CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

2010 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

CHEMISTRY – MARKING GUIDELINES

The sample answers include features that should be found in a response that receives full marks. For the extended response questions, a set of guidelines is included with a sample answer.

Section I
Part A – 20 marks

Questions 1-20 (1 mark each)

Question	Correct Response	Outcomes Assessed	Targeted Performance Bands
1	B	H9	2-3
2	D	H9, H10	3-4
3	D	H6	3-4
4	A	H7	3-4
5	C	H7, H10	5-6
6	D	H9, H14	4-5
7	D	H9, H13	2-3
8	C	H8	2-3
9	B	H9, H10	5-6
10	A	H4, H8	2-3
11	B	H8, H14	3-4
12	C	H12	3-4
13	A	H8	2-3
14	D	H3, H8	2-3
15	C	H10	5-6
16	A	H8, H14	4-5
17	B	H4	2-3
18	C	H4, H8	2-3
19	A	H7	2-3
20	B	H6	3-4

Section I
Part B – 55 marks

Question 21 (3 marks)
(a) (1 mark)
Outcomes Assessed: H6
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies particle ***X*** as a beta particle (electron) AND • Identifies particle ***Y*** as a neutron	1

Sample answer:
X is a beta particle (or electron) ${}^{0}_{-1}e$
Y is a neutron ${}^{1}_{0}n$

(b) (2 marks)
Outcomes Assessed: H5, H6, H7
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes at least TWO similarities or differences in the production of the elements	2
• Describes ONE similarity or difference in the production of the elements	1

Sample answer:
Method 1 uses neutron bombardment and subsequent beta decay to produce the new element compared to Method 2, which uses alpha particle bombardment.
Method 1 takes place in a nuclear reactor where neutrons are produced and Method 2 requires a particle accelerator such as a cyclotron to bombard the nuclei with positively-charged nuclei.
Both methods produce transuranic elements.

Question 22 (5 marks)
(a) (1 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies the process as fermentation	1

Sample answer:
Fermentation

(b) (3 marks)
Outcomes Assessed: H9, H10
Targeted Performance Bands: 2-5

Criteria	Marks
• Correctly calculates the mass of glucose	3
• Calculates the mass of glucose using incorrect stoichiometric relationship OR • Calculates the moles of glucose reacted	2
• Calculates the number of moles of CO_2 produced at 25°C and 100kPa using the volume of gas produced from the graph	1

Sample answer:
$V(CO_2)$ released in 8 days = 2.3 L (from graph)
Mol CO_2 *(g)* at 25°C and 100 kPa = 2.3 L / 24.79 L mol^{-1}
= 0.09278 mol

From the balanced equation:
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
$\therefore$ no. of moles of $C_6H_{12}O_6$ = ½ $n(CO_2)$
= ½ x 0.09278 mol
= 0.04639 mol

$M(C_6H_{12}O_6)$ = 180.156 g

$\therefore$ mass of glucose = 0.04639 mol x 180.156 g mol^{-1} = 8.4 g

(c) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a balanced equation for the production of ethanol from ethylene including a suitable catalyst	1

Sample answer:
C_2H_4 *(g)* + H_2O *(g)* $\overset{H_2SO_4}{\rightleftharpoons}$ C_2H_5OH *(aq)*

Question 23 (4 marks)
Outcomes Assessed: H2, H9, H14
Targeted Performance Bands: 2-6

Criteria	Marks
• Evaluates the effectiveness of the TWO models to explain THREE properties of HDPE and LDPE	4
• Relates the TWO models to the THREE properties of HDPE and LDPE	3
• Relates the TWO models to TWO properties of HDPE and LDPE OR • Relates ONE model to the THREE properties of HDPE and LDPE	2
• Relates the TWO models to ONE property of HDPE and LDPE OR • Relates ONE model to TWO properties OR • Identifies Models A and B as representing HDPE and LDPE respectively	1

Sample answer:
The models constructed by the student allow some of the properties of the two forms of polyethylene to be explained simply.

Model A represents a chain of HDPE (high density polyethylene) and this model explains the higher density of this polymer (no branching on the model explains its ability to pack tightly) in comparison to Model B which represents LDPE (low density polyethylene).

The branching on Model B explains why close packing of polymer chains cannot occur. It is this feature that decreases the density and increases the flexibility.

The intermolecular forces between neighbouring polymer chains would be greater for Model A due to close packing of chains. This partially explains the melting point.

These models do not explain the insoluble nature of polyethylene in water. Solubility in water is due to the presence of polar bonds and the models give no indication of the types of bonds, polarity or atoms present.

<u>Evaluation</u>
The student's models are effective in that they can be used to explain the properties of melting point and flexibility for polyethylene adequately but they fail to explain the lack of solubility. A more appropriate model would show the bonding and atoms within the polymers.

Question 24 (6 marks)

(a) (1 mark)

Outcomes Assessed: H6, H13

Targeted Performance Bands: 3-4

Criteria	Mark
• Correctly balanced net ionic equation	1

Sample answer:

$2Al\ (s) + 3Zn^{2+}\ (aq) \rightarrow 2Al^{3+}\ (aq) + 3Zn\ (s)$

(b) (1 mark)

Outcomes Assessed: H7

Targeted Performance Bands: 2-3

Criteria	Mark
• Correct calculation with units	1

Sample answer:

$E^o = -0.76 + 1.68 = 0.92\ V$

(c) (1 mark)

Outcomes Assessed: H7, H14

Targeted Performance Bands: 3-4

Criteria	Mark
• Identifies manganese as the cathode and a soluble manganese salt solution	1

Sample answer:

Manganese cathode and manganese (II) nitrate solution

(d) (3 marks)
Outcomes Assessed: H3, H4, H7
Targeted Performance Bands: 2-5

Criteria	Marks
• Discusses the statement by: • Relating production of electrical energy to galvanic cells and oxidation-reduction reactions • Including at least TWO significant reasons why the use of galvanic cells may become increasingly important as sources of energy	3
• Discusses the statement by: • Relating production of electrical energy to galvanic cells and oxidation-reduction reactions • Including ONE significant reason why the use of galvanic cells may become increasingly important as sources of energy	2
• Discusses the statement by relating production of electrical energy to galvanic cells and oxidation-reduction reactions	1

Sample answer:
Galvanic cells are formed when oxidation and reduction reactions at the anode and cathode bring about a transfer of electrons through an external circuit. Thus electrical energy can be generated from oxidation-reduction reactions. Commercial batteries, consisting of one or more galvanic cells, are used as sources of electrical energy.

As world supplies of fossil fuels (petrol, diesel, etc.) diminish, electrical energy may become increasingly important. Battery powered (electric) cars have been produced in recent years, as have hybrid vehicles which use both battery power and petrol. Electric cars are environmentally more acceptable, as they do not directly release carbon dioxide.

The use of electrical energy may reduce society's dependence on renewable carbon-based energy sources such as ethanol and cellulose. Fuels are derived from these energy sources by fermentation reactions, which are inefficient. Furthermore, fuels derived from biomass still release carbon dioxide into the atmosphere.

Hence the use of electrical energy may become increasingly important as long as the recharging of the batteries can use solar, wind or other clean energy sources.

Question 25 (3 marks)
(a) (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Writes TWO correctly balanced equations	2
• Writes ONE correctly balanced equation	1

Sample answer:
$N_2\,(g) + O_2\,(g) \rightleftharpoons 2NO\,(g)$

$2NO\,(g) + O_2\,(g) \rightleftharpoons 2NO_2\,(g)$

(b) (1 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies an appropriate problem associated with the presence of oxides of nitrogen in the atmosphere	1

Sample answer:
Several possible answers.

e.g. Nitrogen dioxide is an acidic oxide. As a result its presence in the atmosphere contributes to acid rain and to the change in pH of natural water supplies.

(Nitrogen oxides also contribute to air pollution in that the reaction between nitrogen dioxide and oxygen, in the presence of UV light, can increase the concentration of ozone. This, in turn, has negative health implications.)

Question 26 (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 3-4

Criteria	Marks
• Identifies NH4Cl as forming an acidic solution AND • Explains that NH4+ ion acts as an acid AND • Writes a correct and appropriate equation	2
• Identifies NH4Cl as forming an acidic solution OR • Explains that NH4+ ion acts as an acid OR • Writes a correct and appropriate equation	1

Sample answer:

NH_4Cl is an acidic salt as in water NH_4^+ donates a proton to water, forming hydronium ions in solution, thus decreasing the pH of the solution.

