



## CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

### 2009 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	H4, H9	3-4
3	B	H6, H8	3-4
4	D	H6	3-4
5	B	H3, H6	3-4
6	C	H8	4-5
7	C	H6, H13	3-4
8	B	H8, H14	4-5
9	A	H8, H10	5-6
10	B	H10	3-4
11	C	H9, H10	5-6
12	D	H4, H8	3-4
13	A	H8, H11	2-3
14	D	H4	2-3
15	A	H8, H13	3-4

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**Section I**  
**Part B – 60 marks**

**Question 16 (2 marks)**

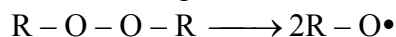
**Outcomes Assessed: H2, H8, H9**

**Targeted Performance Bands: 2-4**

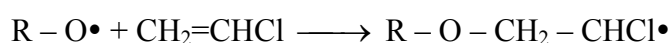
Criteria	Marks
• Describes the steps in the formation of the addition polymer poly(vinyl chloride)	2
• Describes some correct information about the formation of an addition polymer	1

**Sample answer:**

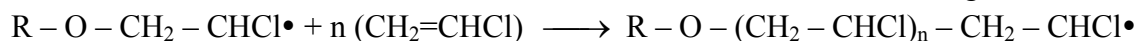
An initiator splits to form free radicals.



These free radicals react with the double bond in the monomer, vinyl chloride (chloroethene) to form a monomer radical.



The monomer radical reacts with other chloroethene monomers and chain growth occurs.



This produces a long chain of repeating – (CH<sub>2</sub> – CHCl) units, which is poly(vinyl chloride).

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**Question 17 (9 marks)**

(a) (2 marks)

**Outcomes Assessed: H8, H9****Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Provides a thorough description of the conditions required to produce ethanol by fermentation of glucose</li> </ul>	2
<ul style="list-style-type: none"> <li>Describes at least TWO correct conditions required to produce ethanol by fermentation of glucose</li> </ul>	1

**Sample answer:**

The conditions for the production of ethanol by fermentation of glucose are:

- an absence of oxygen
- a dilute aqueous solution containing suitable sugar or other carbohydrate
- a temperature of 37°C
- the presence of yeast

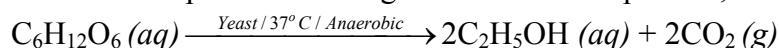
(b) (2 marks)

**Outcomes Assessed: H9, H10, H13****Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"> <li>Explains how mass changes can be used to monitor the fermentation reaction</li> </ul> AND <ul style="list-style-type: none"> <li>Includes a suitable equation</li> </ul>	2
<ul style="list-style-type: none"> <li>Explains how mass changes can be used to monitor the fermentation reaction</li> </ul> OR <ul style="list-style-type: none"> <li>Includes a suitable equation</li> </ul>	1

**Sample answer:**

As ethanol is produced during the fermentation process, CO<sub>2</sub> (g) is also produced.



If the fermentation is carried out in an open container, the mass of the container will fall as the reaction proceeds because carbon dioxide escapes into the air. Monitoring the loss in mass (and hence the progress of the reaction) can be achieved using a data logger or electronic balance.

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(c) (3 marks)

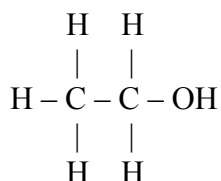
**Outcomes Assessed: H6, H9**

**Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Relates the polar nature of the ethanol molecule to its use as a solvent</li></ul> AND <ul style="list-style-type: none"><li>Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent</li></ul> AND <ul style="list-style-type: none"><li>Provides a justification</li></ul>	3
<ul style="list-style-type: none"><li>Relates the polar nature of the ethanol molecule to its use as a solvent</li></ul> AND <ul style="list-style-type: none"><li>Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent</li></ul>	2
<ul style="list-style-type: none"><li>Relates the polar nature of the ethanol molecule to its use as a solvent</li></ul> OR <ul style="list-style-type: none"><li>Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent</li></ul>	1

**Sample answer:**

Ethanol is often used as a solvent due to its structure:



It has the alkanol functional group (–OH) on one end which makes it polar and hydrophilic (water-loving) and able to dissolve other polar substances, such as water.

It also has a non-polar (hydrophobic) hydrocarbon chain (CH<sub>3</sub>CH<sub>2</sub>–) which enables it to dissolve non-polar substances, such as petrol.

#### Justification

Since ethanol has this “dual nature” due to the two different parts of its structure, it is an ideal solvent for both polar and non-polar chemicals and hence for a wide range of materials. It is especially useful when mixtures of polar and non-polar substances are produced (as in the production of cosmetics and pharmaceutical preparations).

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(d) (2 marks)

**Outcomes Assessed: H3, H9**

**Targeted Performance Bands: 2-4**

Criteria	Marks
• Identifies a logical sequence of steps including fractional distillation, catalytic cracking and hydration	2
• Identifies a logical sequence including TWO of fractional distillation, catalytic cracking and hydration	1

**Sample answer:**

Crude oil is separated into its fractions by fractional distillation.

The long-chain fractions are cracked to produce short chains and alkenes, including ethylene.

Ethylene is hydrated to form ethanol, using water and sulfuric acid catalyst.

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**Question 18** (5 marks)

(a) (2 marks)

**Outcomes Assessed:** H6, H8**Targeted Performance Bands:** 2-4

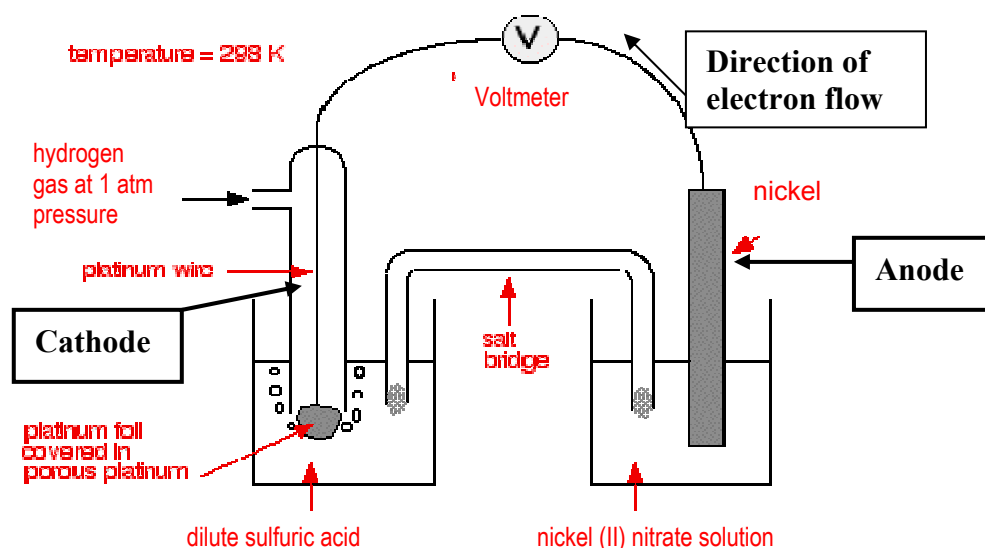
Criteria	Marks
<ul style="list-style-type: none"> <li>Writes TWO correct half-equations</li> <li>Shows the direction of electron flow on the diagram (must be consistent with half-equations)</li> </ul>	2
<ul style="list-style-type: none"> <li>Writes TWO correct half-equations</li> </ul> OR <ul style="list-style-type: none"> <li>Shows the direction of electron flow on the diagram</li> </ul>	1

**Sample answer:**

The electrons flow from the anode (the nickel electrode) through the external circuit to the cathode (the platinum electrode), where the hydrogen ions gain the electrons.

At the anode:  $\text{Ni}(s) \rightleftharpoons \text{Ni}^{2+}(aq) + 2e^{-}$

At the cathode:  $2\text{H}^{+}(aq) + 2e^{-} \rightleftharpoons \text{H}_2(g)$



(b) (1 mark)

**Outcomes Assessed:** H6, H8**Targeted Performance Bands:** 2-4

Criteria	Mark
<ul style="list-style-type: none"> <li>Labels the anode and cathode</li> </ul>	1

**Sample answer:**

See diagram above.

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(c) (2 marks)

**Outcomes Assessed: H4**

**Targeted Performance Bands: 2-3**

Criteria	Marks
• Suggests TWO valid reasons	2
• Suggests ONE valid reason	1

**Sample answer:**

The reaction only produces a voltage of 0.24 V, too small for commercial use.

The hydrogen half-cell has a platinum electrode. This would make the cell very expensive.

(The reaction produces hydrogen gas which would build up pressure inside a sealed commercial cell.)

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**Question 19** (4 marks)

(a) (2 marks)

**Outcomes Assessed: H3, H4, H6, H12****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"> <li>Explains the choice of phosphorus-32, in terms both of radiation emitted and half-life</li> </ul>	2
<ul style="list-style-type: none"> <li>Deduces that the isotope cannot be an alpha emitter</li> </ul> OR <ul style="list-style-type: none"> <li>Deduces that the isotope has a half-life of 14 days</li> </ul>	1

**Sample answer:**

The radioisotope has to be a beta or gamma emitter because the paper between the rock and the film would have blocked alpha particles.

The time difference for the development of the image of the same intensity (20 minutes versus 5 minutes) means that the scintillation rate had dropped to a quarter of its original value, meaning that two half-lives had passed in the interim 28 days. Thus the half-life of the isotope must be 14 days. The isotope must be a beta emitter or gamma emitter with a half-life of 14 days. The only isotope in the table that has both of these properties is phosphorus-32.

(b) (1 mark)

**Outcomes Assessed: H3****Targeted Performance Bands: 2-3**

Criteria	Mark
<ul style="list-style-type: none"> <li>Identifies ONE instrument or process (other than a photographic film) which can be used to detect radiation</li> </ul>	1

**Sample answer:**

Geiger-Müller counter

(c) (1 mark)

**Outcomes Assessed: H6, H13****Targeted Performance Bands: 3-4**

Criteria	Mark
<ul style="list-style-type: none"> <li>Correct answer</li> </ul>	1

**Sample answer:**

Actinium-227

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**Question 20** (6 marks)

(a) (1 mark)

**Outcomes Assessed: H1****Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

Lowry and/or Brønsted

(b) (i) (1 mark)

**Outcomes Assessed: H4****Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

High temperature combustion of nitrogen and oxygen – as in internal combustion engines or coal-fired power stations

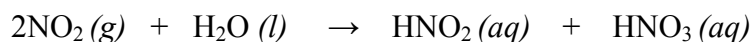
(b) (ii) (2 marks)

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

Criteria	Marks
• Explains the formation of acid rain AND • Writes a balanced equation with states	2
• Explains the formation of acid rain OR • Writes a balanced equation with states	1

**Sample answer:**

The acidic oxide, nitrogen dioxide, reacts with water (from rain) to produce a mixture of nitrous and nitric acids.

