



## CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

### 2008 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 – 15 marks

##### Questions 1-15 (1 mark each)

Question	Correct Response	Outcomes Assessed	Targeted Performance Bands
1	A	H9	2-3
2	C	H9, H10	4-5
3	D	H3, H9	3-4
4	D	H8	2-3
5	A	H6, H13	3-4
6	B	H14	4-5
7	B	H6, H13	3-4
8	C	H10	5-6
9	A	H8, H13	3-4
10	C	H9, H11	3-4
11	A	H14	4-5
12	D	H4, H8	2-3
13	B	H3, H6, H7	3-4
14	D	H3	3-4
15	C	H8, H11	4-5

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**Section I**  
**Part B – 60 marks**

**Question 16 (4 marks)**

(a) (1 mark)

**Outcomes Assessed: H9, H11**

**Targeted Performance Bands: 2–3**

Criteria	Mark
<ul style="list-style-type: none"> <li>Identifies the dependent variable</li> </ul>	1

**Sample answer:**

The colour or lack of colour of the bromine water

(b) (1 mark)

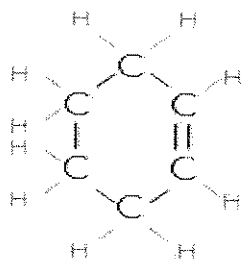
**Outcomes Assessed: H9, H13**

**Targeted Performance Bands: 3-4**

Criteria	Mark
<ul style="list-style-type: none"> <li>Names and draws an appropriate alkene</li> </ul>	1

**Sample answer:**

cyclohexene



(c) (2 marks)

**Outcomes Assessed: H9, H11**

**Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Justifies in terms of toxicity AND state at SLC, explaining the importance of BOTH features</li> </ul>	2
<ul style="list-style-type: none"> <li>Justifies in terms of toxicity OR state at SLC</li> </ul>	1

**Sample answer:**

Cyclohexene is a liquid at room temperature. It can therefore be easily mixed with bromine water in a test tube. The smaller chained alkenes are gases which would make the reaction impractical. Whilst cyclohexene is toxic and highly flammable, it can be handled in small quantities in a fume hood by senior students wearing skin and eye protection.

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**Question 17 (5 marks)**

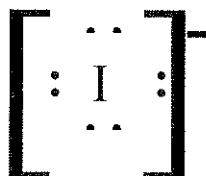
(a) (1 mark)

*Outcomes Assessed: H6, H13*

*Targeted Performance Bands: 3-4*

Criteria	Mark
• Draws an electron dot structure	1

*Sample answer:*



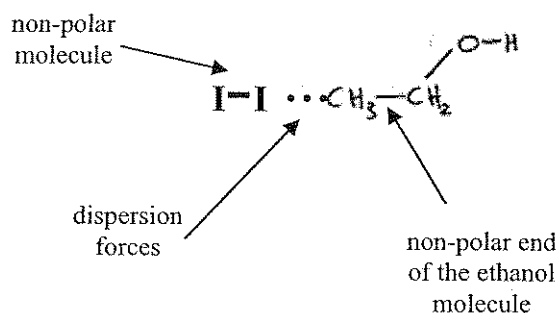
(b) (2 marks)

*Outcomes Assessed: H6, H13*

*Targeted Performance Bands: 3-5*

Criteria	Marks
• Explains the solubility using a labelled diagram that shows the attraction between the non-polar end of the ethanol molecule and the non-polar iodine molecule	2
• Explains with a correctly drawn diagram without appropriate labelling OR	1
• Explains with appropriate labels on a diagram with minor errors	

*Sample answer:*



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(c) (2 marks)

**Outcomes Assessed: H6**

**Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"><li>Explains that triiodide ions are attracted to the positive end of the polar water molecule, unlike iodine molecules which are non-polar</li></ul>	2
<ul style="list-style-type: none"><li>Explains that triiodide ions are attracted to the positive end of the polar water molecule</li></ul> OR <ul style="list-style-type: none"><li>Explains that iodine molecules are non-polar and therefore not attracted to polar water molecules</li></ul>	1

**Sample answer:**

Water is a polar molecule. The triiodide ion is negatively charged and will be attracted to the positive end of the polar water molecules, hence increasing its solubility above that of the iodine molecule which is non-polar and will only experience weak dispersion forces with water.

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**Question 18 (5 marks)****Outcomes Assessed: H14****Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Assesses the validity of the claims, referring to safety, versatility (range of uses), biodegradability and renewability of polymers AND</li><li>Refers BOTH to a recently developed biopolymer AND to a petroleum-based polymer</li></ul>	5
<ul style="list-style-type: none"><li>Assesses the validity of some of the claims made in the source AND</li><li>Refers BOTH to a recently developed biopolymer AND to a petroleum-based polymer</li></ul>	3-4
<ul style="list-style-type: none"><li>Assesses validity of ONE claim made in the source</li></ul> OR <ul style="list-style-type: none"><li>Describes features of a recently developed biopolymer</li></ul>	2
<ul style="list-style-type: none"><li>Identifies a recently developed biopolymer</li></ul> OR <ul style="list-style-type: none"><li>Identifies general characteristics of biopolymers</li></ul>	1

***Sample answer:***

Biopol (PHB) is an example of a recently discovered biopolymer. It is a renewable resource as it is produced by the fermentation of glucose by the bacterium *Alcaligenes eutrophus*. In the face of dwindling fossil fuel reserves, Biopol could provide a sustainable alternative to petroleum-based plastics such as polyethylene.

Biopol is a safe, versatile, biodegradable and renewable alternative to polyethylene. The biopolymer is safe for human consumption. Unlike polyethylene, its biocompatibility makes it useful for dissolving sutures and the administration of slow-release drugs. Polyethylene remains as an almost permanent environmental pollutant. In contrast, Biopol is biodegradable, decaying quite rapidly to carbon dioxide and water when exposed to microbes in landfill, sewage or the ocean. Biopol's versatility enables it to be used not only for medical purposes but for disposable razors, shampoo bottles, plastic films and coatings.

**Assessment.**

When considering the qualities of Biopol, the claims made in the source appear to be quite valid. It is a safe, versatile and biodegradable alternative to polyethylene. However, its importance in our future and as a competitor to polyethylene will depend on the ability of researchers to solve the problems associated with large-scale production and its considerable expense in comparison to petroleum-based alternatives.

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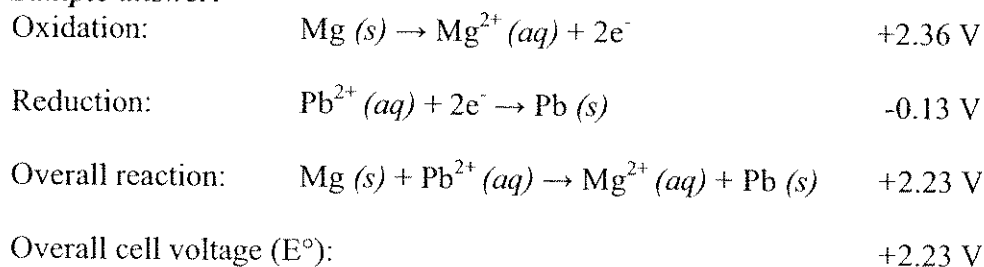
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**Question 19 (3 marks)**

(a) (2 marks)

**Outcomes Assessed: H7, H10****Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Provides correct oxidation and reduction half-equations</li> </ul> AND <ul style="list-style-type: none"> <li>Calculates correct cell voltage</li> </ul>	2
<ul style="list-style-type: none"> <li>Correct oxidation and reduction half-equations only</li> </ul> OR <ul style="list-style-type: none"> <li>Cell voltage consistent with incorrect half-equations</li> </ul>	1

**Sample answer:**

(b) (1 mark)

**Outcomes Assessed: H8****Targeted Performance Bands: 3-4**

Criteria	Mark
<ul style="list-style-type: none"> <li>Provides appropriate explanation</li> </ul>	1

**Sample answer:**

The cell voltage was not measured under standard conditions; e.g. the concentration of electrolyte solutions was not  $1.0 \text{ mol L}^{-1}$  or the temperature varied from  $25^\circ\text{C}$ .

*or pressure varied from 1 atm.*

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**Question 20 (3 marks)****Outcomes Assessed: H1, H4****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Identifies a radioisotope</li><li>• Provides a correct example of its use in industry or medicine</li><li>• Identifies some appropriate physical or chemical properties of the named isotope</li><li>• Links these properties to the identified uses</li></ul>	3
<ul style="list-style-type: none"><li>• Identifies a radioisotope</li><li>• Provides a correct example of its use in industry or medicine</li><li>• Identifies some appropriate physical or chemical properties of the named isotope</li></ul>	2
<ul style="list-style-type: none"><li>• Identifies a radioisotope AND provides a correct example of its use in industry or medicine</li></ul> OR <ul style="list-style-type: none"><li>• Identifies a radioisotope AND identifies some appropriate physical or chemical properties of the named isotope</li></ul>	1

**Sample answer : (choosing cobalt-60)**

Cobalt-60 is used in industry to sterilise surgical instruments, in thickness gauges, and for irradiation of some foods (limited in Australia). It is used in medicine for the radiation treatment of some cancers.

Cobalt-60 is a non-reactive element, has low-energy gamma emissions and a moderately long half-life of about 5½ years. Thus, in industry it will not react with gases or moisture in the air and its moderately long half-life means that it does not need to be replaced very often. The low-energy emissions mean that stringent safety precautions are not necessary.

