of 1.0 M $KNO_3(aq)$, 1.0 M $AgNO_3(aq)$ and 1.0 M $Cu(NO_3)_2(aq)$ are placed in three separate electrolytic cells using platinum electrodes. Over a period of 30 minutes, 96500 coulombs of electric charge are passed through each solution.
Which of the following alternatives correctly indicates the amount, in mole, of metal deposited at the cathode in each cell?

	n(K)	n(Ag)	n(Cu)
a.	0	1	2
b.	0	1	0.5
c.	1	1	0.5
d.	0.5	0.5	1

Q40. At 25ºC, the pH of 0.0050 M $Ba(OH)_2$ is:
a. 2.0
b. 2.3
c. 11.7
d. 12.0
Sol. d. $Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$
$[OH^-] = 2 \times [Ba(OH)_2] = 2 \times 0.0050 = 0.010$ M
$[H_3O^+] = 10^{-14} / 0.010 = 10^{-12}$ M
$pH = -\log10(10^{-12}) = 12$

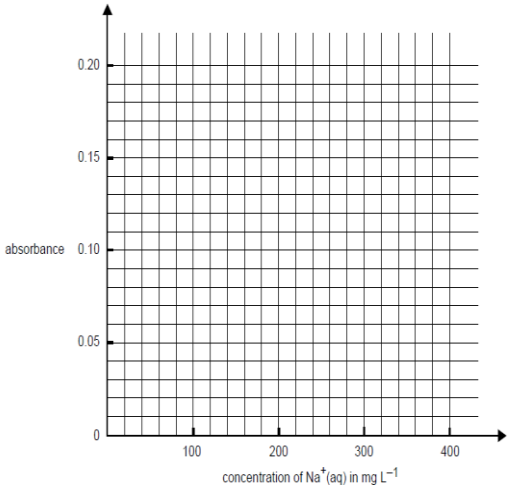
Q41. A group of chemists complain about the smell that they noticed when reading new copies of a particular journal. The publishers of the journal decide to try to identify the substance, or substances, responsible for this smell. Which of the following analytical methods would be the most likely choice for the first stage of an analysis?
a. flame tests.
b. paper chromatography.
c. gas-liquid chromatography.
d. atomic absorption spectroscopy.
Sol. c. The presence of the smell suggests that there are volatile substances in the paper from which journal is produced. The volatile components would best be separated and analysed by gas-liquid chromatography.

Q42. Equal masses of each of the following substances are dissolved in separate samples of water to give 500 mL of solution.
Which substance would produce the solution with the lowest pH?
a. NH_3
b. HCl
c. HNO_3
d. $HClO_4$
Sol. b. HCl(aq), $HNO_3(aq)$ and $HClO_4(aq)$ are all strong monoprotic acids. For equal masses the acid with the lowest molar mass will have the highest n(acid) and hence produce the highest $n(H^+)$, highest $[H^+]$ and lowest pH
$M(HCl) = 36.5$ g mol^{-1}
$M(HNO_3) = 63$ g mol^{-1}
$M(HClO_4) = 100.5$ g mol^{-1}
So HCl will produce the solution with lowest pH.

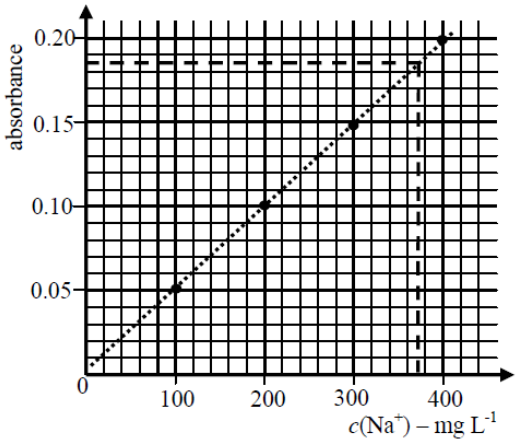
Q43. Sodium is an essential element in our diets. However, the amount of sodium present in some foods is often much higher than levels recommended by doctors. A sauce was analysed using atomic absorption spectroscopy to determine the sodium content. A 25.00 mL sample of the sauce was diluted to 1.00 L with deionised water.
Four aqueous samples of known NaCl concentration were also prepared as standard solutions. The absorbances of the four standard solutions and the diluted sauce solution were measured. The results are given in the table below.

concentration of $Na^+(aq)$	absorbance
100 mg L^{-1}	0.051
200 mg L^{-1}	0.100
300 mg L^{-1}	0.149
400 mg L^{-1}	0.199
diluted sauce	0.185

a. Use the above data for the $Na^+(aq)$ standards to plot a calibration line on the graph below.



Sol.



b. Use your calibration graph to determine the sodium ion concentration in the diluted sample of the sauce and in the original sauce.

Sol. $c(Na^+)$ in diluted sauce = 372 ± 5 mg L^{-1}

$c(Na^+)$ in original sauce = (1000/25) x 372 = 1.49×10^4 mg L^{-1}

c. i. What important assumption must you make in order to calculate the NaCl content of the sauce from the Na+ concentration?

Sol. all the Na^+ in the sauce is present as NaCl or NaCl was the only source of Na+ ions

ii. Calculate the concentration of NaCl in the original (undiluted) sauce in g L^{-1}.

Sol. $m(Na^+)$ in 1 L = 1.49×10^4 mg = 14.9 g

$n(Na^+)$ = 14.9 g / 23.0 = 0.65 mol

$n(NaCl) = n(Na^+)$ = 0.65 mol

m(NaCl) = 0.65 x 58.5 = 38 g in 1.00 L c(NaCl) = 38 g L^{-1}

iii. The maximum recommended daily NaCl intake for a healthy adult is 2.5g. What percentage of a maximum daily recommended intake would be consumed by a person who eats 10 mL of the original (undiluted) sauce?

Sol. m(NaCl) consumed = (10 / 1000) x 38 = 0.38 g (in 10 mL)

% of RDI = (0.38 / 2.5) x 100 = 15 %

d. Why is it that atomic absorption spectroscopy will measure only the sodium ion concentration in your sample and not the concentration of some other substance or substances as well?

Sol. The light source used in the AAS emits wavelengths unique (or specific) to Na / Na+. So the selected

wavelength will only be absorbed by Na / Na+.

Q44. Methanoic acid HCOOH is a weak acid present in the sting of some ants. It ionises in water according to
$HCOOH(aq)$ $HCOO^-(aq) + H^+(aq)$
$K_a = 1.8 \times 10^{-4}$ at 25^oC

a. Explain the meaning of the terms 'weak acid' and 'strong acid'.

Sol. Weak acid– only partially ionises (donates few H^+ ions/protons) in water.
Strong acid – completely ionises (donates many H^+ ions/protons) in water.

b. Write the expression for the K^a of methanoic acid.

Sol.

$$K_a = \frac{[HCOO^-][H^+]}{[HCOOH]}$$

c. Assuming a small degree of dissociation, calculate the concentrations of $H^+(aq)$ and $HCOO^-(aq)$ in 0.10 M methanoic acid at 25o**c.**

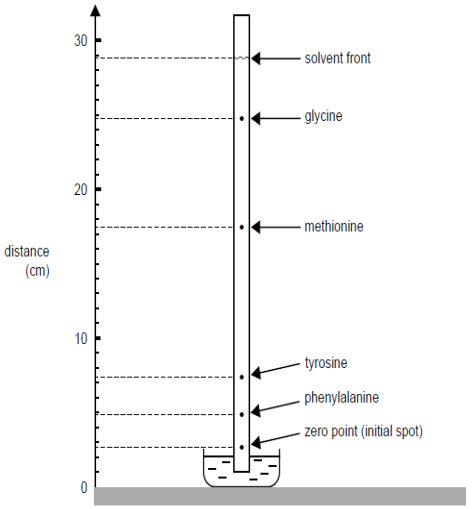
Sol. [HCOOH] = 0.10 M; $[H^+] = [HCOO^-]$

$1.8x10^{-4} = [H^+]2 / 0.10 \rightarrow [H^+]2 = 1.8x10^{-4} \times 0.10$

$[H^+] = \sqrt{(1.8x10^{-5})} = 4.2x10^{-3}$ M

$[HCOO^-] = 4.2x10^{-3}$ M

Q45. Chromatography is often used for the analysis of the mixture of amino acids that is formed when proteins are broken down. The small protein methionine enkephalin has some pain killing activity. An aqueous solution of methionine enkephalin is broken down into its constituent amino acids and the resultant solution of amino acids is subjected to paper chromatography. A strip from such a chromatogram is shown below.



Amino acids are colourless, but the position of an amino acid spot on the strip can be seen by spraying the strip with a solution of ninhydrin, a substance that reacts with amino acids to produce an intense purple colour.

a. The identities of the four amino acids in this particular mixture have been determined by measuring their Rf values.

i. Explain how an R_f value is calculated.

Sol. By working out the ratio of the 'distance moved by the substance from the origin (zero point/initial spot)' to the 'distance moved by the solvent front the origin (zero point/initial spot)'.

ii. Calculate the Rf of the methionine spot.

Sol. Origin (zero point / initial spot) is located at 2.7 cm

$R_f = (17.4 – 2.7) / (28.8 – 2.7)$

$= 14.7 / 26.1 = 0.56 \pm 0.02$

b. Describe how the sample containing the mixture of the four amino acids was added to the paper in order to begin the procedure.

Sol. The mixture was added with a capillary tube or dropping pipette or as a small drop at the zero point/initial spot.

c. What factors determine the different R_f values of the different amino acids?

Sol. The relative extent of the attraction of the amino acids to the stationary phase (paper)/ (adsorption to the stationary phase) and their attraction to the mobile phase (solubility in the mobile phase).

Q46. a. The Earth's oceans contain significant amounts of dissolved carbon dioxide. The dissolving process can be described by the following chemical equilibria.

$CO_2(g)$ $CO_2(aq)$

$CO_2(aq) + H_2O(l)$ $H^+(aq) + HCO_3^-(aq)$

Use this information to explain the likely effect of the increasing concentration of atmospheric CO_2 on the pH of seawater at the ocean surface.

Sol. pH = 7.4 → $[H^+] = 10^{-7}.4$ M or $4.0x10^{-8}$ M

b. Several different acid-base systems contribute to the hydrogen ion concentration in blood. One of these systems is represented by the equilibrium:

$CO_2(aq) + H_2O(l)$ $H^+(aq) + HCO_3^-(aq)$ $K_a = 7.9 \times 10^{-7}$

The concentration of $CO_2(aq)$ in freshly oxygenated blood is approximately 1.3×10^{-5} M and the pH of blood is 7.4.

i. Calculate the concentration of the hydrogen ion, H^+, in fresh blood.

Sol. pH = 7.4 → $[H^+] = 10^{-7}.4$ M or $4.0x10^{-8}$ M

ii. Calculate the concentration of the hydrogen carbonate ion, HCO_3^-, in fresh blood.

Sol. $Ka= [H^+][HCO_3^-] / [CO_2]$

$7.9x10^{-7} = 4.0x10^{-8} \times [HCO_3^-]/ 1.3x10^{-5}$

$[HCO3-] = 7.9x10^{-7} \times 1.3x10^{-5}/ 4.0x10^{-8}$

$= 2.6x10^{-4}$ M

Q47. Pyrolusite, an ore of manganese, contains manganese in the form of MnO_2. A sample of pyrolusite from a newly discovered deposit is analysed to determine the degree of purity of the deposit.

To determine the amount of Mn in the pyrolusite sample, 1.25 g of dried pyrolusite was heated with 100 mL of 0.150 M oxalic acid ($H_2C_2O_4$). The oxalic acid was in excess, so that all of the MnO_2 reacted according to

$MnO_2(s) + H_2C_2O_4(aq) + 2H+(aq) \rightarrow Mn^{2+}(aq) + 2CO_2(g) + 2H_2O(l)$

20.00 mL of the resulting solution is then titrated with an 0.0510 M solution of the triiodide ion

$I_3^-(aq) + H_2C_2O_4(aq) \rightarrow 2CO_2(g) + 2H^+(aq) + 3I^-(aq)$

22.00 mL of the 0.0510 M triiodide solution was needed to react with the remaining oxalic acid.

a. Calculate the amount in mole of oxalic acid remaining in the original 100 mL solution after the pyrolusite had been reacted with the oxalic acid.

Sol.

$n(H_2C_2O_4)$ in 20 mL = $n(I_3^-)$ = 0.0510 x $22.00x10^{-3}$ = $1.12x10^{-3}$ mol

$n(H_2C_2O_4)$ in 100 mL = 100 / 20 x $1.12x10^{-3}$ =$5.60x10^{-3}$ mol ($5.61x10^{-3}$)

b. Calculate the amount in mole of oxalic acid used to reduce the MnO2 in the 1.25 g of pyrolusite.

Sol. $n(H_2C_2O_4)$ initially = 0.150 x $100x10^{-3}$ = $1.50x10^{-2}$ mol

$n(H_2C_2O_4)$ used = $n(H_2C_2O_4)$ initially – n(H2C2O4) remaining

= $1.50x10^{-2}$ – $5.60x10^{-3}$

= 9.40x10-3 mol (**9.39x10**$^{-3}$)

c. Calculate the amount in mole of MnO_2 present in the original 1.25 g of pyrolusite and hence the percentage of MnO_2 by mass present in the pyrolusite.

Sol. $n(MnO_2)$ present = $n(H_2C_2O_4)$ reacting = $9.40x10^{-3}$ mol

$m(MnO_2)$ present = $9.40x10^{-3}$ x 86.9

= 0.816 g

% MnO_2 = (0.816 / 1.25) x 100

= 65.3 %

Q48. The gases evolved at the positive and negative electrodes are

	Positive electrode	Negative electrode
a.	oxygen	hydrogen
b.	hydrogen	oxygen
c.	chlorine	hydrogen
d.	hydrogen	chlorine

Q49. During this electrolysis, the pH of the solution will

a. decrease around the cathode and increase around the anode.

b. increase around the cathode and decrease around the anode.

c. decrease at both electrodes.

d. increase at both electrodes

Q50. Suspicions are raised that a sample of soft drink has become accidentally contaminated with a small amount of lead in the form of Pb^{2+}(aq).The most suitable analytical method of testing for the presence of Pb^{2+} in the sample is

a. gas chromatography.

b. paper chromatography.

c. uv-visible spectroscopy.

d. atomic absorption spectroscopy

Sol. d. atomic absorption spectroscopy. Atomic absorption spectroscopy is commonly used for determining the amount of metal ion present in a solution/ sample.

Q51. Ethanol is now added to some brands of petrol in order to replace some of the hydrocarbons with a renewable resource.

The most suitable analytical method of testing for the presence of ethanol in a sample of petrol is

a. gas chromatography.

b. paper chromatography.

c. flame tests.

d. atomic absorption spectroscopy.

Sol. a. Ethanol and the other components of petrol are volatile and most readily separated and identified by gas chromatography.

Q52. An aqueous mixture of two substances (Y and Z) is subjected to analysis by both paper chromatography and high performance liquid chromatography (HPLC). In both forms of chromatography, component Z of the mixture was bonded more strongly to the stationary phase than component Y.
In terms of Rf and Rt, where Rt is the retention time in HPLC, component Z has the

A.	higher R_f	higher R_t
B.	higher R_f	lower R_t
C.	lower R_f	higher R_t
D.	lower R_f	lower R_t

Sol. c. In paper chromatography the species more strongly attracted to the stationary phase moves the shorter distance up the paper and so has the lower Rf value.
In HPLC the species more strongly attracted to the stationary phase remains inthe column longer and has the higher R_t.

Q53. In the 19th century, relative atomic masses (RAMs) were determined by gravimetric analysis. In a particular experiment, to determine the RAM of a metal (X), 3.27 g of X was completely reacted with oxygen to produce 4.07 g of the oxide of formula XO. The RAM of X is:
a. 12.8
b. 32.7
c. 65.4
d. 130.8
Sol. c. m(X) = 3.27 g
n(X) = 3.27 / M(X)
m(O) = 4.07 – 3.27 = 0.80 g
n(O) = 0.80 / 16.0 = 0.050 mol
Since n(X) = n(O) → 3.27 / M(X) = 0.050
3.27 = 0.050 x M(X)
M(X) = 3.27 / 0.050 = 65.4 g mol^{-1}
Ar(X) = 65.4

Q54. 10^{-2} mole of HCl is added to exactly 1.00 L of pure water at 25ºC**.**
The change in pH of the water is closest to
a. 10^{-2}
b. 2
c. 5
d. 7
Sol. c. pH of pure water at 25°C = 7
Since HCl(aq) is a strong acid, 10^{-2} mol HCl → 10^{-2} mol H^+
Assuming the addition of HCl does not change the total volume
[H+] = n(H^+) / V =10^{-2}/1.00 = 10^{-2} M
[H^+] = 10^{-2} M → pH = 2
So pH has decreased from 7 to 2, i.e. by 5.

Q55. A sample of fertiliser was analysed and found to contain 80% by mass of ammonium nitrate (NH_4NO_3) and 20% by mass of potassium chloride (KCl).
The mass of nitrogen in a 1.00 kg packet of the fertiliser is
a. 140 g
b. 175 g
c. 280 g
d. 350 g
Sol. c. m(NH_4NO_3) = (80/100) x 1000 g = 800 g
n(NH_4NO_3) = 800 / 80.0 = 10.0 mol
n(N) = 2 x n(NH_4NO_3) = 20.0 mol

m(N) = n(N) x M(N)
= 20.0 mol x 14.0 g mol^{-1}= 280 g

Q56. A standard solution of potassium permanganate ($KMnO_4$) has a concentration of 0.0240 M. It is titrated against a solution of iron (II) sulfate ($FeSO_4$).
The equation for the reaction is
$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$
15.60 mL of the $KMnO_4$ solution reacts exactly with 20.00 mL of the $FeSO_4$ solution. The concentration of the $FeSO_4$ solution, in M, is
a. 0.0187
b. 0.0307
c. 0.0936
d. 0.1540
Sol. $n(MnO_4^-)$ reacting = $n(KMnO_4)$ = $c(KMnO_4)$ x $V(KMnO_4)$
= 0.0240 x $15.60x10^{-3}$
= $3.74x10^{-4}$ mol
$n(Fe^{2+})$ reacting = 5 x $n(MnO_4^-)$ = 5 x $3.74x10^{-4}$ = $1.87x10^{-3}$ mol
$c(FeSO_4)$ = $c(Fe^{2+})$ = $n(Fe^{2+})$ / $V(FeSO_4)$ = 1.87x10-3 / $20.00x10^{-3}$
= 0.0936 M

Q57. 25.00 mL of a 0.100 M solution of HCl is added to 25.00 mL of a 0.180 M solution of NaOH.
The concentration of $OH^-(aq)$ remaining in the solution, in M, is
a. 0.0400
b. 0.0500
c. 0.0800
d. 0.1000
Sol. a. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
n(HCl) = c(HCl)V(HCl) = 0.100 x $25.00x10^{-3}$ = $2.50x10^{-3}$ mol
n(NaOH) = c(NaOH)V(NaOH) = 0.180 x $25.00x10^{-3}$ = $4.50x10^{-3}$ mol
n(NaOH) reacting = n(HCl) = $2.50x10^{-3}$ mol
n(NaOH) remaining = $4.50x10^{-3}$ – $2.50x10^{-3}$ = $2.00x10^{-3}$ mol
$[OH^-]$ remaining = $n(OH^-)$ remaining / V(mixture)
= $2.00x10^{-3}$ / $50.00x10^{-3}$
= 0.0400 M

Q58. For the reaction: $H_2O(l)$ $H^+(aq) + OH^-(aq)$, Kw = 10^{-14} at 25ºC, 55.9 kJ mol–1 of heat is evolved when one mole of $H^+(aq)$ reacts with one mole of $OH^-(aq)$.
At 80ºC, the Kw and pH for pure water is

	K_w	pH
A.	greater than 10^{-14}	less than 7
B.	greater than 10^{-14}	greater than 7
C.	less than 10^{-14}	less than 7
D.	less than 10^{-14}	greater than 7

Sol. a. The reaction $H^+(aq) + OH^-(aq) \rightarrow H_2O$ is exothermic. So the equilibrium $H_2O(l)$ $H^+(aq) + OH^-(aq)$ is endothermic
At 25°C; Kw = 10^{-14}, pH = 7
At 80°C the position of equilibrium will lie further to the right, so $[H^+]$ and [OH-] will be greater.
Hence Kw{=$[H^+][OH^-]$} will be>10^{-14} and pH{=-log10$[H^+]$} will be<7.

Q59-61. NaOCl is completely dissociated in water to form $Na^+(aq)$ and $OCl^-(aq)$. In solution, OCl^- hydrolyses according to the equation

$OCl^-(aq) + H_2O(l) \rightarrow HOCl(aq) + OH^-(aq)$

Q59. 100 mL of pure water at constant temperature is added to a 100 mL solution of 0.10 M NaOCl.
When the solution reaches equilibrium again, the
a. $[H^+]$ has decreased.
b. pH of the solution has decreased.
c. concentration of HOCl has increased.
d. value of the equilibrium constant has halved.
Sol. b. The addition of 100 mL of water to 100 mL of 0.10 M NaOCl doubles the volume and instantaneously halves the concentrations of $OCl^-(aq)$, HOCl(aq) and OH.(aq). This halves the value of the concentration fraction, i.e. $[HOCl][OH^-] / [OCl^-]$, so the value of the concentration fraction becomes less than Kc. To restore equilibrium the concentration fraction must increase so the forward reaction is favoured. So the addition of water also pushes the equilibrium
$OCl^-(aq) + H_2O(l) \leftrightarrow HOCl(aq) + OH^-(aq)$ to the right.
Whilst this shift in equilibrium position increases the n(HOCl) and $n(OH^-)$ theincrease is not enough to fully compensate for the impact of the volumeincrease on the [HOCl] and $[OH^-]$.
The overall effect of the addition of 100 mL of pure water is that the [HOCl] decreases and $[OH^-]$ decreases. The decrease in $[OH^-]$ causes an increase in $[H^+]$} and the pH to decrease.

Q60. If K1 is the equilibrium constant for the reaction (1) above, then the value of K_2, the equilibrium constant for the reaction
$2OCl–(aq) + 2H_2O(l) \rightarrow 2HOCl(aq) + 2OH–(aq)$ (2)
at the same temperature, is equal to
a. K1
b. 2 × K1
c. 4 × K1
d. $K1^2$
Sol. d. $K_1 = [HOCl][OH^-] / [OCl^-]$
$K_2 = [HOCl]^2[OH^-]^2 / [OCl^-]^2$
$= ([HOCl][OH^-] / [OCl^-])^2 = K_1^2$

Q61. The HOCl produced in a solution of NaOCl can react further to produce small amounts of chlorine, Cl2(aq), in water according to the equation:
$HOCl(aq) + H^+(aq) + Cl^-(aq)\ Cl_2(aq) + H_2O(l)$
Which of the following, when added to a solution of NaOCl, would not raise the concentration of Cl_2 in the solution?
a. NaCl
b. NaOH
c. H_2SO_4
d. HOCl
Sol. b. An increase in the $[Cl_2]$ results from the position of equilibrium moving to the right. Consider the alternativesa**.** Adding NaCl, increases $[Cl^-]$ and position of equilibrium moves right.
b. Adding NaOH, reduces $[H^+]$ – as it reacts with OH^- so the position of equilibrium moves left.

c. Adding $H_2SO_4(aq)$, increases $[H^+]$ and position of equilibrium moves right.
d. Adding HOCl pushes the position of equilibrium to the right.
So the addition of NaOH will not raise the $[Cl^2]$.

Q62. The Ka of hydrofluoric acid, HF, is 6.8×10^{-4}.
The pH of a 0.10 M solution of HF in water is closest to
a. 1
b. 2
c. 3
d. 4

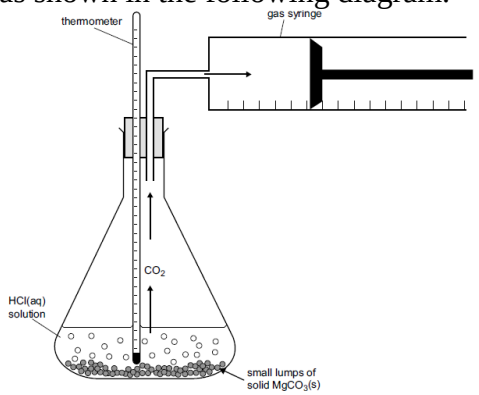
Sol. b. $HF(aq)\ H^+(aq) + F^-(aq)$
$Ka = [H^+][F^-] / [HF]$
Since HF is a weak acid $[H^+]e = [F^-]e$ and $[HF]e = 0.10$
$6.8x^{10-4} = [H^+]^2 / 0.10 \rightarrow [H^+]^2 = 0.10 \times 6.8x10^{-4}$
$[H^+] = \sqrt{(6.8x10^{-5})} = 8.2 \times 10^{-3}$
$pH = -\log10(8.2x10^{-3}) = 2.1$

Q63. 100 mL of 1.00 M HCl is added to a 2 g piece of limestone, $CaCO_3$.
Which of the following will not increase the initial rate of this reaction?
a. adding 150 mL of 1 M HCl in place of 100 mL of 1 M HCl
b. adding 100 mL of 2 M HCl in place of 100 mL of 1 M HCl
c. heating the 100 mL of 1 M HCl before adding it to the limestone
d. adding 100 mL of 1 M HCl to powdered $CaCO_3$ in place of the single piece of limestone

Sol. a. Alternatives B, C and D all refer to factors that increase the rate of reaction, namely increase in concentration, increase in temperature and increase in surface area.

Q64. The main source of the element magnesium in Australia is the ore magnesite, in which magnesium is present as magnesium carbonate ($MgCO_3$).
a. Calculate the percentage by mass of magnesium in magnesium carbonate.

Sol.
1. % Mg = M(Mg) / M($MgCO_3$) x 100 = (24.3 / 84.3) x 100 = 28.8 %
b. Magnesium carbonate reacts with aqueous hydrochloric acid according to the reaction
$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$
A series of laboratory experiments was set up to study the rate of this reaction under some different conditions. The initial reaction rate was determined by measuring the rate of evolution of CO_2 in a gas syringe as shown in the following diagram.



Four experiments were carried out as follows. In each case, the amount of HCl present was in excess.

Experiment	[HCl] (M)	Mass of $MgCO_3$(g)	Initial temp in °C	Final temp in °C	Initial rate of CO_2 evolution in $mL\ min^{-1}$
1	0.10	1.0	20	25	5
2	0.10	1.0	30	35	50
3	0.10	2.0	20	30	10
4	0.20	1.0	20	25	20

i. Is the reaction exothermic or endothermic? Explain how you can tell from these results.

Sol. Exothermic. The temperature increase – final temperature higher than the initial temperature – in each experiment shows that energy is released as reaction proceeds.

ii. Considering experiments 1 and 2, explain why the increase in the initial temperature has raised the reaction rate.

Sol. Increased temperature increases the number of collisions with energy greater than the activation energy* / fruitful collisions / collisions that lead to reaction / energetic collisions / successful collisions.

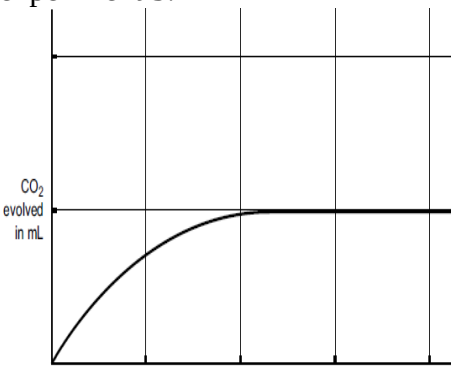
iii. Considering experiments 1 and 3, explain why the greater mass of magnesium carbonate would have increased the reaction rate.

Sol. Increased amount of $MgCO_3$ provides a greater surface area* for reaction.

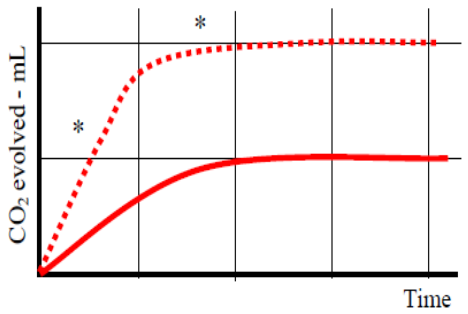
iv. Considering experiments 1 and 4, explain why the higher concentration of HCl would have increased the reaction rate.

Sol. Higher c(HCl), and hence higher $c(H^+)$, means more frequent collisions between $H^+(aq)$ and $MgCO_3$*.

v. Results from experiment 1 are plotted on the sketch graph below. On the same axes, sketch the results from experiment 3.



Sol.



Q65. a. In order to help prevent tooth decay, fluoride ions at a level of 0.9 mg L^{-1} of F^- are added to Melbourne's public water supplies. The fluoride ions are obtained by adding sodium fluoride (NaF) to the water.

i. Calculate the mass of sodium fluoride in mg that must be present in one litre of water to produce a concentration of fluoride ions of 0.90 mg L^{-1}.

Sol. $n(NaF) = n(F^-) = 0.90 \times 10^{-3} / 19$
$= (4.74 \times 10^{-5}$ mol)
$m(NaF) = (4.74 \times 10^{-5}) \times 42.0$
$= 2.0 \times 10^{-3}$ g = 2.0 mg
Alternatively

% F in NaF = [M(F) / M(NaF)] x 100
= (19.0 / 42/0) x 100
= 45.2 %
So 0.90 mg = 45.2 % of m(NaF)
= 0.452 x m(NaF)
m(NaF) = 0.90 / 0.452 = 2.0 mg

ii. What mass of sodium fluoride, in kilogram, must be added to a 750 ML reservoir (1 ML = 106 L) to produce a concentration of fluoride ions of 0.90 mg L–1?

Sol.1. m(NaF)=2.0mg L^{-1}x750x10^{-6} L = 1.5x10^{9} mg = 1.5x10^{6} g = 1.5x10^{3} kg

iii. Calculate the number of fluoride ions swallowed by a person who drank one litre of water from the reservoir.

Sol. n(F^-) in 1 L = 4.74x10^{-5} mol from (i)
N(F^-) in 1 L = 4.74x10^{-5} x 6.02x10^{23} = 2.9x10^{19}

b. One method of determining the concentration of fluoride ions in water uses a red-coloured indicator, In, that reacts with fluoride ions in solution to give a colourless product. The reaction can be represented as

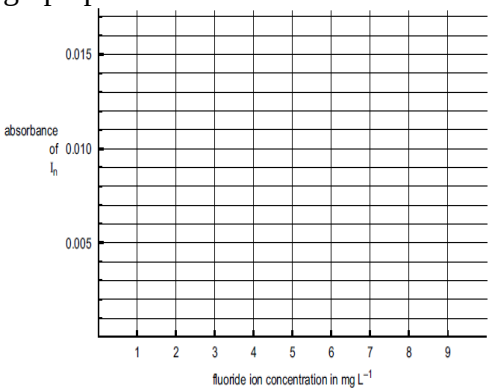
$In(aq) + F^-(aq) \rightarrow FIn^-(aq)$
red-coloured indicator colourless colourless

A calibration curve was prepared using five different aqueous solutions of sodium fluoride, each of known ion concentration. Equation mole of In is then added to 25.00 mL of each of five NaF solutions and an NaF solution of unknown concentration. The intensity of the red In colour of each of the mixtures is then determined using a UV-visible spectrophotometer.

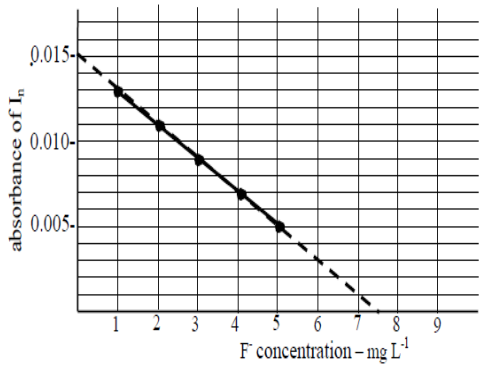
The measured absorbances are given in the following table.

Fluoride ion concentration in mg L^{-1}	Absorbance of I_n
1.00	0.0130
2.00	0.0110
3.00	0.0090
4.00	0.0070
5.00	0.0050
unknown NaF sample	0.0120

i. Draw a calibration curve on the graph provided.



Sol.



ii. Why does the absorbance fall with increasing fluoride ion concentration?

Sol. As the [F^-] increases more In (absorbing species) reacts or [In] decreases.

iii. Use your calibration curve to determine the fluoride ion concentration of the unknown NaF sample in mg L^{-1}.

Sol. 1.5 mg L^{-1} (accept 1.4-1.6mg L^{-1})

iv. What was the value of Q?

Sol. Q mol In was used up at the point the absorbance reached zero.

Q= n(In) = n(F-) at zero absorbance

c(F^-) at zero absorbance = 7.5 mg L^{-1}

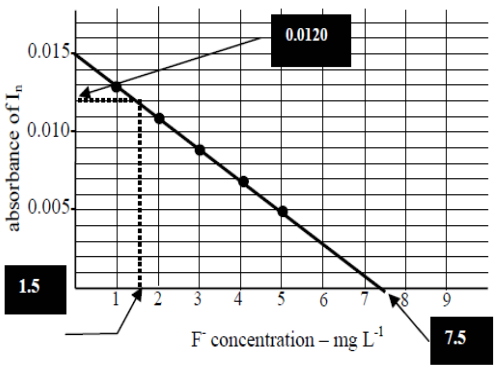
m(F^-) = (25 / 1000) x 7.5

= 0.1875 mg

n(F^-) = 0.1875x10^{-3} / 19

= 9.9x10^{-6} mol

Q= 9.9x10^{-6}



Q66. CO_2 is added to 1.00 L of pure water at 25°C in a pressurised bottle. The pressure of CO_2 above the water was raised to 3.00 atm and the gaseous CO_2 came to equilibrium with the CO_2 dissolved in the water. At equilibrium, the mass of CO_2 dissolved in the water was 5.00 g.

a. The equilibrium constant for this reaction, in atm M^{-1}, can be written as

$$K_n = \frac{p(CO_2, g)}{[CO_2(aq)]}$$

where p(CO_2) represents the pressure of CO_2.