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

Question 27 (3 marks)
(a) (1 mark)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a correct, balanced equation	1

Sample answer:
$Ca\ (s) + 2H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) + H_2\ (g)$

(b) (2 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-5

Criteria	Marks
• Calculates the correct volume of hydrogen (3 sig figures) consistent with equation in (a) above	2
• Calculates correct no. of moles of calcium hydroxide	1

Sample answer:
If $[OH^-]$ $= 3.16 \times 10^{-2}$ mol L^{-1}
Then $[Ca(OH)_2]$ $= 1.58 \times 10^{-2}$ mol L^{-1}

$\therefore$ moles $Ca(OH)_2$ in 100.0 mL solution $= 1.58 \times 10^{-3}$ mol

Moles hydrogen gas formed $= 1.58 \times 10^{-3}$ mol
Volume of hydrogen gas formed $= 1.58 \times 10^{-3} \times 24.79$ L
$= 3.92 \times 10^{-2}$ L (to 3 sig figures)

Question 28 (3 marks)
(a) (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly identifies the criteria for a mixture to be defined as a buffer solution AND • Recognises that hydrochloric acid is a strong acid OR chloride ion is too weak as a base to accept a proton	2
• Correctly identifies the criteria for a mixture to be defined as a buffer solution OR • Recognises that hydrochloric acid is a strong acid OR chloride ion is too weak as a base to accept a proton	1

Sample answer:
A buffer solution must be a mixture of a (moderately) weak acid and its conjugate base. The acid and base must be present in similar concentrations.
Hydrochloric acid is a very strong acid whereas chloride ion is a very weak base (too weak to accept a proton). Hence a mixture of sodium chloride and hydrochloric acid, even if present in similar concentrations, cannot form a buffer solution.

(b) (1 mark)
Outcomes Assessed: H4, H8
Targeted Performance Bands: 2-3

Criteria	Mark
• Accounts for the importance of buffer solutions in natural systems	1

Sample answer:
Buffer solutions, when present in natural systems, help to maintain the pH of the solutions within that system. This in turn enables chemical reactions such as enzyme reactions in living tissues, which require a specific pH, to occur, even if small increases in the concentrations of acids or bases within the living organism occur.

Question 29 (5 marks)

(a) (1 mark)

Outcomes Assessed: H9, H11, H13

Targeted Performance Bands: 3-4

Criteria	Mark
• Names the chemicals used to produce methyl propanoate	1

Sample answer:

Methanol, propanoic acid and concentrated sulfuric acid

(b) (2 marks)

Outcomes Assessed: H9, H14

Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies that ALL of methanol, propanoic acid, sulfuric acid, water and methyl propanoate are present	2
• Identifies that both reactants and products are present in the flask after refluxing	1

Sample answer:

Some of the reactants (methanol and propanoic acid), the catalyst sulfuric acid, water and the ester, methyl propanoate, would be present.

(c) (2 marks)

Outcomes Assessed: H8, H9

Targeted Performance Bands: 3-5

Criteria	Marks
• Justifies the answer to (b) above by explaining that esterification is a slow, equilibrium reaction AND • Identifies that the catalyst is not consumed by the reaction	2
• Justifies the answer to (b) above by explaining that equilibrium is a slow, equilibrium reaction OR • Identifies that the catalyst is not consumed by the reaction	1

Sample answer:

Esterification is a slow reaction, which eventually reaches equilibrium, so after 30 minutes the reaction mixture will include unreacted alcohol and acid, as well as the catalyst, which is not consumed. Some of the products, the ester and water, will be in the reaction mixture.

Question 30 (4 marks)
(a) (3 marks)
Outcomes Assessed: H1, H3, H8
Targeted Performance Bands: 3-6

Criteria	Marks
• Analyses the changes in scientific understanding of the properties of acids • Refers to the ideas put forward by at least THREE individual chemists over two centuries	3
• Discusses the changes in scientific understanding of the properties of acids AND • Refers to the ideas put forward by at least THREE individual chemists over two centuries OR • Analyses the changes in scientific understanding of the properties of acids by referring to the ideas put forward by at least TWO individual chemists over two centuries	2
• Refers to the ideas put forward by at least TWO individual chemists over two centuries	1

Sample answer:
The understanding of acids has developed as scientific knowledge relating to the structure and properties of acids has changed.

In the 18th century (1780), Lavoisier's theory proposed that acids were substances containing oxygen and had a sour taste. It was soon disproved as many oxygen containing substances had basic or neutral properties.

By the early 19th century, an acid was defined as a substance containing replaceable hydrogen. Davy, who had been experimenting with electrolysis, found that acids in solution produced hydrogen gas at the cathode and acids could react with metals to form hydrogen.

Arrhenius, in 1884, redefined the concept by defining acids as substances which ionised in aqueous solution to produce hydrogen ions. Hence acids, by definition, were always in aqueous solution and the extent of ionisation was used to classify strong and weak acids.

By 1923, Bronsted and Lowry, working individually, defined an acid as a substance capable of donating a proton (hydrogen ion) in the presence of a base. The base could be water or any other substance with a non-bonding pair of electrons able to accept the hydrogen ion. Acids did not need to be in aqueous solution and could react with bases in a gaseous phase.

(b) (1 mark)
Outcomes Assessed: H1, H3
Targeted Performance Bands: 3-4

Criteria	Mark
• Uses an appropriate example to identify a benefit of collaboration between scientists in the 21st century	1

Sample answer:
The breadth of scientific knowledge means that scientists now specialise in a particular area and they need collaboration with others in different or related specialities to piece together parts of the information which may lead to new discoveries or techniques. This collaboration allows new discoveries to be made faster than if a single scientist were working in isolation.

For example, scientists collaborating to monitor the environmental impact on waterways would each specialise in different areas. They could be working as analytical chemists, in forensic science, as laboratory technicians, as biochemists, and use a wide range of specialist tools for their analyses (AAS, gas chromatography, measurement of bacterial levels).

Question 31 (6 marks)
(a) (2 marks)
Outcomes Assessed: H4, H5
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes AAS	2
• Identifies AAS	1

Sample answer:
Atomic absorption spectroscopy would be an appropriate technique for measuring the concentration of metallic elements in parts per million. An atomised sample containing the trace element is illuminated by light from a lamp which emits light of the same frequency as absorbed by the element being analysed. The amount of light absorbed by the sample is measured. Comparison of the absorbance of the sample with results from standard solutions can be used to determine the concentration of the trace element.

(b) (4 marks)
Outcomes Assessed: H4
Targeted Performance Bands: 2-6

Criteria	Marks

• Identifies a trace element
AND
• Assesses by:
  • outlining some effects of the named trace element
  • outlining the difficulty of detection prior to AAS
  • explaining how AAS enabled us to understand these effects
  • assessing the impact on this understanding
	4

• Indentifies a trace element AND • Explains how AAS enabled us to understand the effects of the named trace element	3
• Indentifies a trace element AND • Identifies an impact of AAS on our understanding of the effects of the named trace element	2
• Indentifies a trace element OR • Identifies an impact of AAS on our understanding of the effects of a trace element	1

Sample answer:
Prior to the development of AAS it was not uncommon for lead to go undetected in the environment as there was no known analytical technique that could accurately determine such low concentrations. Prior to AAS, analysis of lead could only be achieved by methods such as precipitation reactions. These methods required concentrations much greater than 1 ppm.

By monitoring lead levels (using AAS) and the symptoms of those exposed to lead, a detailed picture has emerged about the very low levels of lead responsible for minor symptoms such as irritability, tiredness and headaches and the higher levels responsible for major symptoms such as neurological problems, seizures and coma. It was discovered that the safe level of exposure was zero. No amount of lead is safe for humans. It is essential to avoid or limit exposure and to assess the level of lead in those exposed.

Legislation could then be introduced to prevent the inclusion of lead in products such as paints, petroleum and toys. Public awareness has been increased so that home renovators, parents and industry can avoid exposure and be aware of symptoms.

Assessment

Thus, AAS has had a significant impact on our understanding of the effects of lead and how we should regulate its use. The gains in terms of better public health have been significant.

Question 32 (6 marks)
(a) (1 mark)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a correct, balanced chemical equation	1

Sample answer:
$N_2\ (g) + 3H_2\ (g) \rightleftharpoons 2NH_3\ (g)$

(b) (1 mark)
Outcomes Assessed: H14
Targeted Performance Bands: 3-4

Criteria	Mark
• Identifies correct pressure and temperature	1

Sample answer:
5×10^4 kPa (500 atm) and 373°C (±2 °C)

(c) (4 marks)
Outcomes Assessed: H3, H5, H7, H8, H14
Targeted Performance Bands: 2-6

Criteria	Marks

• Explains by:
  • identifying the differences between the conditions suggested by the graph and those actually used
  • relating the higher temperature to the need to increase the rate despite the exothermic nature of the reaction
  • relating the lower pressure to cost and/or safety despite the prediction of Le Chatelier's principle
  • explaining additional features of the process such as the use of a catalyst and the removal of ammonia from the system
	4

• Explains using THREE of the above FOUR points	3
• Relates the temperature AND pressure selected to Le Chatelier's principle AND the rate of reaction	2
• Relates the temperature OR pressure selected to Le Chatelier's principle OR the rate of reaction	1

Sample answer:
These conditions vary significantly from those suggested in the graph. The graph does not take into consideration the slow rate of the reaction to produce ammonia. Whilst the yield at equilibrium is greater at lower temperatures due to the exothermic nature of the reaction, the time taken to reach equilibrium is extreme. Hence, the reaction is faster when carried out at higher temperatures such as 450°C. The rate is also enhanced by the inclusion of an iron/iron oxide catalyst. The low yield that results when higher temperatures are used can be increased

by constant removal of ammonia from the system. This will constantly shift the reaction towards the production of more ammonia.
The pressure suggested by the graph is much higher than the pressure actually used in the industrial process. According to Le Chatelier's principle, the yield of ammonia is increased at higher pressures as 4 moles of reactants produces only 2 moles of product. Lower pressures however are less expensive to maintain and are safer. The effect on yield of this lower pressure is compensated by the strategies mentioned above; use of a catalyst and additional heat to increase the reaction rate and constant removal of ammonia.