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**Question 21 (2 marks)****(a) (1 mark)****Outcomes Assessed: H11****Targeted Performance Bands: 2-3**

Criteria	Mark
• Outlines a valid procedure	1

**Sample answer:**

Red cabbage leaves were collected and cut into small pieces. The pieces were placed into a beaker and covered with water, which was then heated over a Bunsen burner until the water became purple/blue because of the colour leaching from the leaves. The coloured water and leaves were separated by straining and the leaves were discarded.

**(b) (1 mark)****Outcomes Assessed: H11****Targeted Performance Bands: 2-3**

Criteria	Mark
• Outlines an appropriate procedure	1

**Sample answer:**

Small samples of the indicator solution prepared were added to each of THREE test tubes containing an acid (hydrochloric), a base (sodium hydroxide) and a neutral solution (water). The indicator would be appropriate for use to test the acidity of a substance, if it had different colours in acid and in base.

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**Question 22 (4 marks)**

(a) (2 marks)

**Outcomes Assessed: H8****Targeted Performance Bands: 3-4**

Criteria	Marks
• Uses Le Chatelier's Principle to predict the effect on solubility of an increase in temperature	2
• Predicts the effect on solubility of an increase in temperature	1

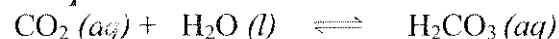
**Sample answer:**

At high temperature, since the dissolution reaction ( $\text{CO}_2 (\text{g}) \rightleftharpoons \text{CO}_2 (\text{aq})$ ) is exothermic, the backward reaction is favoured because that is the direction that absorbs heat and so, according to Le Chatelier, tends to counteract the temperature increase. The solubility of carbon dioxide decreases and bubbles of carbon dioxide gas are produced.

(b) (2 marks)

**Outcomes Assessed: H8, H13****Targeted Performance Bands: 3-4**

Criteria	Marks
• Explains why a solution of carbon dioxide in water is acidic AND • Writes an appropriate equilibrium equation	2
• Explains why a solution of carbon dioxide in water is acidic OR • Writes an appropriate equilibrium equation	1

**Sample answer:**

OR



The solution is acidic since carbonic acid is formed, which is a weak acid. It partially ionises to produce hydronium ions.

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**Question 23 (6 marks)**

(a) (2 marks)

**Outcomes Assessed: H11****Targeted Performance Bands: 3–5**

Criteria	Marks
• Outlines, in logical order, the steps needed to standardise the sodium hydroxide solution, starting from a primary standard	2
• Outlines a step which reacts the sodium hydroxide with an acid of known concentration	1

**Sample answer:**

The sodium hydroxide solution must be standardised by titrating it with an acid of exactly known concentration. This can be a primary standard (can be accurately weighed out) such as oxalic acid or a solution of (say) hydrochloric acid which has been previously standardised against a primary standard such as anhydrous sodium carbonate.

(b) (2 marks)

**Outcomes Assessed: H10, H11****Targeted Performance Bands: 3–4**

Criteria	Marks
• Calculates the concentration of acetic acid	2
• Calculates the correct number of moles of sodium hydroxide	1

**Sample answer:**

$$\text{Moles NaOH} = n = cV = 0.105 \times 17.6/1000 = 0.00185 \text{ mol}$$

$$\text{Moles CH}_3\text{COOH} = \text{moles NaOH} = 0.00185 \text{ mol}$$

$$\therefore [\text{CH}_3\text{COOH}] = n/V = 0.00185/0.0250 = 0.0739 \text{ mol L}^{-1}$$

(c) (2 marks)

**Outcomes Assessed: H11****Targeted Performance Bands: 3–4**

Criteria	Marks
• Justifies why methyl orange is unsuitable for use in this titration in terms of BOTH the pH at the equivalence point AND the colour change range for methyl orange	2
• Outlines some correct information about the indicator colour change OR the pH at the equivalence point of the titration	1

**Sample answer:**

The titration involves a weak acid and a strong base. As a result, at the equivalence point, the pH will be  $>7$  (in the alkaline range).

Hence methyl orange is NOT a suitable indicator since it changes colour at acidic pH values, between pH 3 and 5. It would not change colour at the equivalence point. At the commencement of this titration, the acetic acid is in the flask and the methyl orange will already be orange/yellow in colour. It will not change colour as sodium hydroxide is added to the flask. Hence a valid end point cannot be achieved.

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**Question 24 (4 marks)**

(a) (1 mark)

**Outcomes Assessed: H6, H8****Targeted Performance Bands: 2-3**

Criteria	Mark
• Explains classification of sodium oxide as a basic oxide	1

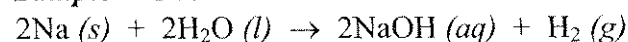
**Sample answer:**

Sodium oxide is a basic oxide as it is an oxide of an active metal, sodium. It reacts with water to form hydroxide ions and hence an alkaline solution and is neutralised by acids.

(b) (1 mark)

**Outcomes Assessed: H6, H8****Targeted Performance Bands: 2-3**

Criteria	Mark
• Writes a balanced equation for the reaction of sodium with water	1

**Sample answer:**

(c) (2 marks)

**Outcomes Assessed: H10****Targeted Performance Bands: 3-5**

Criteria	Marks
• Calculates the mass of sodium reacted	2
• Calculates the number of moles of sodium hydroxide (per 100 mL water)	1

**Sample answer:**

$$[\text{NaOH}] = 3.16 \times 10^{-2} \text{ mol L}^{-1}$$

Since the volume of the solution was 100.0 mL

$$\therefore \text{moles of NaOH present in 100 mL solution} = 3.16 \times 10^{-3} \text{ mol}$$

Hence moles Na reacted must have been the same ( $3.16 \times 10^{-3} \text{ mol}$ )

$$\begin{aligned} \therefore \text{mass of sodium reacted} &= 3.16 \times 10^{-3} \times 22.99 \text{ g} \\ &= 7.26 \times 10^{-2} \text{ g} \end{aligned}$$

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**Question 25 (4 marks)**

(a) (1 mark)

**Outcomes Assessed:** H9, H11**Targeted Performance Bands:** 2–3

Criteria	Mark
• Correct answer	1

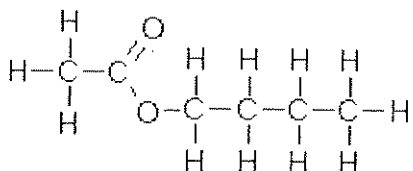
**Sample answer:**

1-butyl ethanoate

(b) (1 mark)

**Outcomes Assessed:** H9, H13**Targeted Performance Bands:** 3–4

Criteria	Mark
• Correct answer	1

**Sample answer:**

(c) (2 marks)

**Outcomes Assessed:** H8, H10, H13**Targeted Performance Bands:** 2–4

Criteria	Marks
• Correctly outlines TWO purposes for the use of concentrated sulfuric acid	2
• Correctly outlines ONE purpose for the use of concentrated sulfuric acid	1

**Sample answer:**

Concentrated sulfuric acid

- is used as a catalyst to speed up the rate of reaction, and
- acts as a dehydrating agent and absorbs water, which helps prevent the equilibrium reaction (1-butanol + ethanoic acid  $\rightleftharpoons$  1-butyl ethanoate + water) from shifting back to the left.

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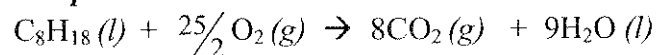
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**Question 26 (3 marks)**

(a) (1 mark)

**Outcomes Assessed: H9, H13****Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

(b) (2 marks)

**Outcomes Assessed: H10****Targeted Performance Bands: 2-4**

Criteria	Marks
• Correct answer (to 4 significant figures) OR • Answer consistent with incorrect equation in (a) (to 4 significant figures)	2
• Correct answer (but to incorrect number of significant figures) OR • Correct moles of carbon dioxide OR • Moles of carbon dioxide consistent with incorrect equation in (a)	1

**Sample answer:**

Molar mass of octane

= 114.26 g

Moles of octane

= 1000.0/114.26

= 8.7520 mol

Hence moles of carbon dioxide

= 8 x 8.7520 mol = 70.016 mol

Volume carbon dioxide

= 70.016 x 24.79 L = 1736 L

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**Question 27 (6 marks)**

(a) (2 marks)

**Outcomes Assessed: H11, H13**

**Targeted Performance Bands: 2–3**

Criteria	Marks
<ul style="list-style-type: none"><li>Explains the difference between an invalid experiment and an unreliable experiment</li></ul>	2
<ul style="list-style-type: none"><li>Explains what is meant by an invalid experiment</li></ul> OR <ul style="list-style-type: none"><li>Explains what is meant by an unreliable experiment</li></ul>	1

**Sample answer:**

An invalid experiment cannot achieve a valid result because the method of the experiment is incorrect or partially incorrect.

An unreliable experiment is one that does not give the same result when repeated many times, using the same method.

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(b) (4 marks)

**Outcomes Assessed: H11, H12, H14**

**Targeted Performance Bands: 3-6**

Criteria	Marks
• Evaluates thoroughly the validity of the conclusions	4
• Explains why some aspects of the experimental method are invalid and hence the conclusions are invalid	2-3
• Outlines some invalid aspect of the method or conclusions	1

**Sample answer:**

The experimental method needs to be designed to determine whether

- the water is hard or soft, and
- calcium ions are present.