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(c) (2 marks)

**Outcomes Assessed: H14**

**Targeted Performance Bands: 2-4**

Criteria	Marks
• Models the substances and their quantities, correctly showing no HA present, equal quantities of $\text{H}_3\text{O}^+$ and $\text{A}^-$ and the same amount of $\text{H}_3\text{O}^+$ and $\text{A}^-$ as the original HA	2
• Models the substances qualitatively showing no HA present and both $\text{H}_3\text{O}^+$ and $\text{A}^-$	1

**Sample answer:**



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**Question 21** (5 marks)

(a) (2 marks)

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

Criteria	Marks
• Calculates the mass with correct units and THREE significant figures	2
• Calculates the mass	1

**Sample answer:**

$$V_{\text{NaOH}} = 100.0 \text{ mL} = 0.1000 \text{ L}$$

$$c_{\text{NaOH}} = 0.100 \text{ mol L}^{-1}$$

$$\begin{aligned} n_{\text{NaOH}} &= c_{\text{NaOH}} \times V_{\text{NaOH}} \\ &= 0.100 \text{ mol L}^{-1} \times 0.1000 \text{ L} \\ &= 0.0100 \text{ mol} \end{aligned}$$

$$\begin{aligned} m_{\text{NaOH}} &= n_{\text{NaOH}} \times M_{\text{NaOH}} \\ &= 0.0100 \text{ mol} \times 39.998 \text{ g mol}^{-1} \\ &= 0.400 \text{ g (3 significant figures)} \end{aligned}$$

(b) (3 marks)

**Outcomes Assessed: H14****Targeted Performance Bands: 2-6**

Criteria	Marks
• Evaluates the appropriateness of THREE aspects of the method, demonstrating a thorough knowledge of primary standards and an understanding of accuracy and titration techniques	3
• Discusses the appropriateness of TWO aspects of the method	2
• Identifies ONE inappropriate or appropriate step in the method	1

**Sample answer:**

The use of the deionised water and the volumetric flask were appropriate, as both would contribute to the production of a pure solution of accurate concentration.

A primary standard should be solid, extremely pure, stable, with a high molecular weight and high solubility. Sodium hydroxide is a solid having a high solubility. However, it is not stable in air, being hygroscopic (absorbing water) and readily reacting with carbon dioxide from the air. Therefore the sample weighed out was probably impure and would produce a solution of lower concentration than expected, as some of the weight would be water or sodium carbonate, rather than sodium hydroxide. As sodium hydroxide does not have a high molecular weight, the error when weighing will be more significant than with other heavier bases.

Sodium hydroxide is highly corrosive to skin and eyes and releases heat when dissolved in water. The choice of a hazardous chemical, when safer options are available, is inappropriate.

The student's method would have produced a much more accurate result if the sodium hydroxide solution had first been standardised against an acidic primary standard such as oxalic acid or potassium hydrogen phthalate.

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### Evaluation

Sodium hydroxide as a primary standard is a highly inappropriate choice as it would lead to an inaccurate determination of the concentration of the vinegar. The method introduces hazards (the weighing out of a corrosive solid) and more accurate results would have been obtained if the sodium hydroxide had been standardised against an acidic primary standard prior to titration against the vinegar.

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**Question 22** (5 marks)**Outcomes Assessed:** H8, H14**Targeted Performance Bands:** 2-6

Criteria	Marks
<ul style="list-style-type: none"> <li>Analyses and explains all concentrations and pH readings, demonstrating a thorough knowledge of pH, equilibrium, acid strength and the related degree of ionisation</li> </ul>	5
<ul style="list-style-type: none"> <li>Analyses and explains all concentrations and pH readings, demonstrating a sound knowledge of pH, equilibrium, acid strength and the related degree of ionisation</li> </ul>	3-4
<ul style="list-style-type: none"> <li>Explains some aspects of concentrations AND pH readings</li> </ul>	2
<ul style="list-style-type: none"> <li>Relates a feature in the table to equilibrium or acid strength</li> </ul>	1

**Sample answer:**

Despite having the same initial pH of 2.4, which indicates the  $[H^+]$  in both were equal, the actual concentrations of the acids were very different.

This reflects the different strengths of the two acids. Hydrochloric acid is strong and totally ionises whereas acetic acid is weak and only ionises partially. Therefore, despite the acetic acid having a much higher acid concentration of  $1.0 \text{ mol L}^{-1}$ , the  $[H^+]$  in acetic acid must be only  $0.0040 \text{ mol L}^{-1}$ .

After addition of the salts the hydrochloric acid pH remained the same whilst the acetic acid pH rose to 2.6 indicating a drop in  $[H^+]$ .

As acetic acid is a weak acid it only partially ionises according to the following equilibrium:

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

The addition of sodium acetate increases the concentration of acetate ions.

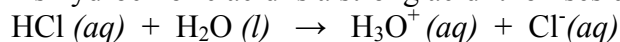
Le Chatelier's Principle states:

*If a chemical system at equilibrium experiences a change in concentration, temperature, volume or pressure, then the equilibrium shifts to counteract the imposed change.*

According to this principle, the equilibrium shown in the above equation would shift to the left to reduce the concentration of acetate ions.

This would reduce the concentration of  $H^+$  and hence would raise the pH.

As hydrochloric acid is a strong acid it ionises completely:



The addition of sodium chloride ions will produce more chloride ions. As there is no equilibrium, the addition of these ions will have no effect. The pH will remain unchanged.

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**Question 23** (4 marks)

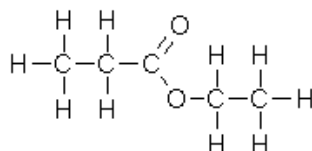
(a) (2 marks)

**Outcomes Assessed:** H9, H13**Targeted Performance Bands:** 2-4

Criteria	Marks
• Correctly names and writes the structural formulae for X AND Y	2
• Correctly names and writes the structural formula for X OR Y	1

**Sample answer:**

One of the compounds is ethyl propanoate.



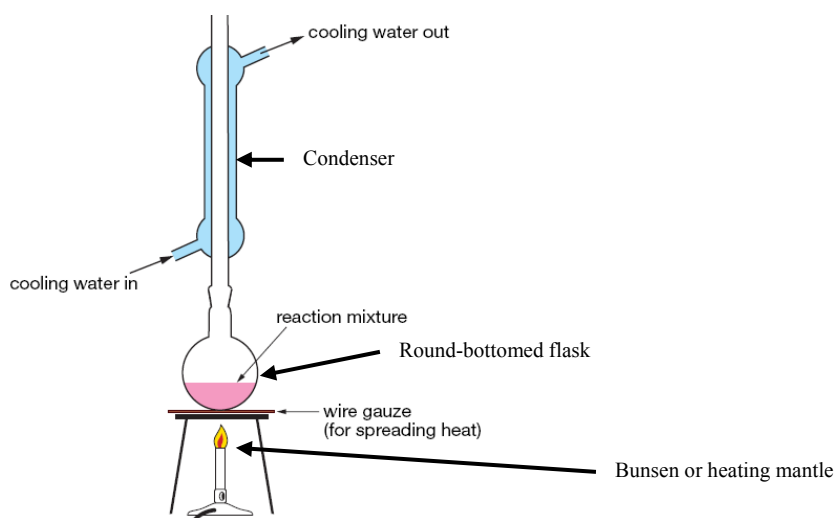
The other compound is water.



(b) (2 marks)

**Outcomes Assessed:** H9, H11, H13**Targeted Performance Bands:** 3-4

Criteria	Marks
• Draws AND labels correctly a reflux apparatus	2
• Partially correct and labelled drawing of a reflux apparatus	1

**Sample answer:****DISCLAIMER**

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**Question 24 (4 marks)****Outcomes Assessed: H4, H8****Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Analyses the statement</li><li>Recognises that the reaction is exothermic</li><li>Recognises that compromises (balancing acts), relating to temperature and use of a catalyst, need to be made to achieve an optimal yield, rather than a high yield or high rate of reaction</li></ul>	4
<ul style="list-style-type: none"><li>Recognises that the reaction is exothermic</li><li>Recognises that compromises (balancing acts), relating to temperature and use of a catalyst, need to be made to achieve an optimal yield, rather than a high yield or high rate of reaction</li></ul>	3
<ul style="list-style-type: none"><li>Recognises that compromise conditions are necessary to achieve an optimal yield</li></ul>	2
<ul style="list-style-type: none"><li>Outlines some correct information with respect to the Haber process concerning reaction energy OR reaction rate OR equilibrium</li></ul>	1

**Sample answer:**

The Haber process is managed to provide the optimal yield of ammonia. In industry an optimal yield is not necessarily the highest yield; it may also reflect the rate of production, the costs of production and the safety of the production method.

Since the enthalpy change (reaction energy) is negative, this means that the overall reaction gives out energy. So, by Le Chatelier's Principle, a low temperature will give a high yield of ammonia but at a slow rate.

A catalyst (iron on the surface of iron oxide) is used to increase the rate of reaction; the catalyst reduces the activation energy for the reaction and hence increases the rate of reaction.

Slow rates are not good for production on an industrial scale, so a compromise (balancing act) is achieved by using a moderate temperature; fast enough to achieve a moderate rate but not so high that the yield is unacceptably low.

The conditions are manipulated (by removing the product as it forms and using high pressure) to compensate for the use of a moderate rather than low temperature.

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**Question 25** (4 marks)

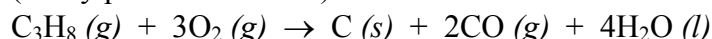
(a) (1 mark)

**Outcomes Assessed: H7, H9, H13****Targeted Performance Bands: 3-4**

Criteria	Mark
• Writes an appropriate balanced equation producing CO or C or a mixture	1

**Sample answer:**

(Many possible answers)



(b) (3 marks)

**Outcomes Assessed: H4, H7, H9****Targeted Performance Bands: 3-5**

Criteria	Marks
• Discusses why incomplete combustion is an issue for society AND • Discusses monitoring and management to achieve a correct oxygen:fuel ratio	3
• Outlines why incomplete combustion is an issue for society AND • Outlines monitoring and management to achieve a correct oxygen:fuel ratio	2
• Outlines why incomplete combustion is an issue for society OR • Outlines monitoring and management to achieve a correct oxygen:fuel ratio	1

**Sample answer:**

Incomplete combustion results in the formation of poisonous carbon monoxide or soot (carbon) or a combination of both. Less energy is released than for complete combustion, the flame is cooler, so valuable fuel is wasted by inefficient combustion. The air quality (soot and carbon monoxide) is impacted. All these aspects make incomplete combustion an issue for society.