Question 33 (5 marks)
Outcomes Assessed: H1, H3, H4, H13, H14
Targeted Performance Bands: 2-6

Criteria	Marks
• Assesses the validity of the statement in terms of the scientific evidence gathered AND • Assesses the validity of the statement in terms of human-made chemicals and their impact on ozone depletion AND • Includes appropriate equations	5
• Discusses thoroughly the scientific evidence for ozone depletion AND the impact of human-made chemicals on ozone depletion AND • Includes appropriate equations	4
• Discusses thoroughly the scientific evidence for ozone depletion AND the impact of human-made chemicals on ozone depletion OR • Discusses some aspects of the scientific evidence for ozone depletion AND the impact of human-made chemicals on ozone depletion AND • Includes appropriate equations	3
• Discusses some aspects of the scientific evidence for ozone depletion AND • Discusses some aspects of the impact of human-made chemicals on ozone depletion	2
• Discusses some aspects of the scientific evidence for ozone depletion OR • Discusses some aspects of the impact of human-made chemicals on ozone depletion	1

Sample answer:
In 1976, the British Antarctic Survey noted a 10% drop in ozone levels in the stratosphere over the spring months from August to October. This was unusual as levels had remained fairly constant since measurements began in the 1950s. By 1985 measurements showed a 50% drop in ozone levels over the previous decade. This result was backed up by independent measurements recorded by TOMS (total ozone mapping spectrometers) and the Nimbus-7 orbiting satellite.

Measurements of chlorine oxide levels in the atmosphere provided the first piece of evidence that led to an explanation for the ozone layer thinning.

In 1974 Molina and Sherwood published a paper describing how chemically inert gases like man-made CFCs (chlorofluorocarbons) released from refrigerator gases and air-conditioners could be transported to the stratosphere and undergo photo-dissociation to produce reactive chlorine radicals that can destroy ozone. The chlorine oxide radicals undergo photo-dissociation causing the regeneration of reactive chlorine radicals which can cause a chain reaction and hence more ozone decomposition.

Ozone gas in the stratosphere is vital to life on Earth due to its ability to absorb UV radiation (wavelength 200-320 nm), which is harmful to cells of living organisms. Normally ozone forms naturally due to stratospheric oxygen absorbing UV-C radiation and making oxygen radicals which can then combine with other oxygen molecules to form ozone.

$O_2\ (g) + UV \rightarrow 2O\bullet\ (g)$
$O_2\ (g) + O\bullet\ (g) \rightarrow O_3\ (g)$

Ozone formed in the stratosphere in this way can then absorb 200-310 nm radiation and return to oxygen molecules.
$O_3\ (g) + UV \rightarrow O_2\ (g) + O\bullet\ (g)$
$O_3\ (g) + O\bullet\ (g) \rightarrow 2O_2\ (g)$

The presence of chlorine free radicals in the stratosphere (due to the breakdown by UV energy of CFCs and other man-made chemicals such as HCFCs) causes the depletion of ozone as shown in the equations below.

$Cl\bullet\ (g) + O_3\ (g) \rightarrow ClO\bullet\ (g) + O_2\ (g)$

$2ClO\bullet\ (g) + UV \rightarrow O_2\ (g) + 2Cl\bullet\ (g)$

Assessment
The statement is valid as significant evidence collected over the last 4 to 5 decades (by TOMS and orbiting satellites) has led to the discovery of stratospheric ozone depletion.

The statement is also valid in that it has been shown that the release of human-made chemicals, such as CFCs and HCFCs, has caused this depletion of ozone. The study of free-radical reactions involving UV light and chlorine free radicals has demonstrated that the man-made chemicals which can produce these free radicals are responsible for the ozone depletion. Steps have been taken to alleviate the problem by a worldwide ban on CFC and HCFC use. There is further evidence that this cut in CFC and HCFC use is leading to a recovery of stratospheric ozone which will continue for some years to come.

Section II – OPTIONS

Question 34 – Industrial Chemistry (25 marks)
(a) (i) (1 mark)
Outcomes Assessed: H7, H8, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Provides an appropriate definition	1

Sample answer:
Electrolysis is a process using electrical energy to bring about an otherwise non-spontaneous chemical reaction.

(a) (ii) (2 marks)
Outcomes Assessed: H7, H8
Targeted Performance Bands: 2-4

Criteria	Marks
• Compares the products of both electrolysis reactions	2
• Identifies the products of ONE of the electrolysis reactions	1

Sample answer:
The electrolysis of molten sodium chloride results in the formation of products sodium and chlorine.

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

The electrolysis of concentrated aqueous sodium chloride solution results in the formation of products $Cl_2(g)$, $H_2(g)$ and $NaOH(aq)$.

$2NaCl\ (aq) + 2H_2O\ (l) \rightarrow Cl_2\ (g) + H_2\ (g) + 2NaOH\ (aq)$

(b) (i) (3 marks)

Outcomes Assessed: H10

Targeted Performance Bands: 2-4

Criteria	Marks
• Correctly calculates the number of moles of all THREE substances at equilibrium	3
• Correctly calculates the number of moles of TWO of the THREE substances at equilibrium OR • Calculates the number of moles of ONE substance correctly and TWO substances incorrectly with one minor error carried	2
• Correctly calculates the number of moles of ONE of the THREE substances at equilibrium OR • Calculates values for all THREE substances incorrectly with ONE minor error carried	1

Sample answer:

$$CH_4\,(g) \quad + \quad H_2O\,(g) \rightleftharpoons CO\,(g) \quad + \quad 3H_2\,(g)$$

Moles of:	$CH_4\,(g)$	$H_2O\,(g)$	$CO\,(g)$	$H_2\,(g)$
Initially	1.00 mol	2.00 mol	0.00 mol	0.00 mol
Change	-0.954 mol	-0.954 mol	+0.954 mol	+(3 x 0.954) mol
At equilibrium	0.046 mol	1.046 mol	0.954 mol	2.862 mol

(b) (ii) (2 marks)

Outcomes Assessed: H10, H12

Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly calculates K for the reaction at 1400K OR • Calculates K consistent with the incorrect numbers of moles calculated in (b) (i) above	2
• Correctly calculates the concentration of each of the substances at equilibrium OR • Correctly calculates the concentration of each of the substances at equilibrium consistent with the incorrect numbers of moles from (b) (i) above OR • Correctly writes an equilibrium expression for the reaction	1

Sample answer:

In 10 L vessel:

$$K = \frac{[CO(g)][H_2(g)]^3}{[CH_4(g)][H_2O(g)]} = \frac{\left(\frac{0.954}{10}\right)\left(\frac{2.862}{10}\right)^3}{\left(\frac{0.046}{10}\right)\left(\frac{1.046}{10}\right)} = 4.65$$

(b) (iii) (2 marks)
Outcomes Assessed: H7, H10
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly states the reaction is endothermic with detailed explanation	2
• Correctly states the reaction is endothermic with limited explanation	1

Sample answer:

$$K = \frac{[CO(g)][H_2(g)]^3}{[CH_4(g)][H_2O(g)]}$$

When K decreases at 1200K (3.20 at a lower temperature) there must have been a decrease in the concentration of products (i.e. the reaction shifted left). Likewise when K increases at 1600K (5.90 at a higher temperature) there must have been an increase in the concentration of products (i.e. the reaction shifted right).
This implies (using Le Chatelier's principle) that the reaction is:

$CH_4\,(g) + H_2O\,(g) + \text{energy} \rightleftharpoons CO\,(g) + 3H_2\,(g)$

i.e. the reaction is endothermic.

(c) (i) (3 marks)

Outcomes Assessed: H6, H9

Targeted Performance Bands: 2-5

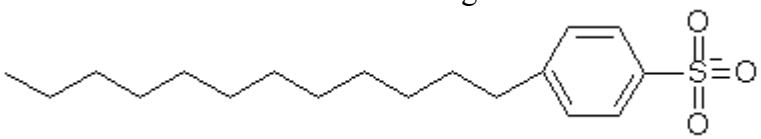
Criteria	Marks
• Compares the structures of soap, anionic detergents and cationic detergents	3
• Describes correctly the structures of TWO of soap, anionic detergents and cationic detergents	2
• Describes correctly the structure of ONE of soap, anionic detergents and cationic detergents	1

Sample answer:

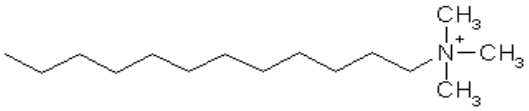
Soap and detergents have a common structure in that they have a long carbon chain which is hydrophobic (lipophylic) and a charged head which is hydrophilic (lipophobic).