Step 1. This would be a valid qualitative method for classifying the water as hard or soft, if comparison test tubes, using deionised water and water known to be hard, had been used. Since no controls were used for comparison, the conclusion is not valid.

Step 2. This would be a valid method for quantitatively determining the hardness of the water, if the mass of precipitate per given volume of solution had been determined and the precipitate had been identified as calcium or magnesium carbonate. Hardness is expressed quantitatively in milligrams of  $\text{CaCO}_3$  per litre. As the method retained the filtrate (not the precipitate) and did not include determining quantitatively the mass of precipitate, it cannot be considered valid for determination of hardness. The precipitate could also have been one of many white insoluble carbonates (not necessary calcium or magnesium carbonates, which cause hardness of water).

Step 3. A flame test can be used to identify the presence of calcium ions – but the student used the filtrate, rather than the residue, to carry out the flame test. If calcium ions were present, they would have been precipitated out (to a great extent) as calcium carbonate. Minimal calcium ions would remain in the filtrate. The yellow colour of the flame would indicate sodium ions, not calcium ions, remaining in the filtrate.

Hence overall, the method used was inadequate and therefore invalid for determining whether the water was hard or soft and hence the conclusion that the water was soft is invalid.

The conclusion that the water contained calcium ions is also invalid, as the filtrate (instead of the residue) was used to carry out the flame test. Since the method is invalid, then a correct or valid conclusion cannot be drawn.

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**Question 28** (4 marks)

(a) (1 mark)

**Outcomes Assessed:** H9, H13**Targeted Performance Bands:** 3-4

Criteria	Mark
• Identifies isomer using correct systematic name	1

**Sample answer:**

2, 2-dichloro-1,1,1,2-tetrafluoroethane

(b) (3 marks)

**Outcomes Assessed:** H4, H9**Targeted Performance Bands:** 3-5

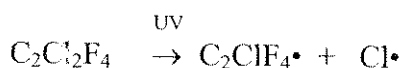
Criteria	Marks
<ul style="list-style-type: none"> <li>Explains THREE chemical reactions</li> <li>Writes THREE correct equations for these reactions</li> <li>Explains that a chain reaction can occur</li> </ul>	3
<ul style="list-style-type: none"> <li>Explains TWO chemical reactions</li> <li>Writes TWO correct equations for these reactions</li> </ul>	2
<ul style="list-style-type: none"> <li>Explains ONE chemical reaction AND</li> <li>Writes ONE correct equation for this reaction</li> </ul>	1

**Sample answer:**

Reaction 1:

 $\text{C}_2\text{Cl}_2\text{F}_4$  is a CFC.

UV light splits a chlorine free radical from a CFC.



Reaction 2:

The chlorine free radical destroys an ozone molecule.



Reaction 3:

The  $\text{ClO}\cdot$  free radical reacts with an oxygen free radical (produced by breakdown of either ozone or oxygen by UV light), to produce an oxygen molecule and to free up the  $\text{Cl}\cdot$  again.Thus the  $\text{Cl}\cdot$  free radical can repeat steps 2 and 3, to destroy many ozone molecules (i.e. a chain reaction can occur).**DISCLAIMER**

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**Question 29 (3 marks)****Outcomes Assessed: H3, H4, H8****Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Explains the role of the catalyst in the Haber process</li><li>Recognises the particular requirement for an efficient catalyst to increase the rate of reaction when only moderate temperature conditions apply</li><li>Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated</li></ul>	3
<ul style="list-style-type: none"><li>Explains the role of the catalyst in the Haber process</li><li>Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated</li></ul>	2
<ul style="list-style-type: none"><li>Explains the role of the catalyst in the Haber process</li></ul> OR <ul style="list-style-type: none"><li>Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated</li></ul>	1

**Sample answer:**

The role of the catalyst in the Haber process is to allow the gaseous equilibrium reaction to occur on its surface so that the reaction can occur at a faster rate than if no catalyst were present. The catalyst lowers the activation energy for both the forward and backward reactions and so the rate of production of ammonia at a given temperature is greater. Since the greatest yield of ammonia is produced at low temperature, an efficient catalyst is essential to ensure the highest rate of reaction.

The condition of the catalyst must be monitored by industrial chemists to ensure that its surface has not become deactivated. This can occur if sulfur compounds, carbon monoxide or carbon dioxide are present in the gases entering the catalytic chamber. The catalytic surface is most effective when it is granular and porous, to provide the biggest surface area. The catalyst must be monitored and replaced if the efficiency of the catalytic process is endangered.

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**Question 30 (4 marks)****Outcomes Assessed: H3, H4, H8****Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Outlines thoroughly all the steps used to purify water supplies prior to chlorination AND discusses the need for purification of the water supply</li></ul>	4
<ul style="list-style-type: none"><li>• Outlines some of the steps used to purify water supplies prior to chlorination AND discusses the need for purification of the water supply</li></ul>	2-3
<ul style="list-style-type: none"><li>• Some correct information about the need to purify water supplies</li></ul> OR <ul style="list-style-type: none"><li>• Some correct information about the steps used for purification</li></ul>	1

**Sample answer:**

Water flowing in a river or water that is held in reservoirs contains both chemicals and living things that can be potentially harmful to human beings. The source of the water, the geology of the area and the extent of human activity in the catchment area can affect the purity of the water supply.

Prior to the sanitisation of water (by addition of chlorine to destroy the microbes which could cause disease and death), the dissolved oxygen content is increased and the water is clarified to remove sediments, inorganic matter which could be damaging to health and coloured organic material.

The water is aerated by spraying it into the air or by allowing it to fall from a dam into holding tanks. This increases the dissolved oxygen content and assists in oxidising sulfur compounds (to sulfate ions) and iron salts (to iron (III) oxides) which are later removed. The increased oxygen concentration assists in the oxidation of organic materials which are broken down by aerobic bacteria in the water supply.

The clarity of the water is increased by removal of small suspended particles. These are separated out by a process called flocculation. Chemicals such as alum or iron (III) salts are added to the water to produce a gelatinous precipitate of aluminium or iron (III) hydroxide. This traps other suspended particles, including iron oxides and some microbes. The precipitate is then left to sediment out and the purified water is drawn from above the level of the sludge and passed through a series of filters made from sand and gravel. If the water passing out of the filter contains coloured organic matter, the water is further clarified by passing it through charcoal filters that adsorb the coloured matter onto the charcoal surface. Membrane filters can remove finer sediment (and some microbes), if the clarity of the water does not meet the required level of purity prior to the subsequent sanitisation step.

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## Section II – OPTIONS

### Question 31 – Industrial Chemistry (25 marks)

(a) (i) (1 mark)

*Outcomes Assessed: H11*

*Targeted Performance Bands: 2-3*

Criteria	Mark
• Identifies ONE safety precaution	1

*Sample answer:*

When diluting always add acid to water.

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(a) (ii) (4 marks)

**Outcomes Assessed:** H4, H8.

**Targeted Performance Bands:** 2-5

Criteria	Marks
<ul style="list-style-type: none"><li>Describes the Frasch process AND</li><li>Relates the method of extraction to the properties of sulfur which allow its extraction AND</li><li>Describes at least TWO environmental issues associated with the Frasch process</li></ul>	4
<ul style="list-style-type: none"><li>Describes the Frasch process AND</li><li>Relates the method of extraction to the properties of sulfur which allow its extraction</li></ul> OR <ul style="list-style-type: none"><li>Describes the Frasch process AND</li><li>Identifies relevant physical properties of sulfur AND</li><li>Describes at least TWO environmental issues associated with the Frasch process</li></ul>	3
<ul style="list-style-type: none"><li>Describes the Frasch process AND</li><li>Identifies relevant physical properties of sulfur</li></ul> OR <ul style="list-style-type: none"><li>Describes the Frasch process AND</li><li>Describes at least TWO environmental issues associated with the Frasch process</li></ul>	2
<ul style="list-style-type: none"><li>Describes the Frasch process</li></ul> OR <ul style="list-style-type: none"><li>Identifies relevant physical properties of sulfur</li></ul> OR <ul style="list-style-type: none"><li>Describes an environmental issue associated with the Frasch process</li></ul>	1

**Sample answer:**

In the Frasch process, superheated water ( $160^{\circ}\text{C}$ ) is forced down the outermost of three concentric pipes into the sulfur deposit. This melts the sulfur (mp  $113^{\circ}\text{C}$ ) and forms an emulsion. Compressed air is forced down the innermost pipe. This forces the water-sulfur emulsion up the middle pipe into the collection vessel. The sulfur then solidifies, separating itself from the water; it is 99.9% pure at this point.

Sulfur has a low melting point ( $113^{\circ}\text{C}$ ) and low density ( $2.07\text{ g/ml}$ ). Thus it easily melts and its low density allows compressed air to easily lift it to the surface through the middle pipe. Sulfur is also insoluble in water so it is easily separated from water.

Sulfur is non-volatile and odourless, thus it does not escape into the atmosphere. It is, however, easily oxidised to sulfur dioxide or reduced to hydrogen sulfide, both being air pollutants. Therefore it is vital that neither oxidation nor reduction occur in the Frasch process. The water should be reused since other impurities, which may be harmful to the environment, may have dissolved from the ore into the water. It is also very difficult to backfill underground caverns left by extraction, since sulfur beds are deep under clay, quicksand, sand and limestone deposits.