In order to reduce the possibility of incomplete combustion, the oxygen: fuel ratio must be monitored and managed so that excess oxygen is available. With excess oxygen, carbon dioxide rather than carbon monoxide or carbon will be produced and the maximum energy from a given amount of fuel will be released.

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**Question 26** (5 marks)

(a) (2 marks)

**Outcomes Assessed: H1, H3, H4****Targeted Performance Bands: 2-4**

Criteria	Marks
• Outlines at least TWO methods used to measure ozone concentration	2
• Outlines ONE method used to measure ozone concentration	1

**Sample answer:**

Early measurements of atmospheric ozone concentration were made using ground-based Dobson UV spectrometers as well as on air samples collected by high-altitude balloons and aircraft. More recent instruments include the total ozone mapping spectrometer (TOMS) and a solar ultraviolet detector orbiting the Earth in the Nimbus-7 satellite.

(b) (1 mark)

**Outcomes Assessed: H1, H3, H4****Targeted Performance Bands: 2-3**

Criteria	Mark
• Outlines the international agreements to phase out the use of ozone-destroying chemicals OR identifies a replacement chemical used	1

**Sample answer:**

Since 1987, there have been international agreements whereby nations have undertaken to phase out the use of CFCs, halons and other ozone-destroying compounds.

Alternate answer: There are now replacements for CFCs that are less damaging molecules, such as HCFCs (most of which are broken down in the troposphere due to less stable bonds) and HFCs (which do not contain any chlorine or bromine atoms).

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(c) (2 marks)

**Outcomes Assessed: H4, H13**

**Targeted Performance Bands: 3-5**

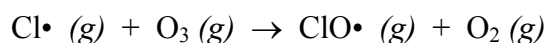
Criteria	Marks
<ul style="list-style-type: none"><li>Explains, using an equation, the formation of a chlorine free radical</li></ul> AND <ul style="list-style-type: none"><li>Explains, using an equation, the reaction of a free radical with ozone</li></ul>	2
<ul style="list-style-type: none"><li>Explains, using an equation, the formation of a chlorine free radical</li></ul> OR <ul style="list-style-type: none"><li>Explains, using an equation, the reaction of a free radical with ozone</li></ul>	1

**Sample answer:**

A CFC molecule, such as  $\text{CCl}_3\text{F}$ , is broken down by UV light to form a chlorine radical,  $\text{Cl}\cdot$ .



The chlorine radical reacts with ozone, reducing the ozone concentration.



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**Question 27 (3 marks)****Outcomes Assessed: H3, H4****Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Discusses at least TWO uses of chemical treatments for mass water supplies AND</li><li>• Discusses the use of membrane filters for purification of mass water supplies</li></ul>	3
<ul style="list-style-type: none"><li>• Discusses at least ONE use of a chemical treatment for mass water supplies AND</li><li>• Discusses the use of membrane filters for purification of mass water supplies</li></ul>	2
<ul style="list-style-type: none"><li>• Discusses at least ONE use of a chemical treatment for mass water supplies OR</li><li>• Discusses the use of membrane filters for purification of mass water supplies OR</li><li>• Identifies ONE chemical treatment for mass water supplies AND identifies a use of membrane filters</li></ul>	1

**Sample answer:**

Drinking water must be purified from its raw state before consumption. Both chemicals and membrane filters are used for purification of water supplies but are used at different stages in the purification processes and when different levels of purity are desired.

Water, for use as drinking water, must be treated by chemicals to precipitate dissolved ions, adjust the pH and flocculate the water to assist in filtration. Chlorination is also used to destroy any disease-carrying bacteria. These methods are relatively cheap and used in treating mass water supplies. They ensure that the purity of the water falls within the parameters allowed by the monitoring body of the local catchment.

Membrane filters increase the level of purity of the water, by removing substances not usually removed in the normal treatment process, such as viruses and even some ions, and are usually only used in the final steps of water treatment. Water is forced under pressure through membranes which have small pores that block the passage of any particles larger than the diameter of the pore. The smaller the pore size of the membrane, the greater the purity of the water. Membrane filters would not be suitable for purifying water directly from a reservoir as the pores would clog quickly. In addition, the cost of the membranes is relatively expensive, thus they are in limited use in treatment of mass water supplies but are used in the production of soft drinks and beer, or treatment of water for medical use. They are used in some community swimming pools to reduce the risk of spread of viruses within a community.

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**Question 28** (4 marks)

(a) (2 marks)

**Outcomes Assessed: H10, H11****Targeted Performance Bands: 3-5**

Criteria	Marks
• Calculates the percentage of sulfate in the lawn fertiliser	2
• Calculates the no. of moles of sulfate precipitated	1

**Sample answer:**

Mass of barium sulfate precipitate = 1.80 g  
 Moles of barium sulfate precipitate =  $1.80/233.40$   
 $= 7.712 \times 10^{-3} \text{ mol}$   
 Hence moles of sulfate ion =  $7.712 \times 10^{-3} \text{ mol}$   
 Mass of sulfate ion =  $7.712 \times 10^{-3} \times 96.06 \text{ g}$   
 $= 0.741 \text{ g}$

% of sulfate in fertiliser =  $0.741/1.03 \times 100\%$   
 $= 71.9\%$

(b) (2 marks)

**Outcomes Assessed: H10, H11****Targeted Performance Bands: 3-5**

Criteria	Marks
• Explains the impact of incorrect techniques on the accuracy of the result	2
• Identifies sources of inaccuracy in washing and drying the precipitate	1

**Sample answer:**

The accuracy of the result could be impacted by failure to wash the precipitate completely. More than one wash stage is required to remove the excess barium or chloride ions or other ions from the fertiliser which might remain adsorbed onto the barium sulfate precipitate. This would mean that the final dried solid would have a greater mass and the value for the percentage of sulfate would be too high.

The precipitate might not have been dried completely and water might remain in the sample weighed. This also would result in an error in the mass of sample and a higher than correct calculation of the percentage of sulfate. Repeated drying and weighing stages (drying to constant mass) are needed to ensure that all water has been removed.

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## Section II – OPTIONS

### Question 29 – Industrial Chemistry (25 marks)

(a) (2 marks)

**Outcomes Assessed: H1, H3, H4**

**Targeted Performance Bands: 2-3**

Criteria	Marks
<ul style="list-style-type: none"><li>Describes the issues associated with the shrinking world resources of one natural material which is not a fossil fuel</li></ul> AND <ul style="list-style-type: none"><li>Identifies a suitable replacement material</li></ul>	2
<ul style="list-style-type: none"><li>Describes the issues associated with the shrinking world resources of one natural material which is not a fossil fuel</li></ul>	1

#### **Sample Answer:**

Many possible answers.

Rubber is a natural product manufactured from the latex obtained from certain varieties of rubber trees. The use of rubber for all aspects of everyday life (hollow tubes, threads for clothing, waterproof shoes and raincoats, balls for tennis and golf, bedding, tyres on bicycles and most significantly, on motor vehicles) continues to grow, and the supplies from rainforests and plantations cannot keep up with the demands.

Synthetic rubbers, based on butadiene from crude oil, have been developed over the past century. In future decades, limitations on the availability of crude oil may force society to seek alternate raw materials for production of synthetic rubber. Research into the use of polymers based on lactic acid derived from crops (wheat, sugar beet) indicates that synthetic rubbers based on biopolymers, rather than on petroleum, may be used in future decades.

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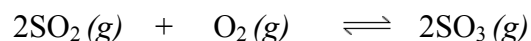
(b) (i) (4 marks)

**Outcomes Assessed: H10, H12**

**Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Gives correct answer with working and equations</li></ul>	4
<ul style="list-style-type: none"><li>Gives correct equilibrium moles for gases</li></ul> AND <ul style="list-style-type: none"><li>Gives correct equilibrium expression</li></ul> AND <ul style="list-style-type: none"><li>Gives correct chemical equation</li></ul>	3
<ul style="list-style-type: none"><li>Gives correct equilibrium expression</li></ul> AND <ul style="list-style-type: none"><li>Gives correct chemical equation</li></ul>	2
<ul style="list-style-type: none"><li>Gives correct equilibrium expression</li></ul> OR <ul style="list-style-type: none"><li>Gives correct chemical equation</li></ul>	1

**Sample Answer:**



Initially      0.360 mol      0.300 mol      0.000 mol

Change      -0.240 mol      -0.120 mol      +0.240 mol

At equil.      0.120 mol      0.180 mol      0.240 mol

In 1 L vessel:

$$\begin{aligned} K &= \frac{[\text{SO}_3(g)]^2}{[\text{SO}_2(g)]^2 [\text{O}_2(g)]} = \frac{(0.240)^2}{(0.120)^2 (0.180)} \\ &= 22.2 \end{aligned}$$

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(b) (ii) (2 marks)

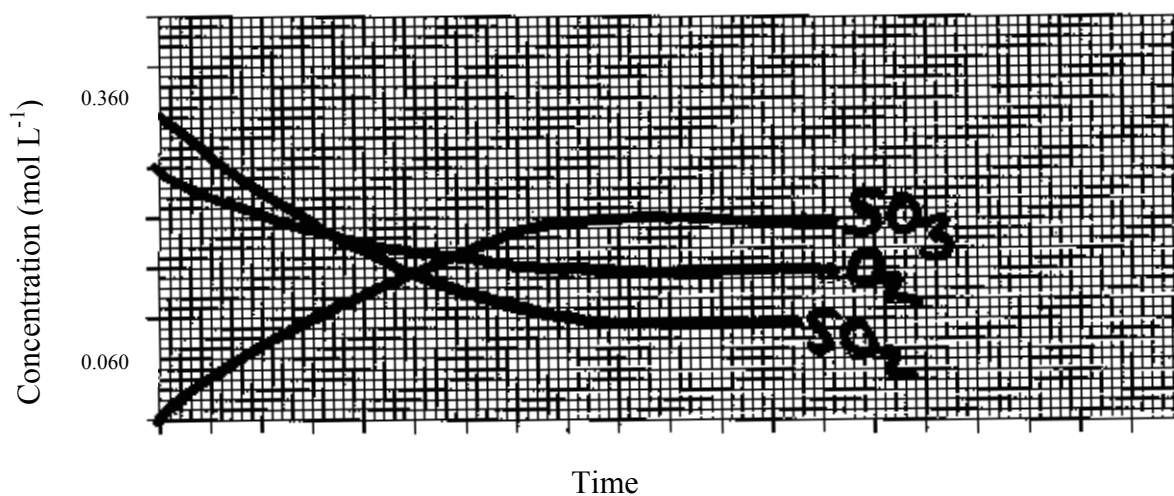
**Outcomes Assessed: H10, H13**

**Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Correctly sketches the data on a graph, consistent with part (b) (i)</li></ul> AND <ul style="list-style-type: none"><li>Clearly labels axes and has an appropriate scale</li></ul>	2
<ul style="list-style-type: none"><li>Correctly sketches the data on a graph, consistent with part (b) (i)</li></ul> OR <ul style="list-style-type: none"><li>Clearly labels axes and has an appropriate scale</li></ul>	1

**Sample Answer:**

Concentrations of Reactants and Product for the Contact Process



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(c) (i) (1 mark)

**Outcomes Assessed: H13**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Correctly defines saponification	1

**Sample Answer:**

Saponification is the process of making soap from a base (e.g. NaOH) and a fat or oil (eg. olive oil).