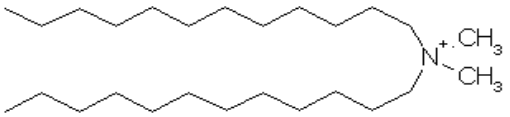
Soaps have carboxylate groups ($-COO^-$) as their negatively charged head.

Anionic detergents are similar to soap in that their charged head is negative. The negative head varies in different anionic detergents but is often a benzene sulfonate group.



Cationic detergents have a positively charged head, usually an alkyl ammonium group. Generally there are one or two long hydrocarbon chains and two or three methyl groups attached to a charged nitrogen atom.





(c) (ii) (3 marks)
Outcomes Assessed: H4, H6, H9
Targeted Performance Bands: 2-5

Criteria	Marks
• Identifies different uses for each of soap, anionic detergents and cationic detergents AND • Outlines how the uses for each are related to the structures or properties	3
• Identifies different uses for TWO of soap, anionic detergents and cationic detergents AND • Outlines how the uses for each are related to the structures or properties	2
• Identifies a use for ONE of soap, anionic detergents or cationic detergents AND outlines how the use is related to the structure or properties	1

Sample answer:
Soaps are used for personal hygiene. They are manufactured from naturally occurring fats and oils and thus are biodegradable. The hydrocarbon chains do not remove all natural body oils and hence are suitable for personal hygiene.

Anionic detergents are not made from natural fats and oils. These synthetic surfactants are used in laundry detergents and dishwashing liquids. Like soaps, they act in the same way as cleaning agents and emulsifiers, but the synthetic agents are more effective and remove too much oil from the skin and hair, so are not used for personal hygiene.

Cationic detergents are used to condition fabrics or to clean and condition hair. The –ve charges on the surface of wet fabric attract the cationic head groups which bind strongly. The surface of the fabric then becomes coated with the long hydrocarbons tails which act to reduce static and fibre tangling. They are also biocides (kill micro-organisms) so are used in disinfectants.

(d) (i) (2 marks)
Outcomes Assessed: H4, H7, H9, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes a correct reaction including observations	2
• Identifies a correct reaction	1

Sample answer:
To perform this demonstration, sucrose was placed in a glass beaker and some concentrated sulfuric acid added. The mixture was stirred. The sulfuric acid removed water from the sugar in a highly exothermic reaction, releasing heat, steam, and sulfur dioxide fumes. Aside from the sulfurous odour, the reaction smelt a lot like caramel. The white sugar turned into a black carbonised tube that pushed itself out of the beaker.

(d) (ii) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies safety precautions and relates these to a property of sulfuric acid	1

Sample answer:
Since sulfuric acid is a strong dehydrating agent (strong oxidising agent), safety precautions must protect against burns and reactions with skin, eyes and clothes. It is essential that gloves, eye protection, and a lab coat be worn. The demonstration must be performed inside a fume cupboard, to extract sulfur dioxide fumes which are toxic.

(d) (iii) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a correctly balanced equation	1

Sample answer:

$$C_{12}H_{22}O_{11}\ (s) \xrightarrow{H_2SO_4} 12C\ (s) + 11H_2O\ (g)$$

(e) (5 marks)

Outcomes Assessed: H4, H8, H13, H14

Targeted Performance Bands: 2-6

Criteria	Marks
• Makes a judgement about the value of the way in which the environmental issues are addressed • Demonstrates a knowledge of the Solvay process • Identifies environmental issues or potential environmental issues associated with either reactants, intermediates or products of the process • Demonstrates knowledge of procedures used to address environmental issues	5
• Demonstrates a knowledge of the Solvay process • Identifies environmental issues or potential environmental issues associated with either reactants, intermediates or products of the process • Demonstrates knowledge of procedures used to address environmental issues	4
• Identifies some reactants and/or products of the Solvay process AND • Some knowledge of procedures used to control environmental issues or potential environmental issues OR • Identifies some reactants and/or products of the Solvay process AND • States some environmental issues associated with the process	2-3
• Identifies some reactants and/or products of the Solvay process OR • States a procedure used to control a potential environmental problem associated with the process OR • States an environmental problem associated with the process	1

Sample answer:

The raw materials required in the Solvay process are sodium chloride, ammonia and calcium carbonate (limestone). The products are sodium carbonate and calcium chloride.

Overall process:

$CaCO_3\ (s) + 2NaCl\ (aq) \rightarrow Na_2CO_3\ (aq) + CaCl_2\ (aq)$

The process involves 4 steps:

Brine purification

Hydrogen carbonate formation

$NH_3\ (aq) + CO_2\ (aq) + NaCl\ (aq) + H_2O\ (l) \rightarrow NaHCO_3\ (aq) + NH_4Cl\ (aq)$

Formation of sodium carbonate

Sodium hydrogen carbonate is converted into sodium carbonate by heating to about 300ºC.

$2NaHCO_3\ (s) \rightarrow Na_2CO_3(s) + CO_2\ (g) + H_2O\ (g)$

Ammonia recovery

$Ca(OH)_2\ (s) + 2NH_4Cl\ (aq) \rightarrow 2NH_3\ (g) + CaCl_2\ (aq) + 2H_2O\ (l)$

The Solvay process uses abundant and cheap starting materials, brine and calcium carbonate (limestone), to produce a useful product, sodium carbonate. By-products, ammonia and carbon dioxide, are recycled and reused.

However, there are many environmental problems associated with the Solvay process, including the following:

Over production of calcium chloride – Calcium chloride is produced as a by-product in the Solvay process. It is used to melt ice and snow on roads in cold countries, treat soils, as a drying agent and in concrete mixtures. However, there is a significant excess of supply. Usually this problem is overcome by locating the Solvay plant near the ocean, where the calcium chloride can be diluted and released safely into the environment. If the Solvay plant is located inland, there is the potential for calcium chloride to be dumped into the environment, causing significant levels of dissolved salts in rivers and lakes and release of heat (caused by the exothermic dissolving of calcium chloride in water). Both these problems would endanger aquatic life. An alternative way of disposing of calcium chloride is by evaporation to dryness and disposal to suitable land sites.

Ammonia losses – Although a large amount of ammonia is recycled in the Solvay process, there are still some losses. Ammonia causes significant air pollution that is very dangerous to human lives. Levels of ammonia gas release are usually kept below regulatory standards.

The generated heat – The Solvay process produces large amount of heat. Disposal of excess heat into the ocean is the method used when Solvay plants are located near the coastline. Water from lakes and rivers can be used as coolant to absorb waste heat. However, hot water cannot be returned to the rivers or lakes immediately as this will destroy aquatic life. Water can be cooled using heat diffusers, but this process is very expensive to use.

<u>Evaluation</u>
Overall, the methods used to address the environmental issues of the Solvay process are effective as they manage to meet Government regulations. However, there are still significant effects on aquatic life and thermal pollution if Solvay plants are located away from the coastline. Further research into the production of sodium carbonate continues, with the aim of reducing these environmental issues further.

Question 35 – Shipwrecks, Corrosion and Conservation (25 marks)

(a) (i) (1 mark)

Outcomes Assessed: H6, H8

Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies correctly	1

Sample answer:

Reaction 3

(a) (ii) (2 marks)

Outcomes Assessed: H8

Targeted Performance Bands: 2-4

Criteria	Marks
• Explains by describing the transfer of electrons involved in Reaction 3 AND that no such transfer occurs in the other two reactions	2
• Identifies that Reaction 3 involves a transfer of electrons OR • Identifies the species reduced and oxidised in Reaction 3	1

Sample answer:

Reaction 3 involves the transfer of electrons, which is essential for an oxidation-reduction reaction. Zinc is oxidised, losing 2 electrons to form Zn^{2+}. Copper ions are reduced, gaining 2 electrons to form copper atoms. The other two equations involve the movement of ions without any transfer of electrons.

(b) (i) (1 mark)
Outcomes Assessed: H1
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies Volta as the correct scientist	1

Sample answer:
Volta

(b) (ii) (2 marks)
Outcomes Assessed: H1, H7, H8
Targeted Performance Bands: 2-4

Criteria	Marks
• Relates Volta's work to the early concept of electric current AND • Describes how the structures in the Voltaic Pile form a series of galvanic cells	2
• Relates Volta's work to the early concept of electric current OR • Describes how the structures in the Voltaic Pile form a series of galvanic cells	1

Sample answer:
The Voltaic Pile was a device invented by Volta in 1800 following the first generation of an electric current (credited to Galvani in 1780).
The Voltaic Pile consisted of alternating layers of two metals, usually copper and zinc discs, separated by cardboard or cloth soaked in a brine (salt) solution. Thus the pile was a series of galvanic cells with the copper discs acting as cathodes, the zinc discs acting as anodes and the brine acting as the electrolyte. This series of cells linked to form a battery of cells. An electric current was produced when the external wires were connected.