Calculate the value of this equilibrium constant at 25°C**.**

Sol.

n(CO_2) = 5.00/44 = 0.1136 mol

Since V= 1.00 L, [CO_2] = 0.1136 M

Kn = p(CO_2) / [CO_2(aq)]

= 3.00 / 0.1136 = 26.4

b. 500 mL of the aqueous solution of CO_2 is heated to 30°C and then opened to the atmosphere so that effectively all the CO_2 in the aqueous solution escapes into the gas phase. Calculate, in litre, the volume of CO_2 that would be evolved at 1.00 atm pressure and 30°C**.**

Sol. n(CO_2) evolved = n(CO_2) in 0.500 L of the solution

= 0.1136/2 = 0.0568 mol

p(CO_2) = 101.325 kPa

V(CO_2) = nRT / p

= 0.0568 x 8.31x (30+273)/ 101.325

= 1.41 L

c. Dissolved CO_2 acts as a weak acid in water according to the equation

$CO_2(aq) + H_2O(l)$ H+(aq) + HCO_3^- (aq)

and the acidity constant of CO_2 in water at 25°C is given by

$$K_a = \frac{[H^+][HCO_3^-]}{[CO_2]} = 4.5 \times 10^{-7} M^2$$

Some CO2 is added to a solution of NaHCO3 at 25°C**.** In the solution, the concentration of the hydrogen carbonate ions (HCO_3^-) is 0.050 M and the CO2 concentration is 0.0020 M. Calculate the pH of the solution.

Sol. [H^+] = Ka x [CO_2] / [HCO_3^-]

= 4.5x10^{-7} x 0.0020 / 0.050*

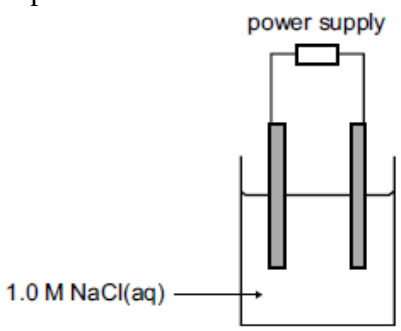
= 1.8x10^{-8}

pH = -log10(1.8x10^{-8})* = 7.7

Q67. A student is planning to set up a demonstration of a galvanic cell using half cells constructed as follows.
• Half cell 1: a calcium electrode in a beaker containing an aqueous solution of Ca^{2+} ions
• Half cell 2: a platinum electrode in a beaker containing an aqueous solution of a mixture of Sn_{4+} and Sn2+ ions
A salt bridge would connect the two beakers. The electrodes would be attached to a voltmeter.
This particular cell is impractical because
a. solid calcium (Ca) will react directly to reduce water to hydrogen gas.
b. there is no solid tin (Sn) in the half cell containing Sn_{4+}(aq) and Sn_{2+}(aq).
c. there are no known ionic compounds of calcium that are soluble in water.
d. Sn^{4+}(aq) will be in contact with Ca and will oxidise it to Ca^{2+}(aq).
Sol. a. solid calcium (Ca) will react directly to reduce water to hydrogen gas.

Q68. 96.5 C of electricity is used to completely deposit silver metal (Ag) from an aqueous solution in which the silver ion is present as Ag^{+}(aq). Another 96.5 C is used to completely deposit copper (Cu) from an aqueous solution in which the copper ion is present as Cu^{2+}(aq).
The silver metal deposited would
a. have half the mass of the copper deposited.
b. have twice the mass of the copper deposited.
c. be half the mole of the copper deposited.
d. be twice the mole of the copper deposited.
Sol. d. be twice the mole of the copper deposited
The same mole of electricity is used to deposit silver from Ag^{+} and copper from Cu^{2+}. It will therefore take two electrons to deposit one copper atom and one electron to deposit one silver atom. Hence, half a mole of copper for every mole of electrons and one mole of silver for each mole of electrons. Twenty per cent of students inverted the result by choosing response c.

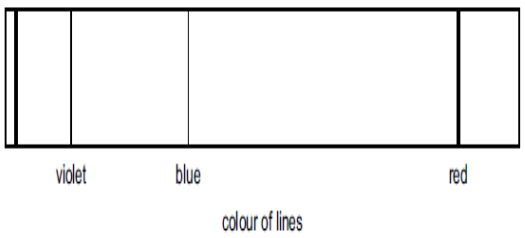
Q69. A student carries out the electrolysis of a 1.0 M solution of sodium chloride using graphite electrodes. The set-up for this experiment is shown below.



a. Write an equation for the half reaction that occurs at the cathode
Sol. $2H_2O + 2e^- \rightarrow H_2 + 2OH$
b. Two different gases are produced at the anode. Write equations for the two half reactions that result in the formation of these two gases.
i. Equation for half reaction that produces gas 1
Sol. $2Cl^- \rightarrow Cl_2 + 2e^-$

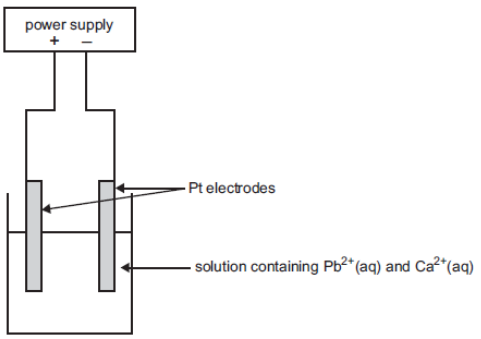
ii. Equation for half reaction that produces gas 2.
Sol. $2H_2O + O_2 + 4H^+ + 4e^-$
c. Using the same current and electrodes, the student carries out a second electrolysis, this time of a saturated solution (approximately 6 M) of sodium chloride instead of a 1.0 M solution. What difference, if any, would you expect in the product or products formed at the
i. cathode?
Sol. No change
ii. anode?
Sol. A greater proportion of chlorine evolved (or only chlorine evolved).

Q70. When a high-voltage electric current is passed through hydrogen gas, light is produced. If the light is passed through a spectrometer an emission spectrum is observed. The visible part of the spectrum is shown in the diagram.



a. Explain how the study of the emission spectrum of hydrogen, with its single electron, has been used to develop an understanding of its electron structure.
Sol. An emission line indicates the existence of a specific energy level difference (between two electron levels); many lines allow us to deduce the existence of a range of energy levels/shells/subshells in the atom.
b. Hydrogen has three isotopes: 1H, 2H, 3H. Would you expect the three isotopes to produce essentially the same atomic emission spectrum?
Sol. The same (or 'nearly the same'). They have the same nuclear charge (or the same number of electrons).

Q71. A mineral ore contains a mixture of compounds of lead and calcium, in approximately equal proportions. A chemist extracts the metal ions by roasting the ore in air and treating the product with acid. The solution that contains the $Pb^{2+}(aq)$ and $Ca^{2+}(aq)$ is then placed in an electrolytic cell as shown in the diagram below.



a. Label the anode and cathode of the cell.
Sol. Students had to correctly label the positive electrode on the left as the anode and the negative electrode as the cathode.
b. When the current begins to flow in the cell, write equations for the half reaction that is likely to occur at the
- positive electrode _____
- negative electrode _____

Sol.

• positive electrode: $2H_2O \rightarrow O^2 +\_4H^+ + 4e^-$

• negative electrode: $Pb^{2+} + 2e^- \rightleftharpoons Pb$ or $2H^+ + 2e^- \rightarrow H_2$

c. After some time has elapsed, a new half reaction occurs at one of the electrodes. Write the equation for this half reaction.

Sol. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ or $Pb^{2+} + 2e^- \rightarrow Pb$

d. If the chemist had used copper electrodes instead of platinum electrodes, how would this have affected the half reaction at the anode?

Sol. The reaction $Cu \rightleftharpoons Cu^{2+} + 2e^-$ would have occurred (or copper would be oxidised/a stronger reductant).

Q72. One type of.breathalyser. instrument used by police for the measurement of the concentration of alcohol in a driver.s breath is a fuel cell. An acidic electrolyte is used. Ethanol is oxidised to ethanoic acid at one electrode and oxygen from the air is converted to water at the other.

The overall equation for this reaction is: $C_2H_5OH(aq) + O_2(g) \rightarrow CH_3COOH(aq) + H_2O(l)$

a. Write the equation for the half reaction at the anode.

Sol. $C_2H_5OH + H_2O \rightleftharpoons CH_3COOH + 4H^+ + 4e^-$

b. A motorist who has consumed alcohol blows into the fuel cell. If the breath entering the cell provides alcohol at the rate of 3.0×10.5g per second, calculate the maximum current, in amps, that the cell would produce.

Sol.

$$\frac{3\times10^{-5}}{46} * = 6.52 \times 10^{-7}\ mol\ s^{-1} \rightarrow$$

$$6.52 \times 10^{-7}\ mol\ s^{-1} \times 4 \times 96\,500\ C\ mol^{-1} *$$

$$= 0.25\ C\ s^{-1} = 0.25\ A *$$

c. The nature of the electrodes in the cell is essential to the effective operation of the breathalyser. State **two** important functions that the electrodes must perform.

Function 1---------

Function 2---------

Sol. Any two of:

• carry current

• catalyse electrode reactions

• porous to oxygen/air

• unreactive.

Q73. The flame test method of analysis can be used to distinguish between:

a. methanol and ethanol.

b. sulfuric acid and nitric acid.

c. lithium nitrate and calcium nitrate.

d. sodium carbonate and sodium chloride.

Sol. c. Flame tests are a simple form of qualitative analysis used to test metallic compounds for the presence of particular metals. They provide a quick means of distinguishing the presence of different metals.

Q74. The molar volume of oxygen, in L, at 1.00 atmosphere and 100°C, is closest to:

a. 30.6

b. 24.5
c. 22.4
d. 8.2
Sol. Molar volume = volume occupied by 1 mol.

$$V = \frac{nRT}{p}$$
$$= \frac{1 \times 8.31 \times 373}{101.3}$$
$$= 30.6 \text{ L}$$

Q75. Sulfuric acid (H_2SO_4) and nitric acid (HNO_3) are both strong acids. Ethanoic acid (CH_3COOH) is a weak acid. 20.00 mL solutions of 0.10 M concentration of each of these three acids were separately titrated with a 0.10 M solution of sodium hydroxide (NaOH).
In order to react completely
a. all three acids would require the same amount of NaOH.
b. HNO_3 would require more NaOH than CH_3COOH but less than H_2SO_4.
c. H_2SO4 and HNO_3 would require the same amount of NaOH but CH_3COOH would require less.
d. CH_3COOH and HNO_3 would require the same amount of NaOH but H_2SO_4 would require more.
Sol. The n(NaOH) required to neutralise an acid depends on the $n(H^+)$ available from the acid rather than the acid strength. So, the fact that CH_3COOH is a weak acid was not a key factor in this equation.
Since the same number of mole of each acid was used, the n(NaOH) required would depend on whether the acid was monoprotic or diprotic.
$CH_3COOH(aq)$ and $HNO_3(aq)$ are both monoprotic and would require the same n(NaOH), hence the same volume of NaOH.
$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$
$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$
H_2SO_4 is diprotic so requires double the n(NaOH), hence double the volume of NaOH, compared to CH_3COOH and HNO_3.
$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
Hence, alternative D is correct.

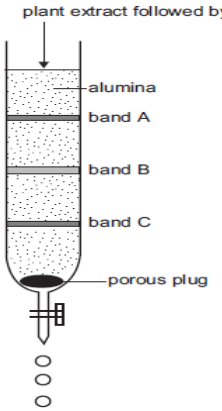
Q76. A student used paper chromatography to separate two components, I and II, in a solution. A spot of the solution was initially placed at the origin.
When the spot corresponding to component I (R_f = 0.50) had advanced 4.0 cm, the spot corresponding to component II was 1.0 cm behind.
The R_f value of component II is closest to
a. 0.68
b. 0.38
c. 0.25
d. 0.13
Sol. b. Since the solvent front moves the same distance for both components,

$$\frac{R_f(II)}{R_f(I)} = \frac{d(II)}{d(I)}$$
$$\frac{R_f(II)}{0.50} = \frac{3.0}{4.0}$$
$$R_f(II) = \frac{0.50 \times 3.0}{4}$$
$$= 0.38$$

Q77. The concentration of K+ ions in 100 mL of 0.0500 M K2CO3 solution, in g L.1, is:
a. 0.196
b. 0.391
c. 1.96
d. 3.91
Sol. d. $K_2CO_3(aq) \rightarrow 2K^+(aq) + CO_3^{2-}(aq)$
$c(K^+) = 2 \times 0.0500$
$0.100 = \text{mol } L^{-1}$
$0.100 = \text{mol } L^{-1} \times 39.1 \text{ g } L^{-1}$
$= 3.91 \text{ g } L^{-1}$

Q78. Methanoic acid and ethanoic acid are both weak acids with the following acidity constants.
K_a in M at 25°**c.**
methanoic acid (HCOOH) 1.82 × 10.4-
ethanoic acid (CH_3COOH) 1.74 × 10.5-
Two separate solutions were prepared, one of 0.1 M methanoic acid and the other of 0.1 M ethanoic acid. Which one of the following would be present in the highest concentration at 25oC?
a. CH_3COOH in the ethanoic acid solution
b. CH_3COO. in the ethanoic acid solution
c. HCOOH in the methanoic acid solution
d. HCOO-. in the methanoic acid solution
Sol. a. $HCOOH(aq) \rightleftharpoons H^+(aq) + HCOO^-(aq)$; $Ka = 1.82 \times 10^{-4}$
$CH3COOH(aq) \rightleftharpoons H^+(aq) + CH3COO^-(aq)$; $Ka = 1.74 \times 10^{-5}$
Since both are weak acids (have low Kas)
$[CH_3COO^-] < [CH_3COOH]$ and $[HCOO^-] < [HCOOH.[$
Since the Ka for methanoic acid is greater than the Ka for ethanoic acid, more of the methanoic ionises in aqueous solution. Consequently،
$]HCOO^-] > [CH_3COO^-]$ and $[HCOOH] < [CH3COOH[$
Therefore, CH_3COOH is the species with the highest concentration.

Q79. A burette packed with Þ nely divided alumina powder (Al_2O_3) was used to separate the components in a plant extract by chromatography. The alumina acts as the stationary phase and water was used as the mobile phase.
A solution of the plant extract was placed at the top of the alumina and, once it had been adsorbed, further water was added periodically. The components separated as three coloured bands, as shown in the diagram below.



a. i. In which one of the three bands, A, B or C, were the components most strongly adsorbed to the stationary phase?

Sol. band A

ii. Band B starts to show signs of separating into two different bands just before it emerges from the bottom of the burette. Give one possible modifcation that could be made to this experiment to more effectively separate band B into its separate components.

Sol. Acceptable solutions included:

• change/ modify the stationary phase; for example, make the column longer or use more finely divided Al_2O_3.

• change the mobile phase

• change the temperature.

b. In another experiment, the components in the plant extract were separated in a similar way to paper chromatography, using a glass sheet coated with alumina and water as the mobile phase. Which one of the three bands, A, B or C, contains the component that would be most likely to have the smallest Rf value?

Sol. Band A because:

• it is the band most strongly attracted/adsorbed to the stationary phase

• it moves the least distance from the origin relative to the solvent front.

c. Which one of the three bands, A, B or C, contains the component that would have the smallest retention time if this separation was conducted using a high-performance liquid chromatograph with alumina as the stationary phase?

Sol. Band C because:

• it is the band that passes through the column fastest

• it is least strongly attracted/adsorbed to the stationary phase.

Q80. A soluble fertiliser contains phosphorus in the form of phosphate ions (PO_4^{3-}). To determine the PO_4^{3-} Content by gravimetric analysis, 5.97 g of the fertiliser powder was completely dissolved in water to make a volume of 250.0 mL. A 20.00 mL volume of this solution was pipetted into a conical flask and the PO_4^{3-} ions in the solution were precipitated as $MgNH_4PO_4$. The precipitate was Þ ltered, washed with water and then converted by heating into $Mg_2P_2O_7$. The mass of $Mg_2P_2O_7$ was 0.0352 g.

a. Calculate the amount, in mole, of $Mg_2P_2O_7$.

Sol.

$$n(Mg_2P_2O_7) = \frac{0.0352}{222.6}$$
$$= 1.58 \times 10^{-4} \text{ mol}$$

b. Calculate the amount, in mole, of phosphorus in the 20.00 mL volume of solution.

Sol.

$$n(\mathrm{P}) = 2 \times n(\mathrm{Mg_2P_2O_7})$$
$$= 2 \times 1.58 \times 10^{-4}$$
$$= 3.16 \times 10^{-4} \text{ mol}$$

c. Calculate the amount, in mole, of phosphorus in 5.97 g of fertiliser.

Sol.

$$n(\mathrm{P}) \text{ in fertiliser sample} = n(\mathrm{P}) \text{ in 250 mL of solution}$$
$$= \left(\frac{3.16 \times 10^{-4}}{20}\right) \times 250$$
$$= 3.95 \times 10^{-3} \text{ mol}$$

d. Calculate the percentage of phosphate ions (PO_4^{3-}.) by mass in the fertiliser. Ensure you express your **Sol.** to an appropriate number of signifcantfgures.

Sol.

$$n(PO_4^{3-}) = n(P)$$
$$= 3.95 \times 10^{-3} \text{ mol}$$
$$m(PO_4^{3-}) = 3.95 \times 10^{-3} \times 95.0 \ *$$
$$= 0.376 \text{ g}$$
$$\%PO_4^{3-} = \left(\frac{0.376}{5.97}\right) \times 100$$
$$= 6.29\% \ *$$

e. i. Several actions which could occur during this analytical procedure are listed below (**A.D**). For each action, indicate the likely effect on the calculated percentage of phosphate ions in the fertiliser by placing a tick in the appropriate box.

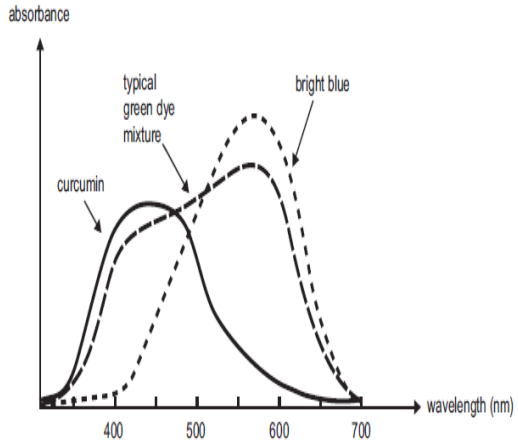
Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The $MgNH_4PO_4$ precipitate was not washed with water.			
B. The conical flask had been previously washed with water but not dried.			
C. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			
D. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.2 g higher than the actual mass.			

Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The $MgNH_4PO_4$ precipitate was not washed with water.			✓
B. The conical flask had been previously washed with water but not dried.		✓	
C. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			✓
D. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.2 g higher than the actual mass.	✓		

ii. In the case of action B above, explain your reasoning for the solution that you have given.

The presence of water does not affect the n(PO_4^{3-}) or the n(P) in the conical flask or the amount of fertiliser (solution) added to the flask; hence, the m($Mg_2P_2O_7$) or m(precipitate) is not affected.

Q81. A green dye used to colour tinned peas is made by mixing the yellow chemical, curcumin, with another colouring agent called bright blue. The individual spectra of curcumin, bright blue and a typical green dye are represented below.



UV-visible spectroscopy is used to analyse the curcumin content of tinned peas.

a. Circle the wavelength below which would be best used for absorbance measurements to determine the curcumin content of the peas.

400 nm 450 nm 500 nm 550 nm 600 nm 650 nm

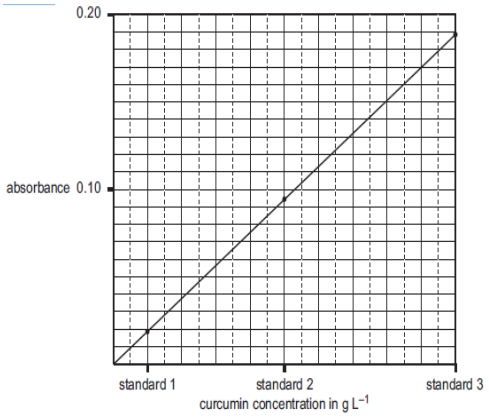
Sol. 400 nm

b. In one analysis, a stock solution of curcumin was prepared by dissolving 0.100g of curcumin ($C_21H_{20}O_6$; molar mass = 368.0 g mol.1) in 250.0 mL of water.

The stock solution was then diluted to make the following three standard solutions.

standard solution	curcumin concentration in g L^{-1}
standard 1	1.00×10^{-3}
standard 2	5.00×10^{-3}
standard 3	1.00×10^{-2}

The absorbances of the standard solutions at the chosen wavelength were measured and the following calibration line was obtained.



i. Calculate the concentration of curcumin in the stock solution in mol L.1.

Sol.

$$n(\text{curcumin}) \text{ in stock solution} = \frac{0.100}{368}$$
$$= 2.72 \times 10^{-4} \text{ mol } *$$
$$c(\text{curcumin}) \text{ in stock solution} = \frac{2.72 \times 10^{-4}}{250.0 \times 10^{-3}}$$
$$= 1.09 \times 10^{-3} \text{ mol L}^{-1} *$$

Alternatively:

m(curcumin) in 1 L = 0.400 g *

$$n(\text{curcumin}) \text{ in 1 L} = \frac{0.400}{368}$$
$$= 1.09 \times 10^{-3} \text{ mol } *$$
$$c(\text{curcumin}) = 1.09 \times 10^{-3} \text{ mol L}^{-1}$$

ii. What volume of water must be added to 10.0 mL of the stock solution to make standard 3?

Sol.

$$m(\text{curcumin}) \text{ in standard 3} = m(\text{curcumin}) \text{ in 10 mL stock solution}$$
$$= \left(\frac{0.400}{1000}\right) \times 10 \text{ or } \left(\frac{0.100}{250}\right) \times 10$$
$$= 4.00 \times 10^{-3} \text{ g}$$

$$c(\text{curcumin}) \text{ in standard 3} = 1.00 \times 10^{-2} \text{ g L}^{-1}$$
$$V(\text{stock solution}) = \frac{m(\text{curcumin})}{c(\text{curcumin})}$$
$$= \frac{4.00 \times 10^{-3} \text{ g}}{1.00 \times 10^{-2} \text{ g L}^{-1}}$$
$$= 0.400 \text{ L}$$
$$= 400 \text{ mL } *$$

$$V(\text{water}) = 400 - 10$$
$$= 390 \text{ mL } *$$

iii. The curcumin in a 9.780 g sample of peas was extracted into solution. The solution was faltered and made up to 100 mL in a volumetric flask. The absorbance of the solution at the wavelength used in the above calibration was found to be 0.170.
Calculate the curcumin content of the peas in milligram per gram of peas.

Sol. From the graph, an absorbance of 0.170 corresponds to c(curcumin) = 9.00×10^{-3} g L^{-1}
Since the curcumin from the peas was extracted into 100 mL of solution,

$$m(\text{curcumin}) \text{ in peas sample} = 0.100 \text{ L} * \times 9.00 \times 10^{-3} \text{ g L}^{-1}$$
$$= 9.00 \times 10^{-4} \text{ g}$$
$$= (0.900 \text{ mg})$$

$$\text{curcumin content} = \frac{m(\text{curcumin}) \text{ in mg}}{m(\text{peas}) \text{ in g}}$$
$$= \frac{0.900}{9.780}$$
$$= 0.0920 * \text{ mg/g}$$

Q82.a. The hydrogen carbonate ion (HCO_3) can act both as an acid and as a base.

i. Write a chemical equation that shows HCO_3 acting as an acid when it reacts with water.

Sol. $HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$, or

$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$

ii. Write a chemical equation that shows HCO_3 acting as a base when it reacts with water.

Sol.

$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$, or

$HCO_3^-(aq) \rightleftharpoons CO_2(g \text{ or } aq) + OH^-(aq)$

b. Hypochlorous acid (HOCl) is a weak acid with an acidity constant, Ka, of 3.0 × 10.8 M at 25°C**.** Calculate the pH of a 0.50 M solution of hypochlorous acid at that temperature.

Sol.

$$HOCl(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$$
$$K_a = \frac{[H^+][ClO^-]}{[HOCl]} \text{ or } \frac{[H_3O^+][ClO^-]}{[HOCl]}$$
$$= \frac{[H^+]^2}{[HOCl]}$$
$$3.0 \times 10^{-8} = \frac{[H^+]^2}{0.50} *$$
$$[H^+]^2 = 0.50 \times 3.0 \times 10^{-8}$$
$$[H^+] = \sqrt{(0.50 \times 3.0 \times 10^{-8})}$$
$$= 1.2 \times 10^{-4} \text{ M } *$$
$$\text{pH} = -\log(1.2 \times 10^{-4})$$
$$= 3.9*$$

c. The hydrogen ion concentration of a solution is described by the term pH. The hydroxide ion (OH.) concentration is described in the same way by the term pOH.
A solution has a pOH of 3 at 25°C**.**

i. Calculate the hydroxide ion concentration of the solution, in mol L.1.

Sol.

$$[OH^-] = 10^{-\text{pOH}}$$
$$= 10^{-3} \text{ M}$$

ii. Calculate the hydrogen ion concentration of the solution, in mol L.1.

$$[H^+] = \frac{10^{-14}}{10^{-3}} = 10^{-11}\ M$$

Q83. In solution, pale yellow-coloured Fe3+(aq) and colourless SCN.(aq) form an equilibrium with $FeSCN^{2+}$(aq). $FeSCN^{2+}$(aq) is red in colour.

Fe^{3+}(aq) + SCN.(aq) ⇌ $FeSCN^{2+}$(aq); ΔH negative red colour

a. A student investigates this reaction using separate samples of an equilibrium mixture in which significant quantities of Fe^{3+}, SCN. and $FeSCN^{2+}$ are present. In each case changes are made as indicated in the table below.

Complete the table by placing ticks in the appropriate boxes to indicate the effect of each change on

I. the intensity of the red colour of the solution; and

II. the concentration of Fe^{3+}(aq)

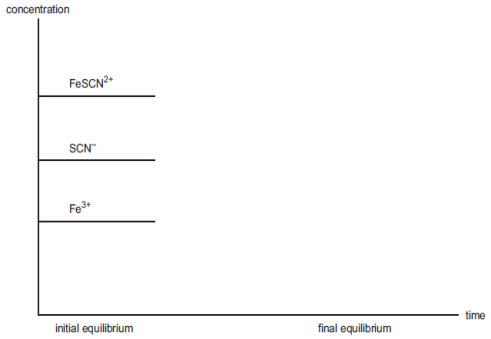
once the new equilibrium has been established.

Change to the equilibrium	I. Colour at new equilibrium compared with initial equilibrium		II. $[Fe^{3+}]$ at new equilibrium compared with initial equilibrium	
	less red	more red	decreased	increased
Sample 1: 1 drop of a concentrated solution of Ag^+(aq) is added, which forms a AgSCN precipitate				
Sample 2: 1 drop of a concentrated solution of Fe^{3+}(aq) is added				
Sample 3: 1 drop of a concentrated solution of HPO_4^{2-}(aq) is added, which forms colourless $FeHPO_4^+$(aq)				
Sample 4: Addition of a large volume of water				

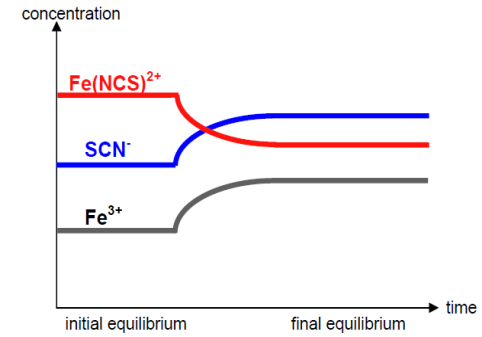
Sol.

Change to the equilibrium	I. Colour at new equilibrium compared with initial equilibrium		II. $[Fe^{3+}]$ at new equilibrium compared with initial equilibrium	
	less red	more red	decreased	increased
Sample 1: 1 drop of a concentrated solution of Ag^+(aq) is added, which forms a AgSCN precipitate	✓			✓
Sample 2: 1 drop of a concentrated solution of Fe^{3+}(aq) is added		✓		✓
Sample 3: 1 drop of a concentrated solution of HPO_4^{2-}(aq) is added, which forms colourless $FeHPO_4^+$(aq)	✓		✓	
Sample 4: Addition of a large volume of water	✓		✓	

b. The reaction is exothermic. The graph below represents the initial concentrations of the ions at equilibrium. Sketch the changes that would be expected to occur to these concentrations if the temperature of the equilibrium mixture was increased to a new, constant value.



Sol.



Q84. Tin metal is electroplated onto sheets of iron using a tin anode and a

well-stirred solution containing Sn^{2+} ions.
During this process
a. the anode increases in mass.
b. Sn^{2+} ions move towards the cathode.
c. the concentration of Sn^{2+} in the solution decreases.
d. the concentration of Sn^{2+} in the solution increases.

Q85. The calibration factor of a calorimeter can be determined by performing in the calorimeter a reaction which produces a known quantity of energy, and measuring the rise in temperature.
In one experiment, 50.0 mL of 0.400 M lead nitrate was added to 50.0 mL of 0.760 M potassium iodide in a solution calorimeter encased in a polystyrene insulating jacket. The mixture was stirred continuously and the temperature rose from 18.42°C to 20.50°C as the following reaction occurred.
$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$; $\Delta H = -49.0$ kJ mol.1
a. Calculate the amount, in mole, of lead nitrate.
Sol. $0.0500 \times 0.400 = 0.0200$ mol
b. Calculate the amount, in mole, of potassium iodide.
Sol. $0.0500 \times 0.760 = 0.0380$ mol
c. Calculate the energy released by the reaction in the calorimeter, in J.2
Sol.

$$\text{Energy} = \left|\frac{0.038}{2}\right| \times 49000 = 931 \text{ J}$$

d. Calculate, to an appropriate number of significant figures, the calibration factor of the calorimeter and its contents, in J°C.1.
Sol.

$$\frac{931}{20.5 - 18.42} = 448$$

e. Two errors that might have occurred during this experiment are listed below. For each error, indicate the likely effect on the calculated calorimeter factor by placing a tick in the appropriate box.

Error	Calculated calibration factor too low	No effect on calculated calibration factor	Calculated calibration factor too high
i. The concentration of the lead nitrate solution had been incorrectly recorded and was actually 0.410 M			
ii. The calorimeter was not placed in its polystyrene jacket			

Sol.

Error	Calculated calibration factor too low	No effect on calculated calibration factor	Calculated calibration factor too high
i. The concentration of the lead nitrate solution has been incorrectly recorded and was actually 0.410 M		✓	
ii. The calorimeter was not placed in its polystyrene jacket			✓

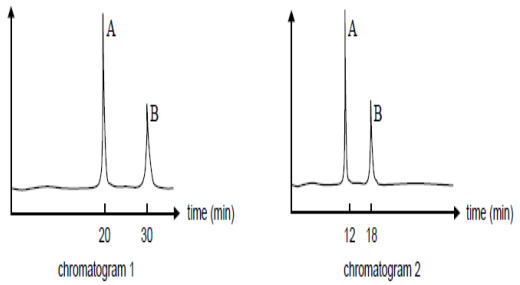
iii. Give an explanation for your solution to part **ii.** above.
Sol.
A lower temperature change leads to a high calibration factor.

Q86. Analysis of the components of a mixture using gas-liquid chromatography normally involves measuring the

a. R_f values of components, using a gas as the mobile phase.
b. R_f values of components, using a liquid as the mobile phase.
c. retention time of components, using a gas as the mobile phase.
d. retention time of components, using a liquid as the mobile phase.
Sol. c. R_f values are characteristic of paper or thin-layer chromatography. Retention times are characteristic of column chromatography, and in gas-liquid chromatography a non-reactive gas is used as the mobile phase.

Q87. Which one of the following analyses is best performed using atomic absorption spectroscopy?
a. measuring the amount of potassium in salt
b. determining the amount of caffeine in coffee
c. measuring the carbonate content of mineral water
d. detecting the presence of ethanoic acid in a sample of wine
Sol. a. Atomic absorption spectroscopy is used to determine the amount of a particular metal present in the sample being analysed.

Q88. Chromatogram 1 was obtained by analysis of a sample of a mixture of two sugars, A and B, using highperformance liquid chromatography (HPLC). Chromatogram 2 was obtained by analysing another sample of the same mixture by HPLC under different conditions.



Consider the following changes which could be made to the operating conditions for HPLC.
I decreasing the pressure of the mobile phase
II decreasing the temperature
III using a less tightly packed column
Which of the changes would be most likely to produce chromatogram 2?
a. I only
b. II only
c. III only
d. I and II only
Sol. c. The lower retention times evident on chromatogram 2 could only be caused by using a less tightly packed column, which would reduce interaction with the stationary phase and speed up progress through the column. Decreasing the pressure of the mobile phase or the temperature would slow down the movement of the mobile phase through the column and thus increase the retention times.

Q89-90. One liter of an aqueous solution of potassium hydroxide (KOH) has a pH of 12.0 at 25°C**.**

Q89. The amount of solid KOH, in mol, that must be added to the solution to raise the pH to 13.0 would be:

a. 10.13
b. 10.12
c. 0.09
d. 0.10
Sol. Since the volume of solution is one litre, n(OH^-) increases by 0.1 – 0.01 = 0.09 mol.
0.09 mol KOH must be added.