(c) (ii) (3 marks)

**Outcomes Assessed: H11, H12**

**Targeted Performance Bands: 3-5**

Criteria	Marks
• Correctly outlines the procedure used AND • Outlines how the product was identified	3
• Correctly outlines the procedure used OR • Partially outlines the procedure used AND outlines how the product was identified	2
• Partially outlines the procedure used	1

**Sample Answer:**

Approximately 3 g NaOH was dissolved in 15 mL water in a beaker, and 5 mL olive oil added.

The mixture was heated over a Bunsen for 30 minutes and water was slowly added during the heating process to maintain the volume of the solution. The solution was kept simmering and not allowed to boil vigorously.

After 30 minutes, sodium chloride (solid) was added to salt out the soap.

The solid which formed was filtered from the liquid using a Buchner funnel and retained.

The soap precipitate was washed using a small amount of water.

To identify the soap, a small amount of the soap was placed into a test tube with some water. A stopper was placed in the test tube and the test tube shaken. If soap is present, foam will form.

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(c) (iii) (3 marks)

**Outcomes Assessed: H2, H3, H4, H9**

**Targeted Performance Bands: 2-5**

Criteria	Marks
• Thoroughly accounts for the cleaning action of soap	3
• Identifies water solubility of soaps AND • Identifies polar and non-polar ends of soaps	2
• Identifies water solubility of soaps OR • Identifies polar and non-polar ends of soaps	1

**Sample Answer:**

Soap is an ionic salt composed of a long hydrocarbon chain with a terminal anionic group and a simple cation such as  $\text{Na}^+$  or  $\text{K}^+$ . It is water soluble.

The hydrocarbon tail is hydrophobic (water-hating) whilst the anionic group (charged head) is hydrophilic (water-loving).

In dilute water solutions these soap anions form a surface layer in which the hydrophobic tails are out of water and the hydrophilic heads are stabilised in the water by ion-dipole attractions.

Dirt is usually mixed with grease. The non-ionic hydrocarbon end of the molecule dissolves in the grease and the ionic hydrophilic (water-loving) end dissolves in water. Thus soap molecules help to emulsify the grease, making it into small droplets (called micelles) which can mix with water and be washed away.

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(d) (6 marks)

**Outcomes Assessed: H1, H2, H3, H4, H7, H8**

**Targeted Performance Bands: 2-6**

Criteria	Marks
• Evaluates the THREE industrial production methods for sodium hydroxide, by considering the chemical reactions and technologies involved and evaluates their relative impacts on society and the environment	6
• Demonstrates a thorough knowledge of the THREE industrial production methods for sodium hydroxide, the chemical reactions and technologies involved and discusses their impacts on society and the environment	5
• Demonstrates a limited knowledge of the THREE industrial production methods for sodium hydroxide, the chemical reactions and technologies involved and outlines their impacts on society and the environment	3-4
• Demonstrates a limited knowledge of the THREE industrial production methods for sodium hydroxide	1-2

**Sample answer:**

The production of sodium hydroxide has changed over time from the diaphragm and mercury cells (both 1890s) to the membrane cell process.

For the diaphragm cell process, iron is the cathode (iron mesh). The anode is titanium. Brine flows through the cell.

Anode:  $2\text{Cl}^-(aq) \rightarrow \text{Cl}_2(g) + 2e^-$

Cathode:  $2\text{H}_2\text{O}(l) + 2e^- \rightarrow \text{H}_2(g) + 2\text{OH}^-(aq)$

The chief technical and environmental problem associated with use of this cell was the use of the asbestos membrane. Airborne particles from asbestos can cause major respiratory problems in humans.

The porous asbestos diaphragm allowed the (necessary) migration of sodium ions from the brine into the cathode compartment, but also allowed migration of chloride ions from the anode compartment into the cathode compartment (causing residual sodium chloride in the sodium hydroxide) and migration of hydroxide ions from the cathode compartment into the waste brine (causing the formation of hypochlorite ion ( $\text{OCl}^-$ ) from reaction of hydroxide and chlorine). This hypochlorite ion is a strong oxidant which needs to be removed before discharge of the waste brine into the environment.

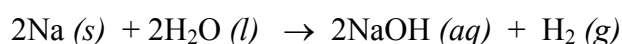
Because of these technical and environmental problems, diaphragm cells are no longer built and few are still in use.

For the mercury cell process, mercury is the cathode and it flows on the floor of a tank. The anodes are titanium plates. Brine flows through the tank.

Anode:  $2\text{Cl}^-(aq) \rightarrow \text{Cl}_2(g) + 2e^-$

Cathode:  $\text{Na}^+(aq) + e^- \rightarrow \text{Na}(\text{amalgam with Hg})(l)$

The sodium from the cathode reaction flows into a second tank where it reacts with water to form sodium hydroxide.



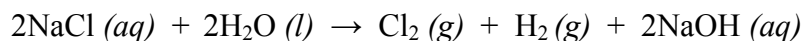
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The cell uses mercury and requires a very high current. It produces very pure sodium hydroxide. However, it is hard to prevent traces of mercury in the waste brine. Metallic mercury, if released into the environment, is insoluble and sinks to the bottom of waterways. Here some bacteria exist which can convert the mercury into mercury compounds which are poisonous (mercury affects the nervous system and the brain). Compounds of mercury in ocean water can be taken up by organisms and passed along the food chain with biological concentration (bioaccumulation) at each stage. The result is that end consumers (humans eating fish) can receive quite significant doses of mercury. As a result, despite their efficiency, very few mercury cells have been built in recent years.

The membrane cell is like the diaphragm cell but has an improved diaphragm – a membrane which is selective in terms of permeability of ions, producing a higher purity of sodium hydroxide. The availability of new polymers, such as the cation exchange PTFE membrane, overcame the disadvantages of the older diaphragm cell, without introducing further problems. Issues that remain are the high cost of electricity and the need to ensure that the products, chlorine and hydrogen, do not come into contact.

All three industrial processes have the same net equation:



### Evaluation

Even though the THREE different electrolytic cells used for the industrial production of sodium hydroxide have used the same chemical reaction (and hence the same raw material, brine), the production of sodium hydroxide via the membrane process is now the preferred method and all new sodium hydroxide plants use this technology.

Whilst the mercury cell is still used in some countries for production of sodium hydroxide and is energy efficient, the purity of the sodium hydroxide from the membrane cell process is far superior and outweighs the extra cost of production.

The membrane cell is also preferred since it does not involve the use of mercury or asbestos, which are hazards to society and the environment. Furthermore, the problems associated with the discharge of the hypochlorite ion with the waste brine have been overcome.

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(e) (4 marks)

**Outcomes Assessed: H1, H3, H4, H5, H7, H8**

**Targeted Performance Bands: 2-6**

Criteria	Marks
• Critically assesses the THREE sites in relation to their suitability for the Solvay process	4
• Discusses the THREE sites in relation to their suitability for the Solvay process	3
• Discusses correctly some aspects of the criteria for selection of sites for the Solvay process	2
• Outlines some correct information about the Solvay process	1

**Sample answer:**

The raw materials required for the production of sodium carbonate are limestone and brine and the products are calcium chloride (waste) and sodium carbonate.

Steps in creation of sodium carbonate:

- Brine (NaCl) is purified so that it is suitable for use in the process.
- Sodium hydrogen carbonate (NaHCO<sub>3</sub>) is formed from the reaction between carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O), ammonia (NH<sub>3</sub>) and sodium chloride (NaCl).
- Sodium hydrogen carbonate (NaHCO<sub>3</sub>) is heated and turned into sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>).
- Ammonium chloride (NH<sub>4</sub>Cl) formed in the reaction is turned back to ammonia (NH<sub>3</sub>) and reused.

The most important factors in determining a site for production include availability of raw materials (brine, limestone), availability of transport, availability of sufficient energy at competitive rates, location of markets for the product (product can be sold), availability of a workforce at reasonable cost, and suitability of nearby sites for disposal of wastes (wastes are excess heat and solid CaCl<sub>2</sub>). In Australia, most Solvay plants are located on the coastline, so that excess heat can be dissipated directly into the ocean, to minimise the impact of thermal pollution.

### Assessment

Site B has the advantage of availability of power at a reasonable cost, as it is so close to the power plant. Site C has the advantage, not only of being on the train line, but also of being close to limestone deposits, close enough to the city to have ready access to the workforce and close enough to a port to be able to have access to brine. However, it does not have ready access to the ocean for direct disposal of the wastes, heat and the calcium chloride.

Site A, inland from a large city, has advantages over the other two sites, in that a workforce is available, the ocean is nearby for the supply of brine, power supplies will be in place for the city and limestone deposits can be transported by rail. However, Site A it is not on the coastline, so disposal of wastes cannot be conveniently achieved.

A better option would be to consider a fourth alternate site, close to A and its port, with the ability to dispose of the wastes directly into the ocean.