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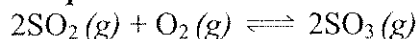
(b) (i) (1 mark)

**Outcomes Assessed: H13**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Writes a correctly balanced equation	1

**Sample answer:**



(b) (ii) (1 mark)

**Outcomes Assessed: H10**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Writes a correct expression for the equilibrium constant	1

**Sample answer:**

$$K = \frac{[\text{SO}_3(\text{g})]^2}{[\text{SO}_2(\text{g})]^2 [\text{O}_2(\text{g})]}$$

(b) (iii) (3 marks)

**Outcomes Assessed: H10**

**Targeted Performance Bands: 3-6**

Criteria	Marks
• Correctly calculates the equilibrium constant	3
• Correctly substitutes CONCENTRATION into equilibrium expression OR	2
• Calculates equilibrium constant using number of moles	
• Correctly calculates the number of moles at equilibrium	1

**Sample answer:**

	$2\text{SO}_2(\text{g})$	+	$\text{O}_2(\text{g})$	$\rightleftharpoons$	$2\text{SO}_3(\text{g})$
Initial moles	$4.325 \times 10^3$		$2.132 \times 10^3$		0
Change in moles	$-3.762 \times 10^3$		$-1.881 \times 10^3$		$+3.762 \times 10^3$
At equilibrium	$0.563 \times 10^3$		$0.251 \times 10^3$		$3.762 \times 10^3$

Change moles to concentration by dividing by 10.00 L

Concentration at equilibrium

$$0.563 \times 10^2 \quad 0.251 \times 10^2 \quad 3.762 \times 10^2$$

$$K = \frac{[\text{SO}_3(\text{g})]^2}{[\text{SO}_2(\text{g})]^2 [\text{O}_2(\text{g})]}$$

$$= \frac{(3.762 \times 10^2)^2}{(0.563 \times 10^2)^2 \times (0.251 \times 10^2)} = \frac{14.15 \times 10^4}{0.07956 \times 10^6}$$

$$= 1.779$$

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(c) (4 marks)

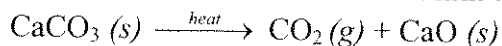
**Outcomes Assessed: H4, H13, H14**

**Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Describes all steps in the stage AND writes TWO relevant balanced equations</li></ul>	4
<ul style="list-style-type: none"><li>Describes all steps in the stage AND writes ONE relevant balanced equation</li><li>OR</li><li>Identifies all steps in the stage AND writes TWO relevant balanced equations</li><li>OR</li><li>Describes all steps in the stage ONLY</li></ul>	3
<ul style="list-style-type: none"><li>Identifies a step in the stage AND writes a relevant balanced equation</li><li>OR</li><li>Identifies all steps in the stage</li><li>OR</li><li>Writes TWO relevant balanced equations ONLY</li></ul>	2
<ul style="list-style-type: none"><li>Writes a relevant balanced equation</li><li>OR</li><li>Identifies a step in the stage</li></ul>	1

**Sample answer:**

Calcium carbonate is heated in a kiln to form carbon dioxide and calcium oxide

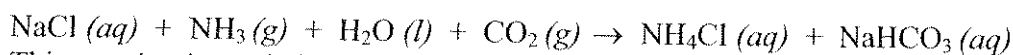


The calcium oxide is removed, to be used in ammonia recovery.

Coke is also present in the kiln, producing more carbon dioxide when heated, as well as providing heat to decompose the calcium carbonate.



Ammonia is dissolved in the purified brine (NaCl) and carbon dioxide is dissolved in this solution.



This reaction is carried out at a low temperature (0°C) so that sodium hydrogen carbonate, which is relatively insoluble at low temperatures, precipitates out. The mixture is filtered. Sodium hydrogen carbonate is washed, dried and used to make sodium carbonate.

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(d) (7 marks)

**Outcomes Assessed:** H3, H4, H8

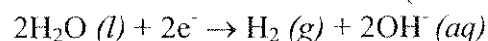
**Targeted Performance Bands:** 2-6

Criteria	Marks
<ul style="list-style-type: none"><li>Describes thoroughly the diaphragm process and products</li><li>Compares the environmental issues and technical considerations in the diaphragm process with those associated with the mercury-cell process</li></ul>	7
<ul style="list-style-type: none"><li>Describes thoroughly the diaphragm process and products</li><li>Describes thoroughly the environmental issues and technical considerations of the diaphragm cell and of the mercury-cell process</li></ul>	5-6
<ul style="list-style-type: none"><li>Describes soundly the diaphragm process and products</li><li>Describes soundly the environmental issues and technical considerations of the diaphragm cell and of the mercury-cell process</li></ul>	3-4
<ul style="list-style-type: none"><li>Identifies some correct information about the diaphragm cell</li><li>Identifies some correct information about the environmental issues and technical considerations in the diaphragm OR the mercury-cell process</li></ul>	1-2

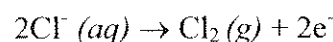
**Sample answer:**

The diaphragm process is one method that has been used in the production of sodium hydroxide. The main products of the process are sodium hydroxide, chlorine gas and hydrogen gas.

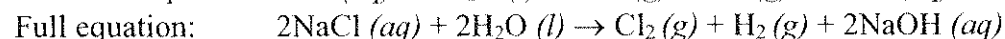
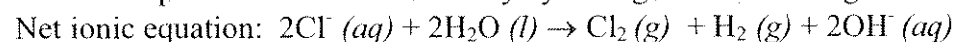
An iron mesh cathode is used (due to no reaction with  $\text{OH}^-$ ).



A titanium anode is used (so as not to react with  $\text{Cl}^-$ ).



Brine flows through the cell which is separated into two chambers by an asbestos diaphragm which completes the flow of electricity by letting  $\text{Na}^+$  ions through.



**Environmental issues** to consider include the asbestos diaphragm (which, if the particles become airborne are extremely harmful when breathed in) and any  $\text{ClO}^-$  (a strong oxidant) in the waste brine. The release of chlorine gas into the environment is another issue as it is a poisonous gas and there are regulations controlling permitted levels in the atmosphere.  $\text{NaOH}$  itself is corrosive and must be stored in plastic containers. Hydrogen gas and chlorine gas react explosively; therefore leaks, sparks and flames must be avoided. There is a need to minimise the effect of the general running of the plant (noise, light, emissions, etc) and of transport operations on the surrounding population.

By comparison, the mercury-cell does not use a diaphragm, so there are no health problems associated with asbestos.  $\text{ClO}^-$  is not produced in a mercury-cell as the chloride ions do not come into contact with the product ( $\text{NaOH}$ ). However, traces of mercury do escape into the environment when spent brine is returned to the ocean. The mercury sinks but in the anaerobic conditions at depth special bacteria convert mercury metal into mercury ions, which are then taken into the food chain. These ions cannot be easily excreted by animals and hence bio-accumulate up the food chain. Mercury ions cause damage to the nervous system and can cause serious illness or death.

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**Technical considerations** in the diaphragm process include availability of transport facilities, workforce (and appropriate accommodation for them) and proximity to electric power (a major issue) and raw materials. The staff needs to be skilled in the handling and disposal of toxic substances (chlorine, sodium hydroxide) and explosive substances (hydrogen). A very high level of plant safety must be maintained and constantly monitored.

There is a need to keep  $\text{Cl}_2$  gas and  $\text{H}_2$  gas separate as they react explosively when together.  $\text{OH}^-$  and  $\text{Cl}^-$  need to be separated as well, as unwanted  $\text{ClO}^-$  may form. To maximise purity of  $\text{NaOH}$ , it is necessary to remove as much  $\text{Cl}^-$  as possible.

By comparison, the mercury-cell produces almost pure  $\text{NaOH}$  because there is no opportunity for the  $\text{NaOH}$  to be contaminated with  $\text{NaCl}$  (as  $\text{NaOH}$  is formed in a separate chamber from the reaction of the amalgamated sodium with water). The mercury-cell process separates the chlorine and hydrogen (released in separated tanks) and no unwanted  $\text{ClO}^-$  can form. The mercury process is more energy-efficient and the electrolysis units can be much larger than in the diaphragm process.

However, both mercury-cells and diaphragm cells are being replaced (because of their environmental and technical limitations) by membrane cells. The cation exchange membrane (which prevents mixing of chloride and hydroxide ions) overcomes a shortcoming of the diaphragm cell. The membrane cell does not use either asbestos or mercury and so has little impact on the environment.

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(e) (4 marks)

**Outcomes Assessed: H4, H8, H9, H11**

**Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Outlines the procedure</li><li>• Identifies safety considerations</li><li>• Describes the results</li><li>• Describes how the product was tested</li></ul>	4
<ul style="list-style-type: none"><li>• THREE of the above</li></ul>	3
<ul style="list-style-type: none"><li>• TWO of the above</li></ul>	2
<ul style="list-style-type: none"><li>• ONE of the above</li></ul>	1

**Sample answer:**

Procedure

Pour 100 mL warm water into a 200 mL beaker and add 10 g sodium hydroxide. Add 25 mL olive oil and heat in a water bath for 30 minutes. Add concentrated NaCl solution to precipitate the soap, filter and wash with a small amount of water.

Safety considerations

NaOH is an alkaline solution, about pH 12, so you must wear safety goggles and work near a tap so that a supply of running water is available. If alkali is splashed on the skin, wash it off immediately and continue washing for 15 minutes.

Results

The NaOH reacts with the ester in the olive oil to produce soap and glycerol. After NaCl has been added, soap will precipitate as a white solid which is then separated from the solution.