Q90. The amount of pure HCl gas, in mol, that must be added to the solution to lower the pH from pH 12.0 to 2.0 would be:
a. 10
b. 2.0
c. 0.02
d. 0.01
Sol. c.

$$\text{pH } 12 \rightarrow \left[H_3O^+\right] = 10^{-12} \text{ M}$$

$$\left[OH^-\right] = \frac{10^{-14}}{10^{-12}} = 10^{-2} \text{ M} = 0.01 \text{ M}$$

$$\text{pH } 2 \rightarrow \left[H_3O^+\right] = 10^{-2} \text{ M} = 0.01 \text{ M}$$

Enough HCl must be added to neutralise the OH^- initially present (i.e. 0.01 mol) and to then increase the amount of H_3O^+ present to 0.01 mol. So the total n(HCl) required
= 0.01 + 0.01 = 0.02 mol.

Q91. A sodium lamp emits yellow-coloured light. If the light from the lamp was passed through a container of sodium vapour, it is likely that the light emerging from the container would appear
a. brighter, due to electrons in atoms in the sodium vapour moving from higher to lower energy levels.
b. brighter, due to electrons in atoms in the sodium vapour moving from lower to higher energy levels.
c. duller, due to electrons in atoms in the sodium vapours moving from higher to lower energy levels.
d. duller, due to electrons in atoms in the sodium vapour moving from lower to higher energy levels.
Sol. d. Light is emitted from a sodium lamp as electrons in excited sodium atoms move from higher energy levels to lower energy levels. The wavelengths of light emitted correspond to the energy needed to promote electrons in sodium atoms from lower energy levels to higher energy levels. So, when light from a sodium lamp is passed through a container of sodium vapour, the intensity of the light decreases as electrons in the sodium vapour absorb energy in moving from lower to higher energy levels.

Q92. Bromophenol blue is a weak acid (represented as BH) that acts as an acid-base indicator. In solution the following equilibrium is established.
BH(aq)B. (aq) + H^+(aq);
Ka = 6.3×10^{-5} M.
yellow blue At low pH bromophenol blue exists mainly as the acid, BH, which is yellow in colour, while at high pH it exists mainly as its conjugate base, B, which is blue. An intermediate colour is observed when the concentration of the acid and the concentration of the conjugate base are similar.
a. Write an expression for Ka in terms of the concentrations of BH,

b. and H^+.

Sol.

$$K_a = \frac{[B^-][H^+]}{[BH]}$$

b. i. When [BH] = [B^-], the mixture appears green. Calculate the pH at which [BH] = [B^-].

Sol.

$$[BH] = [B^-], \text{ so}$$

$$K_a = [H^+]^* \rightarrow [H^+] = 6.3\times10^{-5}\ \text{M}$$

$$\text{pH} = -\log_{10}(6.3\times10^{-5})$$

$$= 4.2\ ^*$$

ii. Calculate the ratio [B^-]/[BH] when the pH of a solution of bromophenol blue is 7.

Sol.

$$\text{pH } 7 \rightarrow [H^+] = 10^{-7}\ \text{M}$$

$$K_a = \frac{[B^-][H^+]}{[BH]}$$

$$6.3\times10^{-5} = \frac{[B^-]\times10^{-7}}{[BH]}$$

$$[B^-]/[BH] = \frac{6.3\times10^{-5}}{10^{-7}}$$

$$= 630\ (6.3\times10^2 \text{ or } 6\times10^2)$$

iii. What colour will the indicator solution appear at pH 7?

Sol. Blue. The concentration of the (blue species) B– is greater than that of the (yellow species) BH.

The link between the ratio determined in part ii. and the colour of the indicator at pH 7 was not well recognised. Some students returned to the stem of the equation and argued that, as the pH increases, the position of equilibrium moves to the right and so the indicator becomes bluer.

Q93. Some rocks were thought to consist of insoluble silica (SiO_2) and calcium carbonate ($CaCO_3$; molar mass 100.1 g mol.1). The fraction of $CaCO_3$ in an 8.64 g sample of the crushed rock was determined by mixing the sample with excess hydrochloric acid. The acid reacts with $CaCO_3$ according to the following equation.

$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

The resulting solution was filtered and the SiO_2 that was collected was washed and dried. The mass of SiO_2 was found to be 1.55 g.

a. Calculate the expected percentage of $CaCO_3$ in the original rock sample.

Sol.

$$m(CaCO_3) = 8.64 - 1.55$$

$$= 7.09\ \text{g}\ ^*$$

$$\%\ CaCO_3 = \frac{7.09}{8.64}\times100$$

$$= 82.1\%\ ^*$$

b. In order to check the result from **part a.**, excess ammonium oxalate solution was added to the faltered solution. The calcium ions present precipitate as $CaC_2O_4.H_2O$.

The $CaC_2O_4.H_2O$ was collected by ltration, washed and dried. It was then heated to convert it to CaO (molar mass 56.1 g mol.1) and a mass of 3.87 g was obtained.

Using this mass of CaO, calculate the percentage of $CaCO_3$ in the rock sample. Ensure that you express your **Sol.** to an appropriate number of significant figures.

$$n(\text{CaO}) = \frac{3.87}{56.1}$$
$$= 0.0690 \text{ mol}$$
$$n(\text{CaCO}_3) = 0.0690 * \text{mol}$$
$$n(\text{CaCO}_3) = 0.0690 \times 100.1$$
$$= 6.91 \text{ g}$$
$$\%\ \text{CaCO}_3 = \frac{6.91}{8.64} \times 100$$
$$= 79.9\% *$$

Sol. c. Suppose that the percentage of $CaCO_3$ determined by the chemical analysis with ammonium oxalate was **less** than the result found in part **a.** above. Provide one possible explanation for the difference.

Sol. Possible solutions included:
not all of the precipitate ($CaC_2O_4.H_2O$) was collected the $CaC_2O_4.H_2O$ was slightly soluble
some precipitate was lost during washing there were other carbonates/soluble salts in the rock sample.

Q94. When the substance CH_3CHO (substance X) is dissolved in water it reacts to form an equilibrium mixture with $CH_3CH(OH)_2$ (substance Y) according to the equation:
X(aq) + H_2O(l) Y(aq)
The concentration of X can be determined using UV-visible spectroscopy. X absorbs strongly at 290 nm. Y shows no absorption at this wavelength. In a particular experimental arrangement at 25°C, the relationship between absorbance at 290 nm and
concentration of X is given by Absorbance = 4.15 × [X]
In the experiment, 0.110 mol of X is dissolved rapidly in 1.00 L of water at 25°C**.** The absorbance of the solution changes as some of the X is converted to Y. The table below shows the change in absorbance over
time (measured in seconds).

Absorbance	0.430	0.303	0.270	0.255	0.250	0.250
Time (s)	6.00	60.0	90.0	120	240	480

a. Calculate the concentration of X, in M, when the reaction reached equilibrium.

Sol.
Absorbance at equilibrium = 0.250
$$[\text{X}] = \frac{0.250}{4.15}$$
$$= 0.0602 \left(6.0 \times 10^{-2}\right) \text{M}$$

b. Calculate the absorbance at the instant that X was dissolved in the water, before any reaction occurred.

Sol.
$$[\text{X}] = 0.110 \text{ M}$$
$$\text{Absorbance} = 4.15 \times 0.110$$
$$= 0.457$$

c. Calculate the percentage of the original 0.110 mol of X that has been converted into Y at equilibrium.

Sol.
$$n(\text{X}) \text{ converted} = 0.110 - 0.0602$$
$$= 0.0498 * (0.050) \text{ mol}$$
$$\%\ \text{X converted} = \frac{0.0498}{0.110} \times 100 *$$
$$= 45.3\ \%$$

d. The average rate of a reaction can be determined by calculating the change in concentration of a reactant per second. Calculate the average

rate, in Ms^{-1}, at which the concentration of X changed during the first 6.00 s of the reaction.

Sol.

$$[X] \text{ initially} = 0.110 \text{ M}$$

$$\text{Absorbance at } 6.00 \text{ s} = 0.430$$

$$[X] \text{ at } 6.00 \text{ s} = \frac{0.430}{4.15}$$

$$= 0.1036 \text{ M } (0.104)$$

$$\Delta[X] = 0.110 - 0.1036 *$$

$$= 0.0064 \text{ M}$$

$$\text{Rate of } \Delta[X] = \frac{0.0064}{6.00} *$$

$$= 0.0011 \text{ Ms}^{-1}$$

Q95. Sulfur dioxide gas is commonly used as a preservative in wine. An important source of SO_2 is solid sodium metabisulfte ($Na_2S_2O_5$; molar mass 190 g mol.1). $Na_2S_2O_5$ reacts readily with acid as follows.

$Na_2S_2O_5(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + 2SO_2(g)$

a. Calculate the volume, in litres, of SO_2 produced at 1.00 atm pressure and 15.0°C when 250 g of $Na_2S_2O_5$ reacts with excess acid.

Sol.

$$n\left(I_3^-\right) \text{in excess} = n{S_2O_3}^{2-}$$

$$= 0.00850 \times 14.70 \times 10^{-3}$$

$$= 0.000125 * \left(1.25 \times 10^{-4}\right) \text{ mol}$$

$$n\left(I_3^-\right) \text{ reacting with } SO_2 = n\left(I_3^-\right) \text{ initially} - n\left(I_3^-\right) \text{ in excess}$$

$$= 6.25 \times 10^{-4} - 1.25 \times 10^{-4} *$$

$$= 5.00 \times 10^{-4} \text{ mol}$$

$$n(SO_2) = 5.00 \times 10^{-4} \text{ mol}$$

$$c(SO_2) = \frac{5.00 \times 10^{-4}}{50.0 \times 10^{-3}} *$$

$$= 0.0100 \text{ M}$$

$$n(SO_2) = 2 \times n(Na_2S_2O_5)$$

$$= 2 \times \frac{250}{190} *$$

$$= 2.63 \text{ mol}$$

$$V(SO_2) = \frac{nRT}{p}$$

$$= \frac{2.63 \times 8.31 \times 288}{101.3} *$$

$$= 62.2 * \text{L}$$

b. The concentration of an aqueous solution of SO_2 (solution a) is to be determined using its reaction with an aqueous solution of triiodide ions (I_3^-). The relevant half reactions are

$SO_2(aq) + 2H_2O(l) \rightarrow 4H^+(aq) + SO_4^{2-}(aq) + 2e.$

$I_3.(aq) + 2e^- \rightarrow 3I^-(aq)$

50.0mL of a 0.0125M solution of I_3^-. is added to 50.0 mL of solution a, providing excess of I_3^-. The final 100.0 mL solution is called solution **b.**

i. Write an overall balanced chemical equation for the reaction that occurs, identifying the substance that is the reductant.

Equation ___ Reductant_____

Sol. Equation: $SO_2 + 2H_2O + I_3^- \rightarrow 3I^- + 4H+ + SO_4^{2-}$

Reductant: SO_2

ii. Calculate the amount, in mol, of I_3^- added to solution **a.**

Sol.

$$n(I_3^-) = 0.0125 \times 50.0 \times 10^{-3}$$

$$= 6.25 \times 10^{-4} \ (0.000625) \text{ mol}$$

iii. The excess I_3 remaining in the solution is determined by titration with a standard solution of sodium thiosulfate ($Na_2S_2O_3$). The equation for the reaction is:

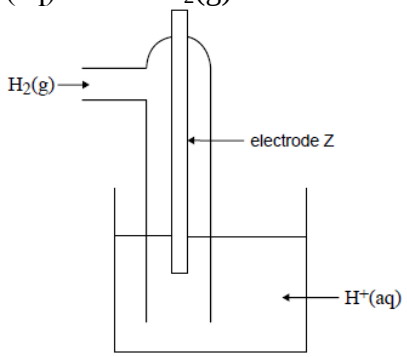
$S_2O_3^{2-}(aq) + I_3(aq) + H_2O(l) \rightarrow 3I.(aq) + SO_4^{2-}(aq) + 2H^+(aq)$

14.70 mL of a 0.00850 M solution of $Na_2S_2O_3$ reacts exactly with all the I_3^- remaining in solution **b.**

Calculate the original concentration of SO_2 in solution **a.**

Q96. The following diagram represents a $H^+(aq)/H_2(g)$ half cell for the reaction

$2H^+(aq) + 2e. \leftrightarrow H_2(g)$



a. i. For this half cell, identify an appropriate material for electrode Z.

Sol. Pt, graphite, Pd or Au.

ii. For this half cell to be a standard half cell, state. The temperature at which it must operate the required pH of the solution of $H^+(aq)$ ions.

Sol.

• 25°C

• 0 (zero)

b. A galvanic cell consists of the following half cells which have been set up under standard conditions.

-Half cell 1: the $H^+(aq)/H_2(g)$ half cell described in part **a.**

-Half cell 2: a cadmium (Cd) electrode in a solution containing $Cd^{2+}(aq)$

After some time, the pH in half cell 1 has increased. Use this information to identify the species in this galvanic cell which is the stronger reluctant and explain how you reached this conclusion. The stronger reluctant is Explanation

Sol.

• Cd

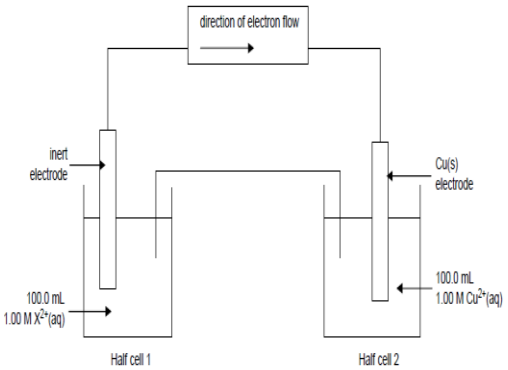
• H^+ has been reduced so it must have been reduced by the Cd.

c. A second galvanic cell consists of the following half cells.

. Half cell 1: an inert electrode in 100.0 mL solution of 1.00 M $X^{2+}(aq)$

. Half cell 2: an electrode of Cu(s) in 100.0 mL solution of 1.00 M $Cu^{2+}(aq)$

This galvanic cell is shown in the diagram below.



After discharging 2654C of electricity, the concentration of the $X^{2+}(aq)$ in solution in half cell 1 was found to be 0.725 M. The volume of the solutions in the two half cells had not changed.

i. Calculate the amount, in mol, of $X^{2+}(aq)$ that reacted in half cell 1.

Sol.

mole of X^{2+} used = (1.00 – 0.725) × 0.1* = 0.0275 mol*

ii. Calculate the ratio of $n(X^{2+})$ reacted to $n(e^-.)$ that passed through the cell.

That is, calculate: n(X^{2+}) reacted: n(e^-).
Sol.

$$\text{mole of electrons} = \frac{2654}{96500} = 0.0274 \text{ mol *. The ratio is therefore 1}$$

iii. State the oxidation state of the product of the half reaction in half cell 1.
Sol. +3
X^{3+} was also accepted.
iv. Write an equation for the half reaction that occurred at the electrode of half cell 1.
Sol. $X^{2+} \rightarrow X^{3+} + e^-$

Q97. Faraday.s constant is defined as the charge on one mole of electrons. The value of Faraday.s constant can be determined experimentally by electrolysis using inert electrodes.
A current of 1.62 A is passed through a solution of copper (II) nitrate for 581 s. At the end of that time, the copper deposited at the negative electrode was collected. Its mass was found to be 0.306 g.
a. Write an equation for the half reaction occurring at the negative electrode of this electrolytic cell.
Sol. $Cu^{2+} + 2e^- \rightarrow Cu$
b. Use the experimental data given above to calculate, to an appropriate number of significant figures, the charge, in coulombs, that was passed through the electrolytic cell
Sol. charge through cell
= 1.62 × 581 = 941 C
amount, in mol, of copper deposited at the negative electrode.
Sol.

$$\text{mole Cu deposited} = \frac{0.306}{63.6} = 4.81 \times 10^{-3}$$

c. Use the values obtained in part **b.** to calculate the experimentally determined value of Faraday constant.
Sol.

$$F = \frac{941}{0.00481} \times 0.5^* = 9.78 \times 10^4 \text{ *}$$

d. The value of Faraday.s constant given in your data sheet is 96500 C mol.1. The experiment above was repeated and a value for Faraday.s constant was found to be 98400 C mol.1. The amount of charge passed is accurately known. Describe one possible source of experimental error which would result in obtaining an experimental value that was higher than the one given in the data sheet.
Sol. Some Cu may have been lost.

Q98-99 Phosphorus (V) chloride, PCl_5, decomposes to form phosphorus (III) chloride, PCl_3, and chlorine, Cl_2 according to the equation:
$PCl_5(g)$ $PCl_3(g) + Cl_2(g)$

Q98. Four different flasks, A, B, C and D, at the same temperature, contain a mixture of PCl_5, PCl_3 and Cl_2. The concentration, in mol L^{-1}, of these components in each of the flasks is shown below.
In three of the four flasks, the mixture of gases is at equilibrium.
In which one is the mixture of gases **not** at equilibrium?
Flask [$PCl_5(g)$] [$PCl_3(g)$] [$Cl_2(g)$]
a. 0.15 0.20 0.30
b. 0.20 0.15 0.15
c. 0.10 0.10 0.40
d. 0.30 0.80 0.15
Sol. b.

a. K = 0.40.
b. K = 0.11,
c. K = 0.40,
d. K = 0.40
Assuming recognition of K = $[PCl_3]x[Cl_2]/ [PCl_5]$, incorrect choices may be attributed to mathematical error and lack of practice with a scientific calculator.

Q99. Some gaseous PCl_5 is placed in an empty container. When equilibrium is reached, the mass of the gas mixture, compared to the initial mass of PCl_5, is:
a. halved.
b. unchanged.
c. one and a half times greater.
d. doubled.
Sol. b. Adding PCl_5 to an empty container will cause the mass of PCl_5 to decrease as the reaction proceeds to equilibrium. However, the law of conservation of mass implies the conversion of PCl_5 to PCl_3 and Cl_2 does not change the total mass of gas present in the container.

Q100. Gaseous NOCl decomposes to form the gases NO and Cl_2 according to the following equation.
$2NOCl(g)\ 2NO(g) + Cl_2(g)$
The numerical value of the equilibrium constant for this reaction is 1.6×10^{-5} at 35°C**.**
What is the numerical value of the equilibrium constant, at 35^oC, for the following reaction?
NO(g) + 1
2 $Cl_2(g)$ NOCl(g)
a. -1.6×10^{-5}
b. 1.6×10^{-5}
c. 2.5×10^{2}
d. 6.3×10^{4}
Sol. c. $2NOCl(g) \rightleftharpoons 2NO(g) + Cl2(g)$; $K = 1.6x10^{-5}$
$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$; $K = (1/1.6x10^{-5})$
$NO(g) + ½Cl_2(g) \rightleftharpoons NOCl(g)$; $K = (1/1.6x10^{-5})½$
$= \sqrt{(1 / 1.6x10^{-5})} = 2.5x102$

Q101. The sodium salt of propanoic acid (sodium propanoate) is used as a preservative in bread and other baked goods. It can be produced by reacting propanoic acid with sodium hydroxide. In a particular experiment 100 mL of 0.080 M NaOH was added to 100 mL of 0.16 M propanoic acid.
Which of the following statements is/are correct?
I The pH of the resulting solution will be less than that of the propanoic acid solution.
II The resulting solution contains equal amounts of propanoic acid and its conjugate base.
III Before the NaOH was added there were no propanoate ions present.
a. II only
b. III only
c. I and II only
d. II and III only
Sol.a. $CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow CH_3CH_2COONa(aq) + H_2O(l)$
100 mL+ 100 mL→ 0.16 M +0.080 M
n = 0.016 mol , n = 0.0080 mol
0.0080 mol CH_3CH_2COOH will react giving 0.0080 mol CH_3CH_2COONa.
In the resulting solution there will be 0.0080 mol $CH_3CH_2COOH(aq)$ and 0.0080 mol $CH_3CH_2COO^-(aq)$, that

is, equal amounts of propanoic acid and its conjugate base. The pH of the resulting solution will be higher than the original propanoic acid solution, since the concentration of CH_3CH_2COOH is lower. As propanoic acid is a weak acid, there was a small (but negligible in this case) amount of $CH_3CH_2COO^-$ ions present before the addition of NaOH.

Q102. At the end of a particular experiment, a chemist was left with several materials to be disposed of in a safe manner. These included:
i. 120 mL of ethyl ethanoate
ii. 150 mL unused 0.10 M NaCl
iii. a solid compound of lead that had been deposited on an electrode and then dried and weighed on filter paper.
Which one of the following alternatives describes an appropriate method of disposal of each of the above wastes from this experiment?

	120 mL ethyl ethanoate	150 mL unused 0.10 M NaCl	Solid lead compound
A.	waste container labelled 'ORGANIC LIQUIDS ONLY'	down the sink	waste container labelled 'DRY SOLIDS ONLY'
B.	waste container labelled 'ORGANIC LIQUIDS ONLY'	a stock bottle of 0.10 M NaCl prepared for the experiment	in the rubbish bin
C.	waste container labelled 'AQUEOUS WASTE ONLY'	waste container labelled 'AQUEOUS WASTE ONLY'	in the rubbish bin
D.	waste container labelled 'AQUEOUS WASTE ONLY'	a stock bottle of 0.10 M NaCl prepared for the experiment	waste container labelled 'DRY SOLIDS ONLY'

Sol. a. Ethyl ethanoate, an ester, is an organic liquid and must be disposed of in an 'organic liquids' waste container. Similarly, lead compounds are hazardous and must be disposed of in a 'dry solids' container.

Q103. The following table lists the pH of 0.10 M solutions of four different acids at 25°C**.**

Acid	pH
I	1.0
II	3.0
III	0.7
IV	2.1

a. Which one of the four acids listed in the table above has the smallest Ka value?
Sol. II /acid with pH 3
b. Which acid must have more than one acidic hydrogen per molecule?
Sol. III* The lowest possible pH of a 0.1 M solution of a monoprotic acid is 1.0 /pH is less than it should be for a 0.1 M solution of a monoprotic acid.
c. Using the concentration and the pH of acid IV, calculate the percentage ionisation of acid IV in the 0.10 M solution.
Sol. % ionisation= $([H^+]/[acid]) \times 100 = (10^{-2.1} / 0.1) \times 100 = 7.9$ (%)
d. Calculate the value of the ratio $[OH^-]$acid II/$[OH^-]$acid I present in the solutions of acids II and I.
Sol.
II – $[OH^-] = 10^{-14} / 10^{-3} = 10^{-11}$ M
I – $[OH^-] = 10^{-14} / 10^{-1} = 10^{-13}$ M
Ratio = $10^{-11} / 10^{-13} = 100$
e. Samples of the solutions of acids I and IV are diluted by a factor of 10. The resulting change in pH units would be (one of the following boxes):

greater for acid I than for acid IV	
greater for acid IV than for acid I	
the same for both acids	

Sol. Greater for acid I than for acid IV

For acid IV the equilibrium [$HA \rightleftharpoons H^+ + A^-$] moves slightly to the right following the dilution*/Acid I is a strong acid whereas acid IV is a weak acid.

f. Methanoic acid is a weak monoprotic acid.

i. Calculate the concentration of a methanoic acid solution that will have the same pH as acid IV.

Sol. Ka (HCOOH) = 1.8×10^{-4}

pH 2.1 → [H+] = $10^{-2.1}$ (7.9×10^{-3})

$1.8 \times 10^{-4} = (10^{-2.1})2$ / [HCOOH] *

[HCOOH] = $(10^{-2.1})2 / 1.8 \times 10^{-4}$

= 0.35 *** (**M)

ii. The dissociation of methanoic acid in water is exothermic. If a solution of the acid is heated, will the pH of the solution increase, decrease or remain constant?

Sol.

• increase

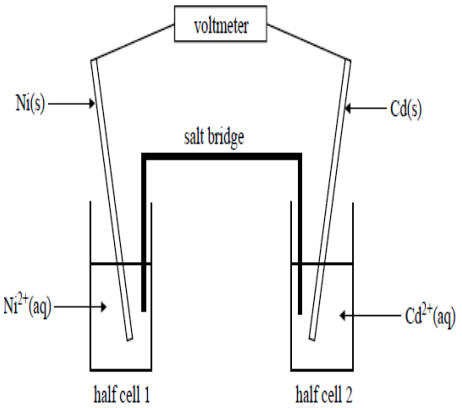
• the increase in temperature pushes the equilibrium [$HCOOH \rightleftharpoons HCOO^- + H^+$] to the left, so the **[H^+]** Decreases .

Q104. a. A galvanic cell is constructed from the following two half cells under standard conditions.

Half cell 1: a nickel electrode in a solution of 1.0 M nickel nitrate

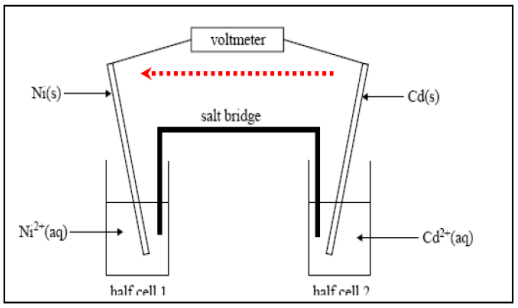
Half cell 2: a cadmium electrode in a solution of 1.0 M cadmium nitrate

A sketch of the cell is given below.



i. Given that the standard reduction potential of $Cd^{2+}(aq)/ Cd(s)$ is –0.40V, show on the above sketch the direction in which electrons will flow in the external circuit of this galvanic cell.

Sol.



ii. Give the equation for the half reaction that takes place at the anode of this cell.

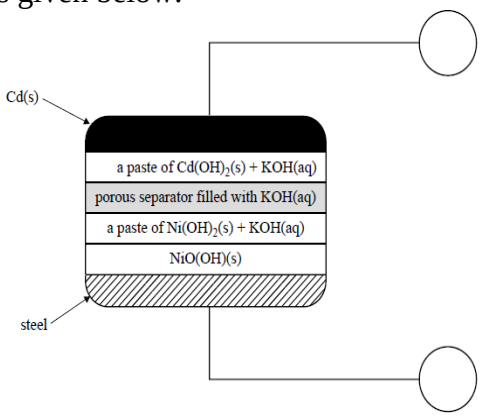
Sol. $Cd(s) \rightarrow Cd^{2+}(aq) + 2e^-$

iii. List two factors that need to be considered when selecting an appropriate substance for use in the salt bridge.

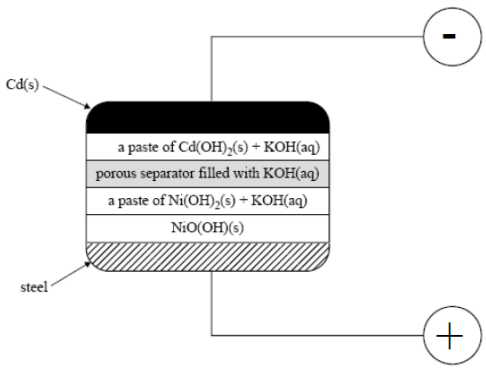
Sol. Must be soluble/ ionic compound/must not react/ will not form precipitate in half-cell

b. A rechargeable galvanic cell, also based on nickel and cadmium (NiCd cell), has been commercially available

for a number of years and has been used to power small appliances such as mobile phones.
A simplified diagram of a NiCd cell is given below.



The overall cell reaction for the cell when discharging is
$Cd(s) + 2NiO(OH)(s) + 2H_2O(l) \rightarrow Cd(OH)_2(s) + 2Ni(OH)_2(s)$
i. Identify the positive and the negative electrodes by writing '+' or '–' in the circles provided in the diagram.
Sol.

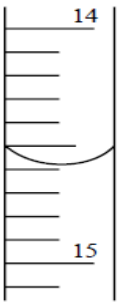


ii. What feature of this secondary cell enables it to be recharged?
Sol. The products of the discharge reaction, $Cd(OH)_2$ and $Ni(OH)_2$, stay in contact with the electrodes*.

iii. Give the equation for the half reaction that takes place at the negative electrode when the cell is discharging.
Sol. $Cd(s) + 2OH^- \rightarrow Cd(OH)_2(s) + 2e^-$*

iv. Give the equation for the half reaction that takes place at the electrode connected to the negative terminal of the power supply when the cell is recharging.
Sol.
$Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$*

Q105. The diagram below shows a section of a 50.00 mL burette containing a colourless solution.



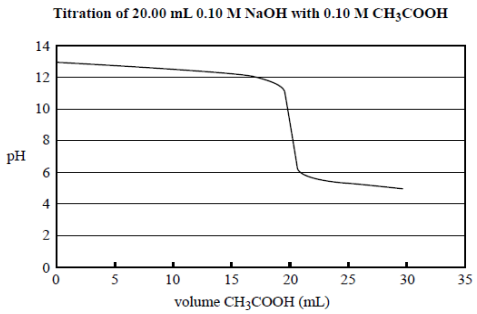
The reading indicated on the burette is closest to
a. 14.50
b. 14.58
c. 15.42
d. 15.50

Q106. Serotonin ($C_{10}H_{12}N_2O$; molar mass = 176 g mol^{-1}) is a compound that conducts nerve impulses in the brain and muscles. A sample of spinal fl uid from a volunteer in a study was found to contain a serotonin

concentration of 1.5ng L^{-1} (1.5 nanograms per litre). How many molecules of serotonin are there in one millilitre of the spinal fl uid?
a. 5.13×10^{9}
b. 9.03×10^{11}
c. 5.13×10^{27}
d. 9.03×10^{29}
Sol. a. 1.5 ng $L^{-1} \rightarrow 1.5 \times 10^{-9}$ g L^{-1} (Table 4 of the data book)
$\rightarrow 1.5 \times 10^{-9}$ g in 1000 mL
$\rightarrow 1.5 \times 10^{-12}$ g serotonin in one millilitre of spinal fluid
n(serotonin) = $1.5x10^{12}/176$
= 8.52 × 10–12 mol
N(serotonin molecules) = $8.52 \times 10^{-12} \times 6.02 \times 10^{23} = 5.13 \times 10^{9}$
Students who chose option **b** perhaps missed the 'number of mole' step. Option **c** resulted from incorrect conversion of nanograms to grams.

Q107. Xylose is a compound that has five carbon atoms in each molecule and contains 40% carbon by mass. What is the molar mass of xylose?
a. 30
b. 67
c. 150
d. It cannot be determined without further information.
Sol. c. Mc. = 12.0 g mol^{-1}
1 mol xylose molecules contains 5 mol C atoms
m(5 mol C atoms) = 60.0 g
60.0 = 40% of M(xylose)
60.0 = 0.40 × M(xylose)
M(xylose) = 60.00.40
= 150 g mol^{-1}

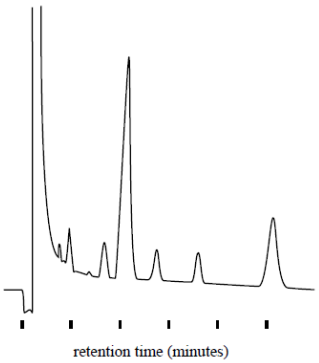
Q108. The graph below shows the change in pH of a reaction solution during a titration of 0.10 M NaOH with 0.10 M CH_3COOH.



A suitable indicator for the titration and the colour change observed is indicator colour change observed.
a. methyl red yellow to red
b. methyl red red to yellow
c. phenolphthalein colourless to red
d. phenolphthalein red to colourless
Sol. d. The titration curve shows that the endpoint for the titration occurs in the pH range 6 to 11. Table 11 of the data book shows that phenolphthalein changes colour in the pH range 8.3–10.0, while methyl red changes colour in the pH range 4.2–6.3. Therefore, phenolphthalein is the better option.
Since the acid is being added to the base, the pH will drop as the endpoint is passed through and hence phenolphthalein will change from red to colourless.

Q109–110. Deadly diseases such as tetanus, botulism and gangrene are caused by related groups of bacteria (clostridiumgenus) found in the soil. Each group of bacteria produces specific volatile fatty acids. These fatty acids can be identified using gas chromatography by comparison with

a control chromatogram of known standards.
The following gas chromatogram is of the fatty acids produced by one such group of bacteria.



Q109. The identity of the fatty acids can be determined by measuring
a. their retention times.
b. the temperature of the column.
c. the flow rate of the carrier gas.
d. the area under each of the peaks.

Q110. The relative amount of each of the fatty acids can be determined by measuring
a. their retention times.
b. the temperature of the column.
c. the flow rate of the carrier gas.
d. the area under each of the peaks.

Q111. Pyrethrins belong to a naturally occurring group of insecticides produced by the chrysanthemum daisy. The formula of one such compound, pyrethrin I, is $C_{21}H_{28}O_3$. The analytical technique that would not provide information that is useful in determining the structure of pyrethrin I is:
a. mass spectroscopy.
b. infrared spectroscopy.
c. atomic absorption spectroscopy.
d. nuclear magnetic resonance spectroscopy.

Q112. A sample of a hydrocarbon for analysis is placed in a strong magnetic field and irradiated with electromagnetic radiation of radio wave frequency. This is most likely to result in:
a. ionisation and fragmentation of molecules.
b. an increase in bond vibrations of molecules.
c. the promotion of electrons to higher energy levels.
d. a change in the energy of the nuclei of the hydrogen atoms.
Sol. d. Radio wave frequencies are used in nuclear magnetic resonance spectroscopy in which the nuclei of C or H atoms are promoted to higher energy levels (option **d**). Option **a** indicated mass spectroscopy, option **b** indicated IR spectroscopy, and option **c** indicated atomic absorption or UV-Visible spectroscopy solution.

Q113: The percentage purity of powdered, impure magnesium sulfate, $MgSO_4$, can be determined by gravimetric analysis. Shown below is the method used in one such analysis.
Method
• 32.50 g of the impure magnesium sulfate is dissolved in water and the solution is made up to 500.0 mL in a volumetric flask.
• Different volumes of 0.100 M $BaCl_2(aq)$ are added to six separate 20.00 mL samples of this solution. This precipitates the sulfate ions as

barium sulfate. The equation for the reaction is

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

• The precipitate from each sample is filtered, rinsed with de-ionised water and then dried to constant mass. The results of this analysis are shown on the next page.