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**Question 30 – Shipwrecks, Corrosion and Conservation (25 marks)**

(a) (i) (1 mark)

**Outcomes Assessed: H4****Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies correctly	1

**Sample answer:**

Cathodic protection

(ii) (2 marks)

**Outcomes Assessed: H8****Targeted Performance Bands: 3-5**

Criteria	Marks
• Explains that the ship will corrode, as the passivating layer transfers the role of anode from the zinc to the iron hull	2
• Describes a passivating layer as a barrier to further oxidation of the zinc	1

**Sample answer:**

The presence of a passivating layer on the zinc anode would prevent further oxidation of the zinc. As the zinc would no longer act as a sacrificial anode, the ship would not act as a cathode and would therefore not be protected from oxidation.

(b) (3 marks)

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

Criteria	Marks
• Explains the process through the use of appropriate equations	3
• Explains some steps with the use of at least one appropriate equation	2
• Describes a feature of the rusting process	1

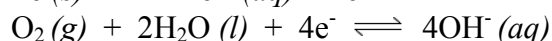
**Sample answer:**

Rusting is the formation of hydrated iron oxide,  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ . It involves the corrosion of iron in the presence of oxygen, water and an electrolyte. The corrosion of iron can be represented by the following equations:

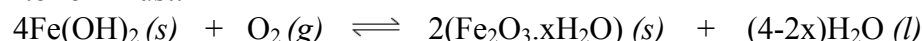
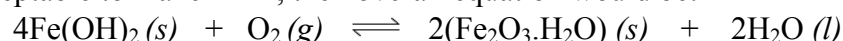
Oxidation of iron:



Reduction of oxygen:

Precipitation of iron (II) hydroxide:  $\text{Fe}^{2+}(aq) + 2\text{OH}^{-}(aq) \rightarrow \text{Fe}(\text{OH})_2(s)$ 

Redox reaction to form rust:

Note: It is acceptable to make  $x = 1$ , then overall equation would be:**DISCLAIMER**

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(c) (i) (1 mark)

**Outcomes Assessed: H4, H8**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies correctly	1

**Sample answer:**

Bacteria or carbon dioxide

(c) (ii) (4 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-5**

Criteria	Marks
• Explains how valid comparisons could be made due to the use of controls, repetition and an appropriate means of measuring the corrosion rate	4
• Explains most of the above features	3
• Describes a valid method	2
• Explains one aspect of the method that allowed for a valid comparison of rates	
• Identifies basic steps in an appropriate method OR	1
• Identifies a requirement of a valid method	

**Sample answer:**

In my investigation three steel nails were placed in a petri dish containing agar gel made from seawater and the indicator potassium ferricyanide. Acid was added to the remaining agar so that three more dishes (each with THREE steel nails) could be set up with pH levels of 6, 5 and 4 respectively.

The nails in each dish were observed at regular intervals to compare the amount of Prussian blue forming due to the oxidation of the iron in the steel nails.

The method allowed for valid comparisons of rates of corrosion as the four dishes were set up under identical conditions (i.e. temperature, agar concentration, salinity, steel nail quality, time, etc) except for the independent variable pH. By observing and comparing the amount of indicator colour at regular intervals, a comparison of oxidation rates (and hence corrosion rates) could be made. Having three nails in each dish (with similar results) ensured the reliability of the experiment.

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(d) (i) (1 mark)

**Outcomes Assessed: H1**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies correctly	1

**Sample answer:**

Voltaic pile or galvanic cell or electrochemical cell

(d) (ii) (2 marks)

**Outcomes Assessed: H7, H8**

**Targeted Performance Bands: 3-5**

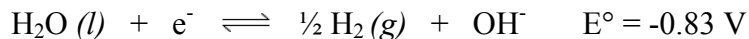
Criteria	Marks
• Explains the preferential reduction of water using standard potentials	2
• Identifies that the reduction of water will occur in aqueous solutions	1

**Sample answer:**

Electrolysis of molten sodium chloride will result in reduction of sodium ions to form sodium metal.



In aqueous solutions the reduction of water will occur as it has a much more positive reduction potential.



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(e) (6 marks)

**Outcomes Assessed: H3, H8**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>• Discusses a range of procedures that both clean and stabilise, identifying issues and points for and against</li><li>• Explains thoroughly differences in the treatments</li></ul>	6
<ul style="list-style-type: none"><li>• Explains a range of procedures</li><li>• Explains some differences in the treatments</li></ul>	4-5
<ul style="list-style-type: none"><li>• Describes some treatments for both artefacts</li></ul>	3
<ul style="list-style-type: none"><li>• Describes a treatment for an iron artefact</li></ul>	2
<ul style="list-style-type: none"><li>• Identifies a treatment for an artefact</li></ul> OR <ul style="list-style-type: none"><li>• Identifies a difference in the condition of the two artefacts</li></ul>	1

**Sample answer:**

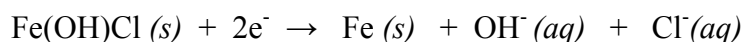
The most significant differences in the situation of the two artefacts are the electrolyte in which they have been submerged and the temperature. The anchor has been in warm sea water and the boiler and engine in cooler fresh water. These differences would have a major impact on the different condition of each artefact, the degree of corrosion and the subsequent treatment.

The anchor could have a significant build-up of **concretions** and coral, etc, due to its location. These carbonates could be removed by abrasion, hitting with hammers or by immersion in a dilute acid solution. Whilst the use of hammers can result in a faster resolution of the problem, the risk of damage to the artefact is higher. The cooler fresh waters of the river would probably mean the boiler and engine were not affected in this manner.

A marine artefact would be expected to be **saturated with chlorides** and sulfates. These must be removed as they can cause physical deterioration of the surface layers as the ions **crystallise** upon drying of the artefact. Therefore, upon removal from the ocean, the anchor should not be allowed to dry out until after these ions have been removed. This would not be the case for the boiler and engine.

Even more seriously, these ions can also react with water to form acids which will result in **chemical degradation** of the treated artefact.

Chloride ions can be removed from the anchor by **electrolysis**. The anchor should be submerged in an electrolyte solution of sodium hydroxide and connected to the negative terminal of an external power supply. The anchor 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. This is an expensive and time and energy consuming process that may take years to complete.

The boiler and engine should not contain dissolved ions and would require **rinsing** in water to remove sediment. This process should be relatively quick and inexpensive.

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At this stage both artefacts could be thoroughly **washed** in pure water, completely **dried** by blowing hot air over them and then **coated with a microcrystalline wax** that both protects from further corrosion and imparts an attractive lustre.

Both artefacts would need regular monitoring to ensure no deterioration.

(f) (i) (1 mark)

**Outcomes Assessed: H7**

**Targeted Performance Bands: 2-3**

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

**Sample answer:**

As the temperature of water increases the solubility of oxygen decreases.

(f) (ii) (3 marks)

**Outcomes Assessed: H8, H12, H14**

**Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"> <li>Explains using a thorough knowledge of availability of oxygen, biological processes and deep ocean currents</li> </ul>	3
<ul style="list-style-type: none"> <li>Explains using some of the above</li> </ul>	2
<ul style="list-style-type: none"> <li>Identifies factors that determine the shape of the graph</li> </ul>	1

**Sample answer:**

Graph A can be divided into three main sections:

1. At the surface of the ocean the concentration of dissolved oxygen is at a maximum because atmospheric oxygen is readily available. Dissolution is also enhanced by wave and wind action. Photosynthetic organisms in the upper 100 m also produce oxygen.
2. Oxygen levels fall dramatically, reaching a minimum at about 1000 m. This is due to the lack of available oxygen gas and the absence of photosynthesis below 100 m due to an inability of light to penetrate below this level. Respiring organisms would also continue to deplete oxygen levels.
3. The graph shows a steady rise in oxygen concentration from 1000 m to 5000 m where it stabilises. This can be explained by the presence of deep ocean currents that bring cold oxygen-rich surface water from polar regions.

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(f) (iii) (1 mark)

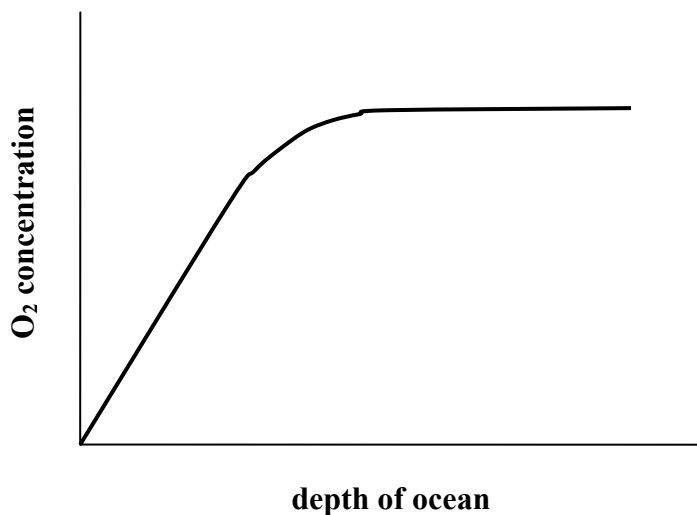
**Outcomes Assessed: H13**

**Targeted Performance Bands: 3-4**

Criteria	Mark
• Identifies the relationship graphically	1

**Sample answer:**

***Relationship that would be expected between depth of ocean and oxygen concentration, if temperature were the only factor determining the relationship***



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**Question 31 – The Biochemistry of Movement (25 marks)**

(a) (i) (1 mark)

**Outcomes Assessed: H9, H13**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Correct answer	1

**Sample answer:**

Carbohydrates or sugars

(a) (ii) (2 marks)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-4**

Criteria	Marks
• States the difference between glucose and glycogen in terms of structure and bonding	2
• States the molecule is glucose and that glycogen is a polymer of glucose	1

**Sample answer:**

The molecule in part (a) is the glucose molecule, whilst glycogen is a highly branched polymer made from thousands of glucose molecules joined together in specific locations. The main polymer chain forms by alpha-1,4 glycosidic bonds, whilst the branches occur every 8-10 glucose molecules at the 1,6 positions.