(c) (i) (1 mark)
Outcomes Assessed: H7, H8
Targeted Performance Bands: 2-3

Criteria	Mark
• Describes an electrolysis reaction	1

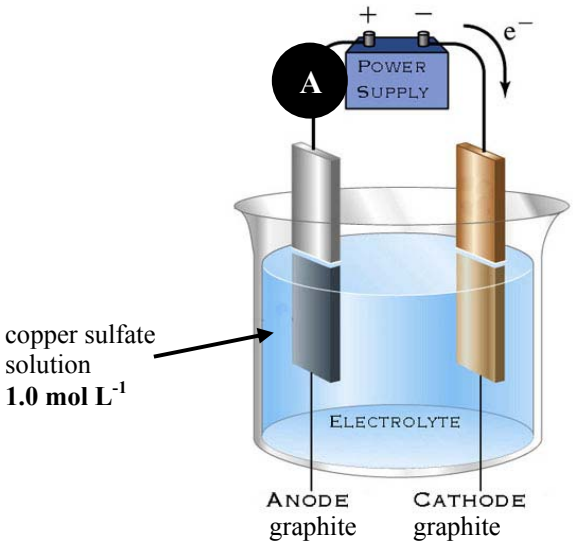
Sample answer:
An electrolysis reaction is a non-spontaneous redox reaction that is driven by an electric current.

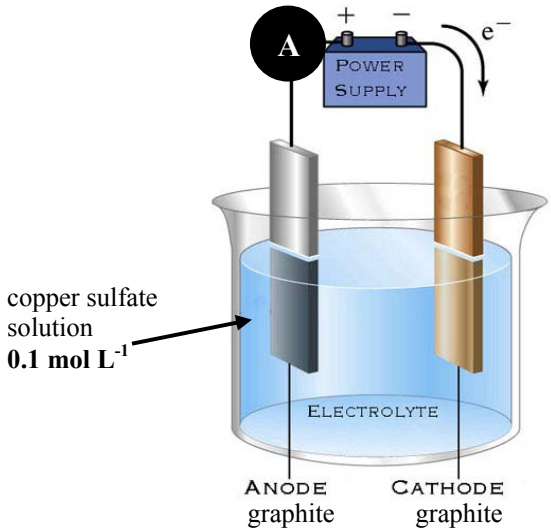
(c) (ii) (3 marks)
Outcomes Assessed: H11
Targeted Performance Bands: 2-5

Criteria	Marks
• Produces an appropriate labelled diagram showing two electrolytic cells that vary in only one way, showing the independent variable and controlled variables OR • Produces an appropriate labelled diagram showing an electrolytic cell, indicating the controlled variables and information about changes in the independent variable	3
• Produces an appropriate labelled diagram showing most of the above	2
• Identifies the independent variable OR • Produces a diagram of an electrolytic cell	1

Sample answer:
(An answer that investigated any of the controlled variables would also be appropriate. The concentration would then need to be controlled.)
Independent variable: electrolyte concentration
Controlled variables: size of electrodes, distance between electrodes, voltage (there are other variables but these are vital to this investigation)

http://engines.rustyiron.com/electrolysis/index.html





(c) (iii) (1 mark)

Outcomes Assessed: H4, H7, H8

Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines cathodic protection using an impressed current	1

Sample answer:

Electrolysis can prevent corrosion if the metal requiring protection is attached to the negative terminal of a DC power source, thus making the metal to be protected the cathode. As this is the site of reduction, the metal will be protected from oxidation and hence corrosion.

(d) (6 marks)

Outcomes Assessed: H3, H8

Targeted Performance Bands: 2-6

Criteria	Marks
• Analyses the statement • Distinguishes clearly between the processes of salvage, conservation and restoration • Discusses the need for planning in terms of cost, time and preservation of objects from shipwrecks • Explains that chemical processes will cause objects to deteriorate if left untreated • Describes a range of chemical processes used to conserve or restore objects from shipwrecks	6
• Distinguishes clearly between the processes of salvage, conservation and restoration • Discusses the need for planning in terms of cost, time and preservation of objects from shipwrecks • Explains that chemical processes will cause objects to deteriorate if left untreated • Describes a range of chemical processes used to conserve or restore objects from shipwrecks	5
• Discusses the need for planning in terms of cost, time and preservation of objects from shipwrecks • Explains that chemical processes will cause objects to deteriorate if left untreated • Describes a range of chemical processes used to conserve or restore objects from shipwrecks	4
• Identifies a need for planning AND • Describes at least TWO chemical processes relevant to the salvage, conservation and restoration of objects from shipwrecks	3
• Describes at least TWO chemical processes relevant to the salvage, conservation and restoration of objects from shipwrecks OR • Identifies a need for planning AND • Describes ONE chemical process relevant to the salvage, conservation and restoration of objects from shipwrecks	2
• Identifies a chemical process relevant to the salvage, conservation and restoration of objects from shipwrecks	1

Sample answer:

Salvage, the removal of an artefact from the ocean or other resting place, requires careful consideration. Often the cold, dark, oxygen-poor waters of the deep ocean can be the safest place for the artefact. To remove it requires an excellent understanding of chemistry.

Salvaged artefacts are often simply conserved in their present state, treating them so that no further deterioration occurs. Others are restored so that they resemble their original condition. All steps in these processes require sound knowledge of the composition of the artefact and the chemical reactions that will occur when it is exposed to the atmosphere. These processes can take years and require careful planning.

Artefacts removed from the ocean will be impregnated with ions, especially chlorides, which can cause significant deterioration if allowed to crystallise in the drying artefact. These ions can cause mechanical damage as they crystallise but will also cause continued corrosion when they react with moisture. Removal of these ions and significant restoration of iron artefacts can be achieved using electrolysis.

Calcareous concretions on artefacts can be safely removed using dilute acids.
Other processes that can be used include:

- the use of zinc epoxy paints which resemble the process of galvanising
- painting with microcrystalline waxes to prevent contact with air or water
- treating with chromate ions in order to form a passivating layer
- storing in low light and humidity.

The conservation and restoration processes must be carefully planned taking into consideration the future location of the artefact. Also worth noting is the likelihood that better techniques will become available in the future. With this in mind it is vital to avoid using conservation and restoration techniques that are irreversible.

The salvage, conservation and restoration of objects can be time consuming and expensive. Some items of great historical significance are extremely valuable.

Hence, before commencing the process of salvage, conservation or restoration of artefacts from shipwrecks, it is essential to plan the process thoroughly and to consider carefully the choice of chemical procedures employed.

(e) (i) (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 3-4

Criteria	Marks
• Writes a balanced equation or half-equation showing the reduction of oxygen to form rust AND • Explains that oxygen is a reactant and hence its concentration affects the rate of reaction	2
• Writes a balanced equation or half-equation showing the reduction of oxygen to form rust OR • Explains that oxygen is a reactant and hence its concentration affects the rate of reaction	1

Sample answer:

$4Fe\ (s) + 3O_2\ (g) + 4H_2O\ (l) \rightleftharpoons 2(Fe_2O_3.xH_2O)\ (s) + (4\text{-}2x)H_2O\ (l)$

OR

$O_2\ (g) + 2H_2O\ (l) + 4e^- \rightleftharpoons 4OH^-\ (aq)$

According to the equation or half-equation, oxygen is a reactant. The oxygen and water are reduced to form hydroxide ions and, after a series of reactions, to form rust (hydrated iron (III) oxide). Therefore the concentration of dissolved oxygen will affect the rate of corrosion.

(e) (ii) (3 marks)
Outcomes Assessed: H6, H8, H9
Targeted Performance Bands: 2-5

Criteria	Marks
• Discusses clearly TWO factors that support the identified high level of dissolved oxygen	3
• Discusses clearly ONE factor that supports the identified high level of dissolved oxygen OR • Discusses factors that affect dissolved oxygen levels	2
• Identifies TWO factors that affect dissolved oxygen levels OR • Identifies high dissolved oxygen levels and relates this to an identified factor	1

Sample answer:

The dissolved oxygen levels should be high.
Oxygen concentration can be affected by <u>biological processes</u> such as photosynthesis. At the surface, where light penetration is good, plants (phytoplankton) will photosynthesise, producing oxygen. This will increase the concentration of O_2 in surface waters.
<u>Temperature</u> affects O_2 concentration. As the water temperature decreases the solubility increases. Thus O_2 concentration will usually be higher in colder waters than in temperate or tropical waters. At the surface of the ocean, <u>wave action</u>, which facilitates mixing of ocean water with atmospheric oxygen, will also increase the levels of oxygen.

(e) (iii) (3 marks)

Outcomes Assessed: H4, H8, H13

Targeted Performance Bands: 2-5

Criteria	Marks
• Describes a process that involves the role of anaerobic bacteria in reduction of sulfate ions, formation of H_2S and H^+ leading to oxidation of iron AND • Writes an appropriate equation	3
• Describes a process that involves the role of anaerobic bacteria in reduction of sulfate ions, formation of H_2S and H^+ leading to oxidation of iron OR • Outlines a process that involves the role of anaerobic bacteria in reduction of sulfate ions AND • Writes an appropriate equation	2
• Outlines a process that involves the role of anaerobic bacteria in reduction of sulfate ions OR • Writes an appropriate equation	1

Sample answer:

Anaerobic bacteria can survive around deep wrecks, where there is often an absence of oxygen, as they respire by reducing sulfate ions.