Testing procedure

To test the product you can either shake the solid with water to see if it suds (forms bubbles/foam) or add it to water and oil and see if it forms an emulsion. Soap, water and oil form an emulsion. In such mixtures, soap acts as the emulsifier (the substance which causes large droplets of oil to break up into very small droplets that can remain dispersed through the water almost indefinitely).

**Question 32 – Shipwrecks, Corrosion and Conservation (25 marks)**

(a) (1 mark)

**Outcomes Assessed: H1**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies Davy	1

**Sample answer:**

Davy

(b) (i) (1 mark)

**Outcomes Assessed: H10**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Calculates the correct percentage	1

**Sample answer:**

99.285%

(b) (ii) (1 mark)

**Outcomes Assessed: H8**

**Targeted Performance Bands: 3-4**

Criteria	Mark
• Identifies oxygen	1

**Sample answer:**

Oxygen

(b) (iii) (2 marks)

**Outcomes Assessed: H8**

**Targeted Performance Bands: 2-4**

Criteria	Marks
• Explains that stainless steel, unlike mild steel, contains chromium which is a passivating metal	2
• Identifies chromium as a component of stainless steel	1

**Sample answer:**

Stainless steel contains chromium metal. Chromium is a passivating metal, reacting with oxygen to form an impermeable and adhesive barrier, protecting the stainless steel from further corrosion. Mild steel does not contain a passivating metal.

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(c) (i) (1 mark)

**Outcomes Assessed:** H3, H8

**Targeted Performance Bands:** 2-3

Criteria	Mark
• Compares correctly	1

**Sample answer:**

Conservation is the treatment of artefacts to prevent further deterioration. Restoration is changing an artefact to return it as close to its original appearance as possible.

(c) (ii) (2 marks)

**Outcomes Assessed:** H3, H8

**Targeted Performance Bands:** 2-4

Criteria	Marks
• Explains the damage resulting from the crystallisation of dissolved chlorides and sulfates	2
• Identifies that artefacts contain dissolved chlorides OR • Identifies that artefacts can split and crack if allowed to dry prior to treatment	1

**Sample answer:**

Artefacts recovered from the ocean are usually saturated with dissolved chlorides and sulfates. If the artefact is allowed to dry, these salts will begin to crystallise and in the process cause more splitting and damage to the artefact. Only after the salts have been removed can the artefact be dried.

(c) (iii) (3 marks)

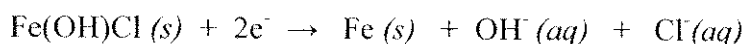
**Outcomes Assessed:** H3, H8, H13

**Targeted Performance Bands:** 2-5

Criteria	Marks
• Describes a chemical procedure used to clean an iron artefact and includes an appropriate equation	3
• Describes a chemical procedure used to clean an iron artefact	2
• Identifies a chemical procedure used to clean an iron artefact	1

**Sample answer:**

Chloride ions can be removed from saturated iron artefacts by electrolysis. The artefact is submerged in an electrolyte solution of sodium hydroxide and connected to the negative terminal of an external power supply. The artefact acts as the cathode, enabling the reduction of  $\text{Fe}^{2+}$  to Fe.



This reaction results in the removal of chloride ions. These are drawn away from the artefact towards the positive anode which is an inert steel mesh basket surrounding the artefact.

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(d) (6 marks)

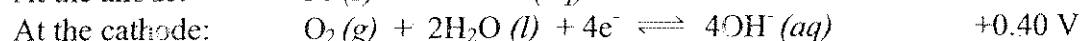
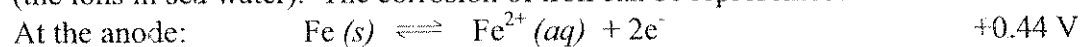
**Outcomes Assessed:** H3, H8

**Targeted Performance Bands:** 2-6

Criteria	Marks
• Thorough analysis of the impact of depth on the corrosion of shipwrecks	6
• Thorough discussion of the effects of oxygen and temperature on the aerobic corrosion of shipwrecks in shallow water AND • Thorough discussion of the effects of anaerobic conditions on corrosion of shipwrecks at depth	4-5
• Sound discussion of the effects of oxygen and temperature on the aerobic corrosion of shipwrecks in shallow water AND • Sound discussion of the effects of anaerobic conditions on corrosion of shipwrecks at depth	3
• Sound discussion of the effects of oxygen and temperature on the aerobic corrosion of shipwrecks in shallow water OR • Sound discussion of the effects of anaerobic conditions on corrosion of shipwrecks at depth	2
• Some correct information comparing corrosion in shallow water and at depth	1

**Sample answer:**

Corrosion of iron in shallow water is due to the presence of oxygen, water and an electrolyte (the ions in sea water). The corrosion of iron can be represented:

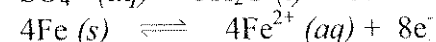
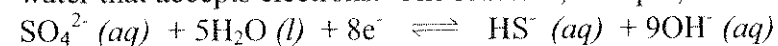


As depth increases, the temperature of the water falls as the distance from the warming effect of sun and atmosphere increases.

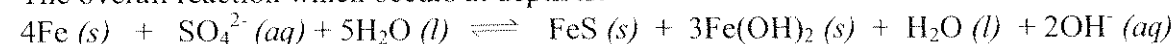
As depth increases, the concentration of oxygen also falls, as (i) the respiration of aerobic organisms removes oxygen from the water, (ii) there is little diffusion downwards from the surface and (iii) the generation of oxygen by photosynthesis falls as the depth increases. Because of both the temperature decline and the reduction in oxygen with depth, scientists expected a corresponding reduction in corrosion with depth.

However, objects recovered from the Titanic and surveys of the condition of parts of the ship's hull indicated that extensive (and unexpected) corrosion at great depth had occurred. The reason for this corrosion at depth is not that the previous understanding of corrosion was incorrect, but that corrosion at depth involves a different reduction process.

Instead of oxygen and water accepting electrons, it is the combination of sulfate ions and water that accepts electrons. The reaction, at depth, is catalysed by sulfur-reducing bacteria.



The overall reaction which occurs at depth is:



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The products are black iron (II) sulfide and white iron (II) hydroxide (which is NOT oxidised to red-brown rust because of the absence of oxygen).

Additionally, the environment in which these sulfur-reducing bacteria live is acidic (and  $\text{HS}^-$ , formed in the above reduction reaction, is acidic) and corrosion of iron is accelerated by acidic solutions. Hence, by Le Chatelier's Principle, the hydroxide ions react with the hydrogen ions (produced from  $\text{HS}^-$ ) and the equilibrium moves further to the right, increasing the corrosion of the iron.

Hence, depth impacts on the corrosion of iron, in that the chemical process changes from an oxidation brought about by reduction of oxygen to one brought about by reduction of sulfate ions, in the presence of sulfur-reducing bacteria. As the temperature of water falls with depth, then depth does impact on the rate of corrosion, as the rate of reaction decreases as the temperature decreases.

(e) (i) (2 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-3**

Criteria	Marks
• Outlines an appropriate method	2
• Identifies some basic steps in a method	1

**Sample answer:**

Iron nails were placed in a solution of agar, phenolphthalein and potassium hexacyanoferrate in three petri dishes. One dish was placed in an incubator at  $30^\circ\text{C}$ . Another was left at room temperature and the last was placed in the refrigerator at  $3^\circ\text{C}$ . The dishes were examined daily for five days. Changes in the colour of the indicators and any appearance of rust were noted.

(e) (ii) (2 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-3**

Criteria	Marks
• Identifies TWO strategies	2
• Identifies ONE strategy	1

**Sample answer:**

The nails were from the same packet. The agar and indicators were mixed in one beaker prior to pouring into the 3 identical petri dishes. All nails were covered by the same amount of solution and the dishes were observed for colour changes at the same time.

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(f) (i) (1 mark)

**Outcomes Assessed: H14**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies a relationship	1

**Sample answer:**

The solubility of oxygen in sea water (or fresh water) decreases as the temperature increases.

OR

The solubility of oxygen is lower in sea water than fresh water between 0°C and 50°C.

(f) (ii) (3 marks)

**Outcomes Assessed: H8, H14**

**Targeted Performance Bands: 3-6**

Criteria	Marks
• Discusses the relative rates of corrosion in sea water and fresh water, considering the oxygen concentrations depicted in the graph AND the need for an electrolyte	3
• Discusses the relative rates of corrosion in sea water and fresh water, considering ONLY the <u>oxygen concentrations</u> depicted in the graph OR • Discusses the relative rates of corrosion in sea water and fresh water, considering ONLY the <u>differences in electrolyte concentration</u> in fresh and sea water OR • Identifies that the rate of corrosion depends on BOTH the oxygen concentration and the concentration of electrolyte	2
• Identifies that the rate of corrosion depends on the oxygen concentration OR • Identifies that the rate of corrosion depends on the concentration of electrolyte	1

**Sample answer:**

The graph indicates that the concentration of oxygen is lower in sea water than in fresh water for any given temperature between 0°C and 50°C. As oxygen is required for the corrosion process it would seem that corrosion would be slower in sea water due to the presence of less oxygen. However, the process of corrosion is also dependent on the presence of an electrolyte. Sea water is an electrolyte containing about 4% (w/w) salt. Fresh water is not an electrolyte. So, despite having more oxygen than sea water, fresh water will not produce faster corrosion due to the absence of an electrolyte.