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(b) (4 marks)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Analyses the statement</li><li>Describes proteins according to the FOUR levels: primary, secondary, tertiary and quaternary</li><li>Describes features of EACH level</li><li>Identifies the types of forces attracting neighbouring polypeptides</li></ul>	4
<ul style="list-style-type: none"><li>Describes proteins according to the FOUR levels: primary, secondary, tertiary and quaternary</li><li>Describes features of EACH level</li><li>Identifies the types of forces attracting neighbouring polypeptides</li></ul>	3
<ul style="list-style-type: none"><li>Identifies the FOUR levels AND identifies some types of bonding forces</li></ul>	2
<ul style="list-style-type: none"><li>Identifies some aspects of the FOUR levels OR identifies some types of bonding forces</li></ul>	1

**Sample answer:**

Proteins are complex molecules made by condensation polymerisation using amino acids as monomers. There are 20 different amino acids each containing the atoms carbon, hydrogen, oxygen and nitrogen (sulfur and phosphorus may also be present). Each amino acid contains the amine group  $\text{-NH}_2$  and the carboxylic acid group  $\text{-COOH}$ . These are the two sites of interaction where amino acids form peptide bonds during the polymerisation process. Proteins range in size from 100 amino acids to 2000 amino acids.

The shape of the protein is paramount to the nature and function of the protein and is determined by a combination of factors and is described as having 4 levels of organisation.

- The primary structure is the sequence of amino acids within the protein. Because there are 20 amino acids the variety of combinations can lead to a huge number of proteins.
- The secondary structure relates to the spatial arrangement and folding patterns; e.g. spiral, helical.
- The tertiary structure refers to the overall folding pattern of the polypeptide chain; it is the 3-D folding superimposed on the secondary structure.
- The quaternary structure is only relevant where a protein includes two or more polypeptide chains. It is the way it forms an aggregate or whole and how each polypeptide interacts.

The many forces and bonds (electrostatic forces, hydrogen bonding, hydrophobic forces, disulfide bonds) lining various parts of the polypeptide chain(s) determine the final shape of a protein molecule.

Hence the statement is correct, in that proteins are complex and are built around the sequence and combination of amino acids but the overall shape, function and properties of the protein are determined by the forces linking these chains of amino acids to each other.

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(c) (i) (3 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"><li>• Outlines a logical sequence for the procedure used in the investigation AND</li><li>• Outlines a significant safety precaution</li></ul>	3
<ul style="list-style-type: none"><li>• Outlines a logical sequence for the procedure used in the investigation OR</li><li>• Outlines some steps for the procedure used in the investigation AND outlines a significant safety precaution</li></ul>	2
<ul style="list-style-type: none"><li>• Outlines some steps for the procedure used in the investigation OR</li><li>• Outlines a significant safety precaution</li></ul>	1

**Sample answer:**

Procedure

- 6 test tubes were filled with 25 mL of milk and numbered 1 to 6.
- A junket tablet (with enzyme rennin) was crushed and dissolved in 30 mL of water.
- 5 mL of enzyme solution was added to each test tube.
  - Test tube 1 was warmed to 37°C.
  - Test tube 2 was heated to 60°C in a hot water bath.
  - Test tube 3 was placed in crushed ice.
  - 10 mL of 1 mol L<sup>-1</sup> NaOH was added to test tube 4.
  - 10 mL of 1 mol L<sup>-1</sup> HCl was added to test tube 5.
  - 10 mL of 5 mol L<sup>-1</sup> HCl was added to test tube 6.
- The observations were recorded for each test tube.

Safety Precautions

- Safety glasses and gloves were worn when dealing with acids and bases.
- Acids were disposed of safely – the acid was poured into a beaker of water slowly and disposed of down the sink with plenty of water running at the time.

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(c) (ii) (2 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-3**

Criteria	Marks
• Describes correct results for all parts of the experiment	2
• Describes some correct results for the experiment	1

**Sample answer:**

Test tube 1: Milk formed visible chunks (coagulated).

Test tube 2: Milk had no visible change.

Test tube 3: Milk had no visible change.

Test tube 4: Milk formed visible chunks (coagulated).

Test tube 5: Milk had no visible change.

Test tube 6: Milk had no visible change.

(c) (iii) (1 mark)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 3-4**

Criteria	Mark
• Outlines an appropriate conclusion	1

**Sample answer:**

The optimum conditions for the functioning of the enzyme rennin, which cause milk to coagulate, are 37°C and approximately 1 mol L<sup>-1</sup> HCl acidic conditions. If the temperature or pH fluctuates from this fairly specific band the enzyme will denature and not function effectively.

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(d) (i) (3 marks)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 3-6**

Criteria	Marks
• Thoroughly compares the appearance of Type 1 AND Type 2 muscle and relates this to the types of exercise	3
• Describes some aspects of the appearance of Type 1 AND Type 2 muscle and relates this to the types of exercise	2
• Identifies the appearance of Type 1 OR Type 2 muscle	1

**Sample answer:**

Type 1 muscles are designed to contract slowly and steadily; e.g. the flight muscles of migratory birds. They have a rich blood supply and therefore have a dark coloured appearance as they have an adequate oxygen supply for use in aerobic respiration. They are the types of muscles that have many mitochondria and obtain most of their ATP by oxidative phosphorylation. Type 1 muscle is useful in light endurance exercise such as long distance running.

Type 2 muscle cells contract rapidly. They contain fewer mitochondria and have a reduced supply of blood and therefore oxygen. Type 2 muscle fibres are therefore lighter (whiter) in appearance due to this lack of adequate blood supply. As a result they mainly respire anaerobically. They are the type of muscle used in high intensity events such as sprinting or short distance swimming.

(d) (ii) (2 marks)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 3-4**

Criteria	Marks
• Identifies lactate production AND states energy comes from glycolysis	2
• Identifies lactate production OR states energy comes from glycolysis	1

**Sample answer:**

When insufficient oxygen is present, anaerobic glycolysis occurs and supplies the energy for muscle contraction. Glucose is converted to pyruvate, which in turn is converted into lactic acid (lactate).

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(d) (iii) (1 mark)

**Outcomes Assessed: H7, H9**

**Targeted Performance Bands: 3-4**

Criteria	Mark
• Makes the appropriate comparison	1

**Sample answer:**

Only 2 molecules of ATP will be produced in the anaerobic environment during the glycolysis of 1 mole of glucose. In full aerobic respiration there would be 38 molecules of ATP produced.

(d) (iv) (1 mark)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Describes and accounts for the symptoms felt in anaerobic conditions	1

**Sample answer:**

An athlete will feel severe pain and cramping of muscles involved, because of the build-up of lactic acid in muscle tissues.

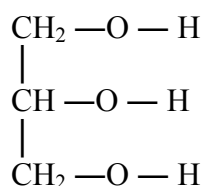
(e) (i) (1 mark)

**Outcomes Assessed: H9, H13**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Draws a correct structural formula	1

**Sample answer:**



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(e) (ii) (2 marks)

**Outcomes Assessed: H6, H9**

**Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"><li>Recognises the high viscosity of glycerol as its resistance to flow</li></ul> AND <ul style="list-style-type: none"><li>Relates the viscosity to the strong H-bonding between adjacent molecules because of 3 –OH groups in each molecule</li></ul>	2
<ul style="list-style-type: none"><li>Recognises the high viscosity of glycerol as its resistance to flow</li></ul> OR <ul style="list-style-type: none"><li>Relates the viscosity to the strong H-bonding between adjacent molecules because of 3 –OH groups in each molecule</li></ul>	1

**Sample answer:**

The viscosity of a liquid is a measure of its resistance to flow. Glycerol has high viscosity because there are strong intermolecular forces (hydrogen bonds) between neighbouring molecules, due to the presence of 3 –OH groups on each molecule.

(e) (iii) (2 marks)

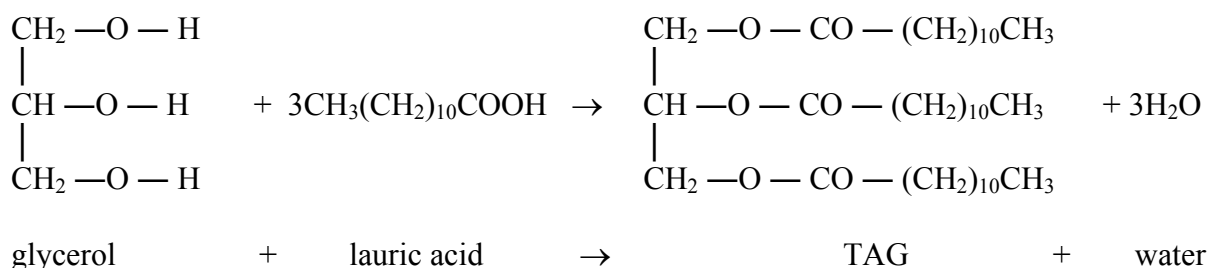
**Outcomes Assessed: H6, H9, H13**

**Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Explains the role of glycerol in the formation of TAGs</li></ul> AND <ul style="list-style-type: none"><li>Writes an equation to show the formation of a TAG</li></ul>	2
<ul style="list-style-type: none"><li>Explains the role of glycerol in the formation of TAGs</li></ul> OR <ul style="list-style-type: none"><li>Writes an equation to show the formation of a TAG</li></ul>	1

**Sample answer:**

TAGs are formed by the reaction of glycerol with fatty acids, such as lauric acid,  $\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$ . Three molecules of the acid react with one molecule of glycerol to form a tri-ester, glyceryl trilaurate.



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**Question 32 – The Chemistry of Art (25 marks)**

(a) (2 marks)

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

Criteria	Marks
<ul style="list-style-type: none"><li>Explains how reflectance spectra are obtained</li></ul> AND <ul style="list-style-type: none"><li>Explains how pigments are identified</li></ul>	2
<ul style="list-style-type: none"><li>Explains how reflectance spectra are obtained</li></ul> OR <ul style="list-style-type: none"><li>Explains how pigments are identified</li></ul>	1

**Sample answer:**

When white light is shone onto a pigment, the spectrum of the light reflected is in many cases unique to the particular pigment used. Many pigments or a mixture of pigments can be identified in this way, by analysing the reflectance spectrum obtained. The frequencies of the lines in the spectrum of the sample are compared with the spectral frequencies of known pigments.

(b) (3 marks)

**Outcomes Assessed: H4****Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>Names at least TWO different pigments once or currently used to produce particular named colours</li></ul> AND <ul style="list-style-type: none"><li>Outlines discoveries of health risks associated with pigments which caused a change in pigment use</li></ul> AND <ul style="list-style-type: none"><li>Outlines discoveries of new materials which allowed replacement of a toxic pigment by a safer option</li></ul>	3
<ul style="list-style-type: none"><li>Names at least TWO different pigments once or currently used to produce particular named colours</li></ul> AND <ul style="list-style-type: none"><li>Outlines discoveries of health risks associated with pigments which caused a change in pigment use</li></ul>	2
<ul style="list-style-type: none"><li>Names at least TWO different pigments once or currently used to produce particular named colours</li></ul> OR <ul style="list-style-type: none"><li>Outlines discoveries of health risks associated with pigments which caused a change in pigment use</li></ul>	1

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**Sample answer:**

The earliest pigments were either pure or near pure minerals, or just coloured rocks, suspended in water. With each ancient discovery of a new mineral, the available range of coloured pigments expanded. Unfortunately, many of the early pigments were poisonous to humans. This became apparent as the use of pigments as cosmetics boomed in some societies.