Results

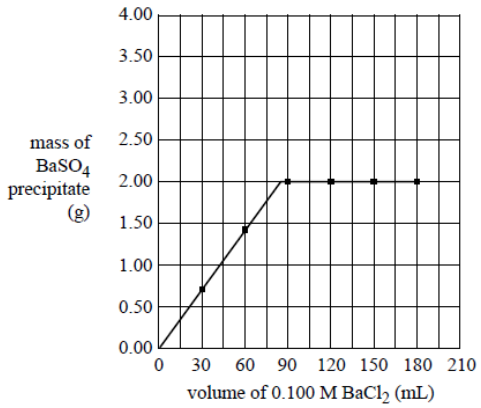
Mass of impure magnesium sulfate = 32.50 g

Volume of volumetric flask = 500.0 mL

Volume of magnesium sulfate solution in each sample = 20.00 ml

Sample	1	2	3	4	5	6
volume of $BaCl_2$(aq) added (mL)	30.0	60.0	90.0	120	150	180
mass of $BaSO_4$(s) precipitated (g)	0.704	1.41	2.00	2.00	2.00	2.00

These results are shown on the graph below.



a. Why is it necessary to rinse the precipitate with de-ionised water before drying?

Sol. To remove any traces of **impurities** from the precipitate.

b. Explain why the amount of $BaSO_4$(s) precipitated remains constant for the last four samples tested even though more $BaCl_2$(aq) is being added.

Sol. Either of:

•All the SO_4^{2-} ions have been precipitated

•$BaCl_2$ is in excess.

c. Calculate

i. the amount, in mole, of $SO4^{2-}$(aq) in the 500.0 mL volumetric flask.

Sol.

$$n\left(SO_4^{2-}\right) \text{ in } 20.00 \text{ mL sample} = n\left(BaSO_4\right)$$
$$= \frac{2.00}{233.4}$$
$$= 8.57 \times 10^{-3} *$$

$$n\left(SO_4^{2-}\right) \text{ in } 500 \text{ mL} = \frac{8.57 \times 10^{-3}}{20} \times 500$$
$$= 0.214 * (\text{mol})$$

ii. The percentage, by mass, of magnesium sulfate in the powder.

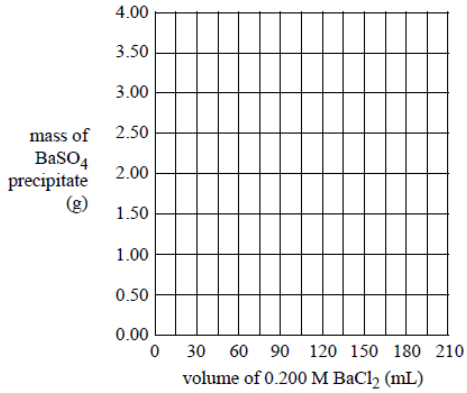
Sol. 1cii

$$m\left(MgSO_4\right) = 0.214 \times 120.4 *$$
$$= 25.8 \text{ g}$$

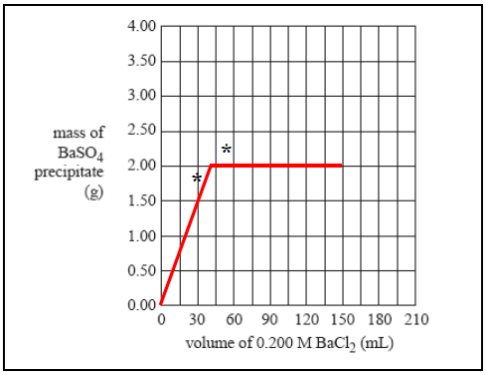
$$\%MgSO_4 = \frac{25.8}{32.50} \times 100$$
$$= 79.4\% *$$

Six further 20.00 mL samples of the magnesium sulfate solution are analysed. However, the concentration of the barium chloride added to those six samples is 0.200 M and not 0.100 M.

d. On the axes below, draw the graph you would expect to obtain when plotting the mass of $BaSO_4$(s) precipitate against volume of 0.200 M $BaCl_2$(aq) used.



Sol.



With 0.200 M $BaCl_2$, the graph levels off (at 2.00g $BaSO_4$) when the V($BaCl_2$) added is half of that used with 0.100 M $BaCl_2$.

Q114. One method of analysing the manganese content of steel is to dissolve the steel in nitric acid; producing a solution of manganese (II) ions, $Mn^{2+}(aq)$.

The $Mn^{2+}(aq)$ ions are then treated with an excess of acidifi ed solution of periodate ions, $IO_4^-(aq)$. The products of this reaction are iodate ions, $IO_3^-(aq)$, and the deeply purple-coloured permanganate ions, $MnO_4^-(aq)$.

The concentration of $MnO_4^-(aq)$ is then determined by UV-visible spectroscopy.

a. i. Calculate the oxidation number of iodine in the $IO_4^-(aq)$ ion.

Sol. +7

ii. Give a half equation for the conversion of $IO_4^-(aq)$ into $IO_3^-(aq)$ in acid solution.

Sol.

$IO_4–(aq) + 2H^+(aq) + 2e^- \rightarrow IO_3^-(aq) + H_2O(l)$

iii. Is the $IO_4^-(aq)$ ion acting as an oxidant or reductant? Explain your choice.

Sol. It is an oxidant, as (any of):

-it oxidises Mn^{2+} to MnO_4^-

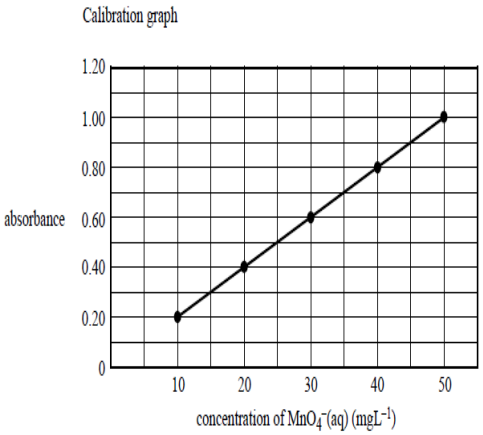
-it increases the oxidation number of Mn

-the oxidation number of I decreases.

An experiment was carried out to determine the percentage of manganese in a particular sample of steel by the above method. A 13.936 g sample of steel was dissolved in acid and the manganese was converted to $MnO_4^-(aq)$ ions.

The solution containing the MnO_4^- (aq) ions was fi ltered and made up to a volume of 1.00 L.

25.00mL of this solution was then further diluted to 100.0 mL in a volumetric fl ask. The absorbance, at 525 nm, of this solution was 0.70. Next, the absorbance, at 525 nm, of a series of solutions of $MnO_4^-(aq)$ ions of known concentration was measured and a calibration graph drawn.



b. i. What is the concentration, in mg L^{-1}, of $MnO_4^-(aq)$ in the diluted solution in the 100 mL volumetric fl ask?

Sol. 35 (mg L^{-1})

ii. Calculate the mass, in mg, of **manganese** in the steel sample.

Sol. The original solution had been diluted from 25 mL to 100 mL.

$$c(MnO_4^-) \text{ in original solution} = 35 \times \frac{100}{25}$$
$$= 140^* (\text{mg L}^{-1})$$

$$m(MnO_4^-) \text{ in solution} = 140 \text{ mg}$$
$$n(Mn) = n(MnO_4^-)$$
$$= \frac{0.140}{118.9}$$
$$= 1.18 \times 10^{-3} \text{ mol}$$
$$m(Mn) = 1.18 \times 10^{-3} \times 54.9$$
$$= 0.0646 \text{ g}$$
$$= 65^* \text{ (mg) } [64.6]$$

iii. Calculate the percentage, by mass, of manganese in the steel sample.

Sol.

$$\%Mn = \frac{0.0646}{13.936} \times 100$$
$$= 0.46\%^* \ [0.463]$$

Q115. 0.415 g of a pure acid, $H_2X(s)$, is added to exactly 100 mL of 0.105 M NaOH(aq).

A reaction occurs according to the equation:

$H_2X(s) + 2NaOH(aq) \rightarrow Na_2X(aq) + 2H_2O(l)$

The NaOH is in excess. This excess NaOH requires 25.21mL of 0.197 M HCl(aq) for neutralisation.

Calculate

i. the amount, in mol, of NaOH that is added to the acid H_2X initially.

Sol.

$$n(\text{NaOH}) = 0.105 \times 100 \times 10^{-3}$$
$$= 0.0105 \text{ (mol)}$$

ii. The amount, in mol, of NaOH that reacts with the acid H_2X.

Sol.

$$n(\text{NaOH}) \text{ in excess} = n(\text{HC1})$$
$$= 0.197 \times 25.21 \times 10^{-3}$$
$$= 4.97 \times 10^{-3}{}^* \text{ (mol) } (0.00497)$$

$$n(\text{NaOH}) \text{ reacting} = 0.0105 - 0.00497$$
$$= 5.53 \times 10^{-3}{}^* \text{ (mol) } (0.00553)$$

iii. The molar mass, in g mol^{-1}, of the acid H_2X.

Sol.

$$n(H_2X) = \frac{1}{2} n(\text{NaOH})$$
$$= \frac{1}{2} \times 5.53 \times 10^{-3}{}^*$$
$$= 2.765 \times 10^{-3} \text{ (mol)}$$

$$M(H_2X) = \frac{m}{n}$$
$$= \frac{0.415}{2.765 \times 10^{-3}}$$
$$= 150^* \text{ (g mol}^{-1})$$

Q116. A sample of compound M is analysed in a mass spectrometer where it forms the molecular ion M+ according to:

$M + e^- \rightarrow M^+ + 2e^-$

Some of the molecular ions fragment as follows:

$M^+ \rightarrow A^+ + B$ and

$M^+ \rightarrow A + B^+$

The mass spectrum would show peaks due to the species

a. M^+, A, A^+, B and B^+ only.

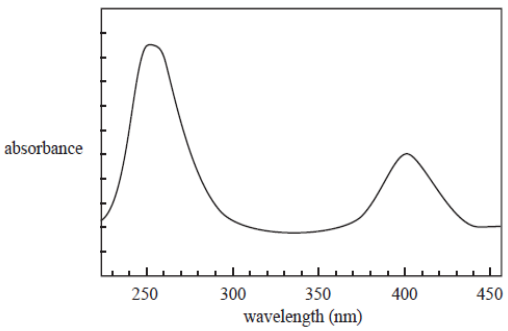
b. M^+, A^+ and B^+ only.

c. A^+ and B^+ only.

d. A and B only.

Sol. b. Peaks on a mass spectrum are associated with ions –both parent molecular and fragment. These are the species deflected and separated in the magnetic field.

Q117. The UV-visible spectrum of a solution of a certain compound is shown below. Consider the following statements about this compound and its UV-visible spectrum.



I) The amount of light absorbed by a solution of this compound depends on its concentration.

II) The amount of light absorbed by a solution of this compound depends on the wavelength of light used.

III) The spectrum is a result of electrons falling back from higher to lower electronic energy levels.

IV The concentration of a solution of this compound can only be determined by UV-visible spectroscopy at 250 nm.

Which of the above statements are true?

a. I and II

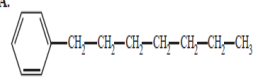
b. II and III

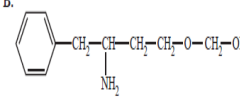
c. I, II and III

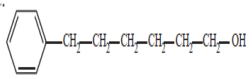
d. I, II and IV

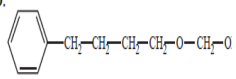
Sol. a. Statements I and II were correct. Statement III was incorrect as energy is absorbed during the transition of electrons from lower to higher energy levels. Statement IV was also incorrect as the spectrum shows two absorbance peaks, at wavelengths of approximately 250 nm and 400 nm. Either of those wavelengths may be used. Ideally the wavelength used should be one at which the compound absorbs strongly but other species in the solution do not.

Q118. Reverse-phase high-performance liquid chromatography (HPLC) uses a non-polar stationary phase together with a polar mobile phase. Which of the following molecules will have the greatest retention time on such a reverse phase column?

A. 

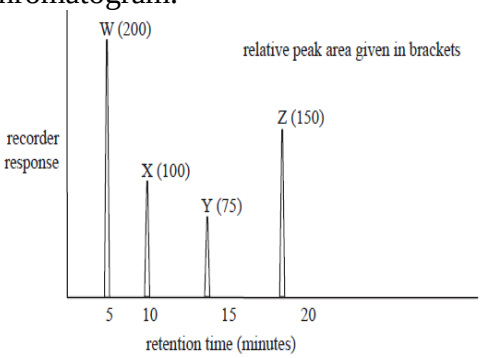
B. 

C. 

D. 

Sol. a. The molecule in option **a** is non-polar and would be most strongly attracted to the non-polar stationary phase (and least strongly attracted to the polar mobile phase). It will have the greatest retention time. Options **b**, **c** and **d** all have some degree of polarity and hence greater attraction to the mobile phase.

Q119. The above diagram shows the gas chromatogram of a sample containing four straight chain alkanes. The following statements refer to this chromatogram.



I The boiling points of the compounds arranged from highest to lowest are Z > Y > X > W.

II The retention times will stay the same if the temperature at which the chromatogram is recorded is increased, all other conditions remaining constant.

III Hydrogen gas could have been used as a carrier gas to obtain this chromatogram. Which of the above statements are true?

a. I only

b. I and II only

c. I and III only

d. II and III only

Sol. c. Statement I is correct as the higher the retention time, the larger the molecules and the higher the boiling temperatures. Statement II is incorrect as at higher temperature the compounds move through the chromatograph faster and have lower retention times. Statement III is correct as the carrier gas must be unreactive with the compounds of the mixture. Alkanes do not react with H_2.

Q120-121. 0.132 g of a pure carboxylic acid (R–COOH) was dissolved in 25.00 mL of water and titrated with 0.120 M NaOH solution. A volume of 14.80 mL was required to reach the endpoint of the titration.

Q120. The carboxylic acid could be:

a. HCOOH

b. CH_3COOH

c. C_2H_5COOH

d. C_3H_7COOH

Sol. c. $n(NaOH) = 0.120 \times 14.80 \times 10^{-3}$
$= 1.78 \times 10^{-3}$ mol

$n(RCOOH) = 1.78 \times 10^{-3}$ mol

$M(RCOOH) = 0.132 g / 1.78 \times 10^{-3}$ mol
$= 74.3$ g mol^{-1}

$M(C_2H_5COOH) = 74.0$ g mol^{-1}

Q121. Which of the following best represents the pH of the solution at the equivalence point and the name of a suitable Indicator for this titration?

pH at the equivalence point suitable indicator

a. less than 7 phenolphthalein

b. less than 7 bromophenol blue

c. greater than 7 phenolphthalein

d. greater than 7 bromophenol blue

Sol. c. At the equivalence point all of the RCOOH will have reacted with NaOH(aq) according to:

$RCOOH(aq) + OH^-(aq) \rightarrow RCOO^-(aq) + H_2O(l)$.

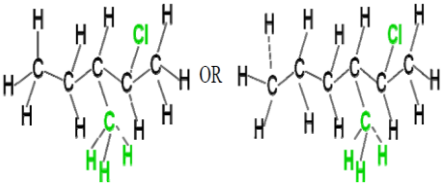
The pH at the equivalence point is due to $RCOO^-(aq)$ which as the conjugate base of the carboxylic acid is a weak base, hence the solution has **pH > 7**. During the titration the pH of the solution increases and to accurately identify the endpoint, as close as possible to the equivalence point, the indicator must change colour once the pH becomes greater than 7. Phenolphthalein fits these criteria.

Q134. 2-chloro-3-methylpentane and 2-chloro-3-methylhexane were dissolved together and the mixture was analysed using gas chromatography. The chromatogram of this mixture produced the following peak areas.

compound	peak area
1.06×10^{-3} mol of 2-chloro-3-methylpentane	922 units
1.53×10^{-3} mol of 2-chloro-3-methylhexane	1570 units

a. Draw a structural formula of **either** 2-chloro-3-methylpentane or 2-chloro-3-methylhexane, clearly showing all bonds.

Sol.



b. Which molecule would you expect to have the shortest retention time in the chromatography column?

Sol. 2-chloro-3-methylpentane because it has smaller molecules/ lower molecular mass and so has weaker dispersion force attraction to the stationary phase and travels faster through the column.

c. In another experiment, 0.57×10^{-3} mol of 2-chloro-3-methylpentane was analysed in a different mixture under the same conditions.

What would be the expected peak area on the chromatogram associated with this amount of 2-chloro-3-methylpentane?

Sol. 1.06×10^{-3} mol → 922 units

0.57×10^{-3} mol → x units

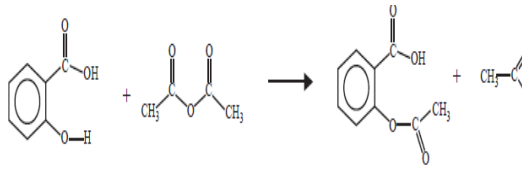
$x / 0.57 \times 10^{-3} = 922 / 1.06 \times 10^{-3}$

$x = (922 / 1.06) \times 0.57$

= 5.0x102* (496) (units)

Q122. A sample of aspirin was prepared by reacting 2.20 g of salicylic acid with 4.20 mL of ethanoic anhydride in a conical flask. After heating for 20 minutes the reaction mixture was cooled and white crystals precipitated. The crystals were then collected, dried to constant mass and weighed.

The equation for the reaction is:



salicylic acid (s) ethanoic anhydride (l) aspirin (s)

The following results were obtained.
- mass of salicylic acid 2.20 g
- volume ethanoic anhydride 4.20 mL
- mass product 2.25 g

Use the following data to solution**.** the equations below.

	molar mass ($g\ mol^{-1}$)	density ($g\ mL^{-1}$)
aspirin	180	
ethanoic anhydride	102	1.08
salicylic acid	138	

a. i. Calculate the initial amount, in moles, of salicylic acid used in this preparation.

Sol.

n(salicylic acid) = 2.20 / 138 = 0**.**0159 * (mol)

ii. What initial amount, in moles, of ethanoic anhydride was used?

Sol.

m(ethanoic anhydride) = Volume x Density = 4.20 x 1.08 g

n(ethanoic anhydride) = 4.20 x 1.08 / 102 = 0.0445 * (mol)

iii. What is the maximum mass of aspirin that can theoretically be produced from these reagents?

Sol.

Salicylic acid is the limiting reagent

n(aspirin) = n(salicylic acid) = 0.0159 mol

m(aspirin) = 0.0159 x 180

= 2.86g* (2.87g if unrounded numbers were used)

iv. Determine the percentage yield in this preparation.

Sol. %yield = [m(aspirin) collected/ m(aspirin) theoretical] x 100

= (2.25 / 2.86) x 100

= 78.4 % (78.7) (78.1)

b. Describe how the purity of the product could be qualitatively determined using thin layer chromatography.

Both salicylic acid and aspirin can be detected using ultraviolet light. Ethyl ethanoate can be used as a suitable solvent.

Sol. Run a thin layer chromatogram of the product*, that is, the aspirin produced, and check the chromatogram under UV light If the chromatogram shows two or more spots, the sample is impure*/(single spot, the sample may be assumed to be pure).

Salicylic acid reacts with aqueous $FeCl_3$ to form a purple compound. Aspirin does not react with aqueous $FeCl_3$.

c. Describe how the purity of the product could be quantitatively determined using UV-visible spectroscopy.

Sol. Three of:

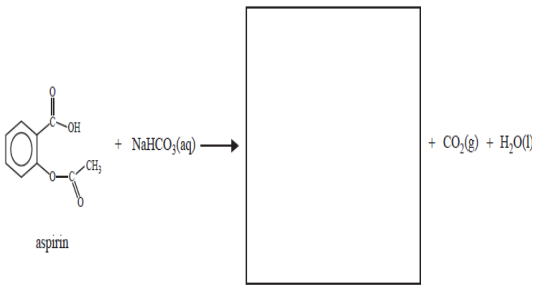
• identify the appropriate wavelength at which a solution of the purple compound (salicylic acid/ $FeCl_3$) absorbs strongly

• make up a set of standards of salicylic acid/ $FeCl_3$(aq) and measure absorbances to construct a calibration curve

• make up a solution of a measured amount of the product/ $FeCl_3$(aq) and measure its absorbance

• use the absorbance to calculate the amount of salicylic acid (hence aspirin) in the compound.

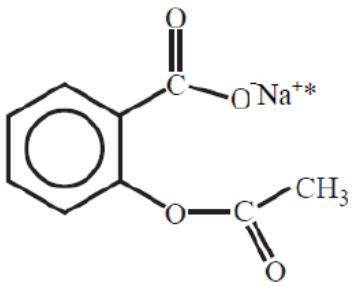
d. The sodium salt of aspirin is more soluble than aspirin itself. This salt may be synthesised by reaction between aspirin and sodium hydrogen carbonate as follows.



aspirin

i. In the box provided, give the complete structure for the sodium salt of aspirin.

Sol.



ii. Explain why the sodium salt of aspirin is more water-soluble than aspirin.

Sol. Ion-dipole bonds between -COO- and H_2O are stronger* than hydrogen bonds between between -COOH and H_2O. Only a small proportion of students recognised that in the sodium salt, the carboxyl group on aspirin (acetylsalicylic acid) molecules had been deprotonated to COO- and so aspirin is present as acetylsalicylate ions.

Q123. A student is to accurately determine the concentration of a solution of sodium hydrogencarbonate in a titration against a standard solution of hydrochloric acid, HC1. The first step in this experiment is to accurately dilute 100.0 mL of a 1.00 M HCl stock solution to a 0.100 M solution using a 1.00 L volumetric flask. However, instead of using distilled water in the dilution, the student mistakenly adds 900.0 mL of 0.0222 M sodium hydroxide, NaOH, solution.

a. Write an equation for the reaction that occurs in the 1.00 L volumetric flask.

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ or $H_+(aq) + OH_-(aq) \rightarrow H_2O(l)$

b. Calculate the concentration of the hydrochloric acid in the 1.00 L volumetric flask after the student added the sodium hydroxide solution.

Sol.

n(NaOH) in flask = 0.0222 x 900.0×10^{-3} = 0.0200 mol

n(HCl) reacted = 0.0200 mol*

n(HCl) added to flask = 1.00 x 100.0×10^{-3} = 0.100 mol

n(HCl) remaining = 0.100 – 0.0200 = 0.080 mol

c(HCl) = 0.080 (M)

The student then uses this contaminated hydrochloric acid solution to determine the accurate concentration of the unknown sodium hydrogencarbonate solution.

c. Will the calculated concentration of sodium hydrogencarbonate solution be greater or smaller than the true value?

Sol. Greater, since a larger volume of the HCl solution will be required

Q124. Elemental sulfur can be used to control outbreaks of powdery mildew on grapes. However, sulfur remaining on the grapes after harvest can be converted to a number of undesirable compounds during fermentation in wine production.

A wine chemist uses atomic absorption spectroscopy to determine the amount of sulfur remaining on grapes. In a particular analysis, 100.0 g of grapes are treated with 100.0 mL of surfactant solution to remove the sulfur remaining on the grapes when they were harvested.

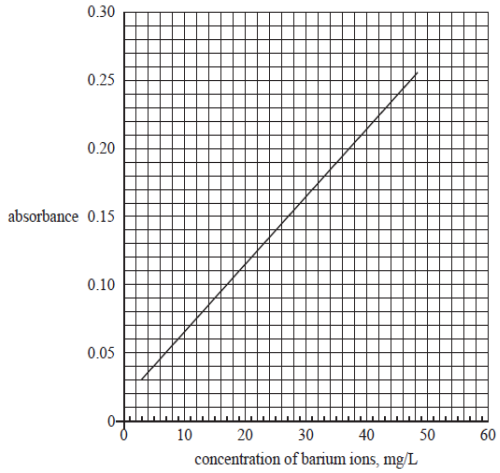
25.00 mL of this surfactant solution is treated to convert all of the sulfur to sulfate ions and then dried to produce an ash containing the sulfate ions.

This ash is transferred to a 10.00 mL volumetric flask containing 2.00 mL of 200 mg/L solution of barium Ba2+ ions.

The volume of solution in the volumetric flask is then made up to the calibration line. A precipitate of $BaSO_4$ forms and settles to the bottom of the volumetric flask.

A small amount of the solution containing the unreacted Ba2+ ions is removed from the volumetric flask and analysed using atomic absorption spectroscopy. This solution gave an absorbance of 0.11.

A calibration curve was prepared using standard solutions of 10, 20, 30 and 40 mg/L $Ba^{2+}(aq)$.



a. Determine the concentration of barium ions remaining in the 10.00 mL sample solution. Hence determine the mass of barium ions, in mg, remaining in the 10.00 mL sample solution.

Sol. c. (Ba^{2+}) remaining = 19 mg L^{-1}* m(Ba^{2+}) in 10.00 mL = (19 / 1000) x 10 = 0.19* (mg)

b. Determine the amount of barium ions, in moles, that reacted to produce the barium sulfate precipitate.

Sol. m(Ba^{2+}) added to volumetric flask = (2.00 / 1000) x 200 = 0.400 mg m(Ba^{2+}) remaining in volumetric flask = 0.19 mg

m(Ba^{2+}) reacted = 0.400 – 0.19 = 0.21 mg* (0.00021 g)

n(Ba^{2+}) reacted = 0.21x10-3 / 137.3 = 1.5x10-6* (mol)

c. Determine the mass of sulfur, in mg, remaining on the 100 g of harvested grapes.

Sol.

n(S) in 25 mL surfactant = n($BaSO_4$) precipitated in volumetric flask

= n(Ba^{2+}) reacted = $1.5x10^{-6}$ mol

n(S) in 100 g of grapes = n(S) in 100 mL surfactant =$4x1.5x10^{-6}$*

$= 6.0 \times 10^{-6}$ mol

m(S) in 100 g of grapes = $6.0 \times 10^{-6} \times 32.1 = 1.9 \times 10^{-4}$ g = 0.19* mg

The amount of sulfur remaining on the grapes can also be determined using gravimetric analysis.

d. Give one reason why atomic absorption spectroscopy is a better way to determine the residual sulfur on the grapes compared to gravimetric analysis.

Sol. AAS is more accurate/ Gravimetric analysis is less accurate/ AAS is more effective with low concentrations/A large amount of grapes is needed for effective gravimetric analysis

Q125. In a flask, 10.0 mL of a 0.100 M HCl solution is diluted to 1.00 L. In a second flask, 10.0 mL of a 0.100 M KOH solution is also diluted to 1.00 L. Which statement best describes the changes in pH in these flasks?

pH change of the HCl solution pH change of the KOH solution

a. increases by 2 decreases by 2

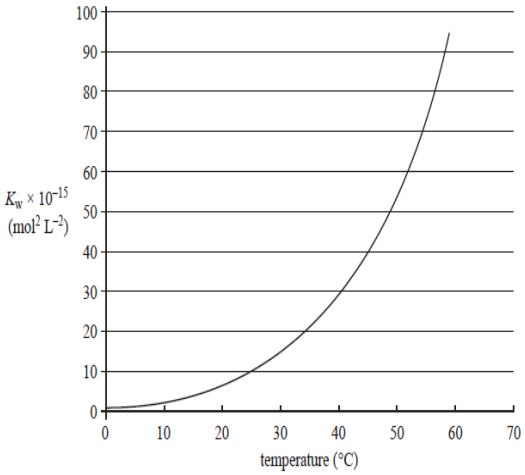
b. increases by 2 increases by 2

c. decreases by2 increases by 2

d. decreases by 2 decreases by 2

Sol. a. When an acidic solution is diluted the pH increases, and when a basic solution is diluted the pH decreases. When 10.0 mL of 0.100 M HCl(aq) is diluted to 1.00 L at 25°C, the pH increases from 1 to 3. When 10.0 mL of 0.100 M KOH(aq) is diluted to 1.00 L at 25°C, the pH decreases from 13 to 11.

Q126. The value of the ionisation constant, Kw, of a sample of pure water at different temperatures is shown in the graph below.



Which one of the following statements about the effect of increasing temperature on the pH and acidity of water is correct?

a. The pH is always 7 and the water remains neutral.

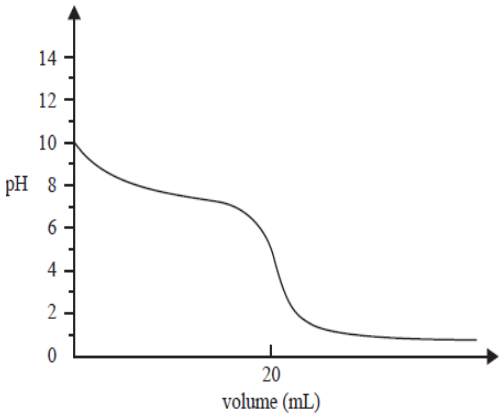
b. The pH decreases and the water remains neutral.

c. The pH decreases and the water becomes acidic.

d. The pH increases and the water remains neutral.

Sol. c. The graph showed that Kw increases as the temperature increases. This is consistent with the self ionisation of water equilibrium, that is, $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ moving to the right as temperature increases and the $[H_3O^+]$ and $[OH^-]$ increase. The water remains neutral but the pH decreases.

Q127-128. The following titration curve was obtained by measuring the pH in a reaction flask during an acid-base titration.



Q127. The graph represents the change in pH in the reaction flask when

a. a weak acid is added to a strong base.

b. a weak base is added to a strong acid.

c. a strong acid is added to a weak base.

d. a strong base is added to a weak acid.

Sol. c. The starting pH of 10 is indicative of a weak base.

The drop in pH to 1 would be due to titration with a strong acid; therefore, a strong acid was added to a weak base.

Q128. Which one of the following is a suitable indicator for use in this titration?

a. phenol red

b. thymol blue

c. phenolphthalein

d. bromophenol blue

Sol. d. The titration curve suggests that the endpoint isaround pH 4. Of the indicators listed, onlybromophenol blue (3.0–4.6) would be suitable for identifying the endpoint.

Q129. A sample of the insecticide dichlorodiphenyltrichloroethane (DDT), $C_{14}H_9Cl_5$, was found to contain 0.120 g of carbon.

What mass of chlorine was present in the sample?

a. 0.127 g

b. 0.355 g

c. 0.994 g

d. 1.01 g

Sol. a.

n**c.** = 0.120 / 12.0= 1.00×10^{-2} mol

$n(C_{14}H_9Cl_5) = 1.00 \times 10^{-2} / 14$

$n(Cl) = 5 \times 1.00 \times 10^{-2} / 14$

$= 3.57 \times 10^{-3}$ mol

$m(Cl) = 3.57 \times 10^{-3} \times 35.5 = 0.127$ g

Q130. When 1.0 mole of Cu_3FeS_3 and 1.0 mole of O2 are mixed and allowed to react according to the equation

$2Cu_3FeS_3(s) + 7O_2(g) \rightarrow 6Cu(s) + 2FeO(s) + 6SO_2(g)$

a. no reagent is in excess.

b. 5 mole of O_2 is in excess.

c.5/7 mole of Cu_3FeS_3 is in excess.

d. 2/7 mole of $Cu3FeS_3$ is in excess.

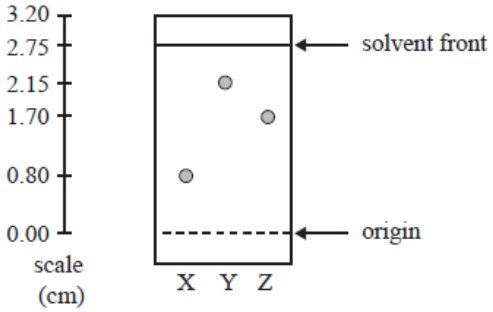
Sol.

	$2Cu_3FeS_2 + 7O_2 \rightarrow 6Cu + 2FeO + 6SO_2$					
Initial	1.0	1.0				mol
Reacting	$^2/_7$	1.0 $\rightarrow$	$^6/_7$	$^2/_7$	$^6/_7$	mol
Final	$^5/_7$	-	$^6/_7$	$^2/_7$	$^6/_7$	mol

Hence, $^5/_7$ mol Cu_3FeS_2 is in excess.

Q131. Consider the following TLC plate of compounds X, Y and Z

developed using a suitable mobile phase on a polar stationary phase.



The Rf value of the most polar component in this TLC separation is

a. 0.29
b. 0.62
c. 0.78
d. 0.80

Sol. a. The most polar substance will be most strongly attracted to the polar stationary phase, and hence will move least along the stationary phase and will have the lowest Rf value.
Rf(X) = 0.80 / 2.75 = 0.29

Q132. Which of the following would be the most suitable analytical technique to determine the ratio of 235U to 238U in a sample of uranium metal?

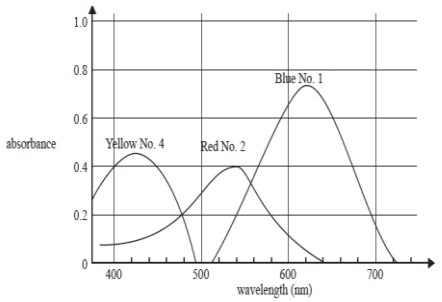
a. mass spectroscopy
b. gas liquid chromatography
c. atomic absorption spectroscopy
d. nuclear magnetic resonance spectroscopy

Sol. a. Isotopes are separated and quantified by mass spectroscopy.

Q133. When a sample absorbs infrared radiation

a. covalent bonds are broken.
b. covalent bonds stretch and vibrate.
c. the spin alignment of certain nuclei changes.
d. electrons in atoms move to higher energy levels.

Q134. The graph shows the absorption spectra of three food dyes: Blue No. 1, Red No. 2 and Yellow No. 4.