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**Question 33 – The Biochemistry of Movement (25 marks)**

(a) (1 mark)

**Outcomes Assessed: H9****Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

Glucose

(b) (i) (1 mark)

**Outcomes Assessed: H8, H9****Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

Temperature and pH

(b) (ii) (2 marks)

**Outcomes Assessed: H8, H9, H11****Targeted Performance Bands: 3-5**

Criteria	Marks
• Identifies an enzyme AND explains how changes in pH or temperature affect the enzyme	2
• Identifies an enzyme OR • Explains how changes in pH or temperature affect the enzyme	1

**Sample answer:**

The enzyme used was rennin which catalyses a reaction which coagulates milk.

At pH outside of its range the enzyme is denatured. As a result, the enzyme does not fit into the substrate because of a breakdown in the secondary and tertiary structure of the enzyme due to the altered pH. The enzyme loses its catalytic activity.

(b) (iii) (2 marks)

**Outcomes Assessed: H11****Targeted Performance Bands: 3-5**

Criteria	Marks
• Any TWO relevant safety precautions	2
• Any ONE relevant safety precaution	1

**Sample answer:**

Wear safety glasses and gloves when dealing with acids and bases.

Dispose of acids safely – pour into beaker of water slowly and dispose down sink with plenty of water running at the time.

Dispose of the organic wastes (coagulated milk, etc) in the garbage.

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(c) (5 marks)

**Outcomes Assessed: H7, H9**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies ATP as the energy currency</li><li>Thorough analysis of glycolysis and the TCA cycle in terms of the energy output</li></ul>	4-5
<ul style="list-style-type: none"><li>Identifies ATP as the energy currency</li><li>Sound analysis of glycolysis and the TCA cycle in terms of the energy output</li></ul>	2-3
<ul style="list-style-type: none"><li>Some correct information about the energy output in glycolysis</li></ul>	1

**Sample answer:**

ATP (adenosine triphosphate) is the “universal energy currency” in biological systems. It is the source of energy for all reactions in the cell. When energy is needed, ATP reacts with water to give ADP (adenosine diphosphate) and releases energy. ATP is formed in an enzyme-controlled endothermic reaction.

An initial enzyme-controlled hydrolysis of carbohydrates to glucose and other sugars must occur before energy production can start in the cell.

Glycolysis is an anaerobic process, preliminary to the TCA cycle. In glycolysis, 6-carbon sugars are converted into two 3-carbon pyruvate ions. This process releases energy which results in the production of 2 ATP molecules.

Glycolysis also involves the reduction of two  $\text{NAD}^+$  molecules to NADH. This coenzyme is then responsible by oxidative phosphorylation for the production of another 6 ATP molecules.

The tricarboxylic acid (TCA) cycle is a series of reactions that oxidises the 2 acetyl-CoA molecules from a 6-carbon sugar into  $\text{CO}_2$  and 2 molecules of ATP.

The TCA cycle also involves the reduction of six  $\text{NAD}^+$  molecules to NADH and of two FAD molecules to  $\text{FADH}_2$ . These coenzymes are then responsible by oxidative phosphorylation for the production of another 22 ATP molecules.

Overall, glycolysis produces 8 ATP molecules whereas the TCA cycle is responsible for the production of 24 molecules of ATP.

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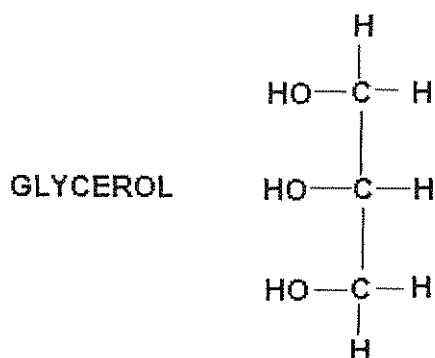
(d) (i) (1 mark)

**Outcomes Assessed:** H9, H13

**Targeted Performance Bands:** 2-3

Criteria	Mark
• Correct answer	1

**Sample answer:**



(d) (ii) (1 mark)

**Outcomes Assessed:** H8, H9

**Targeted Performance Bands:** 3-4

Criteria	Mark
• Indicates that glycerol has high solubility in water and provides an explanation	1

**Sample answer:**

The glycerol molecule contains 3 -OH groups which provide multiple points for hydrogen bond formation with water. These hydrogen bonds lead to glycerol's high solubility in water.

(d) (iii) (1 mark)

**Outcomes Assessed:** H7, H9

**Targeted Performance Bands:** 2-3

Criteria	Mark
• Identifies use of TAGs	1

**Sample answer:**

TAGs are an efficient storage unit of fats used in metabolism as a source of energy.

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(e) (6 marks)

**Outcomes Assessed:** H7, H9

**Targeted Performance Bands:** 3-6

Criteria	Marks
<ul style="list-style-type: none"><li>• Demonstrates a thorough understanding of the respiratory processes involved in sprinting and long distance running</li><li>• Compares thoroughly the TWO processes in terms of the sources of energy, the aerobic or anaerobic nature of the respiration processes and the rate of production of energy</li></ul>	5-6
<ul style="list-style-type: none"><li>• Demonstrates a sound understanding of the respiratory processes involved in sprinting and long distance running</li><li>• Compares soundly the TWO processes in terms of the sources of energy, the aerobic or anaerobic nature of the respiration processes and the rate of production of energy</li></ul>	3-4
<ul style="list-style-type: none"><li>• Discusses some issues involved in aerobic and anaerobic respiration</li></ul>	1-2

**Sample answer:**

In explosive exercise, such as sprinting, the first source of energy is the glucose present in the blood. This store lasts only a short time, after which the main source of energy changes to anaerobic respiration fuelled by glycogen stores within the cell. Anaerobic processes produce less energy compared to aerobic processes but are able to supply large amounts of energy over a short period of time. The sprinter's muscles must be able to provide glucose and any extra carbohydrate required through the quick breakdown of glycogen. This anaerobic process is called glycolysis and produces pyruvate ions and an immediate supply of 2 molecules of ATP. Under anaerobic conditions, the pyruvate is reduced to lactic acid or lactate ions, which are transported to the liver to be converted back to glucose. Anaerobic glycolysis also produces hydrogen ions which change the pH of muscles and alter the action of certain enzymes which lead to muscle cramp and fatigue – thought to be the body's defence mechanism against draining completely its supply of ATP.

Long distance running, which is less explosive, relies on aerobic respiration to provide the energy. This energy can come from the metabolism of carbohydrates, fat or proteins. A long distance runner uses a mixture of carbohydrate and fat metabolism when racing. In the first 10 minutes the majority of fuel used is carbohydrate. As the runner consumes the available carbohydrate, fat metabolism increases whilst carbohydrate metabolism steadily decreases. The TCA cycle is referred to as aerobic respiration because it relies on large quantities of oxygen. In this process, the end product of glycolysis, pyruvate ions, are further metabolised in a series of steps to produce ATP and high energy compounds NADH and FADH<sub>2</sub> which are converted into ATP in the process called oxidative phosphorylation, where oxygen is essential. The end product is 38 molecules of ATP per 1 molecule of glucose metabolised.

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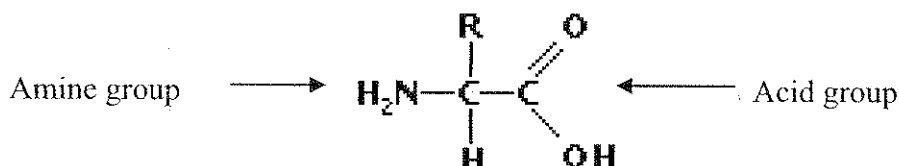
(f) (i) (2 marks)

**Outcomes Assessed:** H8, H9, H13

**Targeted Performance Bands:** 3-4

Criteria	Marks
• Draws correct structure and labels the acid and amine groups	2
• Draws correct structure ONLY OR • Correctly labels the acid and amine groups ONLY	1

**Sample answer:**



(f) (ii) (1 mark)

**Outcomes Assessed:** H8, H9

**Targeted Performance Bands:** 3-5

Criteria	Mark
• Identifies at least THREE types of forces which determine the shape of a protein molecule	1

**Sample answer:**

The shape of a protein molecule is determined by the mixture of electrostatic forces, hydrogen bonds, dispersion forces and disulfide bonds (if present).

(f) (iii) (2 marks)

**Outcomes Assessed:** H8, H9

**Targeted Performance Bands:** 3-5

Criteria	Marks
• Defines denaturation AND accounts for the process using examples of agents of denaturation	2
• Defines denaturation OR accounts for the process using examples of agents of denaturation	1

**Sample answer:**

Protein denaturation is the disruption to the three dimensional shape of the protein that renders it biologically inactive.

Increases in temperature, changes in pH, bacteria and addition of certain chemicals can cause these bonds and forces to be disrupted.

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**Question 34 – The Chemistry of Art (25 marks)**

(a) (1 mark)

**Outcomes Assessed: H6, H7****Targeted Performance Bands: 2–3**

Criteria	Mark
• Identifies TWO examples	1

**Sample answer:**

Fireworks and coloured lighting (such as neon lights and sodium lights) are two other examples of our modern use of colour.