Some yellow pigments, such as orpiment, were especially deadly as they contained arsenic. Orpiment was eventually replaced by lead oxide, a brilliant yellow solid which was safer than orpiment, but still caused lead poisoning. However, Naples yellow (lead (II) antimonite) is a relatively safe yellow pigment originally mined from the slopes of Mount Vesuvius and still in use today.

The red pigments cinnabar and vermillion, both containing mercury (II) sulfide (HgS), were used extensively in Greece until the health effects of HgS became obvious. Like almost all mercury compounds, it is highly 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. Cadmium red is now used instead of cinnabar or vermillion.

(c) (i) (2 marks)

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

**Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"><li>Refers to the table of reduction potentials to identify the high tendency of the permanganate ion to gain electrons</li></ul> AND <ul style="list-style-type: none"><li>Relates the ability of the permanganate ion to gain electrons to its strength as an oxidising agent</li></ul>	2
<ul style="list-style-type: none"><li>Refers to the table of reduction potentials to identify the high tendency of the permanganate ion to gain electrons</li></ul> OR <ul style="list-style-type: none"><li>Relates the ability of the permanganate ion to gain electrons to its strength as an oxidising agent</li></ul>	1

**Sample answer:**

The table of reduction potentials shows that the permanganate ion has a high tendency to gain electrons (only fluorine (F<sub>2</sub>) has a greater tendency to gain electrons).



Since the permanganate ion readily gains electrons (is reduced), this makes it a strong oxidising agent (strong ability to bring about the oxidation of another species).

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(c) (ii) (2 marks)

**Outcomes Assessed: H6, H7**

**Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies the oxidation state of manganese in the permanganate ion as +7</li></ul> AND <ul style="list-style-type: none"><li>Relates the oxidising strength of potassium permanganate to the high oxidation state (number) of the manganese atom in the permanganate ion</li></ul>	2
<ul style="list-style-type: none"><li>Identifies the oxidation state of manganese in the permanganate ion as +7</li></ul> OR <ul style="list-style-type: none"><li>Relates the oxidising strength of potassium permanganate to the high oxidation state (number) of the manganese atom in the permanganate ion</li></ul>	1

**Sample answer:**

The manganese (Mn) atom in the permanganate ion ( $\text{MnO}_4^-$ ) has an oxidation state of +7. This means it has 7 fewer electrons when compared with the atom of Mn in the elemental form. Because of this high oxidation state, it has a high tendency to gain electrons (be reduced). When the permanganate ion is reduced to manganese (II) ions, it has gained 5 electrons.

In general, the higher the oxidation state of an atom in a species, the greater the tendency to gain electrons from a reducing agent.

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(c) (iii) (4 marks)

**Outcomes Assessed: H6, H7**

**Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies the electron configuration of manganese (VII) ions and manganese (II) ions in terms of s, p, d and f levels</li></ul> AND <ul style="list-style-type: none"><li>Recognises that the manganese (VII) ions and manganese (II) ions have different colours due to different electron configurations</li></ul> AND <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>	4
<ul style="list-style-type: none"><li>Identifies the electron configuration of manganese (VII) ions and manganese (II) ions in terms of s, p, d and f levels</li></ul> AND <ul style="list-style-type: none"><li>Recognises that the manganese (VII) ions and manganese (II) ions have different colours due to different electron configurations</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>	3
<ul style="list-style-type: none"><li>Identifies the electron configuration of manganese (VII) ions and manganese (II) ions in terms of s, p, d and f levels</li></ul> OR <ul style="list-style-type: none"><li>Recognises that the manganese (VII) ions and manganese (II) ions have different colours due to different electron configurations</li></ul> AND <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>	2
<ul style="list-style-type: none"><li>Identifies the electron configuration of manganese (VII) ions in terms of s, p, d and f levels</li></ul> OR <ul style="list-style-type: none"><li>Identifies the electron configuration of manganese (II) ions in terms of s, p, d and f levels</li></ul> OR <ul style="list-style-type: none"><li>Recognises that the manganese (VII) ions and manganese (II) ions have different colours due to different electron configurations</li></ul>	1

**Sample answer:**

The electron configuration of the Mn (VII) ion is  $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$ .

The electron configuration of the Mn (II) ion is  $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$ .

Changing the oxidation state of a transition metal alters the number of d orbitals that are occupied by 0, 1 or 2 electrons.

The Mn (VII) ion has no electrons in d orbitals, while the Mn (II) ion has 5 d orbitals individually occupied by electrons.

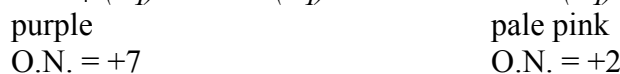
Transition metals exhibit certain colours due to the fact that energy differences between outermost orbitals correspond to visible light frequencies, so changing the electron arrangement even slightly will change the frequencies associated with those jumps.

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When the following reduction process occurs, changes occur in colour because of the changes in oxidation state and in electron configurations.



**Targeted Performance Bands: 2-3**

KMnO<sub>4</sub> is a powerful oxidant and can oxidise many organic materials such as those in our skin, so handling this compound poses some risk. Gloves should be worn during the experiment.

**Targeted Performance Bands: 3-5**

Once the first three electrons have been removed, removing the fourth takes a significantly greater amount of energy, as the next electron will be removed from a 2p orbital, which is much closer to and therefore more tightly held by the nucleus. The energy required to remove subsequent electrons increases until all 8 electrons from the 2s and 2p sub-shells have been removed. There is then another jump in energy, as the last two electrons are removed from the innermost (rather than the second) shell.

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(e) (6 marks)

**Outcomes Assessed: H6, H13**

**Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Analyses the statements</li><li>Explains why almost all the 3d transition metals exhibit variable valency AND uses appropriate examples, referring to electron configurations of these examples</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state AND uses appropriate examples, referring to electron configurations of these examples</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li></ul>	6
<ul style="list-style-type: none"><li>Explains why almost all the 3d transition metals exhibit variable valency AND uses appropriate examples, referring to electron configurations of these examples</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state AND uses appropriate examples, referring to electron configurations of these examples</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li></ul>	5
<ul style="list-style-type: none"><li>Explains why almost all the 3d transition metals exhibit variable valency</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li><li>Uses at LEAST TWO appropriate examples referring to electron configurations of these examples</li></ul>	4
<ul style="list-style-type: none"><li>Explains why almost all the 3d transition metals exhibit variable valency</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li></ul> OR <ul style="list-style-type: none"><li>TWO of the THREE points above</li></ul> AND <ul style="list-style-type: none"><li>Uses at LEAST TWO appropriate examples referring to electron configurations of these examples</li></ul>	3
TWO of the THREE points: <ul style="list-style-type: none"><li>Explains why almost all the 3d transition metals exhibit variable valency</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li></ul> OR <ul style="list-style-type: none"><li>ONE of the THREE points above, with an appropriate example referring to the electron configuration of the example</li></ul>	2
ONE of the THREE points: <ul style="list-style-type: none"><li>Explains why almost all the 3d transition metals exhibit variable valency</li><li>Explains why the 3d transition metals usually exhibit a +2 oxidation state</li><li>Identifies zinc and explains why zinc only exhibits +2 and 0 oxidation states</li></ul>	1

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**Sample answer:**

“...almost all the 3d transition metals exhibit variable valency ...”

This part of the statement is correct, as a characteristic of the 3d transition metals is that they can lose the 2 electrons from their 4s sub-shell only, or can lose the two 4s electrons plus some or all from the 3d sub-shell.

Iron (the metal element) has an electron configuration  $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6, 4s^2$ .

Iron can lose 2 electrons to form  $Fe^{2+} (1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6)$  or can lose 3 electrons to form  $Fe^{3+} (1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5)$ .

Manganese has an electron configuration  $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5, 4s^2$ . The manganese (II) ion ( $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$ ) has lost two electrons from the 4s sub-shell, whereas the manganese (IV) ion ( $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^3$ ) has lost 4 electrons, 2 from the 4s and 2 from the 3d sub-shells. The manganese (VII) ion ( $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$ ) has lost the two 4s electrons and all 5 3d electrons.

These are 2 typical first transition series metals and hence show variable valency.

Because all the metals of the first transition series have two 4s electrons, it is a normal pattern for them to lose these 2 electrons in the formation of ions.

$Fe^{2+} - (1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6)$

$Mn^{2+} - (1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5)$

$Cu^{2+} - (1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^9)$

Hence the part of the statement “...the 3d transition metals usually exhibit a +2 oxidation state” is correct.

The part of the statement “...one of the metals of the first transition series does not exhibit variable valency and only exists in the 0 and +2 oxidation states” is also correct.

The metal referred to here is zinc.

Zinc has an electron configuration  $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2$ . The 3d sub-shell is totally filled, with 10 electrons. Zinc does not show variable valency. Its structure is stable, by having a filled inner 3d level and the only ion it forms is  $Zn^{2+}$ , by loss of the two 4s electrons. Hence zinc only exists in the 0 oxidation state, as the metal, and in the +2 oxidation state, as the ion  $Zn^{2+}$ .

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(f) (3 marks)

**Outcomes Assessed: H6, H13**

**Targeted Performance Bands: 2-5**

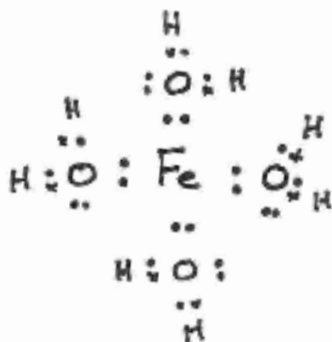
Criteria	Marks
<ul style="list-style-type: none"><li>Explains that hydrated ions have a central ion surrounded by water molecules and are hence classified as complex ions</li><li>Identifies the bond joining the water to the central ion as a co-ordinate bond</li><li>Draws a Lewis formula for a hydrated ion</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:**

All hydrated ions have a simple ion surrounded by water molecules. The central ion and the water molecules form a stable unit, known as a complex ion, with the charge spread over the whole structure. The water 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.