Which one of the following is the best wavelength to determine the concentration of Red No. 2 dye in a solution containing a mixture of all three dyes?

a. 430 nm
b. 500 nm
c. 540 nm
d. 620 nm

Sol. b. The best wavelength to use is one where Red No. 2 dye absorbs strongly but no other dye in the mixture does, i.e. 500 nm. According to the absorption spectra provided, Red No. 2 absorbs most strongly at 540 nm. However, because Blue No.1 dye also absorbs significantly at 540 nm, it is not the best wavelength to use.

Q135. The amount of iron in a newly developed, heat-resistant aluminium alloy is to be determined. An 80.50 g sample of alloy is dissolved in

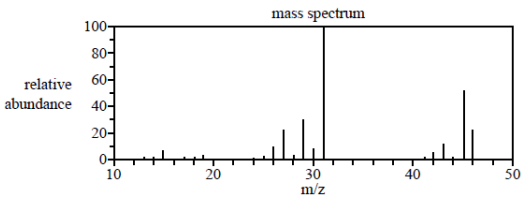
concentrated hydrochloric acid and the iron atoms are converted to $Fe^{2+}(aq)$ions.
This solution is accurately transferred to a 250.0 mL volumetric flask and made up to the mark. 20.00 mL aliquots of this solution are then titrated against a standard 0.0400 M potassium permanganate solution.
$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$
Four titrations were carried out and the volumes of potassium permanganate solution used were recorded in the table below.

Titration number	1	2	3	4
Volume of $KMnO_4$ (mL)	22.03	20.25	21.97	21.99

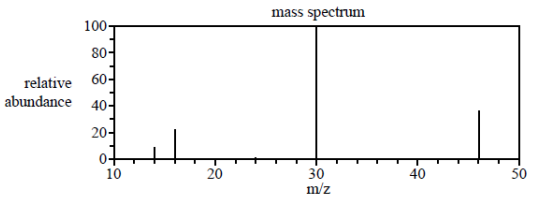
a. Write a balanced half-equation, including states, for the conversion of MnO_4 – ions, in an acidic solution, to Mn_2^+ ions.
Sol. Either of:
• $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$
• $MnO4\text{-}(aq) + 8H_3O^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 12H_2O(l)$.
b. Calculate the average volume, in mL, of the concordant liters of the potassium permanganate solution.
Sol.
(22.03 + 21.97 + 21.99)/3 = 22.00 mL
c. Use your solution to part **b.** to calculate the amount, in mol, of MnO_4–(aq) ions used in this titration.
Sol. $n(MnO_4^-) = 0.0400 \times 22.00 \times 10^{-3}$
$= 8.80 \times 10^{-4}$* (mol) or 0.000880
d. Calculate the amount, in mol, of $Fe_2^+(aq)$ ions present in the 250.0 mL volumetric flask.
Sol. $n(Fe_2^+)$ in 20 mL aliquot = 5 x $n(MnO_4^-) = 5 \times 8.80 \times 10^{-4}$*
$= 4.40 \times 10^{-3}$ (mol)
$n(Fe^{2+})$ in 250 mL flask = 4.40×10^{-3} x (250/20) = 5.50×10^{-2}* (mol)
e. Calculate the percentage, by mass, of iron in the 80.50 g sample of alloy.
Sol. n(Fe) in 80.50g alloy = 5.50×10^{-2} (mol)
m(Fe) in 80.50 g alloy = 5.50×10^{-2} x 55.9* = 3.07 (g)
% Fe in alloy = (3.07 / 80.50) x 100*
= 3.82 % (3.81)

Q136. The molecules ethanol and nitrogen dioxide have the same molar mass (M = 46 g mol^{-1}). They can be easily distinguished by mass spectrometry.
The mass spectra of the two molecules are shown below.

Spectrum A



Spectrum B



a. Write an equation showing how either an ethanol molecule or a nitrogen dioxide molecule becomes ionised in the mass spectrometer.
Sol. Any of:
• $CH_3CH_2OH(g) + e^- \rightarrow [CH_3CH_2OH]^+(g) + 2e^-$

• $CH_3CH_2OH(g) \rightarrow CH_3CH_2OH^+(g) + e^-$
• $C_2H_6O(g) \rightarrow [C_2H_6O]^+(g) + e^-$
• $NO_2(g) + e- \rightarrow [NO_2]+(g) + 2e-$
• $NO_2(g) \rightarrow NO^{2+}(g) + 2e-$.

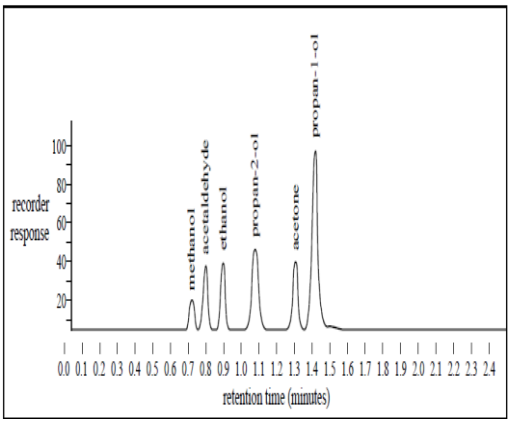
b. Which mass spectrum cannot be that of nitrogen dioxide? What evidence does the mass spectrum provide to support your solution?

Sol. Either of:
• Spectrum A
• Peaks at m/e = 45 **(**or 31 or 29 or 27) will not result from fragmentation of $[NO_2]+$ or NO^{2+}, since molecules with only three atoms cannot produce as many fragmentation peaks.

c. What is the formula of the species that produces the peak seen at m/z 30 in spectrum B?

Sol. [NO]+ or NO+ or NO•+

Q137. A forensic chemist wants to test the accuracy of a gas chromatograph that is to be used for the analysis of blood alcohol content. A blood sample may contain a number of volatile chemicals that can interfere with the identification and measurement of ethanol in the blood. A sample containing a mixture of ethanol and several other volatile chemicals was injected into the gas chromatograph. The following chromatogram was obtained.



a. The forensic chemist claims that the presence of these volatile chemicals would not affect the qualitative analysis of ethanol.

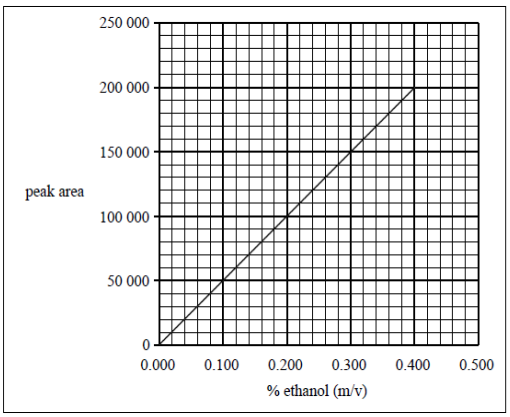
i. What evidence is presented in the chromatogram to support this claim?

Sol. Acceptable responses included:
• ethanol has a unique retention time/peak
• each chemical produces a distinct peak on the chromatogram.

ii. To determine the percentage of alcohol in a blood sample only the peak at a retention time of 0.9 minutes is measured. Explain why.

Sol. Acceptable responses included:
• the analysis is to determine the amount of ethanol in blood
• 0.9 is the retention time of ethanol, the alcohol in blood which is analysed.

The following calibration graph was constructed using simulated standard blood alcohol samples ranging in concentration from 0.000% to 0.400% m/v ethanol. Each standard was run through the chromatography column and the area under the peak produced at a retention time of 0.9 minutes was measured.



The blood alcohol content of a car driver was determined using this chromatographic technique.

b. Determine the percentage (m/v) of alcohol in the driver's blood if the peak area at a retention time of 0.9 minutes was found to be 110 000.

Sol. 0.220(%)

Q138. The factors which influence the rate of reaction between dilute hydrochloric acid and powdered calcium carbonate were investigated.

Which one of the following changes would **not** increase the rate of the reaction?

a. stirring the mixture.

b. heating the reaction mixture.

c. increasing the concentration of the acid.

d. replacing the powder with a lump of calcium carbonate

Q139. A 10 mL sample of 0.010 M HCl is diluted by adding distilled water at constant temperature.

Which one of the following items correctly shows the effect of the dilution on the concentrations of H+ and OH– ions in the solution?

	$[H^+]$	$[OH^-]$
A.	decrease	decrease
B.	decrease	increase
C.	increase	decrease
D.	increase	increase

Sol. b.

HCl(aq) is a strong acid and it ionises completely so the concentration changes on dilution can be related to the equilibrium:

$2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

$K_w = [H_3O^+][OH^-] = 10^{-14}$ at 25°C**.**

On dilution, the [H3O+] and [OH-] both decrease, and since $[H_3O^+][OH^-] < K_w$, the forward reaction is favoured and both concentrations increase. The effect of this return to equilibrium impacts significantly more on the $[OH^-]$ than the $[H_3O^+]$.

Consider 0.010 M HCl(aq) at 25°C

$[H_3O^+] = 10^{-2}$ M and [OH-] = 10^{-12} M

On dilution, by say a factor of 10, $[H_3O^+]$ immediately decreases to 10-3 M and $[OH^-]$ to 10^{-13} M and so $[H_3O^+][OH^-]$ = 10-16, i.e. < 10^{-14}.

As the system moves to the right to return to equilibrium, the $[OH^-]$ increases from 10^{-13} M to 10-11 M, that is, by 9.9×10^{-12} M. The $[H3O^+]$ also increases by 9.9×10^{-12} M, a negligible amount compared to its concentration, 10^{-3} M, on dilution.So while the $[H_3O^+]$ has decreased due to the dilution, the [OH-] has increased overall. More simply, HCl is a strong acid and so it is completely ionised in aqueous solution. On dilution, the [H+] decreases.

Since the temperature is constant, Kw – [H][OH^-] – does not change. Hence

as $[H^+]$ decreases, $[OH^-]$ must increase.
The choice of option **a** suggested that a significant number of students did not deal with the equilibrium issues involved. Students are expected to know that the value of $[H_3O^+][OH^-]$ at equilibrium will be the same before and after the dilution. This makes it impossible for both $[H_3O^+]$ and $[OH^-]$ to decrease overall as a result of the dilution.

Q140. A chemist prepares 0.10 M aqueous solutions of each of the following acids.
Which solution has the lowest pH?
a. CH_3COOH
b. HNO_2
c. HCN
d. HOCl
Sol. b. All the acids listed were weak acids, so the solution with the lowest pH, due to the highest $[H_3O^+]$, is the one with the largest Ka value.

Q141. Barium hydroxide is soluble in water. The pH at 25 °C of a 0.0050 M solution of $Ba(OH)_2$ is:
a. 2.0
b. 2.3
c. 11.7
d. 12.0
Sol. d. $Ba(OH)^2(aq) \rightarrow Ba_2+(aq) + 2OH-(aq)$
$c(OH^-) = 2 \times 0.0050 = 0.010$ M
$c(H_3O^+) = 10^{-14} / 0.010 = 1.0 \times 10^{-12}$ M
pH = 12
The significance of the chemical formula of $Ba(OH)_2$ was overlooked by students who selected options **b** and **c.**

Q142. a. Lactic acid, $CH_3CH(OH)COOH$, is a weak acid found in milk. The molar mass of lactic acid is 90.0 g mol^{-1}. In an experiment a student dissolved 4.50 g of lactic acid in 500.0 mL of water.
$CH_3CH(OH)COOH(l) + H_2O(l) \rightleftharpoons CH_3CH(OH)COO^-(aq) + H_3O^+(aq)$
i. Calculate the equilibrium molar concentration of H_3O^+ ions in the lactic acid solution.
Sol. n(lactic acid) = 4.50/90.0
= 0.0500 mol
$c(\text{lactic acid}) = 0.0500/500.0 \times 10^{-3}$
= 0.100 M
$Ka = [A-][H_3O^+] / [HA]$
$Ka = [H_3O^+]^2 / [CH_3CH(OH)COOH]$
$1.4 \times 10^{-4} = [H_3O^+]^2/0.100$
$[H_3O^+] = (0.100 \times 1.4 \times 10^{-4})^{1/2}$
$= 3.7 \times 10^{-3}$ (M)
ii. Calculate the pH for the lactic acid solution.
Sol. $pH = -\log 10 (3.74 \times 10^{-3}) = 2.43$
iii. Calculate the percentage ionisation of lactic acid in this experiment.
Sol. % ionisation = $(3.74 \times 10^{-3}/0.100) \times 100 = 3.74$
iv. State one assumption that you made when calculating your solution to part **i.**
Sol. Acceptable reponses included:
• ionisation of lactic acid is negligible
• contribution to $[H_3O^+]$ from the self-ionisation of water is negligible
• $[CH_3CH(OH)COOH]$ at equilibrium is the same as its initial concentration
• $[H_3O^+] = [CH_3CH(OH)COO^-]$.
The statement 'ionisation of lactic acid produces equal amounts (in mol) of $CH_3CH(OH)COO-$ and H_3O^+ ions' is astatement of fact, not an

assumption. The assumption is that $[H_3O^+]$ = $[CH_3CH(OH)COO^-]$ is linked to the negligible impact of the self-ionisation of water.

b. A 1.0 M solution of lactic acid is prepared at 25°C**.**

When distilled water is added to this solution

i. the pH will decrease increase not change

Sol. Increase

Although the amount of $H3O^+$ present increases following dilution as the equilibrium shifts right, the $[H_3O^+]$ is lower overall and so the pH increases.

ii. the percentage ionisation of the acid will decrease increase not change

Sol. Increase

The amount of $H_3O^+(aq)$ and $A^-(aq)$ increases during the dilution of a weak acid, HA(aq), as the position of equilibrium shifts to the right. Hence, the percentage ionisation of a weak acid increases on dilution. Students should be aware that increased ionisation on dilution is a characteristic of weak acids.

iii. Provide an explanation for your solution to part **ii.**

Sol.

Acceptable responses included:

• adding water (dilution) decreases the overall concentration and the reaction shifts to produce more particles

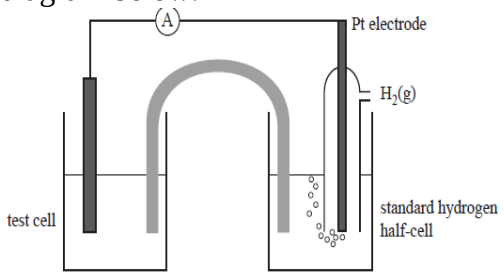
• increasing the volume decreases the concentration fraction so forward reaction is favoured

• water is a reactant and so, according to Le Chatelier's principle, there is net forward reaction.

Q143. In a problem-solving activity a student is given the following information regarding three half-equations. However, although the three numerical values of E0 are correct, they have been incorrectly assigned to the three half-equations.

Half-equation	E^0
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	–0.40 V
$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	–0.36 V
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	+0.22 V

The objective of this task is to correctly assign the E_0 values to the corresponding half-equation.To do this, the student constructs standard half-cells for each of the above half-reactions. These half-cells are connected, one at a time, to a standard hydrogen half-cell as indicated in the diagram below.



The following observations were made either during or after the electrochemical cell discharged electricity for several minutes.

Experiment	Half-cell reaction being investigated	Experimental notes
1	$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	Electron flow was detected passing from the standard hydrogen half-cell to the half-cell containing the silver electrode.
2	$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	The mass of the cadmium electrode decreased.
3	$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	The pH of the solution in the standard hydrogen half-cell increased.

a. The above information can only be used to assign one of the E_0 values to its corresponding half-equation. Identify this half-equation by placing the correct E_0 value next to its corresponding half-equation in the table below.

Half-equation	E^0
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	
$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	

Sol.

Half-equation	E^0
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	+0.22
$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	

b. Explain why the other two E_o values cannot be correctly assigned to their half-equations.

Sol. Acceptable responses included:

• both of the other half-equations have negative E_o values, but to determine their locations, the potential difference of each when connected to the standard hydrogen electrode needed to be recorded.

• both E_o values are below the $H+/H_2$ half-cell, but there is not enough information to identify their relative positions.

• both undergo oxidation by $H^+(aq)$, but there is not enough data to determine which has the stronger reductant.

• the data indicates that electrons flow from the two other half-cells to the SHE but does not give the potential differences.

c. Explain why the pH of the solution in the standard hydrogen half-cell increased in experiment 3.

Sol. Acceptable responses included:

• $[H^+(aq)]$ decreases so pH increases

• reaction occurring is $2H^+(aq) + 2e^- \rightarrow H_2(g)$

• $H^+(aq)$ is the oxidant and is consumed.

Q144. Which 0.1M solution of following acids has the highest pH?

a. mitrous acid

b. ethanoic acid

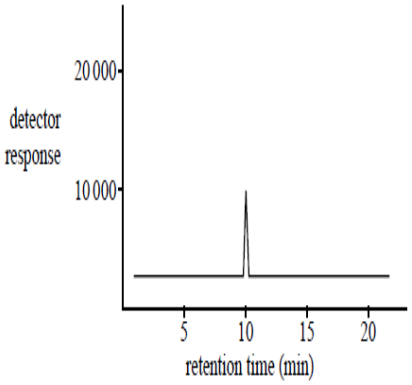
c. methanoic acid

d. hyporomous acid

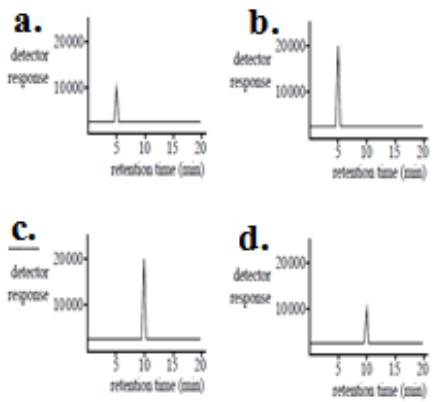
Sol. d. With no other information supplied, the Data Book should have been an immediate reference for students.

All the acids are weak acids. The acid with the highest pH will have the lowest $[H_3O^+]$. Since all acid solutions were 0.1 M, the acid with the lowest $[H_3O^+]$ is the one that ionises least in aqueous solution. This will be the acid with the lowest Ka, i.e. hypobromous acid.

Q145. The following chromatogram was produced when 0.1 μg of decane was passed through a gas chromatography column.



The chromatogram produced when 0.2 μg of decane is passed through the same column under identical conditions is best represented by



Q146. 15.0 mL of 10.0 M HCl is added to 60.0 mL of deionised water. The concentration of diluted acid is:

a. 3.33 M

b. 2.50 M

c. 2.00 M

d. 0.500 M

Sol. c. n(HCl) present = 10.0 mol L^{-1} × 15.0 × 10^{-3} L = 1.50 × 10^{-3} M

Volume of diluted acid = 15.0 + 60.0 = 75.0 mL

c(diluted acid) = 1.50 × 10^{-3} mol ÷ 75.0 × 10^{-3} L = 2.00 M

Alternatively, since the volume of the acid increases by a factor of 5 (15.0 mL to 75.0 mL) the concentration decreases by a factor of 5 from 10.0 M to 2.00 M.

Option **b** is consistent with calculating the concentration of the diluted acid based on the volume of diluted solution being 60.0 mL.

Q147. A sample of the anticancer drug Taxol®, $C_{47}H_{51}NO_{14}$, contains 0.157 g of carbon.

The mass, in grams, of oxygen in the sample is

a. 0.0468

b. 0.0624

c. 0.209

d. 0.703

Sol. b. Taxol® $C_{47}H_{51}NO_{14}$

nc present = 0.157 g ÷ 12.0 g mol^{-1} = 0.0131 mol

n(Taxolc) = nc ÷ 47

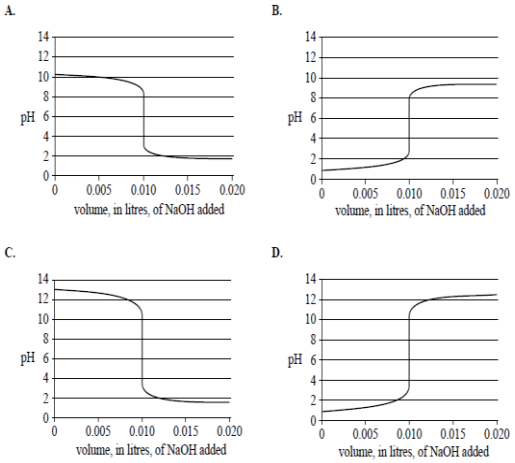
n(O) present = 14 × n(Taxol®) = 14 × nc ÷ 47 = 14 × 0.0131 ÷ 47 = 0.00390 mol

m(O) present = 0.00390 × 16.0 = 0.0624 g

Option **a** was consistent with using the 14/47 ratio to calculate the m(O) directly from the mc. Students should know that ratios deduced directly from a formula, or an equation, are mole ratios not mass ratios.

Option **c** was consistent with overlooking the 14/47 ratio in calculating the n(O) from the nc.

Q148. Which titration curve best represents the change in pH as 0.100 M NaOH solution is added to a 10.0 mL aliquot of 0.100 M HCl solution?



Sol. d. The solution to be titrated was 0.100 M HCl, so the pH at the start of the titration was 1 as indicated on graphs **b** and **d.** As 0.100 M NaOH is added beyond the endpoint – that is, after 0.010 L (10 mL) NaOH has been added–the solution becomes increasingly basic and the pH approaches 13 (the pH of 0.100 M NaOH). Hence option **d** was correct.

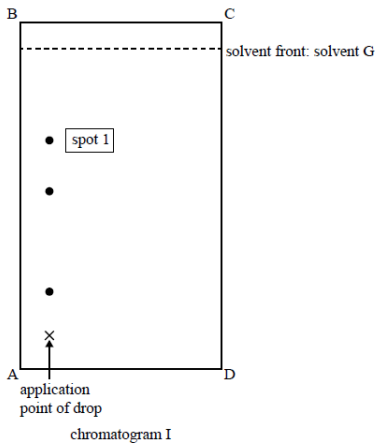
After 0.020 L (20 mL) of 0.100 M NaOH has been added, there will be 0.0010 mol OH^- in excess in 30 mL of solution

$\therefore [OH^-] = 0.033$ M

$\therefore$ pH = 12.5

Options **a** and **c** were not consistent with a starting solution of 0.100 M HCl.

Q149. A drop that contains a mixture of four amino acids was applied to a thin layer chromatography plate. The plate was placed in solvent G and the following chromatogram was obtained.



The R_f values for each of the amino acids in solvent G are provided in Table 1 below.

Table 1. R_f values in solvent G

amino acid	R_f (solvent G)
alanine	0.51
arginine	0.16
threonine	0.51
tyrosine	0.68

a. Name the amino acid that corresponds to spot 1.

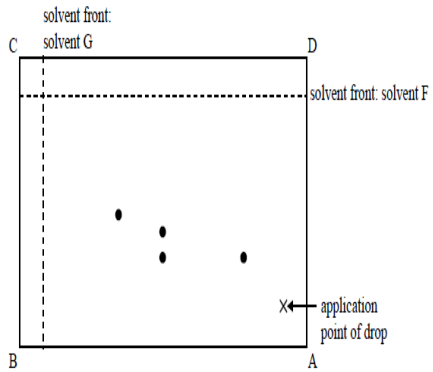
Sol. Tyrosine

The plate was dried, rotated through 90° in an anticlockwise direction and then placed in solvent F. The R_f values for each of the amino acids in solvent F are provided in Table 2 below.

Table 2. R_f values in solvent F

amino acid	R_f (solvent F)
alanine	0.21
arginine	0.21
threonine	0.34
tyrosine	0.43

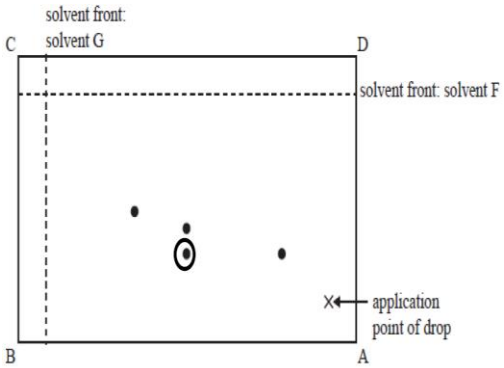
The following chromatogram was obtained.



chromatogram II

b. Circle the spot on chromatogram II that represents alanine.

Sol.



chromatogram II

c. Explain, in terms of the data provided, why only three spots are present in chromatogram I while four spots are present in chromatogram II.

Sol. In chromatogram I, which used solvent G, alanine and threonine appeared as the same spot/were not separated since both had the same Rf value (0.51). In chromatogram II, which used solvent F, alanine and threonine had different R_f values and were separate.

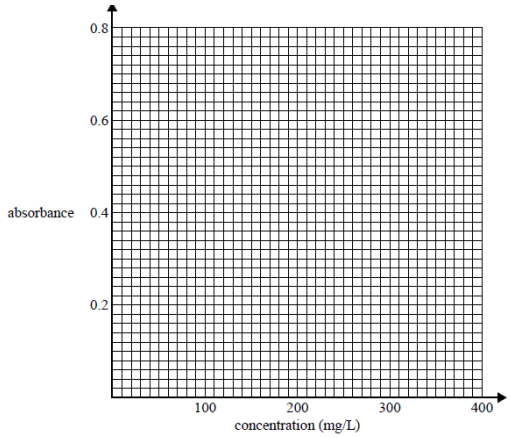
Q150. The iron content in multivitamin tablets was determined using atomic absorption spectroscopy. The absorbances of four standards were measured.

Three multivitamin tablets were selected. Each tablet was dissolved in 100.0 mL of water. The absorbance of each of the three solutions was then measured.

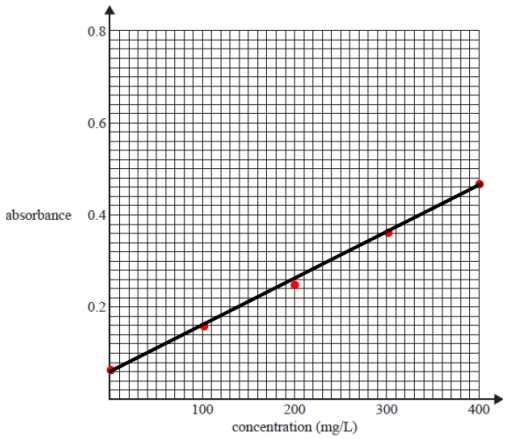
The following absorbances were obtained.

Solution	Concentration mg/L	Absorbance
Standard 1	0.00	0.06
Standard 2	100.0	0.16
Standard 3	200.0	0.25
Standard 4	300.0	0.36
Standard 5	400.0	0.46
Tablet 1	–	0.39
Tablet 2	–	0.42
Tablet 3	–	0.45

a. i. Use the grid below to construct a calibration graph of the absorbances of the standard solutions.



Sol.



ii. Determine the average iron content, in milligrams, of the multivitamin tablets.

Sol. Average absorbance of the iron tables = 0.42

c(Fe) = 360 mg L^{-1}

Average m(Fe) in each tablet (in 100 mL solution) = 36 mg

Average iron content = 36 (mg)

Spectroscopic techniques work on the principle that, under certain conditions, atoms, molecules or ions will interact with electromagnetic radiation. The type of interaction depends on the wavelength of the electromagnetic radiation.

b. Name one spectroscopic technique that you have studied this year.

i. Which part of the electromagnetic spectrum does this technique use?

Sol. the part of the electromagnetic spectrum used by the technique nominated

ii. How does this part of the electromagnetic spectrum interact with matter? What information does this spectroscopic technique provide?

Sol.

Spectroscopic technique	Part of spectrum	How it interacts	Information provided
AAS (Atomic Absorption)	visible radiation	Electrons (in atoms) move to higher energy levels	Concentration of the absorbing species
UV-visible	ultraviolet and/or visible radiation	Electrons (in molecules or ions) move to higher energy levels	Concentration of the absorbing species
IR (infrared)	infrared radiation	'Change' in bond vibration/ stretching/polarity in molecules	Types of bonds/functional groups in a molecule
1H NMR (Nuclear magnetic resonance)	radiowave radiation	1H nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of H atoms in a molecule
13C NMR (Nuclear magnetic resonance)	radiowave radiation	13C nuclei, in molecules, change to nucleus energy levels/spin states	Bonding environments of C atoms in a molecule

Q152. The solubility of highly soluble, thermally unstable salts such as ammonium chloride may be determined by back titration.

In one experiment a 5.00 mL saturated solution of ammonium chloride, NH_4Cl, at 20.0°C, was diluted with distilled water to 250.0 mL in a standard fl ask.

A 20.0 mL aliquot of this solution was added to 10.0 mL of 0.400 M NaOH solution. The solution was heated to drive off the ammonia formed by this reaction.

When the flask had cooled, the excess hydroxide ions were neutralised by 14.7 mL of 0.125 M HCl solution.

The molar mass of ammonium chloride is 53.5 g mol^{-1}.

a. i. Write an equation for the neutralisation reaction.

Sol. Either of:

• $NaOH(aq) + HCl(aq) \rightleftharpoons NaCl(aq) + H^2O(l)$

• $OH^-(aq) + H^+(aq) \rightleftharpoons H_2O(l)$.

ii. Determine the amount, in mole, of NaOH that was originally added to the ammonium chloride solution.

Sol.

$n(NaOH) = 0.400 \times 10.0 \times 10^{-3}$

$= 4.00 \times 10^{-3}$ (mol)

iii. Determine the amount, in mole, of ammonium chloride in the 20.0 mL aliquot.

Sol. $n(NH_4Cl)$ in 20.0 mL aliquot = n(NaOH) reacting with NH_4Cl in the 20.0 mL aliquot

= n(NaOH) initially – n(NaOH) in excess

n(NaOH) in excess = n(HCl)

$= 0.125 \times 14.7 \times 10^{-3}$ mol

$= 1.84 \times 10^{-3}$ mol

n(NH4Cl) in 20.0 mL aliquot = $4.00 \times 10^{-3} - 1.84 \times 10^{-3}$

$= 2.16 \times 10^{-3}$ mol

iv. Calculate the amount, in mole, of ammonium chloride in 5.00 mL of the saturated solution.

Sol.

$n(NH_4Cl)$ in 5.00 mL saturated solution = $n(NH_4Cl)$ in 250 mL diluted solution

= ($n(NH_4Cl)$ in 20mL diluted solution/ 20) × 250

$= (2.16 \times 10^{-3} \div 20) \times 250$

= 0.0270 mol

v. Calculate the solubility, in gL^{-1}, of ammonium chloride in water at 20°C.

Sol. $n(NH_4Cl)$ in one litre = $(0.0270/5) \times 1000 = 5.41$ mol

$m(NH_4Cl)$ in one litre = 5.41×53.5

= 289 g

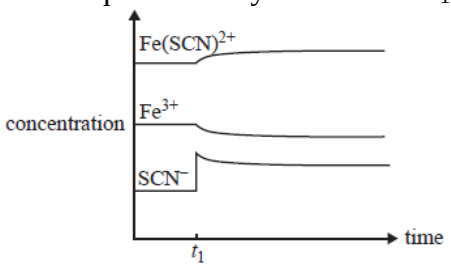
Solubility 289 g L^{-1} (288–290)

b. If the burette was rinsed with water instead of acid before the titration, how would the calculated solubility of ammonium chloride be affected? Explain your **Sol.**

Sol.

Since the HCl(aq) in the burette was diluted, a larger V(HCl) (liter) was required to react with the excess NaOH. Hence the n(NaOH) in excess was calculated as higher than true, leading to a smaller calculated n(NaOH) reacted with NH_4Cl and a lower calculated amount (solubility) of NH_4Cl.

Q153. The concentration profi le below represents a change to the above equilibrium system at time t_1.



Which one of the following would account for the changes in concentration at time t_1?

a. the addition of SCN^-

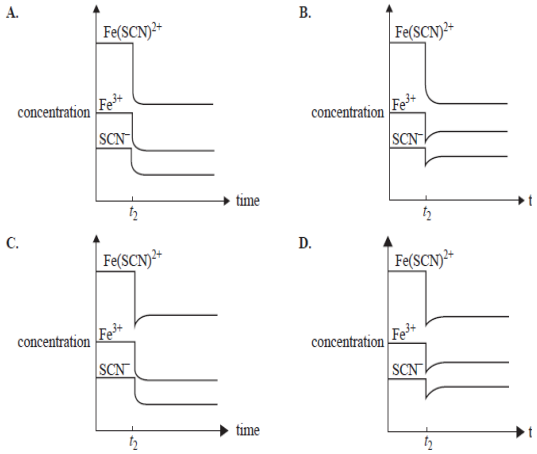
b. the removal of $Fe(SCN)_2^+$

c. an increase in temperature

d. a decrease in temperature

Q154. Which one of the following best represents the changes in

concentration when the equilibrium mixture is diluted at time t_2?



Sol. b. On dilution, the concentrations of $Fe^{3+}(aq)$, SCN–(aq) and $Fe(SCN)^{2+}(aq)$ all decrease. The system responds to partially oppose this instantaneous decrease in 'total' concentration by moving to increase 'total' concentration; that is, favouring the reaction direction that produces more particles. The equilibrium $Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons Fe(SCN)_2^{+}(aq)$ moves to the left, so the $[Fe(SCN)_2^{+}]$ continues to decrease as the $[Fe^{3+}]$ and $[SCN^{-}]$ both increase.

Q155. In an experiment, 1.0 mol of pure phosgene, $COCl_2$, is placed in a 3.0L flask where the following reaction takes place.

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ $K = 2.1 \times 10^{-8}$ M

a. It can be assumed that, at equilibrium, the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol. On the basis of the data provided, explain why this assumption is justified.

Sol. Both of

- the equilibrium constant is extremely small
- The amount of CO and Cl_2 produced /$COCl_2$ reacted in getting to equilibrium is so small that (to two significant figures) the n($COCl_2$) at equilibrium will still be 1.0 mol.

b.i. Calculate the equilibrium concentration, in mol L^{-1}, of carbon monoxide, CO. Assume that the amount of unreacted $COCl_2$ is approximately equal to 1.0 mol.