(b) (3 marks)

**Outcomes Assessed: H4****Targeted Performance Bands: 2–4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Names a pigment used in ancient times</li> <li>Correctly describes that pigment's chemical composition</li> <li>Assesses the health risk(s) linked to the use of that pigment and its composition</li> </ul>	3
<ul style="list-style-type: none"> <li>Names a pigment used in ancient times</li> <li>Correctly describes that pigment's chemical composition</li> <li>Describes the health risk(s) linked to the use of that pigment</li> </ul>	2
<ul style="list-style-type: none"> <li>Names a pigment used in ancient times</li> <li>Correctly describes that pigment's chemical composition</li> </ul> OR <ul style="list-style-type: none"> <li>Describes the health risk(s) linked to the use of that pigment</li> </ul>	1

**Sample answer:**

Cinnabar vermillion was a red pigment used by the Greeks and adopted by the Romans through conquest of Egypt. Its main cosmetic use was as a lipstick or rouge. It was often mixed with red lead or white lead to make pink shades that were used extensively.

Cinnabar is actually mercury (II) sulfide, HgS, and like almost all mercury compounds is highly toxic. HgS is toxic by inhalation as a vapour or by direct ingestion or skin contact. The mercury in cinnabar is capable of causing serious central nervous system damage and also kidney disease.

Assessment.

The continued regular use of such a compound directly applied to one's skin was highly dangerous to the health of the user.

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(c) (i) (2 marks)

**Outcomes Assessed: H1, H6, H7**

**Targeted Performance Bands: 3–5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Links oxidation state to electrons in d orbitals</li><li>• Links d orbital energy to frequency of light that can be absorbed or emitted, hence colour</li></ul>	2
<ul style="list-style-type: none"><li>• Links oxidation state to electrons in d orbitals</li></ul> OR <ul style="list-style-type: none"><li>• Links d orbital energy to frequency of light that can be absorbed or emitted, hence colour</li></ul>	1

**Sample answer:**

Changing the oxidation state of a transition metal alters the number of d orbitals that are occupied by 1 or 2 electrons.

Transition metals exhibit certain colours due to the fact that energy differences between outermost orbitals correspond to visible light frequencies, so changing the energy profile slightly will change the frequencies associated with those jumps. This means that different colours of light will be absorbed or not absorbed by different oxidation states of the same transition metal, resulting in different colours.

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### Targeted Performance Bands: 2–5

Criteria	Marks
<ul style="list-style-type: none"> <li>• Outlines a logical procedure for the investigation AND describes the results</li> <li>• Identifies the change in oxidation state of the transition metal</li> <li>• Writes a half-equation for the oxidation or reduction reaction described</li> </ul>	4
<ul style="list-style-type: none"> <li>• Outlines a logical procedure for the investigation AND describes the results</li> <li>• Identifies the change in oxidation state of the transition metal</li> </ul>	3
<ul style="list-style-type: none"> <li>• Outlines a logical procedure for the investigation AND describes the results</li> </ul>	2
<ul style="list-style-type: none"> <li>• Outlines a logical procedure for the investigation only</li> </ul>	1

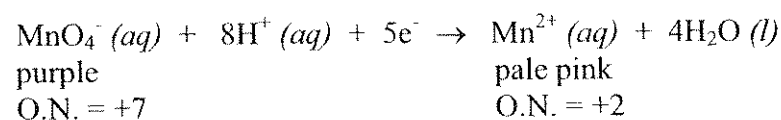
## Procedure

Procedure  
A purple solution of acidified potassium permanganate was placed in a test tube and an equal volume of ethanol added to the test tube. The test tube was heated gently in a water bath. The test tube was observed to record a colour change. The odour of the contents of the test tube after the colour change was compared with the odour of a control test tube containing only ethanol.

The purple solution changed initially to a brown and then to a very pale pink (almost colourless).

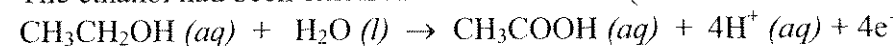
The final solution had an odour (resembling vinegar) which was different from that of the original ethanol.

The following reduction process had occurred.



The oxidation state of the manganese atom had changed from +7 to +2. This change was accompanied by the change in colour. The intermediate brown colour would have been due to the intermediate,  $\text{MnO}_2$ , in which the oxidation number of manganese is +4.

The ethanol had been oxidised to ethanoic acid (hence the smell of vinegar).



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(d) (6 marks)

**Outcomes Assessed: H3, H4**

**Targeted Performance Bands: 2–6**

Criteria	Marks
<ul style="list-style-type: none"><li>Describes the Bohr model of the atom, including electrons orbiting in discrete energy levels and electrons not losing energy as they did so</li><li>Contrasts this with the Rutherford model to show how Bohr's model improved understanding</li><li>Discusses evidence supporting the Bohr model</li><li>Discusses the limitations of the Bohr model</li></ul>	5-6
<ul style="list-style-type: none"><li>Describes the Bohr model of the atom, including electrons orbiting in discrete energy levels and electrons not losing energy as they did so</li><li>Contrasts this with the Rutherford model to show how Bohr's model improved understanding</li><li>Discusses evidence supporting the Bohr model</li></ul>	4-5
<ul style="list-style-type: none"><li>Describes the Bohr model of the atom, including electrons orbiting in discrete energy levels and electrons not losing energy as they did so</li><li>Contrasts this with the Rutherford model to show how Bohr's model improved understanding</li></ul>	2-3
<ul style="list-style-type: none"><li>Describes the Bohr model of the atom in terms of discrete energy levels</li></ul>	1

**Sample answer:**

The Bohr model of the 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 2 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.

This theory solved one of the biggest questions surrounding the earlier model of the atom as proposed by Rutherford. Rutherford's planetary view of electron movement involved electrons moving around a central nucleus. A charged particle moving in a curved path should release electromagnetic radiation and thus become less energetic and unable to maintain its orbit. The Bohr model removed the possibility of a gradual loss of energy through the proposed fixed discrete energy levels.

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 throw out a model if it cannot provide answers for more than a minimal number of examples.

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(e) (i) (2 marks)

**Outcomes Assessed: H6, H7**

**Targeted Performance Bands: 3–5**

Criteria	Marks
• Identifies TWO differences	2
• Identifies ONE difference	1

**Sample answer:**

The electrons in each of the sub-levels occupy differently shaped regions of space around the nucleus. (Electrons in s sub-shells occupy spherical regions whereas in the p sub-shells the electrons occupy dumbbell shaped spaces.)

The electrons in the s and p sub-shells in the same shell have different energies.

(e) (ii) (1 mark)

**Outcomes Assessed: H13**

**Targeted Performance Bands: 3–4**

Criteria	Mark
• States the Pauli Exclusion Principle	1

**Sample answer:**

No two electrons belonging to the same atom can exist in the same quantum state (can have the same 4 quantum numbers – principal shell, sub-shell, orbital and spin)

(e) (iii) (1 mark)

**Outcomes Assessed: H6, H7, H13**

**Targeted Performance Bands: 4–5**

Criteria	Mark
• Correct answer	1

**Sample answer:**

$1s^2 2s^2 2p^6 3s^2 3p^5 3d^3 4s^2$

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(e) (iv) (2 marks)

**Outcomes Assessed: H6, H13**

**Targeted Performance Bands: 3–5**

Criteria	Marks
• Identifies the transition metal AND draws the electron spin orbital diagram for the +3 ion	2
• Identifies the transition metal OR • Draws the electron spin orbital diagram for the +3 ion	1

**Sample answer:**

The metal is iron.

The electron spin orbital diagram for the +3 ion is represented:



(f) (i) (1 mark)

**Outcomes Assessed: H6, H13**

**Targeted Performance Bands: 3–4**

Criteria	Mark
• Correct answer	1

**Sample answer:**

A chelated ligand

(f) (ii) (2 marks)

**Outcomes Assessed: H6, H13**

**Targeted Performance Bands: 3–5**

Criteria	Marks
• Describes a lone/non-bonding pair from N occupying an orbital of Fe • Identifies the bond as dative/coordinate bond	2
• Describes a lone/non-bonding pair from N occupying an orbital of Fe OR • Identifies the bond as dative/coordinate bond	1

**Sample answer:**

The bond is a dative/coordinate bond, formed when the lone/non-bonding pair of electrons on the N atom is attracted to, and occupies, an unoccupied d orbital of the Fe atom.

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**Question 35 – Forensic Chemistry (25 marks)**

(a) (2 marks)

**Outcomes Assessed: H4****Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Identifies examples of inorganic compounds or metals found in soils</li> <li>Provides examples of how inorganic compounds or metals can be used to provide very specific location details</li> <li>Indicates that soil evidence can be used to link a suspect to a crime scene</li> </ul>	2
<ul style="list-style-type: none"> <li>Identifies examples of inorganic compounds or metals found in soils</li> </ul> OR <ul style="list-style-type: none"> <li>Provides examples of how inorganic compounds or metals can be used to provide very specific location details</li> </ul>	1

**Sample answer:**

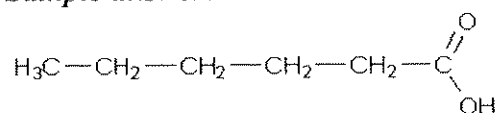
Soil particle size varies considerably as does the chemical composition of soils.

An example of this is the high proportions of quartz located in Eastern Australia, with the analysis of other minerals, such as calcium carbonate, being used to make a more specific prediction of the location of the source. Comparison of soil particle size and chemical content can be used as evidence to link the suspect to a particular location.