The resulting hydrogen sulfide (H_2S) can ionise to form H^+. Under these acidic conditions the oxidation of iron is accelerated, producing characteristic black deposits of iron sulfide.

The overall reaction which occurs at depth, in the presence of sulfur-reducing bacteria, is:

$$4Fe\ (s) + SO_4^{2-}\ (aq) + 5H_2O\ (l) \rightleftharpoons FeS\ (s) + 3Fe(OH)_2\ (s) + H_2O\ (l) + 2OH^-\ (aq)$$

Question 36 – The Biochemistry of Movement (25 marks)

(a) (2 marks)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-3

Criteria	Marks
• Identifies the molecule as ATP AND • Identifies mitochondria as the site of production	2
• Identifies the molecule as ATP	1

Sample answer:

The molecule is ATP.
ATP is produced in the mitochondria.

(b) (2 marks)

Outcomes Assessed: H9

Targeted Performance Bands: 3-4

Criteria	Marks
• Names an enzyme AND discusses substrate specificity	2
• Names an enzyme OR discusses substrate specificity	1

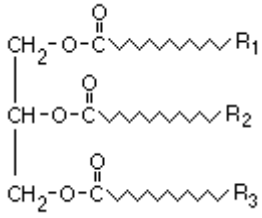
Sample answer:

An example of an enzyme is catalase. It is responsible for breaking down potentially toxic hydrogen peroxide into oxygen and water. Enzymes possess an active site located within the folded protein structure. The substrate (hydrogen peroxide) makes a perfect fit with the area of the enzyme called the active site, much like a lock and key, which facilitates the interaction between substrate and enzyme.

(c) (6 marks)
Outcomes Assessed: H4, H9
Targeted Performance Bands: 2-6

Criteria	Marks
• Assesses the importance of TAGs as an energy dense store for humans • Relates the structure of TAG molecules to the storage of energy • Compares TAGs with glycogen as a source of energy	5-6
• Relates the structure of TAG molecules to the storage of energy • Compares TAGs with glycogen as a source of energy	3-4
• Compares TAGs with glycogen as a source of energy	2
• Identifies some correct information about TAGs OR glycogen as sources of energy	1

Sample answer:
Triacylglycerols (TAGs), commonly known as lipids, are esters formed from glycerol and fatty acids. Lipids that are important in the diet of humans range from 14-20 carbon atoms. Like all esters, TAGs have a similar structure to carboxylic acids except that an alkyl group is attached to the oxygen atom of the former hydroxyl group instead of the hydrogen atom.



TAGs act as efficient storage molecules for energy due to their hydrophobic (water hating) nature. The -COOH bonds of fatty acids are very polar but the -COOR group of the TAG, although polar, has a very small influence on the overall polarity of the TAG molecule. A TAG molecule can therefore be stored efficiently away from water in a very dense form, making it a very important form of long-term energy storage in humans. TAGs are stored in the cells of fat tissue and can be hydrolysed to give fatty acids, which can be transported to cells and broken down into carbon dioxide and water. This process occurs in mitochondria and produces ATP.

By comparison, glycogen is the carbohydrate store in animals. After a meal, the rising blood glucose level is controlled by the excess glucose being taken into liver and muscle cells and converted by enzymes to glycogen. The glycogen forms granules in the cytoplasm of these cells. Between meals, the blood glucose levels are constantly replenished from the liver glycogen stores so that there is a reasonably constant level of glucose in the blood. Glycogen granules are also stored in skeletal muscle cells and used by type 2 muscle cells to supply much of the energy for anaerobic respiration during intense use. The liver stores do not usually last much longer than about 12 hours so glycogen acts as a short-term energy store.

TAGs are used in competition with glucose in aerobic respiration. They produce ATP in greater amounts than carbohydrates but at a slower rate, limited by the rate at which the body's respiratory and circulatory systems can supply oxygen to the mitochondria. Resting muscle gets its energy from glucose and TAGs. During exercise, muscle can obtain its energy

aerobically as long as the oxygen supply keeps up. If it doesn't keep up, anaerobic respiration begins to take over, using the carbohydrate granules to provide fast ATP without the consumption of oxygen. Aerobic respiration continues but with less efficiency, producing less ATP and also producing lactic acid.

Assessment

TAGs are important as they are the body's long-term larder. They are the most efficient way to store large amounts of energy, and produce the most ATP when metabolised, although at a much slower rate than glycogen, which is the small store of instant, intense energy; the emergency supply. The liver's entire store of glycogen, for example, can last an average human about 12 hours on its own whereas an average healthy human should have enough TAG reserves to last about two months.

(d) (i) (2 marks)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	Marks
• States the name of the enzyme used AND identifies correctly the group of compounds	2
• States the name of the enzyme used OR identifies correctly the group of compounds	1

Sample answer:
The enzyme used in the experiment is called rennin.
Enzymes are proteins.

(d) (ii) (3 marks)
Outcomes Assessed: H11, H14
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains fully the experimental results AND discusses appropriate conclusions	3
• Describes the experimental results AND discusses appropriate conclusions	2
• Describes the experimental results OR discusses appropriate conclusions	1

Sample answer:
In the experiment, three test tubes containing milk at temperatures of 0^oC, 37^oC and 60^oC had the enzyme rennin added. After some time, the milk at 37^oC was seen to coagulate whilst the milk in the other two test tubes (at cold and hot temperatures) was unaffected.

The function of the enzyme, rennin, is to coagulate milk so that it remains in the stomach longer to be metabolised.

The experimental conclusion is that the enzyme works efficiently at 37^oC (or normal body temperature) whilst it is not effective at temperatures that are either too cold or too hot. At high temperatures it is denatured, while at low temperatures the reaction rate is too slow for coagulation to be observed.

(d) (iii) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies an appropriate safety precaution	1

Sample answer:
When heating the test tube, hold it with a peg to reduce the likelihood of burns and do not point the test tube towards other students.

(e) (i) (2 marks)
Outcomes Assessed: H9
Targeted Performance Bands: 3-4

Criteria	Marks
• Describes the generalised structure of skeletal muscle cells	2
• Identifies some correct information about skeletal muscle cells	1

Sample answer:
Skeletal muscle is also called striated muscle because of its banded appearance. Skeletal muscle consists of bundles of fibres. Each fibre consists of about 1000 fibrils. These fibrils consist of alternating sections of thick filaments that contain the protein myosin and thin filaments that contain the protein actin.

(e) (ii) (3 marks)
Outcomes Assessed: H4
Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies the type of muscle in the TWO different types of fish and relates the use of the muscle to its appearance	3
• Identifies ONE type of muscle and relates the use of the muscle to its appearance	2
• Identifies ONE type of muscle	1

Sample answer:
Marlin and tuna, being active fish, swim constantly, often over very long distances. They typically contain Type I, slow oxidative, slow twitch, or "red" muscle cells. This type of muscle cell is dense with capillaries and is rich in mitochondria, giving the muscle tissue its characteristic red colour. It can carry more oxygen and sustain the aerobic activity required by these active fish.

Flounder and flathead drift around the ocean slowly over smaller distances. They typically contain Type II muscle, which is less dense in mitochondria and myoglobin than Type I muscle. Therefore the muscle is paler by comparison with the flesh of marlin and tuna. It can contract more quickly and with a greater amount of force than oxidative muscle, but can sustain only short, anaerobic bursts of activity before muscle contraction becomes painful. These types of fish can escape from predators quickly but cannot continue to swim over long periods of time.

(f) (i) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Identifies the correct common and systematic name of the compound	1

Sample answer:
Pyruvate is the common name and 2-oxopropanoate is the systematic name.

(f) (ii) (1 mark)
Outcomes Assessed: H7
Targeted Performance Bands: 2-3

Criteria	Mark
• States the correct answer	1

Sample answer:
Two molecules of ATP are produced in glycolysis.

(f) (iii) (2 marks)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Describes the formation of lactate AND includes an appropriate equation	2
• Describes the formation of lactate	1

Sample answer:
During vigorous exercise the demand for ATP in muscles is high and oxygen levels are soon depleted. Under these conditions, pyruvate ions are reduced to lactate ions, accompanied by the oxidation of NADH to NAD^+.

$CH_3COCOO^- + NADH + H^+ \rightarrow CH_3CHOHCOO^- + NAD^+$
pyruvate ion lactate ion

Question 37 – The Chemistry of Art (25 marks)
(a) (i) (1 mark)
Outcomes Assessed: H6
Targeted Performance Bands: 2-3

Criteria	Mark
• Correct answer	1

Sample answer:
The Pauli Exclusion Principle states that no two electrons can have the same four quantum numbers (related to shell, sub-shell, orbital and spin).

(a) (ii) (2 marks)
Outcomes Assessed: H6, H7
Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies a blue-green flame as associated with copper's presence AND • Explains that the blue-green light is EM radiation of a fixed frequency corresponding to the difference in energy levels between the ground state and the excited state of electrons in a copper atom	2
• Identifies a blue-green flame as associated with copper's presence OR • Outlines some correct information to explain why the colour is always the same	1

Sample answer:
The presence of copper is indicated by a blue-green flame in a flame test. Electrons in the copper atom are given extra energy by the flame and temporarily jump to a higher energy level than their normally occupied one. When they almost instantly return, they lose a fixed amount of energy equivalent to the energy difference between the two orbitals, and this energy is released in the form of EM radiation. In copper's case, the energy difference matches the energy of an EM wave in the blue-green region of the visible spectrum, hence copper always provides a characteristic blue-green flame.