Sol. At equilibrium, [CO] = 'y' M = $[Cl_2]$

$[COCl_2] = 1.0 \div 3.0$

$= 0.33$ M

$K = [CO][Cl_2] \div [COCl_2]$

$'y' \times 'y' \div 0.33 = 2.1 \times 10^{-8}$

$'y'^2 = 2.1 \times 10^{-8} \times 0.33$

$'y' = (2.1 \times 10^{-8} \times 0.33)^{1/2}$

$'y' = 8.3 \times 10^{-5}$

$[CO] = 8.3 \times 10^{-5}$ M ($8.3 \times 10^{-5} - 8.4 \times 10^{-5}$)

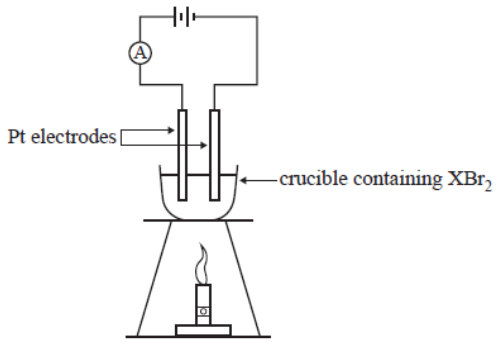
ii. What is the equilibrium concentration of chlorine gas?

Sol. 8.3×10^{-5} mol L^{-1} (M)

The required solution was effectively the solution to part **bi**. with appropriate units. If no units are specified in the equation, as in **bii.**

Q156. A teacher demonstrated the process of electrolysis of a molten salt using an unknown metal salt, XBr_2.

The apparatus was set up as shown below.



At the conclusion of the demonstration, the students were provided with the following information.

• A current of 1.50 amperes was applied for 30.0 minutes.

• 2.90 g of metal X was produced.

a. Write a balanced half-equation for the anode reaction in this electrolytic cell.

Sol. $2Br^-(l) \rightarrow Br_2(l + g) + 2e^-$

b. i. Determine the amount, in mol, of metal X that was deposited on the cathode.

Sol.

$Q = It = 1.50 \times 30.0 \times 60$

$= 2.70 \times 10^3$ C

$n(e^-) = Q \div F$

$= 2.7 \times 10^3 \div 96500$

$= 2.80 \times 10^{-2}$ mol

Reduction of metal $X^{2+} + 2e^- \rightarrow X$

$n(X) = n(e^-) \div 2$

$= 2.8 \times 10^{-2} \div 2 = 1.4 \times 10^{-2}$ mol

ii. Identify metal X.

Sol. $M(X) = m \div n$

$= 2.90 \div 1.4 \times 10^{-2} = 207.2$ g mol^{-1}

Lead (Pb)

Since the solution to this equation was dependent on the solution to part **i**, it may seem strange that significantly more students obtained full marks for part **ii**. This shows how 'consequential' marks are applied. If the element identified in part **ii**. was consistent with the n(X) calculated in part **i**, and forms ions with a+2 charge, full marks were awarded for part **ii**. Therefore, if:

• n(X) = 0.0280 mol in part **i** due to not dividing n(e), then:

$M(X)=103.6$g mol$^{-1}\rightarrow$ Rhodium (Rh)

• n(X) = 0.0560 mol in part ii. due to multiplying $n(e^-)$ by 2, then:

$M(X)=51.8$g.mol$^{-1}\rightarrow$ Chromium (Cr).

Q157. Pure water is approximately what molar concentration:

a. 0.55 molar

b. 5.5 molar

c. 55 molar

d. 550 molar

Q158. Which of the following is the weakest acid?

a. hydrochloric acid

b. hydrofluoric acid

c. sulfuric acid

d. nitric acid

Q159. A process in which substances are separated through differences in the rates at which the components migrate is called:

a. filtration

b. chromatography

c. elution

d. titration

Q160. Which separation technique is based on differences in the volatility of the substances to be separated?

a. filtration

b. distillation

c. solvent extraction
d. paper chromatography

Q161. A buffer solution made with NH3 and NH4Cl has a pH of 10.0. Which procedure(s) could be used to lower the pH?

1. adding HCl
2. adding NH_3
3. adding NH_4Cl

a. 1 only
b. 2 only
c. 1 and **3** only
d. 2 and **3** only

Q162. The principal reason that solid sodium hydroxide is not used as a primary standard for acid-base titrations is that it:
a. absorbs water from air.
b. has a low molar mass.
c. reacts slowly with many acids.
d. ionizes in water.

Q163. A 1.50 mL sample of a sulfuric acid solution from an automobile storage battery is titrated with 1.47 M sodium hydroxide solution to a phenolphthalein endpoint, requiring 23.70 mL. What is the molarity of the sulfuric acid solution?
a. 23.2 M
b. 11.6 M
c. 6.30 M
d. 0.181 M

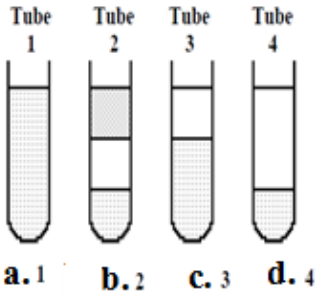
Q164. The ionization of benzoic acid is represented by this equation.
$C_6H_5COOH(aq)$ ¾$H^+(aq)$ + $C_6H_5COO^-(aq)$
If a 0.045 M solution of benzoic acid has an $[H^+] = 1.7 \times 10^{-3}$, what is the Ka of benzoic acid?
a. 7.7×10^{-5}
b. 6.4×10^{-5}
c. 3.8×10^{-2}
d. 8.4×10^{-1}

Q165. A standard HCl solution is titrated to a pink phenolphthalein endpoint by adding a NaOH solution while stirring. If a solution becomes pink throughout but loses its color upon standing for a short time, what should be done to restore the color?
a. Add more phenolphthalein indicator.
b. Add an additional drop of NaOH solution.
c. Add an additional drop of HCl solution.
d. Stir more vigorously

Q166. Which is the best procedure to follow if a student spills several drops of concentrated HCl on his hand?
a. Cover the area with solid sodium hydrogen carbonate.
b. Rinse with large amounts of cold water.
c. Wash with concentrated sodium hydroxide solution.
d. Wrap the hand with sterile gauze.

Q167. Hexane, C_6H_{14}, is immiscible with water and ethanol. Water and ethanol are miscible. C6H14 has the lowest density. Which diagram represents the results when

equal volumes of these three liquids are placed in a test tube and shaken?



Q168. Which of these mixtures constitute buffer solutions?
Mixture **1** 25 mL of 0.10 M HNO_3 and 25 mL of 0.10 M $NaNO_3$
Mixture **2** 25 mL of 0.10 M $HC_2H_3O_2$ and 25 mL of 0.10 M NaOH
a. 1 only
b. 2 only
c. both **1** and **2**
d. neither **1** nor **2**

Q169. Which piece of apparatus can measure a volume of 25.0 mL most precisely?
a. 25 mL beaker
b. 25 mL conical flask
c. 25 mL graduated cylinder
d. 25 mL pipet

Q170. A saturated solution of which compound has the lowest $[Ca^{2+}]$:

	K_{sp}
CaF_2	4.0×10^{-11}
$CaCO_3$	8.7×10^{-9}
$Ca(OH)_2$	8.0×10^{-6}
$CaSO_4$	2.4×10^{-5}

a. CaF_2
b. $CaCo_3$
c. $Ca(oH)_2$
d. $CaSO_4$

Q171. The emission spectrum of hydrogen in the visible region consists of:
a. a continuous band of light.
b. a series of equally spaced lines.
c. a series of lines that are closer at low energies.
d. a series of lines that are closer at high energies.

Q172. How can 0.1 g samples of the two white solids, lead (II) chloride and silver chloride be distinguished from one another?
a. Add 10 mL of cold water to each. The silver chloride will dissolve.
b. Add 10 mL of hot water to each. The lead (II) chloride will dissolve.
c. Add 10 mL of sodium chloride to each solution. The lead (II) chloride will become warm and release chlorine gas.
d. Add 10 mL of zinc chloride solution to each. The silver chloride will change to metallic silver.

Q173. What is the $[H^+]$ in a solution in which $[HA] = 4.0\times10^{-2}$ and $[A^-] = 2.0\times10^{-2}$. $[Ka = 3.0\times10^{-6}]$
a. 1.5×10^{-6}
b. 3.0×10^{-6}
c. 6.0×10^{-6}
d. 3.8×10^{-3}

Q174. I am going to mix 50 ml of a solution that is saturated in PbI2 with 10 ml of **a.** 5M KI solution. What is the final concentration of I^- and Pb^{+2} in this solution? (Show all calculations. If you had to use the solver function on your calculator, state the equation that you used. If

you make any assumptions, state the assumptions that you used and prove they are good).

Sol. This is a common ion problem. We have a solution that is saturated in PbI_2, and we add a second solution that has a much higher concentration of the common ion I^-. Since this common ion is a product in the solubility reaction, Le Chatlier's principle says that the reaction will be pushed toward the reactants, and even more PbI_2 will come out of solution.

Since you are mixing two solutions together, you first have to come up with the concentraton of the ions in the individual solutions, and then see how this changes due to the simple mixing and dilution of one solution into the other.

The KI solution is easy $[I^-] = .5$

Now let's find the concentration of Pb and I in the saturated PbI_2 solution

$Ksp = 7.9x10^{-9} = [Pb][I] +2 - 2$

If $[Pb^{+2}] = X$, $[I^-] = 2X$, so

$7.9x10^{-9} = X(2X)2 = 4X3$; X=1/3 root of $7.9x10^{-9}/4 = 1.25x10^{-3}$ M

$Pb^{+2} = 1.25x10\text{-}3$ M

$I^- = 2.50x10^{-3}$ M

Now I am going to mix 50 mls of this solution with 10 ml of

a. 5M KI solution. This is not a simple dilution problem because both solutions contain I-, so the best solution is to calculate the moles of I- in each solution and then divide by the total volume I^- (50ml).

$05R \times 2.5x10^{-3}M = 1.25x10^{-4}$ moles

(10 ml) $0.01R \times .5M = 0.005$moles

$(0.005+1.24x10^{-4})$ mole/ .06R =.0854 M Pb^{+2}.

Since the only one solution has Pb+2 you can apply the dilution equation here: $(M_1V_1=M_2V_2)$

$50(1.25x10^{-3})=X(60); X=1.046x10^3$ M

Now for the rest of the problem. The quick and dirty solution. The Ksp equation is $7.9x10^{-9}=[Pb^{+2}][Cl^{-1}]^2$.

1. We are going to solve for X, the amount of Pb^{+2} in solution.

2. Since we are adding an excess of I^-, let's assume that I^- isn't going to change much, so call $Pb^{+2} = X$ and $I^- = 0.0854$

$Ksp = 7.9x10^{-9} = (X)(.0854)$

$Y = 7.9x10^{-9} /.08542 = 1.08x10^{-6} = [Pb^{+2}]$ (bit off from the exact)

The exact solution.

Your reaction table should look like this: Pb^{+2} $I^- \rightarrow PbI$

Before reaction $1.046x10^{-3}$ .0854 0

After reaction where x of PbI forms

$1.046x10^{-3}$-X.0854-2X X

Using the above in the Ksp

$7.9x10^{-9}=(1.046x10^{-3}-X)(0.0854-2X)^2$

plug into solver and you find that X =0.0010389M so:

Pb^{+2} =0.001046-0.0010389 = $7.1x10^{-6}$

I^- =0.0854-2(0.0010389) =0.0833

Q175. Which piece of laboratory equipment should be used to deliver a 10.00 mL sample of acid from a stock container to a flask for a titration?

a. 1.0 mL Beral pipet used 10 times

b. 10 mL graduated cylinder

c. 10 mL volumetric pipet

d. 25 mL beaker

Q176. Which is the weakest acid?

a. ascorbic acid ($Ka = 8.0\times10^{-5}$)

b. boric acid ($Ka = 5.8\times10^{-10}$)

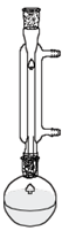
c. butyric acid ($Ka = 1.5\times10^{-5}$)

d. hydrocyanic acid ($Ka=4.9\times10^{-10}$)

Q177. What happens to the pH of a buffer solution when it is diluted by a factor of 10?
a. The buffer pH decreases by 1 unit.
b. The buffer pH increases by 1 unit.
c. The change in pH depends on the buffer used.
d. The pH does not change appreciably.

Q178. Green light has a wavelength that is slightly shorter than that of
a. gamma rays.
b. orange light.
c. violet light.
d. X-rays.

Q179. The apparatue show would be used to:
a. distill a liquid.
b. reflux a solution.
c. filter a precipitate.
d. chromatograph a mixture.



Q180. What is the conjugate base of HSO_4^-?
a. H+
b. H_2SO_4
c. OH^-
d. $SO4_2^=$

Q181. Which pair of solutions forms a buffer solution when equal volumes of each are mixed?
a. 0.20 M HCl and 0.20 M NaOH
b. 0.40 M $HC_2H_3O_2$ and 0.20 M NaOH
c. 0.20 M HCl and 0.20 M NH_3
d. 0.40 M HCl an 0.20 M NH_3

Q182. Which type of radiation has the highest frequency?
a. infrared
b. microwave
c. ultraviolet
d. X-ray

Q183. Which salt is colorless?
a. $KMnO_4$
b. $BaSO_4$
c. Na_2CrO_4
d. $CoCl_2$

Q184.Which technique can be used to determine the number of components in a plant pigment?
a. calorimetry
b. chromatography
c. colorimetry
d. gravimetry

Q185. What volume (in mL) of 0.0500 M phosphoric acid is needed to titrate completely 25.0 mL of 0.150 M barium hydroxide solution to a phenolphthalein end point?
$3Ba(OH)_2+ 2H_3PO_4 \rightarrow Ba_3(PO_4)_2 + 6H_2O$
a. 50.0
b. 75.0
c. 100.
d. 150.

Q186. In the determination of the molar mass of a solid acid by titrating it with a standardized base, which procedural error will yield a molar mass that is smaller than the actual value?
a. adding the standardized base to a buret containing drops of water

b. dissolving the weighed solid acid in twice the recommended volume of water
c. using half as many drops of indicator as suggested
d. weighing out half of the recommended mass of solid acid

Q187. A solid can be separated from a liquid by all the following means except:
a. decantation
b. distillation
c. filtration
d. hydration

Q188.A student determined the density of a solid to be 2.90, 2.91 and 2.93g.cm^{-3}. If the actual density of this solid is 2.70g.cm^{-3}, how should the student's results be described?
a. high accuracy and high precision
b. low accuracy and high precision
c. high accuracy and low precision
d. low accuracy and low precision

Q189. Which of the following is NOT a laboratory safety rule?
a. You should never mix acids with bases
b. You should tie back your long hair
c. You should never add water to acid
d. All of the above are valid safety rules**.**

Q190. What piece of laboratory equipment is best-suited for accurately measuring the volume of a liquid?
a. graduated cylinder
b. beaker
c. Erlenmeyer flask
d. more than one of the above

Q191. "Qualitative results" refer to:
a. Results that can be observed during an experiment.
b. Results that is difficult to observe during an experiment.
c. Results that require numerical data.
d. none of these is correct.

Q192. Accuracy is defined as:
a. A measure of how often an experimental value can be repeated.
b. The closeness of a measured value to the real value.
c. The number of significant figures used in a measurement.
d. None of these

Q193. How many significant figures are present in the number 10,450?
a. three
b. four
c. five
d. none of these

Q194. Why doesn't water conduct electricity well?
a. Huh? Water is an excellent conductor of electricity!
b. Pure water contains very few ions.
c. The hydrogen bonding in water cause the molecules to move slowly from one place to another.
d. None of the above is correct.

Q195. Hydrochloric acid reacts with calcium to form hydrogen and calcium chloride. If 100 grams of hydrochloric acid reacts with 100 grams of calcium chloride, what is the limiting reagent?
a. hydrochloric acid

b. hydrogen
c. calcium chloride
d. calcium

Q196. Chromatography is used to:
a. Separate two or more compounds based on their polarities.
b. Separate two or more compounds based on their masses.
c. Separate two or more compounds based on how strongly they interact with other compounds.
d. More than one of the above.

Q197. An unsaturated solution:
a. Hasn't dissolved as much solute as is theoretically possible
b. Has dissolved exactly as much solute as is theoretically possible
c. Is unstable because it has dissolved more solute than would be expected.
d. none of these

Q198. If a compound has a pH of 6.5, it has a pOH of:
a. 6.5
b. 7.5
c. 3.16×10^{-7}
d. 3.16×10^{-8}

Q199. What is the difference between the endpoint and equivalence point in a titration?
a. The endpoint is when the pH is exactly 7
b. The equivalence point is when the pH is exactly 7
c. The endpoint and the equivalence point are the same thing.
d. None of these solutions is correct.

Q200. If it takes 5 mL of 1.4 M NaOH to neutralize 150 mL of HCl with an unknown concentration, what was the original concentration of the acid?
a. 0.47 M
b. 0.047 M
c. 0.014 M
d. none of these

Q201. What is the pH of a 0.001 M formic acid solution? Ka = 1.8×10^{-4}.
a. 3.74
b. 10.3
c. 3.37
d. 10.6

Q202. Buffers keep the pH of a solution from changing by:
a. converting strong acids to weak ones
b. converting weak acids to strong ones
c. converting weak bases to strong ones
d. more than one of the above solutions is correct.

Q203. What's the concentration of Ag+ ion in a saturated silver chloride solution? Ksp = 1.56×10^{-10}.
a. 1.25×10^{-5} M
b. 4.90 M
c. 3.39×10^{-4} M
d. none of these

Q204. Later this semester you will probably analyze a water sample from my well. Last year my well had a calcium level of 193 ppm. What would this concentration be if you expressed in as molarity?

Sol. ppm=g solute/g solution × $1x10^6$
I'll use 1 l of solution and assume it weighs 1000 g
193 = X/1000g ×$1x10^6$
X=193(1000)/$1x10^6$
X =0.193 g
0.193 g Ca/40.08g = 4.82 mmole, so my solution was 4.82 mM

Q204. In the lab I may want you to make a very accurate 0.1000 M solution of NaCl by weighing out.5844 g of NaCl and placing it in a 100.00 ml volumetric flask. Let's assume, however, that you had a hot date that night, and wanted to get out of the lab as quickly as possible, so you used a triple beam balance to weigh your material and a beaker to measure your volume. What is the uncertainty in your molarity, assuming the following measurements and errors.
1. Initial weight of paper -0.4 ±0.02 g
2. Weight of paper and NaCl 1.00 ±.02 g
3. Volume of water 100. ±1 ml
Sol. Weight = 1.00-0.42 =0.58g
error in weight (absolute) = sqrt(.022 +0.022) =0.028 g
Molarity = (.58g/ 58.44g) /0.1l
=0.0992471 M
In error analysis I will assume that the error in the molecular weight is insignificant when compared to error in weight and volume. This calculation is multiplcation/division so there error here is:
error in molarity (relative) = $\sqrt{(0.028/.58)^2 + (1/100)^2}$ =0.0493
Remember that this error is relative, so I must either say this in the way I write the solution, or convert it into absolute error:
Molarity =0.0992471M ±4.9% -or- (.0992471x.0493=.005) 0.099±.005M

Q205. Write the molarity of the above solution with the proper number of significant figures to reflect the uncertainty calculated in 2a.
Sol. Rounding to the first uncertain digit in my absolute solution**.** Above 0.099M

Q206. Define or give a mathematical equation for the following terms:
Sol.
1. Accuracy: How close you are to the actual value.
2. Precision: How close together your solution.
3. Determinate error: Error that is unidirectional and reproducible.
4. Absolute uncertainty: Error that is recorded in the same units as the measurment itself.
5. Mode (of a distribution): The value that occur the most often in a set of data.
6. A Gaussian distribution: A 'normal' distribution that follows the standard bell shaped curve.
7. Method of Least squares: A method of fitting a line to a set of data that minimizes the sum of the squares of the deviations of the points from the line in the Y dimension.
8. Degrees of Freedom: Usually the number of data point -1.

9. A Primary Standard: A chemical that is of sufficient purity and stability that it can be weighed and used directly in an analytical procedure without further standardization.
10. A back titration: A titration method in which a known excess of titrant is added to an analyte, and then the excess titrant is determined. The difference between the known amount of titrant, and the amount of titrant that remains is then used to determine that amount of analyte.

Q207. How many millileters of 0.100M KI are needed to react with 40.00 ml of 0.0400 M $Hg_2(NO_3)$ if the reaction is: $Hg^{2+} + 2I^- \rightarrow Hg_2I_2(s)$
Sol. 40 ml ×.04M $Hg_2(NO_3)$ = 1.6 mmole $Hg_2(NO_3)$ = 1.6 mmoles Hg_2^{2+}
1.6 mmoles Hg_2 x 2 mole I /1 mole Hg_2 = 3.2 mmole I
Molarity= mole/liter;.10000 = 3.2 mmole/V; V=3.2 mmole/.1 = 32 mL KI

Q208. In the lab I get the following 4 numbers for the concentration of chloride in a
sample: 0.1015, 0.0991, 0.1016, and 0.1017. What is the mean, the 95% confidence interval, and the relative standard deviation for this data set.
Sol.
Mean =0.100975
s = 1.25×10^{-3}
c.I. = mean ±s(t)/sqrt(n)
=0.100975±3.182(1.25×10^{-3})/√(4)
=0.101±0.002

Q209. In **Q208** there is one value that looks like a ringer. Calculate equation for this one bad value and determine if it can be rejected from the date set.
Sol.
Q= gap/ range = (0.1015 - 0.0991)/ (0.1017-0.0991) =0.92
Qtable =0.76; Qcalc>Qtable, bad value may be rejected.

Q210. In **Q209** I had you calculate a relative standard deviation. I usually regard the relative standard deviation as a measure of the relative error on your mean. You also calculated a confidence interval, which is also a measure of the uncertainty of the mean. Compare and contrast these numbers. Which is the better measure of experimental uncertainty?
Sol. The confidence interval is a much better indicator of the relative error in my mean because is includes two additional factors. First using the t statistics, I can state the explicit chance of error in my mean value; ie, there is a 90% (or 95%) chance that the mean is in this range. Second, because the **c.** I. calculation includes the number of samples, my range increases with a few sample and decreases when I have many samples, so my confidence interval gives an estimate of range that reflects the number of data points that I worked with.

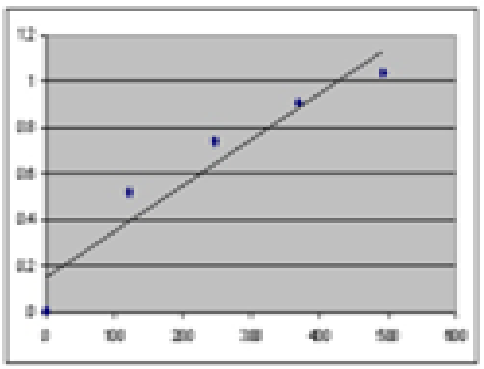
Q211. Below is a set of data for a calibration curve of I used last year to correlate [Ca] concentration with a reading on an atomic emission machine. At the end of this experiment I tested my household tap water and got the reading shown.

Using as much of this data as you want, what is the concentration of Ca in my tap water, and what is the uncertainty in this number.
Include a complete spreadsheet for your analysis and state what assumptions or adjustments you had to make to come up with your final number.

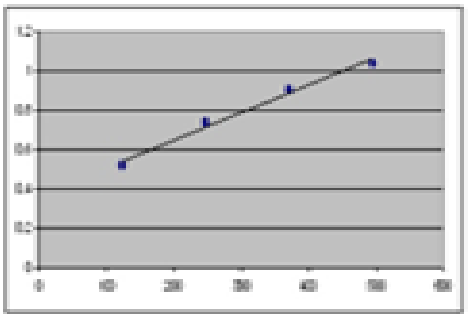
[Ca] ppm	Emission run 1	Emission run 2
493	1.035	1.04
370	.905	.91
247	.735	.745
123	.512	.526
0	0.0	.01
MZ tap water	.790	.810

Sol. When you first plot this data, you should immediately see that something is wrong, either the data is strongly curved or the zero point should be eliminated. Since we haven't talked about how to handle curved data, the easiest fix it to eliminate the zero point and try again.

Original data



Remove first point



After removing the first point, now you can plug the data in to you least squares routine and get: Line of Best fit spreadsheet.

Line of Best fit

n	x	y	xy	x^2
1	493	1.035	510.255	243049
1	493	1.04	512.72	243049
1	370	0.905	334.85	136900
1	370	0.91	336.7	136900
1	247	0.735	181.545	61009
1	247	0.745	184.015	61009
1	123	0.512	62.976	15129
1	123	0.526	64.698	15129
sums				
8	2466	6.408	2187.759	912174

D= 1216236 m=0.001398 b=0.370156

Errors from line

n	x	y	Y predict	Deviation	dev^2
1	493	1.035	1.059227	-0.02423	0.000587
1	370	0.905	0.887309	0.017691	0.000313
1	247	0.735	0.71539	0.01961	0.000385
1	123	0.512	0.542074	-0.03007	0.000904
1	123	0.526	0.542074	-0.01607	0.000258
1	247	0.745	0.71539	0.02961	0.000877
1	370	0.91	0.887309	0.022691	0.000515
1	493	1.04	1.059227	-0.01923	0.00037
				Sum	0.004209

s_y 0.026485 s_m 6.79E-05 s_b 0.022936

Predictio n

Measured Y	Derived X	Uncertainty in X
0.81	314.6891	20.10048

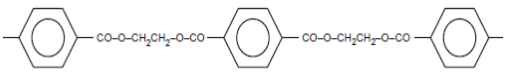
Using this analysis for a measured Y of.790 I get x=300±20, and .810 x=310±20 so I would call my result 305 ±20 ppm.

CHAPTER EIGHT
Polymer Chemistry

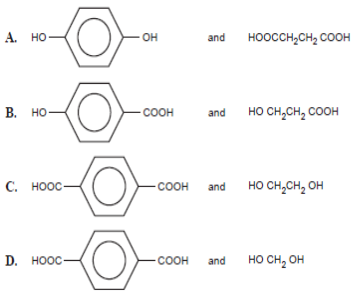
كيمياءالبوليمر

Tests & Answers

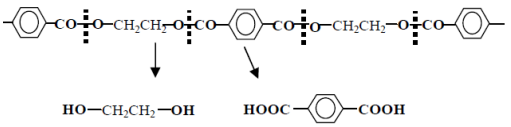
Q1. A representation of a section of a polymer chain that has been produced from two different monomers is given below.



The two monomers are



Sol.



Q2. When a sample absorbs infrared radiation:

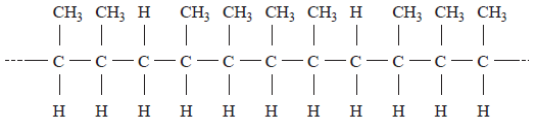
a. covalent bonds are broken.

b. covalent bonds stretch and vibrate.

c. the spin alignment of certain nuclei changes.

d. electrons in atoms move to higher energy levels.

Q3. Copolymers are obtained when two or more different monomers are allowed to polymerise to gether. Part of a copolymer chain is shown below.



The two alkenes that could react together to form this polymer are

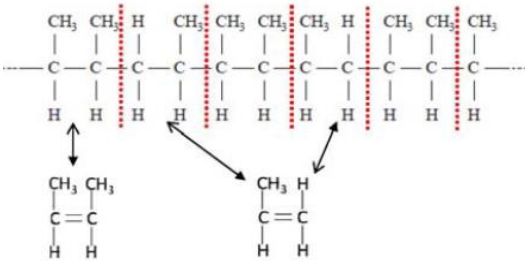
a. propene and but-1-ene.

b. propene and but-2-ene.

c. but-1-ene and but-2-ene.

d. pent-2-ene and but-2-ene.

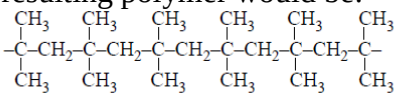
Sol. To identify the two alkenes/ monomers it wasnecessary to identify the 'repeating' units in the section of copolymer chain shown.



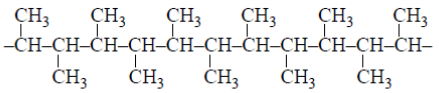
This suggests the copolymer was formed by reaction between but-2-ene, $CH_3CH{=}CHCH_3$ and propene, $CH_3CH{=}CH_2$.

Q4. Consider the addition polymerisation of $CH_3CH = CHCH_3$. The structure of the resulting polymer would be:

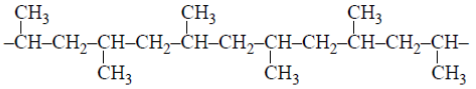
A.



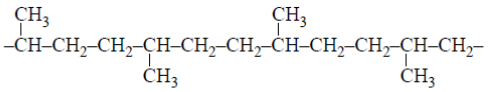
B.



C.



D.

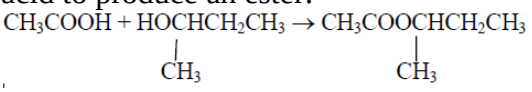


Sol. b.

$CH_3CH{=}CHCH_3 + H_2O \rightarrow CH_3CH_2CHOHCH_3$

2-butene is converted into 2-butanol

2-butanol then reacts with ethanoic acid to produce an ester.

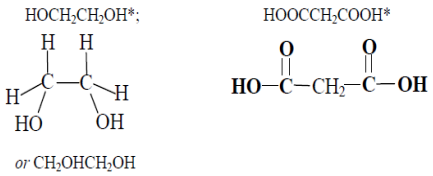


Q5- representation of a section of a polymer chain is:

–O–CH_2–CH_2–O–CO–CH_2–CO–O–CH_2–CH_2–O–CO–CH_2–CO–O–

i. In the two boxes provided, give the structures of the two different monomers needed to make this polymer.

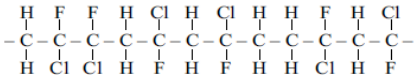
Sol.



ii. In the following box, give the formula of the other molecule formed when the monomers combine to form the polymer.

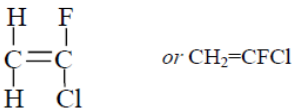
Sol. H_2O

d. A representation of a section of a polymer chain is

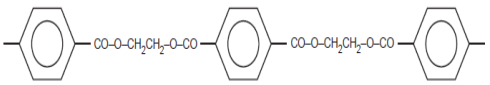


In the following box, give the structure of the monomer from which the polymer is made.

Sol.



Q6. A representation of a section of a polymer chain that has been produced from two different monomers is given below.



Sol. The two monomers are:

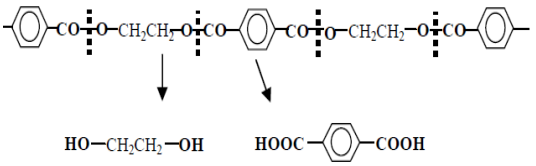
A. HO—⬡—OH and $HOOCCH_2CH_2COOH$

B. HO—⬡—COOH and $HO\,CH_2CH_2\,COOH$

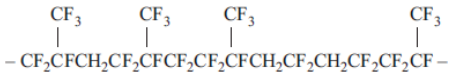
C. HOOC—⬡—COOH and $HO\,CH_2CH_2\,OH$

D. HOOC—⬡—COOH and $HO\,CH_2\,OH$

Sol.



Q7. A representation of a section of a polymer chain that has been produced from two different monomers is given below.



The two monomers are

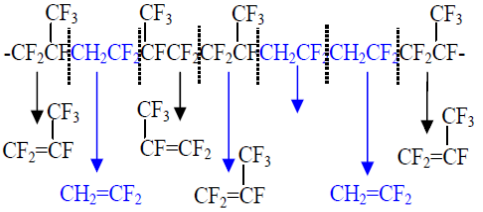
a. $CH_2{=}CF_2$ and $CF_2{=}CFCF_3$

b. $CF_2{=}CF_2$ and $CF_2{=}CFCF_3$

c. $CH_2{=}CF_2$ and $CH_2{=}CFCF_3$

d. $CF_2{=}CF_2$ and $CH_2{=}CFCF_3$

Sol. a. Identify the repeating units in the polymer chain, each of which has a carbon-carbon double bond C=C.



Q8. A short section of a polymer molecule is shown below.

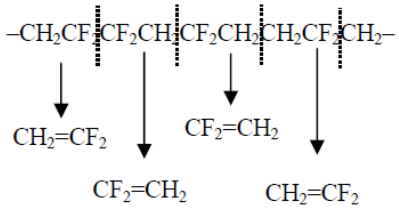
$CH_2CF_2CF_2CH_2CF_2CH_2CH_2CF_2CH_2$

This polymer could have been formed from:

a. CF_2CH_2 only.

b. CF_2CF_2 and CH_2CH_2.
c. CF_2CF_2 and CH_2CHCF_3.
d. CH_3CHCF_2 and CF_3CHCF_2.

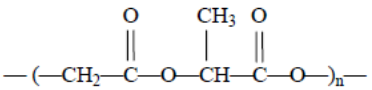
Sol. a. Students should identify the repeating units in the polymer chain, each of which has a carbon–carbon double bond C=C.



Q9. The molecule $HOCH_2CH_2CH_2COOH$ (molar mass = 104 g mol.1) forms a polymer in which the average polymer molecule contains 1000 monomer units. The approximate molar mass of the polymer, in g mol.1, is:
a. 68 000
b. 86 000
c. 95 000
d. 104 000

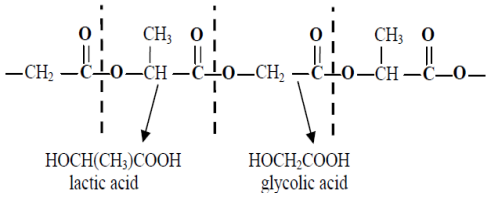
Sol. During the polymerisation, the carboxyl (–COOH) group on one molecule may react with the hydroxyl (–OH) group on an adjacent molecule in a condensation reaction. For each n monomers that react to form the polymer chain, (n–1) ester groups are formed and (n–1) H_2O molecules are condensed out.
The relative molecular mass of the polymer chain will be:
$1000 \times M_r (HOCH_2CH_2CH_2COOH) – 999 \times M_r (H_2O)$
$=1000 \times 10^4 – 999 \times 18$
$=104\,000 – 17\,982 = 86\,018$
So the approximate molar mass of the polymer is 86 000 g mol^{-1}.