(b) (i) (2 marks)

**Outcomes Assessed: H9, H13****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"> <li>Correctly identified diagrams of BOTH 1-hexanol AND hexanoic acid</li> </ul>	2
<ul style="list-style-type: none"> <li>Correctly identified diagram of 1-hexanol</li> </ul> OR <ul style="list-style-type: none"> <li>Correctly identified diagram of hexanoic acid</li> </ul>	1

**Sample answer:**

Hexanoic acid



1-hexanol

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**Targeted Performance Bands: 2-5**

(c) (i) (3 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Clearly outlines procedure used to separate mixture</li><li>Identifies use of electrical potential across a gel or other appropriate medium</li><li>Identifies need for a buffer solution</li></ul>	3
<ul style="list-style-type: none"><li>Clearly outlines procedure used to separate mixture</li><li>Identifies use of electrical potential across a gel or other appropriate medium</li></ul>	2
<ul style="list-style-type: none"><li>Clearly outlines procedure used to separate mixture</li></ul>	1

**Sample answer:**

Many possible responses

The material to be separated is placed on a solid support, such as acrylamide or agarose gel or paper. The support is placed between the electrodes of a DC supply and the amino acids migrate towards the electrode at a characteristic rate, dependent on both the molecular mass and total charge on the molecules. The pH of the electrolyte must be kept constant by using a buffer solution so that the charge-to-mass ratio of the different components of the mixture remains constant. After the separation is complete, ninhydrin dye is added to the sample to make the positions of the amino acids visible.

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(c) (ii) (4 marks)

**Outcomes Assessed:** H3, H9

**Targeted Performance Bands:** 2-5

Criteria	Marks
<ul style="list-style-type: none"><li>Thoroughly explains why amino acids can be separated by electrophoresis, in terms of the zwitterionic structure of amino acids, and the charge/mass ratio</li><li>Explains the use of electrophoresis for forensic investigation</li></ul>	4
<ul style="list-style-type: none"><li>Soundly explains why amino acids can be separated by electrophoresis, in terms of the zwitterionic structure of amino acids, and the charge/mass ratio</li><li>Explains the use of electrophoresis for forensic investigation</li></ul>	2-3
<ul style="list-style-type: none"><li>Some correct explanation about the structure of amino acids which is relevant to the process of electrophoresis</li></ul> OR <ul style="list-style-type: none"><li>Some correct information about the use of electrophoresis for forensic investigation</li></ul>	1

**Sample answer:**

Amino acids can be separated using electrophoresis because amino acids in neutral solution exist as molecules in equilibrium with an ionic form (known as a zwitterion).

If the pH of the solution is altered the amine or carboxylic acid functional groups of an amino acid gain or lose protons, resulting in a species with an overall positive or negative charge. As a result, amino acids will migrate in an electric field. The speed of migration depends upon the charge-to-mass ratio of the amino acid. The pH of the electrophoresis solution (buffer) can be altered to change the charge of the particles to increase the degree of separation.

The distance of migration in a specific time at a specific voltage and at a particular pH is characteristic of each amino acid.

Electrophoresis is a useful analytical method for forensic investigation. A sample of protein can be matched with another at a crime scene, and hence identified, by hydrolysing the protein into its individual amino acids.

The separation by electrophoresis of individual amino acids present within a protein allows identification of the amino acids present and therefore positive identification of, or matching with, the parent protein.

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(d) (6 marks)

**Outcomes Assessed: H3, H4**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>• Describes that coding regions for humans are almost 100% identical, therefore cannot be used to identify individuals</li><li>• Describes how non-coding regions vary in the number of repeats between individuals</li><li>• Explains the process of DNA analysis</li><li>• Provides examples of the ways in which DNA analysis is used in forensic science</li><li>• Outlines advantages of DNA analysis in forensic science</li><li>• Outlines disadvantages of DNA analysis in forensic science</li><li>• Compares current technologies in DNA analysis to previous technologies</li><li>• Provides a clear evaluation statement</li></ul>	6
<ul style="list-style-type: none"><li>• Describes that coding regions for humans are almost 100% identical, therefore cannot be used to identify individuals</li><li>• Describes how non-coding regions vary in the number of repeats between individuals</li><li>• Explains the process of DNA analysis</li><li>• Provides examples of the ways in which DNA analysis is used in forensic science</li><li>• Outlines advantages of DNA analysis in forensic science OR</li><li>• Outlines disadvantages of DNA analysis in forensic science</li><li>• Provides an evaluation statement</li></ul>	5
<ul style="list-style-type: none"><li>• Describes how non-coding regions vary in the number of repeats between individuals</li><li>• Explains the process of DNA analysis</li><li>• Provides examples of the ways in which DNA analysis is used in forensic science</li><li>• Outlines advantages of DNA analysis in forensic science OR</li><li>• Outlines disadvantages of DNA analysis in forensic science</li></ul>	4
<ul style="list-style-type: none"><li>• Describes how non-coding regions vary in the number of repeats between individuals</li><li>• Explains the process of DNA analysis</li><li>• Provides examples of the ways in which DNA analysis is used in forensic science</li></ul>	3
<ul style="list-style-type: none"><li>• Explains the process of DNA analysis</li><li>• Provides examples of the ways in which DNA analysis is used in forensic science</li></ul>	2
<ul style="list-style-type: none"><li>• Explains the process of DNA analysis</li></ul>	1

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**Sample answer:**

DNA analysis is a powerful tool that can be employed to determine the identity of an individual with almost 100% accuracy. While the sections of DNA involved in protein synthesis are almost identical between individuals, it is the non-coding regions of DNA (the introns) that vary between individuals. The introns differ in length and can be used to identify individuals or relatives of that individual.

The steps involved in DNA analysis involve the collection and isolation of DNA, separation of the introns from the rest of the DNA by enzyme digestion, preparation of multiple copies of the introns by polymerase chain reaction, separation of the copied introns by electrophoresis and comparison of the 'unknown' sample to samples taken from identified individuals to establish either the identity of a person at a crime scene (Wee Waa, 1990s, all of the local men were tested to identify a murderer) or a disaster scene (such as the Bali bombing or 2004 Boxing Day tsunami in Indonesia) or a relationship between individuals (paternity testing). Currently in Australia, up to 10 introns are used for comparison to establish identity.

**Evaluation**

In comparison with fingerprinting and blood typing, DNA analysis is a much more effective tool in identifying individuals. Current DNA analysis technology allows for almost 100% accuracy in identifying individuals (identical twins will have identical DNA "fingerprints") and only a very small amount of DNA is required for analysis - thus it is a very sensitive method. However, it is time consuming and expensive to complete and only certain tissues can be used for analysis. Also, contamination can easily occur if the samples are not correctly handled.

Current DNA analysis methods are much more effective than previous technologies in identifying individuals.

(e) (i) (1 mark)

**Outcomes Assessed: H6, H7**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

Chromium and barium are present.

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(e) (ii) (4 marks)

**Outcomes Assessed: H9, H11**

**Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"><li>• Compares the use of BOTH techniques</li><li>• Describes briefly the use of BOTH techniques by forensic scientists</li></ul>	4
<ul style="list-style-type: none"><li>• Explains the use of BOTH techniques</li><li>• Describes briefly the use of BOTH techniques by forensic scientists</li></ul>	3
<ul style="list-style-type: none"><li>• Describes briefly the use of BOTH techniques by forensic scientists</li></ul>	2
<ul style="list-style-type: none"><li>• Describes briefly the use of ONE of these techniques by forensic scientists</li></ul>	1

**Sample answer:**

Both mass spectrometry and emission spectroscopy are destructive techniques, in that the sample analysed is broken up into fragments or atomised to a gaseous form. However, even when the sample needs to be retained for evidence or for further analysis at a later date, the use of mass spectrometry or emission spectroscopy can be justified when only a small percentage of the sample is used. Both techniques are extremely sensitive and reliable and require only a microscopic sample, such as a small scraping or a sliver of material.

In mass spectrometry, a trace of the sample is bombarded with electrons to produce positive ions. These positive ions are formed from individual atoms or from fragments of the whole molecule. The charge-to-mass ratio of each of these fragments is recorded and the total mass spectrum from a molecule is recorded and compared with libraries showing known molecular substances. The mass spectrum for molecules with more than 8 to 10 atoms is unique (and becomes a unique fingerprint for that molecule) and thus of great use in forensic investigations. The technique can give an accurate quantitative measure of the amount of the compound present in the tested sample. It is most commonly used for identification of organic molecules.

Emission spectroscopy involves exciting a minute amount of a forensic sample (usually by heating the sample to a very high temperature). The sample atomises and the atoms absorb energy. The electrons become excited and move to higher energy levels around the nucleus. These excited electrons emit energy of a definite frequency when they fall back to their normal or ground state configuration. The pattern of light frequencies emitted by a particular atom is unique to that atom, and so forms a fingerprint to allow reliable identification of that atom in a compound. The trace of sample is thus destroyed, as molecules or ionic compounds are converted into their individual gaseous atoms. Hence, unlike mass spectrometry, emission spectroscopy cannot identify a compound but can identify the atoms present in that compound. The technique is destructive and is qualitative (unlike mass spectrometry which is quantitative and can give a "fingerprint" of the component compounds) but is of great use in forensic chemistry as it only requires a very small sample. It is most commonly used for identification of elements (particularly metals) and inorganic compounds. It is not useful for identification of organic compounds as it atomises the compounds and most organic compounds are made from the same elements.

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