(a) (iii) (5 marks)
Outcomes Assessed: H6, H7
Targeted Performance Bands: 2-6

Criteria	Marks
• Describes the Bohr model of the hydrogen atom AND • Relates this model to the spectral lines of hydrogen AND • Discusses the merits AND limitations of this model	5
• Describes the Bohr model of the hydrogen atom AND • Relates this model to the spectral lines of hydrogen AND • Identifies some merits AND limitations of this model	4
• Describes the Bohr model of the hydrogen atom AND • Identifies some merits AND limitations of this model	3
• Describes the Bohr model of the hydrogen atom AND • Identifies some merits OR limitations of this model	2
• Describes the Bohr model of the hydrogen atom OR • Identifies some merits OR limitations of this model	1

Sample answer:
The Bohr model of the hydrogen atom (1913) proposed that the electrons in an atom move around the nucleus in a circular orbit. Each electron could only have a restricted number of energy values as only orbits of certain radii and particular energy values were permissible. Bohr proposed that an electron was stable only when in one of these energy levels. Electrons could jump from one level to another and Bohr proposed that the electrons falling back into their stable orbits gave out energy equal to the difference in energy between the two levels. This energy caused the observed spectral lines. For hydrogen, he calculated the energy values for the electrons in the permissible paths and showed that the frequency of the spectral lines for hydrogen could be explained in terms of his model.

Thus Bohr's model was successful in explaining a property of the hydrogen atom. The model had merit in that it led to an explanation of spectral lines for hydrogen. It also had merit in that it offered a simplistic way of visualising atoms and the properties of electrons around a nucleus. The concept of quantised energy levels, introduced by Bohr, remained an important part of later models.

However, Bohr's model was limited in that it failed to account for the spectral lines of atoms which had more than 1 electron, and was replaced by a new model called quantum mechanics. As with many models, the limitation can be beneficial to advancement of scientific knowledge, as scientists work to modify or reject a model if it cannot provide answers for more than a minimal number of examples.

(b) (2 marks)
Outcomes Assessed: H1, H4
Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies the chemical composition of ONE named cosmetic AND • Describes the detrimental effect on humans	2
• Identifies the chemical composition of ONE named cosmetic OR • Describes the detrimental effect on humans	1

Sample answer:
The ancient Egyptians used cinnabar (a red mineral) in rouge. It is a naturally occurring ore constituted almost entirely of mercury (II) sulfide, HgS.

The mercury in cinnabar is causal of many diseases. It is poisonous by ingestion or inhalation. It is also harmful by skin contact and is a cumulative poison, in that your body does not rid itself of mercury over time. The worst effects of prolonged exposure include kidney failure and life threatening central nervous system damage.

(c) (i) (2 marks)
Outcomes Assessed: H11, H14
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains what is meant by the validity of the experiment AND • Describes that using variable concentrations of the species to be oxidised allows any reaction to proceed at a greater rate in one case than in another	2
• Explains what is meant by the validity of the experiment OR • Describes that using variable concentrations of the species to be oxidised allows any reaction to proceed at a greater rate in one case than in another	1

Sample answer:
An experiment is only valid when only one variable is changed at a time, allowing conclusions to be drawn based on a single independent variable.

Given that the results of an experiment involving potassium permanganate hinge on colour changes, any variation which affects the nature of colour changes can lead to invalid results.

When dealing with colour changes, a greater concentration of a reactant allows any reaction to proceed faster, due to a greater frequency of successful collisions. It will also proceed to a greater level of completeness, depending on the stoichiometry of the reaction.

Thus, if you change the concentration of the species to be oxidised, the colour change in the permanganate could be due to factors other than the extent of reduction which occurs.

(c) (ii) (3 marks)

Outcomes Assessed: H6, H8

Targeted Performance Bands: 2-5

Criteria	Marks
• Accounts for the difference in oxidising strengths in terms of different manganese oxidation states • Predicts that the oxidising strength of MnO_2 will fall somewhere between those of the other two compounds, giving a valid reason	3
• Accounts for the difference in oxidising strengths in terms of different manganese oxidation states • Predicts that the oxidising strength of MnO_2 will fall somewhere between those of the other two compounds, but fails to give a valid reason	2
• States that $KMnO_4$ will be a stronger oxidising agent than $MnCl_2$ OR • Accounts for the difference in oxidising strengths in terms of different manganese oxidation states	1

Sample answer:

The oxidation state of Mn in $KMnO_4$ is +7. The oxidation state of Mn in $MnCl_2$ is +2. The higher oxidation state present in the permanganate ion gives Mn a greater ability to attract electrons and hence to oxidise other species, so it has a higher oxidising strength than in $MnCl_2$.

The oxidation state of Mn in MnO_2 is +4, between that of the other two compounds, so it should be predicted that the oxidising strength of MnO_2 would be less than that of $KMnO_4$ but greater than that of $MnCl_2$.

(d) (4 marks)

Outcomes Assessed: H7

Targeted Performance Bands: 2-5

Criteria	Marks

• Explanation includes ALL the following:
  • White light containing all visible wavelengths shines on the permanganate ions
  • One or more specific wavelengths of visible light, corresponding to the middle frequencies of the visible spectrum (orange through to blue), are absorbed by the permanganate ions, as those wavelengths' energies correspond to the amounts of energy needed by some electrons to jump from their ground state
  • The wavelengths of visible light that are not absorbed in this way continue without change to enter our eyes
  • The combination of those wavelengths from each end of the visible spectrum (red and violet) creates what we see as the purple colour of the permanganate solution
	4

• Explanation includes THREE of the above	3
• Explanation includes TWO of the above	2
• Explanation includes ONE of the above	1

Sample answer:

1. White light containing all visible wavelengths shines on the permanganate ions.
2. One or more specific wavelengths of visible light, corresponding to the middle frequencies of the visible spectrum (orange through to blue), are absorbed by the permanganate ions, as those wavelengths' energies correspond to the amounts of energy needed by some electrons to jump from their ground state.
3. The wavelengths of visible light that are not absorbed in this way continue without change to enter our eyes.
4. The combination of those wavelengths from each end of the visible spectrum (red and violet) creates what we see as the purple colour of the permanganate solution.

(e) (i) (2 marks)
Outcomes Assessed: H6
Targeted Performance Bands: 2-4

Criteria	Marks
• Writes TWO correct electron configurations	2
• Writes ONE correct electron configuration	1

Sample answer:

V^{5+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

Fe^{3+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$

(e) (ii) (2 marks)
Outcomes Assessed: H6
Targeted Performance Bands: 3-5

Criteria	Marks
• Relates the stability of each of the TWO ions to its electron configuration	2
• Relates the stability of ONE of the ions to its electron configuration	1

Sample answer:
The two ions have different electron configurations but are both stable ions.

V^{5+} has the same electron configuration as argon, a noble gas. It is an extremely stable configuration with all electrons paired and all energy levels filled.

Fe^{3+} has 5d electrons, 1 in each of the 5d orbitals. The half-filled d sub-shell appears to be a stable arrangement, as Fe^{3+} does not lose electrons to form other ions. By comparison, Fe^{2+} is readily oxidised to Fe^{3+}.

(f) (2 marks)

Outcomes Assessed: H6, H13

Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies $[Co(NH_3)_6]^{3+}$ as the complex ion AND • Describes the bonding between the ammonia molecules and the cobalt ion	2
• Identifies $[Co(NH_3)_6]^{3+}$ as the complex ion OR • Describes the bonding between the ammonia molecules and the cobalt ion	1

Sample answer:

The central cobalt ion and the ammonia molecules form a stable unit, known as a complex ion, with the charge spread over the whole structure.

The ammonia molecules are examples of ligands (atoms or groups of atoms that bond to the central ion by dative or co-ordinate bonding). The dative/co-ordinate bond is formed when the lone/non-bonding pair of electrons on the ligand is attracted to, and occupies, an unoccupied orbital of the central atom.

In this complex, 6 ammonia molecules surround the cation. An electron pair from the nitrogen atom on each ammonia molecule forms a co-ordinate covalent bond with the central ion by placing the pair of electrons into empty orbitals of the cobalt ion.

Question 38 – Forensic Chemistry (25 marks)

(a) (1 mark)

Outcomes Assessed: H9

Targeted Performance Bands: 2-3

Criteria	Mark
• Describes a correct difference	1

Sample answer:

Many possible answers

Organic compounds are compounds of carbon, with the exception of CO, CO_2 and carbonates, hydrogen carbonates and cyanides of metals. Organic compounds are produced by living things. Organic compounds contain carbon-hydrogen bonds.

Inorganic compounds are produced by non-living natural processes or by human intervention in the laboratory. Inorganic compounds do not contain carbon-hydrogen bonds.