Q10. Cuts and wounds are often stitched using a biodegradable polymer with the formula:



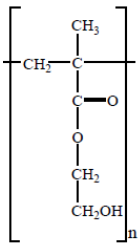
It is made from a condensation polymerisation reaction between lactic acid ($HOCH(CH_3)COOH$) and glycolic acid.
The formula of glycolic acid is:
a. $HOCH_2COOH$
b. $HOCH_2CH2OH$
c. $HOOCCH_2COOH$
d. $HOOCCH_2CH2OH$

Sol. a. The repeating unit of the polymer contains ester groups each of which would have formed from reaction between a carboxyl (–OOH) and a hydroxy (–OH) group on adjacent monomers. Thus the –OH group on a lactic acid molecule must react with a –COOH group on a glycolic acid molecule, whilst the –COOH group on a lactic acid molecule must react with a –OH group on a glycolic acid molecule. So, glycolic acid molecules must contain both a –COOH group and –OH group.
Expanding the repeating unit and focusing on the ester groups enables identification of the monomers.



Q11. The following structure represents the repeating unit of a

polymer used in the manufacture of contact lenses.



Which one of the following is a correct statement about the monomers that react to form this polymer?

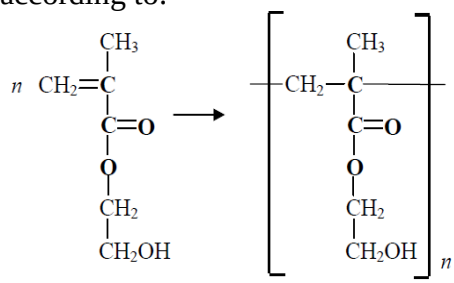
a. Each monomer contains a double bond between carbon atoms which allows addition polymerisation to take place.

b. Two different monomers react to form the polymer, one with carboxyl groups and the other with hydroxyl groups.

c. The total mass of the monomers is greater than the mass of the polymer formed because water is eliminated in the polymerisation reaction.

d. Each monomer contains both a carboxyl and a hydroxy group which allows condensation polymerization to take place, forming a polyester.

Sol. a. The polymer shown would be formed by addition polymerisation according to:



Q12. Starch consists mainly of amylose, which is a polymer made from glucose, $C_6H_{12}O_6$. A particular form of amylose has a molar mass 3.62×10^5 g mol^{-1}.

A molecule of this amylose can be described as:

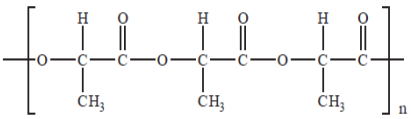
a. an addition polymer of 2235 glucose molecules.

b. an addition polymer of 2011 glucose molecules.

c. a condensation polymer of 2235 glucose molecules.

d. a condensation polymer of 2011 glucose molecules.

Sol. c. Polymers formed from glucose are condensation polymers. The polymer formed from n $C_6H_{12}O_6$ molecules will condense out n–1 H_2O molecules.



The polymer polylactic acid, PLA, shown above, is used to make soluble stitches which are absorbed by the body following surgery.

Other than the peak given by the TMS reference, the monomer from which PLA is formed would give:

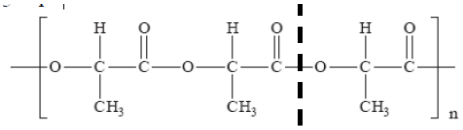
a. One set of peaks in the 1H NMR

b. Two sets of peaks in the 1H NMR

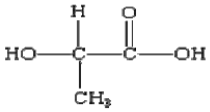
c. Three sets of peaks in the 1H NMR

d. four sets of peaks in the 1H NMR

Sol. d. The section of the polymer, polylactic acid, shown in the equation shows repeating ester groups which can be used to identify the monomer from which the condensation polymer is produced–the ester groups form by reaction between carboxyl and hydroxyl groups.



Hance the monomer, lactic acid, is:



Each lactic acid molecule has four different H environments and would give four peaks in the 1H NMR.

Q13. Which one of the following statements about propene is not correct?

a. It undergoes an addition reaction with hydrogen to form propane.

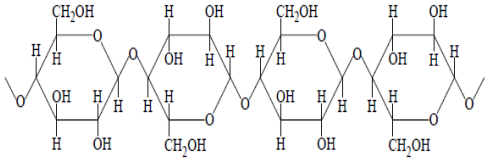
b. It undergoes a polymerisation reaction expelling water in the process.

c. Weak dispersion forces act between propene molecules and consequently it is a gas at room temperature.

d. One propene molecule will react with excess oxygen to produce three molecules of water and three molecules of carbon dioxide.

Sol. b. Being an alkene, propene undergoes addition polymerisation, not condensation polymerisation.

Q14. a. The cellulose that is present in plant matter cannot be directly fermented to produce bioethanol. The cellulose polymer must first be broken down into its constituent monomers. A section of cellulose polymer is shown below.



i. What is the name of the monomer from which cellulose is formed?

Sol. glucose

ii. Complete the following chemical equation to show the formation of ethanol by fermentation of the cellulose monomer.

C6H12O6 (aq) → ….. +…….

Sol. $C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$

C_2H_6O and C_2H_5OH were also acceptable formulas for ethanol.

iii. Ethanol can be manufactured directly from ethene gas in the presence of a catalyst. Write a balanced equation for this reaction.

Sol.

$C_2H_4(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$

Many responses to this equation were marred by the addition of an arbitrary, chemically incorrect catalyst above the arrow. The acid catalyst used is normally phosphoric acid, H_3PO_4.

Q15. If a certain polymer has the formula $(–CH_2CCl_2CH_2CCl_2–)n$, from which monomer is it made?

a. HC CCl

b. ClHC=CClH

c. $Cl_2C=CH_2$

d. $H_2C=CClH$

Q16. What substance is formed when $CF_2=CF_2$ is polymerized?

a. Polyethylene

b. Polyurethane

c. PVC

d. Teflon

Q17. Which is NOT an example of an addition polymer?
a. polyethylene
b. polyethylene terephthalate
c. polystyrene
d. polyvinyl chloride

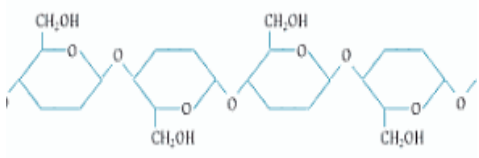
Q18. Which element is used to form cross-liks between the stands of latex ruber?
a. Fe
b. N
c. P
d. S

Q19. A typical polyethene bag from a grocery store weighs 12.4g. How many melecules of ethylene, C_2H_4, must be polymerized to make such a bag?
a. $1.36x10^{24}$
b. $6.02x10^{23}$
c. $5.33x10^{23}$
d. $2.67x10^{23}$

Q20. All of the following are condensation polymers except:
a. nylon
b. polyethens
c. protein
d. starch

Q21. In 2007, Cargill won a green chemistry award for using soybeans instead of petroleum to produce polyols. What is a polyol, and how are polyols used to produce "soybean plastics"?
Sol. As you might suspect from the –ol ending, polyols are alcohols. The "poly" refers to the fact that they have multiple hydroxyl (–OH) groups. Many types of polyols exist, some with only two hydroxyl groups and others with many more. For example, in this chapter, you met ethylene glycol, a polyol with two hydroxyl groups (also called a diol). It served as one of the two monomers for PET. In glycerol (glycerin), which is a polyol that contains three hydroxyl groups (also called a triol). Polyols can serve as monomers for any condensation polymers such as polyesters (made from a "double acid" and a "double alcohol" (diol). A Web search for soybean plastics or soybean-based polymers should give you many examples.

Q22. The diagram shows a linear polymer.



This polymer is:
a. polystyrene
b. polyethylene
c. Teflon
d. cellulose

Q23. Name, and give two uses for, the polymer formed when ethylene polymerises.

Q24. Distinguish between addition polymerisation and condensation polymerisation.

Q25.
a. What are some of the polymers that you encounter every day? Describe their physical properties.

Sol. Sandwich bags, carpets, nylon stockings, stackable chains, milk cartons, etc.

b. Why do different polymers have different properties?

Sol. They have different chemical compositions (different monomer units), different structures, different ways of being fabricated, etc.

Q26.

a. Why are olefins (alkenes) good monomers for polymerization reactions?

Sol. The electrons in the weak p-bonds can be used to form strong s bonds to other monomer units.

b. What kinds of structural changes accompany bond-breaking and bond-forming in olefin polymerization?

Sol. The olefin monomers are flat (two-dimensional) molecules with sp^2-hybridized carbon atoms. The polymers are three-dimensional molecules in which the carbon atoms are sp^3hybridized.

c. Examine samples of LDPE (sandwich bag, squeeze bottle) and HDPE (milk jug, grocery bag). What are some of the differences in the physical properties of these substances?

Sol. LDPE–more transparent, flexible, waxy.

HDPE–more opaque, rigid, non-waxy.

d. How does the molecular-level structure of these polymers influence their physical properties?

Sol. The structure (e.g., extent of branching) determines how the individual polymer molecules can orient (or "pack") in the solid state. This, in turn, influences physical properties such as density, crystallinity, melting point, and strength.

e. How can chemists control which type of polyethylene (LDPE vs. HDPE) is generated?

Sol. Through the choice of appropriate catalysts and reaction conditions.

f. Besides the extent of branching, can you think of any other structural parameters that might lead to differences in physical properties?

Sol. The average value of n (the number of monomer units in the polymer) and the range in individual values of n.

Q27:

a. Does ethylene polymerize under mild conditions in the absence of a catalyst?

Sol.: No, in the absence of a catalyst, ethylene molecules would need to collide at very high energy in order to react with each other.

b. What is the role of a catalyst?

Sol. A catalyst reduces the energy of activation for a reaction by providing an alternative pathway. In this way, it speeds up the reaction and allows it to proceed under milder conditions.

c. Why are metals often good catalysts?

Sol. They provide a site where organic molecules can come together and react.

d. What is the difference between a heterogeneous and a homogeneous catalyst? What are some of the

advantages of homogeneous catalysts?

Sol. Heterogeneous catalysts are insoluble in the reaction medium, while homogeneous catalysts are soluble. Since homogeneous catalysts are generally molecular species, they are more amenable to study using the spectroscopic tools of chemistry. In addition, they can be chemically modified or "tailored" to produce polymers with a particular kind of structure.

e. How would you describe the orientation of the ligands around the Zr center in the homogeneous zirconium catalyst?

Sol. The ligands–the two cp's, the alkyl group, and the olefin (or open site)–are oriented in a tetrahedral fashion around Zr.

f. What is the nature of the bonding interaction between a metal and an olefin?

Sol. The olefin uses the electrons in its p-bond to interact with the metal.

g. Polymer chain growth can be terminated by b-hydride elimination or by reaction with H_2. What is one advantage of the H_2 reaction?

Sol. It allows the chemist to stop chain growth at a desired stage, rather than relying on the "natural" process of b-hydride elimination. Hence, it gives the chemist some control over the value of n.

Q28: The chemists can control the properties of polyethylene by choice of appropriate catalysts and reaction conditions. Based on what you have learned in Session 4, what are some other ways in which chemists can manipulate the properties of polymers?

Sol. By using different monomers. For example, the incorporation of a phenyl (C_6H_5) unit into the monomer leads to polystyrene, while the incorporation of a chloro (Cl) group leads to PVC, a polymer with very different properties.

b. By using different fabrication techniques. For example, polystyrene can be glassy or foamy depending on how it is fabricated.

"Teflon" is the polymer that results from the polymerization of tetrafluoroethylene. Write a chemical formula for this reaction. What are some of the properties of Teflon?

Sol. $n(CF_2 = CF_2) – (—CF_2–CF_2—)_n$. Teflon is highly resistant to chemical attack and has a very low coefficient of friction (it is slippery). In addition, it can be used over a very wide temperature range (-73 ^oC - 260 ^oC.

c. "Co-polymers" consist of two different monomers ("A" and "B") joined in an alternating fashion (ABABAB...). Block co-polymers also consist of two different monomers, but in this case blocks of polymer containing only A units are joined to blocks of polymer containing only B units (AAAAABBBBB...). How might block co-polymers be synthesized?

Sol. After the polymerization has been allowed to proceed with monomer A, the olefin feedstock is changed to B and the polymerization continues.

Q29:

d. A polymer's structure influences its physical properties. Describe two structural variations that are possible for polypropylene but not for polyethylene.

Sol. The orientation of the monomer units along the chain (head-to-tail, head-to-head, random) and the orientation of the methyl groups with respect to the polymer backbone (tacticity).

e. Consider the polymerization of vinylidene chloride, $CH_2=CCl_2$. What structural variations are possible in poly(vinylidene chloride)?

Sol. Orientation of the monomer units along the chain.

f. Consider the polymerization of 1, 2- dichloroethylene, H(Cl)C=C(Cl)H. What structural variations are possible in poly (1, 2-dichloroethylene)?

Sol. Tacticity.

Q30:

A. Head-to-tail polymerization of propylene is observed with the $[cp_2Zr(R)]^+$ catalyst. Explain this result on the basis of molecular-level interactions.

Sol. Each incoming propylene molecular orients with its methyl group in toward R, rather than out toward cp, in order to avoid unfavorable contacts with the bulky cp's. When the R group migrates to propylene, it migrates to the closer olefinic carbon, which is always the one bearing the methyl group (the "b carbon").

B. Atactic polypropylene is always produced with the $[cp_2Zr(R)]^+$ catalyst. Explain this on the basis of molecular-level interactions.

Sol. There is no preference for the methyl group on propylene to be oriented up or down, because in each case it has exactly the same interaction with a cp group. Since there is no up/down preference, a random (atactic**.** orientation of methyls along the chain results.

Q31:

a. What does it mean for a molecule or a ligand to be "chiral"? What properties does chirality impart to a molecule?

Sol. Molecules that are not superimposible on their mirror images are chiral. Mirror image isomers are called enantiomers. Enantiomers have identical physical properties except that they rotate plane polarized light in opposite directions.

b. Explain what is meant by "C_2 symmetry" and "mirror plane symmetry". Can a molecule with "mirror plane symmetry" ever be chiral?

Sol. "C_2 symmetry" means that 180^o rotation about an axis through the molecule results in a geometry equivalent to the starting geometry. "Mirror plane symmetry" means that one half of the molecule can be perfectly reflected into the other half through a symmetry plane. Molecules with mirror plane symmetry cannot be chiral.

c. Consider a homogeneous zirconium catalyst in which two cyclopentadienyl ligands are connected by a —CH_2–CH_2— bridge. Which symmetry elements does the (bridged-cp_2)Zr moiety possess? What is the expected tacticity of the polypropylene produced using this type of catalyst? Why?

Sol. The (bridged-cp_2)Zr moiety possesses both C_2 and mirror plane symmetry. Like the parent unbridged cp_2Zr catalyst discussed in Session 5, it would be expected to produce atactic polypropylene, since the methyl group on the propylene would have no up/down preference.

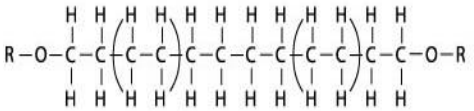
Q32. Due to the present of carbon atom in polymers all large biological molecules are made of_____:
a. covalent bond
b. metallic bond
c. ionic bond
d. triple bond

Q33. Which one **is not** a polymer:
a. carbohydrates
b. nucleic acid
c. proteins
d. carboxylic acid

Q34. Amino acids are the building blocks of _____
a. carbohydrates
b. nucleic acids
c. proteins
d. lipids

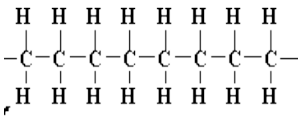
Q35. Which one is a natural polymer?
a. cellulose
b. polypropylene
c. polygon
d. Kevlar

Q36. Which substance is made up of many monomers joined together in long chains?
a. salt
b. ethanol
c. cellulose
d. polygon



Q37. Polyethylene picture on the above is a ___:
a. monomer
b. copolymer
c. polymer
d. elastomer

Q38. Which pattern is not a copolymer:



a. CCDDDCCDDDCCDDD
b. BBBBBBBBAAAAAAA
c. CCCDDDCCCDDDCCC
d. AAAAAAAAAAAAAA

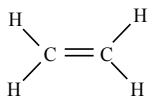
Q39. Which one is not a characteristic of thermoplastic
a. no cross links between chains.
b. resistance to heat won't melt
c. can be molded
d. commonly used as plastic bottle

Q40. Many polymers occur in nature. Name any two naturally occurring polymers.
Sol. Any two of these are correct: cellulose, polysaccharide (carbohydrate, starch), protein, DNA, silk, cotton fibers,

Q41. Describe what is meant by the term "polymer".
Sol. A chain of repeating units called monomers that connected to each other**.**

Q42. What will happen when we begin heating each of the polymers below after it cured?
a. A thermosetting (polymer)
Sol. It will not melt**.**
b. A thermoplastic (polymer)
Sol. It will start to melt and be pliable to mold into any shape**.**

Q43. Below is ethylene, the basic monomer for polyethylene. Draw polyethylene structure.
Sol.



Ethylene

Q44. Give two examples each of natural and of synthetic polymers.
Sol. Examples of natural polymers: Cotton, silk, natural rubber, cellulose, wool, and DNA**.**
Examples of synthetic polymers: Kevlar, vinyl, nylon, Dacron, polyethylene, polypropylene, and synthetic rubber.

Q44. Polymers sometimes are referred to as macromolecules. Explain.
Sol. The size and mass of a polymer makes the name macromolecule seem reasonable, because the prefix macro – means large. Individual polymers may involve thousands of atoms, and molecular masses can reach over a million grams per mole.

Q45. Describe how each of these strategies would be expected to affect the properties of polyethylene. Also provide an explanation at the molecular level for each effect.
a. increasing the length of the polymer chain.
b. aligning the polymer chains with one another.
c. increasing the degree of branching in the polymer chain.
Sol. a. At the molecular level, increasing the length of the polymer chain would increase its molar mass and the extent of its interactions with neighboring chains. This would be expected to somewhat increase the polymer's rigidity, strength, and melting point.
b. At the molecular level, aligning polyethylene chains with one another means that the structure is more crystalline and highly ordered. This would be expected to give the polymer slightly more density, more rigidity, and more strength. The melting point would also increase.
c. At the molecular level, this would be just the opposite of the previous equation. The structure would be less crystalline, less ordered, and possibly

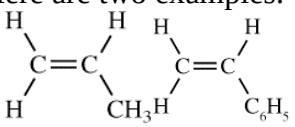
somewhat tangled. This would be expected to make the polymer slightly less dense, less rigid, and not as strong. The melting point would decrease.

Q46. Two bottles made from polyethylene. How do the two bottles differ at the molecular level?

Sol. The bottle on the left appears to be made of low-density polyethylene; the one on the right of high-density polyethylene. The molecular structures of LDPE and HDPE can help explain this difference in properties. LDPE is somewhat more branched, lessening molecular attractions between the chains and causing the plastic to be softer and more easily deformed, as shown in the photo. HDPE molecules, with fewer branches, can approach each other more closely and form regions that are more crystalline. The result is an increase in rigidity, again as shown in the photo.

Q47. Ethylene (ethene) is a hydrocarbon. Give the names and structural formulas of two other hydrocarbons that, like ethylene, can serve as monomers.

Sol. Hydrocarbons contain only the elements carbon and hydrogen, and to serve as monomers, the compound must have a carbon-to-carbon double bond. Here are two examples.



Propylene styrene

Q48. Why is a repeating head-to-tail arrangement not possible for ethylene?

Sol. A repeating head-to-tail arrangement is not possible for ethylene because all the hydrogen atoms in the molecule are identical. Thus, there is no "head" or "tail."

Q49. Determine the number of $H_2C=CH_2$ monomeric units, n, in one molecule of polyethylene with a molar mass of 40,000 g. How many carbon atoms are in this molecule?

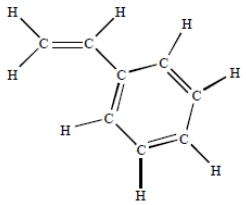
Sol. Each ethylene monomer has a molar mass of 28.052g. To determine the number of monomers in the polymer, divide 40,000 (the molar mass of the polymer) by 28.052 (the molar mass of the monomer) to get 1426 monomers. To determine the number of carbon atoms present in the polymer, note that each monomer contains two carbon atoms ($H_2C=CH_2$). Accordingly, the polymer contains 2×1426 carbon atoms, or 2852 atoms.

Q50. A structural formula for styrene.

a. Redraw it to show all of the atoms present.

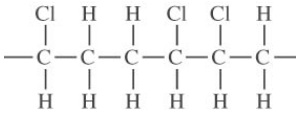
b. Give the chemical formula for styrene.

c. Calculate the molar mass of a polystyrene molecule consisting of 5000 monomers.



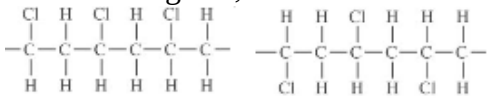
b. Styrene has the chemical formula: C_8H_8.
c. The molar mass of a styrene monomer is 104 grams. A polystyrene molecule made up of 5,000 monomers will have a molecular weight of about 520,000 g. This also can be expressed as 520 kg.

Q51. Vinyl chloride polymerizes to form PVC in several different arrangements, which is shown here?



Sol. This is the head-to-head, tail-to-tail arrangement of PVC**.**

Q52. Here are two segments of a larger PVC molecule. Do these two structures represent the same arrangement? Explain your answer by identifying the orientation in each arrangement.
Hint: See Figures;



Sol. Both of these segments represent the "head-to-tail" arrangement. The chlorine atoms in each case are on alternate carbon atoms. It makes no difference if the atom is on the "top" or on the "bottom" of the chain (these positions are equivalent).

Q53. Butadiene, $H_2C{=}CH{-}HC{=}CH_2$, can be polymerized to make Buna rubber. Would this be by addition or condensation polymerization?

Sol. The polymerization of butadiene would be an example of addition polymerization.

Q54. Which of the "Big Six" most likely would be used for these applications?
a. clear soda bottles
b. opaque laundry detergent bottles
c. clear, shiny shower curtains
d. tough indoor–outdoor carpet
e. plastic baggies for food
f. packaging "peanuts"
g. containers for milk
Sol.
a. PET, polyethylene terephthalate
b. HDPE, high density polyethylene
c. PVC, polyvinyl chloride
d. PP, polypropylene
e. LDPE, low density polyethylene
f. PS, polystyrene
g. HDPE, high density, polyethylene

Q55. Polyethylene is the most widely used synthetic polymer, but it is not the plastic of choice for margarine containers. Similarly it is not used for soft-drink bottles. Explain.
Sol. Polyethylene is not used for margarine containers because it softens on contact with oil. It is not used for soft drink bottles primarily because it lacks the clarity and sparkle of PET (i.e., most people would find HDPE ugly!).

Q56. Plastics are widely used as containers. Check the recycling code on 10 containers of your choice. In your sample, which polymer was the most widely used?

Sol.

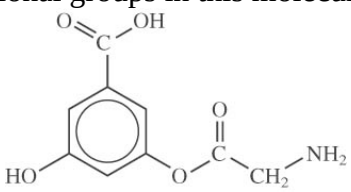
Recycling Code	Plastic
1	PET
2	HDPE
3	PVC

Recycling Code	Plastic
4	LDPE
5	PP
6	PS

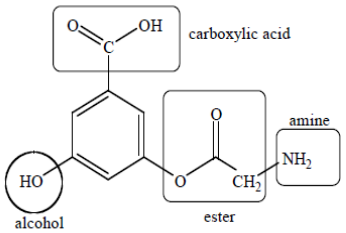
Most of the containers in a food or drug store are HDPE (if they are opaque or translucent) or are PET if they are crystal clear. You will, of course, find other plastics.

Q57. Name the functional group(s) in each of these monomers.
a. styrene
b. ethylene glycol
c. terephthalic acid
d. the amino acid where R=H
e. hexamethylenediamine
f. adipic acid
Sol.
a. phenyl group, alkene
b. hydroxyl group (or alcohol)
c. phenyl group, carboxylic acid
d. amine, carboxylic acid
e. amine
f. carboxylic acid

Q58. Circle and identify all the functional groups in this molecule:



Sol. This molecule contains a carboxylic acid, a hydroxyl group, an ester and an amine functional group. Note: Although beyond the scope of this text, the –OH group attached to a benzene ring is called a phenol, rather than an alcohol.



Q59. Kevlar is a type of nylon called an aramid. It contains rings similar to that of benzene. Because of its great mechanical strength, Kevlar is used in radial tires and in bulletproof vests. The structures for the two monomers, terephthalic acid and phenylenediamine. Name the functional groups in both the monomers and in the polymer.
Sol. Terephthalic acid contains two carboxylic acid groups.
Phenylenediamine contains two amine groups. These two monomers react in a condensation polymerization to form amide linkages between the phenyl groups.

Q60. Explain how a copolymer is a subset of the more general term polymers. Give an example of a polymer that is a copolymer, and one that is not.
Sol. A polymer is a chain of repeating units. Polyethylene, for example, is a polymer made from a single monomer – ethylene. A copolymer is also made of repeating units. However, these repeating units are

from two monomers. PETE is an example of a copolymer.

Q61. Silk is an example of a natural polymer. Name three properties that make silk desirable. Which synthetic polymer has a chemical structure modeled after silk?

Sol. Silk is a natural polymer that is a fiber, so it can be woven into fabrics. Silk is "breathable," making it comfortable to wear. It is also strong and stretchable, and can be dyed many different colors. The synthetic polymer modeled after silk is nylon.

Q62. The Dow Chemical Company has developed a process that uses CO_2 as the blowing agent to produce Styrofoam packaging material.

a. What is a blowing agent?

b. What compound does CO_2 likely replace in the process, and why is this substitution environmentally beneficial?

Sol. a. A blowing agent is a gas (or a substance capable of producing a gas) that is used to manufacture a foamed plastic. For example, a blowing agent produces Styrofoam from PVC**.**

b. The CO_2 replaces CFCs/ HCFCs that were formerly used as blowing agents. This is environmentally beneficial because CFCs and HCFCs deplete the ozone layer.

Q63. Consider these data:

Year	U.S. Population (millions)	Plastics Produced in the United States (billions of pounds)
1997	269	89
2003	290	107

In the United States,

a. How many pounds of plastic were produced in 1997? In 2003?

b. How many pounds of plastic were produced per person in these same years?

c. Between 1997 and 2003, what is the percent change in the number of pounds of plastic produced per person?

Sol.

a. In 1997, 8.9×10^{10} pounds of plastic was produced in the United States. In contrast, 1.07×10^{11} pounds of plastic was produced in 2003.

b. $$\frac{1.07 \times 10^{11} \text{ lb plastic}}{2.90 \times 10^{8} \text{ people}} = 370 \text{ lb/person in 2003}$$

$$\frac{8.9 \times 10^{10} \text{ lb plastic}}{2.69 \times 10^{8} \text{ people}} = 330 \text{ lb/person in 1997}$$

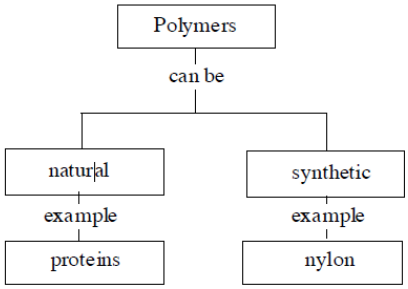
c. $$\frac{370 \text{ lb/person} - 330 \text{ lb/person}}{330 \text{ lb/person}} \times 100 = 12\% \text{ change}$$

Q64. You were asked in Consider This 9.18 to keep a journal of all the plastic products you throw away in one week. Now consider all of the plastic items that you recycle in one week. Are there any from your first list of items thrown away that could be on your second list? Explain.

Sol. Not all plastics are recyclable and not all municipalities support recycling. Nonetheless, you may be able to recycle more items or find ways to recycle new items. Equally important is to reduce the amount of plastic you throw away.

Q65. Draw a diagram to show the relationships among these terms: natural, synthetic, polymer, nylon, protein. Add other terms as needed.

Sol.



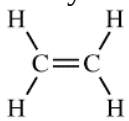
Outline Form:
I. Polymers
a. Natural, example: protein
b. Synthetic, example: nylon

Q66. Celluloid was the first commercial plastic, developed in response to the need to replace ivory for billiard balls and piano keys. Speculate on the properties of celluloid that made it a successful substitute for ivory in these products.
Sol. A replacement for ivory had to be hard, shock-resistant, and have a non-tacky surface. It had to be chemically inert so that it would not discolor from oil on players' skin or from dye on the felt surface of a billiard table.

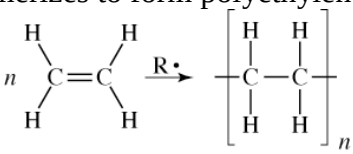
Q67. Glucose from corn is the source of some new bio-based polymer materials. Glucose also is the monomer in cellulose. Earlier in this text you encountered glucose in the chemical reaction of photosynthesis. What is photosynthesis and from what is glucose produced?
Sol. Photosynthesis is the process that occurs when green plants use the energy of sunlight to produce glucose from carbon dioxide and water.

Q68. The properties of a plastic are a consequence of more than just its chemical composition. Name two other features of a polymer chain that can influence its properties.
Sol. Other factors that influence the properties of a polymer include the length of the chain (the number of monomer units), the three-dimensional arrangement of the chains, the degree of branching in the chain, the strength/ types of intermolecular forces between the chains, and orientation of monomer units within the chain.

Q69. Many monomers contain a C-to-C double bond. Select one and draw its structural formula together with the corresponding polymer. Describe the similarities and differences between the monomer and the polymer.
Sol. Here is the ethylene monomer:



With a free radical catalyst, it polymerizes to form polyethylene.



Both the monomer and the polymer are hydrocarbons; that is, they are made from the elements carbon and hydrogen. As such, both burn to produce CO_2 and H_2O. Also both are nonpolar and less dense than water. Beyond this, the compounds are very different. At room temperature,

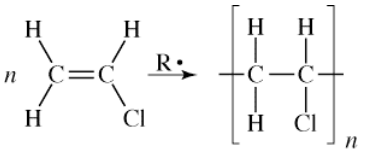
ethylene is a reactive gas, and polyethylene is a relatively unreactive solid.

Q70. What structural features must a monomer possess to undergo addition polymerization? Explain, giving an example. Do the same for condensation polymerization.

Sol. To undergo addition polymerization, the monomer must have a C-to-C double bond. Although some monomers have benzene rings as part of their structures (styrene, for example), the double bond involved in addition polymerization cannot be part of a benzene ring. An example is the formation of PP from propylene.

In condensation polymerization, two functional groups react and eliminate a small molecule. For example, an alcohol (hydroxyl group) and a carboxylic acid can react to eliminate water. Condensation polymerization either features the reaction of (1) many identical monomers, each of which has both a hydroxyl group and a carboxylic acid group, or (2) two monomers, one with two hydroxyl groups and the other with two carboxylic acid groups. An example of (2) is the formation of PET from ethylene glycol and terephthalic acid.

Q71. This equation represents the polymerization of vinyl chloride. At the molecular level as the reaction takes place, how does the Cl-to-C-to-H bond angle change?



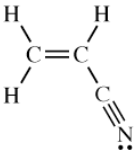
Sol. In vinyl chloride, there are three bonds (two single and a double) around each carbon. Thus the geometry is trigonal planar and the Cl–to–C–to–H bond angle is 120º. In the polymer, each carbon atom is connected to other atoms by four single bonds and the geometry is tetrahedral, with a bond angle of 109.5°.

Q72. Polyacrylonitrile is a polymer made from the monomer acrylonitrile, CH_2CHCN.

a. Draw a Lewis structure of this monomer.

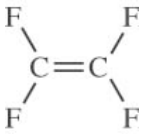
b. Polyacrylonitrile is used in making Acrilan fibers used widely in rugs and upholstery fabric. What danger do rugs or upholstery made of this polymer create in the case of house fires?

Sol. a. This is the Lewis structure.

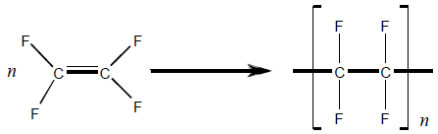


b. When Acrilan fibers burn, one of the combustion products is the poisonous gas hydrogen cyanide, HCN.

Q73. Roy Plunkett, a DuPont chemist, discovered Teflon while experimenting with gaseous tetrafluoroethylene. Here is the monomer.



a. Analogous to equation 9.1, write the chemical reaction for the polymerization of n molecules of tetrafluoroethylene to form Teflon.
b. Why is a repeating head-to-tail arrangement not possible for this polymer?
Sol. a.



b. A repeating head-to-tail arrangement is not possible for Teflon for the same reason it is not possible for ethylene. The monomer does not have a "head" or a "tail."

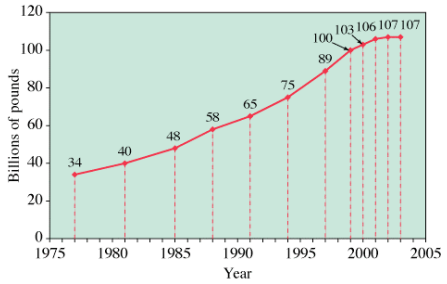
Q74. Equation 9.1 shows the polymerization of ethylene. From the bond energies of Table 4.2, is this reaction endothermic or exothermic?
Sol. It requires 598 kJ/mol to break C-to-C double bonds. The formation of C-to-C single bonds releases 356 kJ/mol. If we consider the reaction of two ethylene monomers, two double bonds are broken and replaced with four single bonds (two bonds between the C atoms of the monomers, one between the first monomer and the second, and a bond extending to what would be the third ethylene monomer). Here is the calculation:
(2 × 598 kJ/mol) + (4 × −356 kJ/mol) = −228 kJ/mol.
Thus, the reaction is exothermic.