(b) (4 marks)

Outcomes Assessed: H9, H11

Targeted Performance Bands: 2-5

Criteria	Marks
• Provides examples of tests that will identify ALL THREE OF an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results AND • Identifies AT LEAST TWO safety precautions taken	4
• Provides examples of tests that will identify TWO of an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results AND • Identifies AT LEAST TWO safety precautions taken OR • Provides examples of tests that will identify ALL THREE OF an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results	3
• Provides examples of tests that will identify ONE of an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results AND • Identifies AT LEAST TWO safety precautions taken OR • Provides examples of tests that will identify TWO of an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results	2
• Provides examples of tests that will identify ONE of an unsaturated hydrocarbon, an alkanol and an alkanoic acid, with expected results OR • Identifies AT LEAST TWO safety precautions taken	1

Sample answer:

1. Divide each sample into 3 test tubes, do not re-use a sample once contaminated with a reagent.
2. Add a small quantity of sodium carbonate solution to each test tube. Bubbles of CO_2 gas will form in the sample of the alkanoic acid. There will not be any bubbles in the other test tubes.
3. Add a very small piece of sodium to new samples in three test tubes. Sodium will immediately react with both the acid and the alcohol. Since the acid has already been identified, the alcohol is now known and the only remaining test tube must be the unsaturated hydrocarbon.
4. Add bromine water to a sample of the final test tube to obtain evidence that it is an unsaturated hydrocarbon. The bromine water will decolourise rapidly in the absence of UV light.

Safety precautions include: Since all alkanes and alkanols are flammable, experiments should not be conducted in the presence of a naked flame.
Alkanoic acids are corrosive; lab coats and goggles should be worn to protect skin and eyes.
Bromine water is toxic and other samples may be pungent and toxic. Experiments should be performed in a well ventilated area or a fume cupboard.

(c) (i) (1 mark)
Outcomes Assessed: H6, H9
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies carbon, hydrogen and oxygen	1

Sample answer:
Carbon, hydrogen and oxygen

(c) (ii) (3 marks)
Outcomes Assessed: H9
Targeted Performance Bands: 2-5

Criteria	Marks
• Describes AT LEAST TWO similarities between the reactions AND • Describes AT LEAST TWO differences between the reactions	3
• Describes ONE similarity between the reactions AND • Describes ONE difference between the reactions	2
• Describes ONE similarity between the reactions OR • Describes ONE difference between the reactions	1

Sample answer:
Similarities:
Both are condensation polymerisation reactions.
Both rely on the action of enzymes for polymerisation to take place.
Both produce water as a by-product of the reaction.

Differences:
Monomers of glucose are all identical whereas monomers of proteins (amino acids) may be different.
Bonding between glucose monomers involves reaction between -OH groups on adjacent monomers whereas bonding between amino acids involves reaction between a -COOH end and an $-NH_2$ end of adjacent monomers. Polysaccharides form glycosidic bonds; proteins form peptide bonds (or linkages).

(d) (2 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies that the mixture to be separated may contain substances that have different solubilities in different solvents • Explains that the differences in solubilities help to separate the components of the mixture in the mobile and stationary phases	2
• Identifies that the mixture to be separated may contain substances that have different solubilities in different solvents OR • Explains that the differences in solubilities help to separate the components of the mixture in the mobile and stationary phases	1

Sample answer:
Chromatography involves separation of the parts of a mixture on the basis of the different solubilities of the parts in the mobile phase and stationary phase, such as the water trapped in the pores of paper (stationary phase) and the solvent travelling through the paper with the mixture (mobile phase). Substances with low solubility in the stationary phase and high solubility in the mobile phase will move quickly, and vice versa. Thus, differences in solubility in the mobile and stationary phases help to separate the components of the mixture.

For example, differences in polarity may be used to separate a mixture of plant chlorophylls using water in paper as the stationary phase and petroleum ether as the mobile phase. The more polar the molecule the less distance it will travel through the paper.

(e) (5 marks)
Outcomes Assessed: H3, H4
Targeted Performance Bands: 2-6

Criteria	Marks
• Includes a clear justification statement based on criteria identified • Specifically identifies that DNA can be found in many different biological samples • Identifies at least THREE examples of uses of DNA analyses • Describes advantages and disadvantages of DNA analysis • Compares DNA analysis with techniques used prior to this technology being available	5
• Identifies that DNA can be found in many different biological samples • Identifies examples of uses of DNA analyses • Describes advantages and disadvantages of DNA analysis • Compares DNA analysis with at least one technique used prior to this technology being available	3-4
• Identifies examples of uses of DNA analyses • Describes advantages of DNA analysis	2
• Identifies examples of uses of DNA analyses OR • Describes advantages of DNA analysis	1

Sample answer:
DNA can be found in many biological samples, including blood, semen, saliva, skin and hair. It can be used to establish, with an error of less than one in 10 million, that two samples came from the same person. Some examples of applications of analysis include: identifying potential suspects whose DNA may match evidence left at crime scenes, exonerating persons wrongly accused of crimes, identifying crime and catastrophe victims, establishing paternity and other family relationships, identifying endangered and protected species as an aid to wildlife officials, detecting bacteria and other organisms that may pollute air, water, soil, and food, authenticating consumables such as caviar and wine.

DNA fingerprinting has established itself as an efficient and highly accurate means of determining identities and relationships, particularly when considered in comparison to previous methods of identification such as blood typing and fingerprinting, which are far less reliable and accurate. However, the information about individuals that can be collected when completing DNA analyses may be sensitive, and there are issues of privacy associated with the collection and storage of the material used for analysis.

DNA analysis techniques are highly sensitive and must be performed without contamination of samples for accuracy. Also, DNA analysis techniques are relatively expensive.

However, on the basis of the accuracy with which the range of DNA analyses can be used for identification purposes, their use in forensic chemistry is justified.

(f) (i) (2 marks)
Outcomes Assessed: H3, H4, H6, H7
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes how a mass spectrometer operates AND • Identifies that particles are identified on the basis of their charge:mass ratio	2
• Outlines how a mass spectrometer operates	1

Sample answer:
A mass spectrometer produces charged particles (ions) from the chemical substance that is to be analysed. The mass spectrometer then uses electric and magnetic fields to measure the charge:mass ratio of the charged particles. Samples are introduced and are bombarded with electrons, resulting in the acquisition of a positive charge. The samples are then accelerated and subjected to a magnetic field. Samples interact with the receptor (detector plate) based on their mass. The masses and relative abundances of the ions in a mass spectrum can be used to determine the structure and elemental composition of the molecule. This can be done with a computer program.

(f) (ii) (3 marks)
Outcomes Assessed: H3, H4
Targeted Performance Bands: 2-5

Criteria	Marks
• Identifies examples of the uses of mass spectrometry • Describes the uniqueness of mass spectra of compounds • Relates the accuracy of the mass spectrometry to its use in forensic chemistry	3
• Identifies an example of the use of mass spectrometry AND • Describes the uniqueness of mass spectra of compounds OR • Relates the accuracy of the mass spectrometry to its use in forensic chemistry	2
• Identifies an example of the use of mass spectrometry OR • Describes the uniqueness of mass spectra of compounds OR • Relates the accuracy of the mass spectrometry to its use in forensic chemistry	1

Sample answer:
The mass spectrum of each compound is unique and, in forensic chemistry, unidentified samples are often matched with a library of known spectra to identify a sample. If no data is available for a match, the information collected from the spectrometer can be used to deduce the structure of the sample and possibly even identify it. The types of samples typically analysed in forensic chemistry using mass spectroscopy include body fluids for drug detection, accelerants used in fires and identification of explosives. This analysis is often performed in conjunction with gas chromatography.
Mass spectrometry is a destructive technique. However, only very small quantities are required for analysis. Thus, mass spectrometry performed with instruments that have a high resolution and high sensitivity can be used to confidently identify compounds from a variety of sources.

(g) (4 marks)
Outcomes Assessed: H3, H4, H7
Targeted Performance Bands: 2-5

Criteria	Marks
• Outlines how emission spectra are created • Describes the specific nature of emission spectra • Provides examples of uses of emission spectra in forensic chemistry • Indicates advantages and disadvantages of the use of emission spectra	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

Sample answer:
Light consists of electromagnetic radiation of different wavelengths. When an element or compound is heated, either in a flame or by an electric arc, it will emit energy in the form of light as the electrons return to their 'ground state". Analysis of this light, with the help of a spectroscope, produces a discontinuous spectrum or line emission spectrum that originates from the atoms found in a sample. Each element has a unique emission spectrum. Therefore, emission spectroscopy can be used to identify the elements in matter of unknown composition or used for chemical analysis of substances. Emission spectroscopy can be used to monitor the concentrations of elements in water supplies and soil samples. Samples collected can be used to identify specific locations on the basis of the elements present and thus can be used to place an individual at a specific location. Samples can also identify the source of a chemical. Line emission spectroscopy provides fast and accurate identification of small amounts of materials. However, it is a destructive technique that only provides information about the elements present, and not about the nature of the compounds in which the elements were found. Hence this technique has greater application to the identification of metals or inorganic sources, than to organic compounds.