Q75. Would your answer from the previous equation differ if tetrafluoroethylene were used as the monomer?
Sol. No. Because only bonds between carbon atoms are involved in the calculation (not the C-H or C-F bonds), the answer would be the same and exothermic for both.

Q76. Do you expect the heat of combustion of polyethylene, as reported in kilojoules per gram (kJ/g), to be more similar to that of hydrogen, coal, or octane, C_8H_{18}? Explain your prediction.
Sol. The heat of combustion of polyethylene would be most similar to that of octane. Both are hydrocarbons consisting of carbon-carbon single bonds. The other fuels contain different atoms (and thus different bonds would be broken.

Q77. Recycling is not the same as waste prevention. Explain.
Sol. Recycling is the reuse of materials that are already in the environment; for example, remaking old soda bottles into new ones. Waste prevention reduces the amount of materials entering the environment at any stage; for example, in the manufacture of an item, in how it is used, and in discarding the materials that it contains. Although both aim to minimize waste, waste production is more comprehensive.

Q78. This graph shows U.S. production of plastics from 1977 through 2003.



a. What is the approximate increase in plastic production for any five-year period before 2003?

b. How many years were required for the production in 1977 to double?

c. Redraw this as a bar graph that shows the relationship between the year and the pounds of plastics produced. Discuss whether the bar graph is easier than the line graph to establish the doubling time.

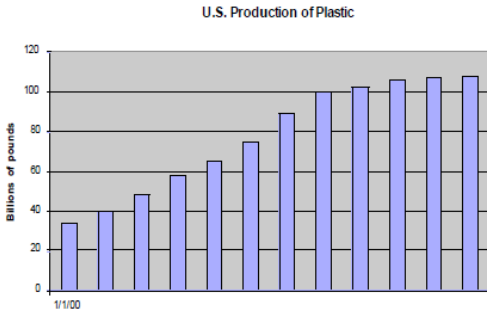
d. Suggest factors that may have contributed to changes in production from 2001 to 2003.

Sol.

a. The approximate increase in plastic production for any five-year period is between 6 and 12 billion pounds.

b. Plastics production in 1977 was 34 billion pounds. A doubling of this production would require an output of 68 billion pounds, a level that, according to the graph, occurred around 1992. Thus, 15 years were required to double the plastics output of 1977.

c. Both ways of representing the data are straightforward, and the choice of graph may be a matter of preference.



d. Changes in production have seemed to begin a leveling off period. Possibilities include an increase in raw material cost (petroleum), increased reuse and recycling of plastic, and just a temporary trend with no long-term implications.

Q79. Consider the polymerization of 1000 ethylene molecules to form a large segment of polyethylene.

$$1000\,CH_2{=}CH_2 \xrightarrow{R\bullet} {+}CH_2CH_2{+}_{1000}$$

a. Calculate the energy change during this reaction.

Hint: Use Table of bond energies.

b. To carry out this reaction, must heat be supplied or removed from the polymerization vessel? Explain.

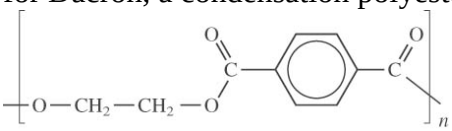
Sol.

a. When two monomers of ethylene join, they release 228 kJ of energy in an exothermic reaction. The heat released is therefore 114 kJ per monomer. With 1000 monomers joining, the heat released will be 114,000 kJ or 1.14×10^5 kJ.

b. The reaction is so exothermic that, in the early days of polymer manufacture, polymerization vessels exploded. Finally, manufacturers realized that heat had to be removed

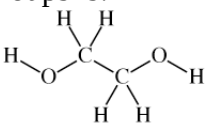
from the polymerization vessels to avoid this.

Q80. Here is the structural formula for Dacron, a condensation polyester:

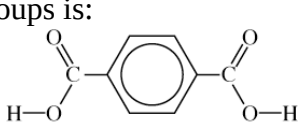


Dacron is formed from two monomers, one with two hydroxyl groups (–OH) and the other with two carboxylic acids (–COOH). Draw the structural formulas for the alcohol and the acid monomers used to produce Dacron.

Sol. The monomer with two hydroxyl groups is:



The monomer with two carboxylic acid groups is:



Q81. Catalysts are used to help control the average molar mass of polyethylene, an important strategy to control polymer chain length. During World War II, low-pressure polyethylene production used varying mixtures of triethylaluminum, $Al(C_2H_5)_3$, and titanium tetrachloride, $TiCl_4$, as a catalyst. Here are some data showing how the molar ratio of the two components of the catalyst affects the average molar mass of the polymer produced.

Moles $Al(C_2H_5)_3$	Moles $TiCl_4$	Average Molar Mass of Polymer, g
12	1	272,000
6	1	292,000
3	1	298,000
1	1	284,000
0.63	1	160,000
0.53	1	40,000
0.50	1	21,000
0.20	1	31,000

a. Prepare a graph to show how the molar mass of the polymer varies with the mole ratio of $Al(C_2H_5)_3$/ $TiCl_4$.

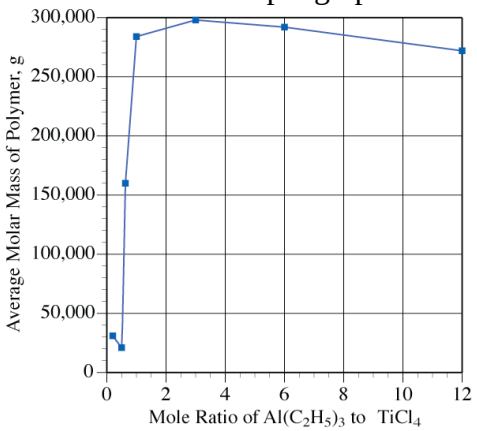
b. What conclusion can be drawn about the relationship between the molar mass of the polymer and the mole ratio of $Al(C_2H_5)_3/TiCl_4$?

c. Use the graph to predict the molar mass of the polymer if an 8:1 ratio of $Al(C_2H_5)_3$ to $TiCl_4$ were used.

d. What ratio of $Al(C_2H_5)_3$ to $TiCl_4$ would be used to produce a polymer with a molar mass of 200,000?

e. Can this graph be used to predict the molar mass of a polymer if either pure $Al(C_2H_5)_3$ or pure $TiCl_4$ were used as the catalyst? Explain.

Sol. a. Here is a sample graph.



b. As the mole ratio of $Al(C_2H_5)_3$ to $TiCl_4$ increases from approximately

0.53:1 to 3:1 the molar mass of the polymer produced also increases. At higher mole ratios, the molar mass of the polymer begins to fall.

c. The average molar mass of the polymer produced is about 280,000 g when the molar ratio of $Al(C_2H_5)_3$ to $TiCl_4$ is 8:1.

d. A molar ratio of about 1.3:1 $Al(C_2H_5)_3$ to $TiCl_4$ will result in production of a polymer with an average molar mass of approximately 200,000 g.

e. There is no direct information for either pure catalyst. Looking at the graph, one might tentatively suggest that using pure $Al(C_2H_5)_3$ could result in production of a polymer with a molar mass of about 40,000. There is not enough information provided to make any suggestion about the molar mass of the polymer that would be produced using a catalyst of pure $TiCl_4$. The mixture of catalysts seems necessary for production of a polymer with the greatest molar mass, with the optimum condition occurring at a ratio of $Al(C_2H_5)_3$ to $TiCl_4$ of approximately 3:1.

Q82. When you try to stretch a piece of plastic bag, the length of the piece of plastic being pulled increases dramatically and the thickness decreases. Does the same thing happen when you pull on a piece of paper? Why or why not? Explain on a molecular level.

Sol. When the piece of plastic is stretched, the strip narrows and "necks down." The molecules become aligned parallel to each other and in the direction of the pull. This alteration of the three-dimensional structure is not reversible, and if the pulling continues, the plastic breaks.

When the same pulling force is applied to a piece of paper, the paper tears rather than stretching to any significant extent. The cellulose molecules in paper are held far more rigidly in place, and are not free to become aligned.

Q83. Consider Spectra, Allied-Signal Corporation's HDPE fiber, used as liners for surgical gloves. Although the Spectra liner has a very high resistance to being cut, the polymer allows a surgeon to maintain a delicate sense of touch. The interesting thing is that Spectra is linear HDPE, which is usually associated with being rigid and not very flexible.

a. Suggest a reason why branched LDPE cannot be used in this application.

b. Offer a molecular level reason for why linear HDPE is successful in this application.

Sol. a. LDPE cannot be used in this application because it does not have the required strength.

b. The molecules of HDPE must line up in a way that produces the required strength. Using a thin liner of HDPE allows sufficient flexibility.

Q84. One limitation of the Big Six is the relatively low temperatures, 90–170 °C, at which they melt. Suggest ways to raise the upper temperature limits while maintaining the other

desirable properties of these substances.

Sol. This is a difficult equation. Best, of course, would be simply to use a different polymeric material. For example, 6, 12-nylon melts slightly higher at 180 °C and other nylons much higher than this. To change the properties of the Big Six, you would need an additive. One possibility is finely divided silica (SiO_2 in sand and quartz), which is heat resistant and does not burn.

Q85. All the Big Six polymers are insoluble in water, but some dissolve or at least soften in. Use your knowledge of molecular structure and solubility to explain this behavior.

Sol. The "Big Six" polymers are generally nonpolar molecules and therefore do not dissolve in polar solvents such as water. The generalization, is that "like dissolves like". Some of the "Big Six" dissolve or soften in hydrocarbons or chlorinated hydrocarbons because these nonpolar solvents interact with the nonpolar polymeric chains.

Q86. When Styrofoam packing peanuts are immersed in acetone (the primary component in some nail-polish removers), they dissolve. If the acetone is allowed to evaporate, a solid remains.The solid still consists of Styrofoam, but now it is solid and much denser. Explain. Hint: Remember that Styrofoam is made with foaming agents.

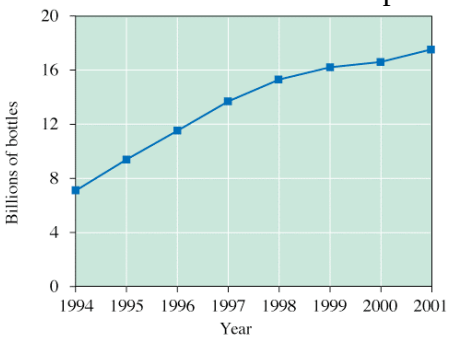
Sol. Acetone dissolves the polymer, allowing the gas of the foaming agent to escape. The polymer collapses on itself and is more dense because the gas has been removed.

Q87. This figure, entitled "Plastic Soda Bottles Wasted," was adapted from one shown in Beverage World magazine. The y-axis is in units of billions of beverage bottles.

a. Which polymer is used in clear plastic beverage bottles?

b. If recycled, to what uses can this polymer be put?

c. More bottles are recycled each year, yet this graph still shows an increase in bottles wasted. Explain.



Sol.

a. Clear plastic beverage bottles are typically PET.

b. PET can be recycled and used for a synthetic fiber in clothing or carpet, photographic film, new bottles, furniture, and tire cord.

c. The number of soft drink bottles manufactured increases each year. This, along with increased recycling awareness, accounts for the increase in bottles recycled. However, the total number of bottles in existence is ever increasing, resulting in a similar increase in the number that find their way into the trash.

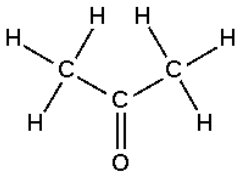
Q88. a. Name two functional groups not discussed in this chapter. Give an example of a molecule containing each one.

b. Find the structural formula for the acetone molecule. What functional group does it contain?

Sol.

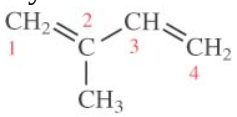
a. Examples of functional groups not discussed in this chapter include ethers, aldehydes, and ketones.

b. The structure of acetone, a ketone, is shown below.



Q89. Cotton, rubber, silk, and wool are natural polymers. Consult other sources to identify the monomer in each of these polymers. Which are addition polymers and which are condensation polymers?

Sol. Cotton is formed from glucose; silk and wool are formed from amino acids. All are condensation polymers. Natural rubber is formed from isoprene (contains a carbon-to-carbon double bond, shown below) and is an addition polymer.



Q90. Until recently, most PET beverage bottles were colorless. Now, however, Dasani water is sold in blue PET, as are other beverages. Similarly, Sprite is sold in green PET. Find out what effect, if any, the blue and green PET is having on recycling.

Sol. In the past, colored bottles often were kept separate from clear ones because the markets for colored plastics differed from those for clear. Today, however, it seems that the types can be mixed, which implies that the end use does not require colorless plastic.

Q91. A Teflon ear bone, fallopian tube, or heart valve? A Gore-Tex implant for the face or to repair a hernia? Some polymers are biocompatible and now used to replace or repair body parts.

a. List four properties that would be desirable for polymers used within the human body.

b. Other polymers may be used outside your body, but in close contact with it. For example, no surgeon is needed for you to use your contact lenses-you insert, remove, clean, and store them yourself. From which polymers are contact lenses made? What properties are desirable in these materials? Either a call to an optometrist or a search on the Web may provide some answers.

c. What is the difference in the material used in "hard" and "soft" contact lenses? How do the differences in properties affect the ease of wearing of contact lenses?

Sol.

a. The benefits for polymers intended for use in the body should far outweigh any risks. The two main properties are (1) stable over time of intended use and (2) non-toxic. Other factors to consider are low cost, lack of solubility in body fluids, lack of

reactivity in body fluids, and the ease of implantation.

b. Several different types of contact lenses are on the market and each uses a different type of polymer. Polymethyl methacrylate (PMMA), one of the earliest polymers used for rigid gas permeable lenses, is structurally similar to Lucite and plexiglas. Silicone-acrylate materials now are more commonly used under trade names such as Kolfocon. Newer rigid gas permeable (RGP) polymers contain fluorine: fluoro-silicone-acrylate polymers and fluorosilicones. Polymacon (38% water) is typical of the polymers used for soft lenses and is a polymer of 2-hydroxyethyl methacrylate (HEMA). Other methacrylates include hioxifilcon (48% water) and methafilcon (55% water) or even lidofilcon (70% water). Manufacturers' websites are good sources of information. Desirable properties include being nontoxic, permeable to oxygen, comfortable to wear, and inexpensive. Also desirable is the ability to conform to the shape of the eye and to be easily cleaned (if not disposable).

c. As mentioned in the previous part, hard contact lenses are typically made of PMMA, a rigid non-gas permeable plastic. The soft contact lenses that replaced them are made of silicone, which is flexible and allows oxygen to reach the eye. Because of these properties, the soft lenses tend to be more comfortable.

Q91. PVC, also known as "vinyl," is a controversial plastic. Do a risk–benefit analysis of using PVC from either the standpoint of a consumer or from a worker in the vinyl industry.

Sol. The cradle-to-grave life cycle of vinyl needs to be considered in answering this equation. An additional factor is that vinyl often includes a plasticizer that is added to the rigid PVC in order to soften it.

With these in mind, risks include (1) those to the worker (occupational exposure to vinyl chloride, a carcinogenic monomer), (2) those to the consumer (from leaching of the plasticizer, which in a few cases carries health risks), and (3) those to the environment (disposal of a plastic that contains chlorine and can produce HCl if burne D**.** The film andwebsite "Blue Vinyl" tells one person's research into the risks of PVC**.** The benefits of vinyl include that it is a beautiful and an incredibly versatile plastic with many uses. These include vinyl siding for buildings, IV tubing and blood bags, clear or shiny plastic containers, plastic charge cards, vinyl hoses, "patent leather" belts and shoes, and PVC pipe for plumbing. Manufacturers' and plastic industry websites describe the benefits.

Q93. The plasticizers used to soften PVC are controversial as well. A common class of plasticizers is phthalates (THAL-ates), esters of phthalic (THAL-iC) acid.

a. Phthalic acid is an isomer of terephthalic acid, one of the two monomers used to synthesize

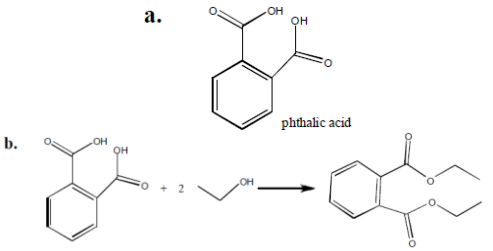
PETE. The structure of phthalic acid is similar to that of terephthalic acid except that the acid groups on the benzene ring are adjacent to each other. Draw the structural formula for phthalic acid.

b. Write the chemical equation where phthalic acid reacts with two molecules of ethanol to form a double ester.

c. The plasticizers DINP and DEHP (here the P stands for phthalate) use a longer chain alcohol than ethanol, resulting in an ester with longer side-chains. Given the role that plasticizers play, why do you think a longer chain alcohol is needed?

d. Use the resources of the Web to research why plasticizers such as DINP and DEHP are controversial.

Sol.



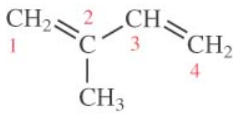
c. The longer side chains mean that the phthalate ester molecule is bigger and bulkier (somewhat in shape like an octopus with two long arms). Phthalate molecules, when mixed with the long polymer molecules, push the polymer chains apart. This makes the polymer less rigid in a manner similar to the role branching plays in making LDPE flexible.

d. New research studies keep appearing, so a careful literature search here is important. As of 2007, studies have established a connection between animal exposure to phthalates and abnormal testicular and sperm development. Male fetuses and infants are expected to be particularly sensitive to exposure to plasticizers, which are used to soften PVC products such as IV bags and tubing.

Q94. Who first synthesized Kevlar? What was the background and academic training of these scientists? Was the potential for using this polymer in radial tires immediately understood? What are other applications of Kevlar? Write a short report on the results of your findings. Be sure to cite your source.

Sol. In 1965, Stephanie Kwolek created Kevlar, the first polymer in a series of synthetic fibers with exceptional strength and stiffness. She was interested in both chemistry and medicine and graduated from Carnegie-Mellon University. She later worked at the DuPont Company in polymer research, where she made her key discoveries. Soon after the discovery of Kevlar, fibers of the material were woven into a bulletproof fabric. Kevlar and its close chemical relatives is used today in boats, airplanes, ropes, cables, tennis racquets, sails, tires, and skis.

Q95. Isoprene is the monomer that forms natural rubber. Here is its structural formula, with the carbons numbered.



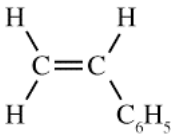
When isoprene monomers add to form polyisoprene (natural rubber), the polymer has a C-to-C double bond between carbon atoms 2 and 3. How does this double bond form? Hint: Each double bond has four electrons in it. When a new single bond is formed between two monomers, that single bond only needs two electrons in it; one from each of the monomers joined by that new bond.

Sol. During polymerization, the electrons in the molecule rearrange, forming one double bond where previously there were two. Of the four electrons between carbons 1 and 2, two are unchanged leaving a single bond after the reaction. The other two electrons are split. One goes to form the bond between one isoprene monomer and another monomer and the second electron moves between carbons 2 and 3. The double bond between carbons 3 and 4 splits similarly with one electron moving between carbons 2 and 3. The net result of this rearrangement is a double bond between carbons 2 and 3 and single bonds between all other carbon atoms.

Q96**. a.** What are the structures of the monomers used in SBR synthetic rubber?

b. How are natural and synthetic rubber alike, and how do they differ?

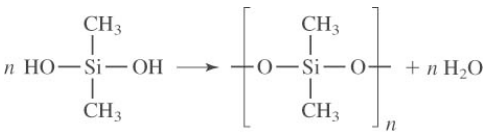
Sol. a. SBR, short for "styrene butadiene rubber," is a synthetic rubber made from the monomers styrene and 1,3-butadiene. Below are the condensed structural formulas.



and $H_2C{=}CH{-}CH{=}CH_2$

b. Natural and synthetic rubbers share many common properties. For example, they are elastic, resistant to bases and many other chemicals, tough, adhesive, and water repellant. They differ in their origin: Natural rubber is obtained from the milky secretion (latex) of various plants, most commonly Hevea brasiliensis. Synthetic rubber is made from petroleum-based raw materials. In this sense, natural rubber is the product of a renewable resource and synthetic rubber is not. Some synthetic rubbers show better resistance to oils, organic solvents, and to oxygen.

Q97. Synthetic rubber is usually formed through addition polymerization. An important exception is silicone rubber, which is made by the condensation polymerization of dimethylsilanediol. This is a representation of the reaction.



a. Predict some of the properties of this polymer. Explain the basis for your predictions.

b. Silly Putty is a popular form of silicone rubber. What are some of the properties of Silly Putty?

Sol.

a. This polymer is nonpolar with a high molar mass. Thus it should not dissolve in water.

b. "Silly Putty" will bounce, but it breaks when it is snapped. When it is formed into a shape and then placed on a surface, it will slowly lose its shape. Ink will stick to Silly Putty and so it can "lift" images from newsprint. These properties are rather unique, and led to the popular acceptance of Silly Putty as a toy long before it was widely used for other products.

Q98. A few decades ago, recycling personal computers was not a concern because not enough of them were around to matter. Today, however, there is good reason to keep keyboards, monitors, and "mice" out of the landfill.

a. Which polymers do your computer and its accessories contain?

b. What are the options for recycling the plastics in computers?

Sol. **a.** Here is a quote from Heidi Schussele, NY Times, November 23, 2000, "Computer components have changed over the years, but a PC today is typically 40 percent steel, 30 percent to 40 percent plastic, 10 percent aluminum and 10 percent other metals, including copper, gold, silver, cadmium and platinum. A monitor adds glass and lead to the components. But in our experience, finding out what which polymers are in the 40% plastic is no easy task. The outer shell of the mouse is typically ABS (acrylonitrile butadiene styrene) plastic that is injection-molded. Keyboards and monitor cases are also ABS and sometimes polystyrene (high-impact polystyrene, HIPS). Being curious to learn more, a member of the author team asked a colleague who is a polymer chemist. He responded with perhaps a bit more technical information than you want to know, but as it is an interesting response, we include it here:

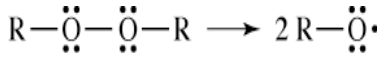
"Computer monitor shells and the like are usually poly(styrene), however, Apple has gone to poly(carbonate) for the shells of their computers and laptops. The textured grips on mice are probably some kind of poly (propylene) or a poly(ethylene-co-1-octene) like the materials that you find on the textured grip of a toothbrush. The ethylene/1-octene materials are relatively new, in that their synthesis was only achieved in the mid 1990's and they came to market in the late 1990's after a messy patent dispute between DOW and Exxon- Mobil. I think the keyboards are mostly ABS materials with high styrene content, which provides the stiffness. As for the rest of the computer, the green circuit boards are actually made of an epoxy thermoset. DOW makes a lot of these materials and markets them as DERs (Dow Epoxy Resins-imaginative marketing!). One of the issues with these bisphenol A derived epoxies is that they are flammable, and you have to mitigate that flammability. DOW does this by using a perbrominated bisphenol A, since the bromine will serve as a radical trap in the combustion reaction and prevent fire.

That being said, the introduction of all of the bromine causes the material to become very brittle. This problem has been recently addressed by adding some block copolymers to the resin which make tubular micelles within the epoxy. These long, tubular structures can entangle like spaghetti and enhance the toughness of the polymer by 3-4 orders of magnitude."

b. The electronic parts of computers are still more widely recycled than the plastics they contain. The options for plastics (although few) appear to be increasing over time. Some companies will take computers and recycle or reuse all of their components, including the plastics. These companies may charge extra for the monitors, because of the lead in the glass.

Q99. Free-radical peroxides promote the polymerization of ethylene into polyethylene. They also play a key role in tropospheric smog formation. Use the Web to learn more about how the peroxides promote ethylene polymerization and how peroxides are involved with photochemical smog formation in the troposphere. Write a brief report comparing the types of peroxides important with each of these cases. Cite all sources.

Sol. Both Cl. and ClO. are involved in the destruction of ozone in the stratosphere. The chapter describes the chemical reactions of both of these. Similarly, Br. catalyzes the destruction of stratospheric ozone as well. With the polymerization of the monomer ethylene to form polyethylene, a different free radical is used, R–O, in which R is likely to be a group containing several carbon atoms. This free radical is generated from a peroxide (a compound with an O-to-O bon D). Being somewhat unstable, the peroxide breaks down to release R–O.



Note: Organic peroxides also play a key role in catalyzing the reactions of photochemical smog.

References

1- Michael T. Mury, Karen L. Anderson., Chemistry in Context: American Chemistry Society, Eighth Edition, McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121. (2012).
2- U. S. National Chemistry Olympiad local section exam, American chemical society Olympiad examinations task force (2002).
3- Ameen F. M., Lagowski J. J, Systemic multiple choice questions in chemistry, 19th icce, seoul, aug. 12-17 (2006).
4- Biosan -Medical-biological Research and Technologies. Final Round, problems (2011) as www.biosan.lv
5-National high School Chemistry Examination Part A - multiple choice questions (2009). http://www.uwlax.edu/chemistry/html/types.htm
6- Chemical Institute of Canada "chemists, engineers and technologists working together"
7- National High School Chemistry Examination Part b – Essay Questions (2002).
8-Chemical Institute of Canada and Canadian Chemistry Olympiad
Final Selection Examination (2002).
9- Hong Kong Examinations and Assessment Authority & Hong Kong Diploma of Secondary Education Examination, Hkdse-Chem (2010).
10- Victorian Certificate of Education Supervisor to Attach Processing Label (2002), http://www.chemheritage.org/classroom/chemach/plastics/kwolek.html
11-American Chemistry Council, A group Representing Major Chemical Manufacturers, has created a website promoting phthalates (2012) at http://www.phthalates.org.
12- U.S. National Chemistry Olympiad, Local Section Exam,
Prepared by the American chemical society chemistry Olympiad examinations task force (2013).
13- Skoog, Holler, Crouch " Principles of Instrumental Analysis) 6th ed. (2007).
14-Wikipedia, the free encyclopedia analytical chemistry (journal) & Chemistry (disambiguation) (2011). http://en.wikipedia.org/wiki/Chemistry.
15- Rouessac F., Rouessa A. "Modern Instrumentation Methods and Techniques" 2 Edition, John Wiley & Sons Ltd, (2007).
16- Arden P. Zibpp, development committee in AP Chemistry, (1999).

الفصل الرابع: الكيمياء الصناعية: تتضمن عمليات التصنيع التي تتم أثناء إنتاج البتروكيماويات، الدواء، البوليمرات، الطلاءات، الزيوت. يتم استخدام علوم الكيمياء والتفاعلات الكيميائية لإنتاج مواد جديدة، أو فصل المواد من بعضها باستخدام خواص عديدة مثل مدى الانحلالية، الشحنة، أو التقطير، بالإضافة إلى التحولات التي تتم باستخدام الحرارة وطرق أخرى.

الفصل الخامس: كيمياء عضوية: هي دراسة تركيب، وخواص، وتفاعلات المركبات العضوية.

الفصل السادس:

(a) الكيمياء غير العضوية وهي دراسة خواص وتفاعلات المركبات غير العضوية. ولا يوجد هناك حد واضح للتفريق بين الكيمياء العضوية وغير العضوية، كما أن هناك تداخل كبير بينهما، ويكون أهمه في فرع آخر يسمى كيمياء الفلزات العضوية.

(b) الكيمياء النووية Nuclear Chemistry هو أحد فروع الكيمياء الذي تتعامل مع النشاط الإشعاعي والعمليات النووية والخواص النووية. ودمج هذا الفرع مع الكيمياء اللاعضوية لان الأسئلة متداخلة وقليلة التي تناولت في هذا المجال.

الفصل السابع: الكيمياء التحليلية: وهي تحليل عينات من المادة لمعرفة التركيب الكيميائي لها وكيفية بنائها.

الفصل الثامن: كيمياء البوليمرات: أو كيمياء الجزيئات الكبيرة علم متشعب يتعامل مع التصنيع الكيميائي والخواص الكيميائي ويتم وصف البوليمر كيميائيا بدرجة البلمرة، توزيع الكتلة المولية، الانتظامية، توزيع البوليمر التساهمي، تفرع البوليمر.

المؤلفان

بغداد–2014

مقدمة الكتاب

يهتم علم الكيمياء بدراسة تكوين وبناء المادة، ويمثل الجسر الذي يربط بين عدد من العلوم مثل الفيزياء والبايولوجي والجيولوجي بعضها إلى البعض ويدعى بالعلم المركزي (Central Science). الباحث في هذا المجال يروم ان يحصل على المعلومة بأبسط واسرع طريقة، ومن هذا الباب ارتى المؤلفان ان يقدمها بشكل سؤال وجواب بصيغتها المقتضبة بشقين. الأول على شكل اختيارات (Multi Choice Equation)، والثاني الأسئلة ذات الأجوبة القصيرة (Short Answer Equation) مع مراعاة تقسيمها إلى فروعها اختصاراً للوقت.

واستدراكاً لما ذكر أعلاه؛ فان الكتاب يفتح نافذة أخرى في مجال علم الكيمياء في إثراء المكتبة العربية في هذا المجال، قد يلبي رغبة المهتمين خاصة المتقدمين منهم للدراسات العليا (الماجستير، الدكتوراه) وطلبة الدكتوراه (الامتحان الشامل) أو الزملاء التدريسيين بان يطوروا فكرة السؤال وصياغته بشكل مناسب لاختصاصه. ومن الجدير بالذكر انه صدر في هذا المجال للمؤلف الدكتور جميل موسى ضباب كتابه الموسوم (طرائق وتقنيات حديثة في التحليل الكيميائي الآلي 2013). ونتقدم بالشكر والتقدير للساده الخبراء لمراجعتهم محتوى الكتاب وما ابدوه من تصحيحات ومقترحات وهم كل من: ا. د. طارق سهيل نجم، ا. د. رمزي رشيد العاني، ا. م. د عبد الجبار خلف عطيه العبودي، ا. م. د. سلمى عبد الرضا، ا. م. د. محمود نجم الجبوري، ا. م. د. صلاح مهدي الشكري، ا. م. د. محمد جاسم حسن الفتلاوي، م. مدير مبارك (الجامعة المستنصرية– كلية العلوم– قسم الكيمياء).

ويتكون الكتاب من ثمانية فصول (باللغة الإنكليزية).

الفصل الأول: مقدمة عن علم الكيمياء باللغتين العربية والإنكليزية.

الفصل الثاني: أسئلة وأجوبة الكيمياء الفيزيائية. هي دراسة الأصل الفيزيائي للتفاعلات والأنظمة الكيميائية. ولمزيد من التحديد فإنها تدرس تغييرات حالات الطاقة في التفاعلات الكيميائية.

الفصل الثالث: الكيمياء الحيوية: هي دراسة المواد الكيميائية، والتفاعلات الكيميائية التي تحدث في الكائنات الحية.


قال الله تعالى :
وَيَسْـَٔلُونَكَ عَنِ ٱلرُّوحِ ۖ قُلِ
ٱلرُّوحُ مِنْ أَمْرِ رَبِّى وَمَآ أُوتِيتُم
مِّنَ ٱلْعِلْمِ إِلَّا قَلِيلًا ٨٥
سورة الإسراء

اسم الكتاب: أسئلة واختبارات في الكيمياء

التصنيف: الكيمياء

المؤلفين: أ. م. د. جميل موسى ضباب أ. م. د. زياد محمد عبود

سنة التأليف: 2014

الطبعة الأولى

لإبداء أي ملاحظات تعمل على تطوير الكتاب في الطبعات القادمة ان شاء الله

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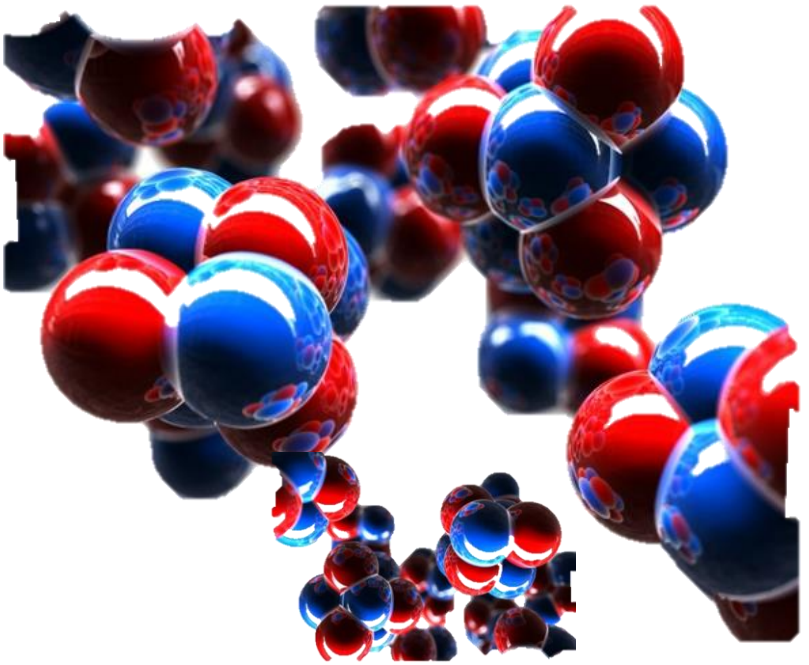
أسئلة واختبارات في الكيمياء

(للمتقدمين للدراسات العليا والامتحان الشامل)



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2014