For example, the iron (II) ion forms a hydrated complex with 6 water molecules surrounding the cation. The structure is  $[\text{Fe}(\text{OH}_2)_6]^{2+}$ . An electron pair from each oxygen atom forms a co-ordinate covalent bond with the central ion by placing the pair of electrons into empty orbitals. The shape of the complex is octahedral – only 4 of the 6 ligands in a plane are shown in the Lewis diagram.



Only 4 of the 6 hydrated waters are shown. The other 2 water molecules are above and below the plane of the page.

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**Question 33 – Forensic Chemistry (25 marks)**

(a) (2 marks)

**Outcomes Assessed: H1****Targeted Performance Bands: 2-3**

Criteria	Marks
<ul style="list-style-type: none"><li>• Outlines TWO precautions</li></ul> AND <ul style="list-style-type: none"><li>• Explains why each is important in forensic chemistry</li></ul>	2
<ul style="list-style-type: none"><li>• Outlines TWO precautions only</li></ul> OR <ul style="list-style-type: none"><li>• Outlines ONE precaution and explains why it is important</li></ul>	1

**Sample answer:**

Many possible answers

When samples are collected from a crime scene they must be carefully sealed in a bag or container and then a chain of custody must be followed to ensure no tampering occurs, if the sample is then to be used in a court case.

Samples must be analysed using sterile techniques in a clean laboratory, to ensure that the sample is not contaminated. Otherwise the results from the testing will not be reliable and of little use in a court case.

(b) (i) (2 marks)

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

Criteria	Marks
<ul style="list-style-type: none"><li>• Names a polysaccharide from an animal AND names a polysaccharide from a plant</li></ul> AND <ul style="list-style-type: none"><li>• Identifies the difference in structure</li></ul>	2
<ul style="list-style-type: none"><li>• Names a polysaccharide from an animal and correctly describes its structure</li></ul> OR <ul style="list-style-type: none"><li>• Names a polysaccharide from a plant and correctly describes its structure</li></ul>	1

**Sample answer:**

(Several possible answers)

Cellulose is a polysaccharide produced by plants. It is formed by the polymerisation of  $\beta$ -glucose monomers joined by  $\beta$ -1,4-glycosidic bonds.

Glycogen is a polysaccharide synthesised by animals from glucose. It has short branches along the chain and the glucose units are linked by  $\alpha$ -1,4- and  $\alpha$ -1,6-glycosidic bonds.

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(b) (ii) (2 marks)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-4**

Criteria	Marks
<ul style="list-style-type: none"><li>Identifies reagents used to test for each named polysaccharide</li></ul> AND <ul style="list-style-type: none"><li>Identifies positive test results</li></ul>	2
<ul style="list-style-type: none"><li>Identifies reagents used to test for each named polysaccharide</li></ul> OR <ul style="list-style-type: none"><li>Identifies one reagent and one positive test result</li></ul>	1

**Sample answer:**

Test for cellulose: (note: only ONE test required)

Schultz' reagent turns blue or purple with cellulose (but is not valid if starch is present).

Schweitzer's reagent can be used to dissolve the sample, and a white precipitate forming after the addition of HCl indicates cellulose.

Calcofluor will fluoresce under UV light in the presence of cellulose.

Test for glycogen:

Iodine turns glycogen brown-red in colour.

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(c) (i) (3 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-5**

Criteria	Marks
<ul style="list-style-type: none"><li>• Describes thoroughly the procedure used</li><li>• Identifies the organic materials to be separated</li><li>• Clearly identifies mobile and stationary phases of the chromatography process</li></ul>	3
<ul style="list-style-type: none"><li>• Describes thoroughly the procedure used</li><li>• Identifies the organic materials to be separated</li></ul>	2
<ul style="list-style-type: none"><li>• Describes the procedure used</li><li>• Identifies the organic materials to be separated</li></ul>	1

**Sample Answer:**

1. Cut a strip of filter paper or chromatography paper so that it just fits inside a 15 cm (or larger) test tube. The filter paper (cellulose, with water in pores of paper) is the **stationary phase** of the chromatography. Cut a point at one end of the filter paper. Draw a faint pencil line to mark original position of plant pigment extract. Bend a paper clip and attach it to a cork stopper to attach the paper strip so that it hangs inside the tube. The sides of the strip should not touch the glass.
2. Tear a spinach leaf into small pieces. Put them into a mortar along with a pinch or two of sand to help with grinding. Add about 5 ml ethanol to the leaf pieces. Crush leaves with the pestle until the mixture is finely ground. The liquid in which the leaf pigments are now dissolved is called the pigment extract.
3. Use a glass rod to touch a drop of the pigment extract to the centre of the pencil line on the paper strip. Let it dry. Repeat as many as 20 times, to build up the pigment spot (letting the dot dry after each drop is added to stop the pigment dot from spreading out too much).
4. Pour 5 ml chromatography solvent (e.g. butanol or acetic acid) into the test tube. The solvent is the **mobile phase** of the chromatography. Fit the paper and cork assembly inside. Adjust it so that the paper point just touches the solvent (but not the sides of the tube). The pigment dot must be above the level of the solvent. Watch the solvent rise up the paper, carrying and separating the pigments as it goes. When the solvent reaches the top, remove the paper and let it dry. Observe the bands of pigments.
5. Record the colours and distance travelled of the chromatogram pigments in your results table.

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(c) (ii) (1 mark)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies at LEAST TWO appropriate safety precautions	1

**Sample Answer:**

Do not have a naked flame near your experiment as the ethanol and butanol are flammable.  
Work in a well ventilated area to reduce a build-up of volatile vapours.  
Ensure that samples chosen to test are not likely to irritate skin.

(c) (iii) (2 marks)

**Outcomes Assessed: H11**

**Targeted Performance Bands: 3-5**

Criteria	Marks
• Explains that separation occurs based on the affinity of the pigments for the solvents used in the stationary and mobile phases	2
• Identifies that separation occurs due to different pigments moving different distances because of the different speeds travelled in the mobile phase solvent	1

**Sample Answer:**

The speed at which a particular part of a sample moves depends on its relative affinities for the two phases. If it has no affinity whatever for the stationary phase (e.g. water), it will travel at maximum speed, just behind the solvent front. However, if the pigment has no affinity whatever for the mobile phase (e.g. non-polar petroleum ether with acetone), it will not move up the filter paper and will remain at the origin of application. Thus, depending on the polarity of the solvents used, the different parts of the mixture will travel different distances in the same amount of time.

(d) (i) (1 mark)

**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-3**

Criteria	Mark
• Identifies a fibrous or structural protein	1

**Sample Answer:**

Keratin, collagen, etc.

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(d) (ii) (2 marks)

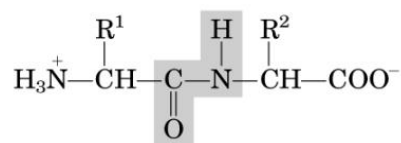
**Outcomes Assessed: H9**

**Targeted Performance Bands: 2-4**

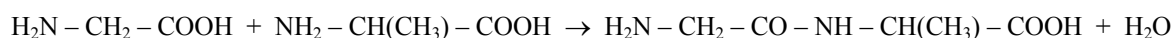
Criteria	Marks
<ul style="list-style-type: none"><li>Explains the formation of a peptide bond</li></ul> AND <ul style="list-style-type: none"><li>Writes a correct equation, using structural formulae, to show the condensation reaction of two amino acids</li></ul>	2
<ul style="list-style-type: none"><li>Explains the formation of a peptide bond</li></ul> OR <ul style="list-style-type: none"><li>Writes a correct equation, using structural formulae, to show the condensation reaction of two amino acids</li></ul>	1

**Sample Answer:**

A peptide bond is formed by the reaction of the carboxylic acid group ( $-\text{COOH}$ ) of one amino acid with the amine group ( $-\text{NH}_2$ ) from the second amino acid. As the amino acids join together to form the peptide bond, water forms by the combination of the  $-\text{OH}$  from the  $-\text{COOH}$  group and  $-\text{H}$  from the  $-\text{NH}_2$  group.



The shaded area shows the peptide bond between 2 amino acids.



↑  
This is the peptide bond

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(e) (4 marks)

**Outcomes Assessed: H1, H4**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>• Discusses the statement</li><li>• Discusses some advantages of DNA analysis in forensic cases</li><li>• Discusses some disadvantages of DNA analysis in forensic cases</li><li>• Compares DNA analysis to a method previously used to identify individuals in forensic cases</li></ul>	4
<ul style="list-style-type: none"><li>• Describes some advantages of DNA analysis in forensic cases</li><li>• Describes some disadvantages of DNA analysis in forensic cases</li><li>• Compares DNA analysis to a method previously used to identify individuals in forensic cases</li></ul>	3
<ul style="list-style-type: none"><li>• Identifies some advantages of DNA analysis in forensic cases</li><li>• Identifies some disadvantages of DNA analysis in forensic cases</li></ul>	2
<ul style="list-style-type: none"><li>• Identifies some correct information about DNA analysis</li></ul>	1

**Sample Answer:**

DNA is located in most cells of organisms and is often left in trace amounts at crime scenes in the form of skin cells, hair roots or bodily fluids. DNA analysis involves generating a DNA profile for a known individual and comparing it to the DNA profile generated from a sample collected from a crime scene (or another individual, in the case of paternity testing). DNA profiles are generated using the non-coding regions of DNA (introns) and are different for all individuals except identical twins; the more distantly related, the more differences in the profile, therefore a matching DNA profile can confirm or eliminate a suspect. Once a person is arrested, a biological sample may be collected, and the DNA analysed and stored in a data base.

DNA profiling is a time-consuming and relatively expensive procedure. Samples collected from crime scenes need to be stored so they do not degrade, which can also be costly.

DNA profiling is very accurate and can conclusively identify a suspect and exonerate other suspects. It is much more precise than previous methods of identifying individuals, such as fingerprinting or blood typing. It is very sensitive and only very small samples need to be collected as whatever amount of DNA is available can be amplified and analysed.

However, the statement “DNA analysis is not infallible in forensic cases” is correct, in that the smallest contamination in a sample may lead to the evidence being rendered useless. Also, criminals can collect samples from other individuals and leave them at the crime scene to try to confuse the evidence or have the incorrect person convicted. Identical twins have identical DNA.

Despite these limited drawbacks, if ultimate care is taken in the gathering and storing of DNA samples, a DNA match is the best evidence available in forensic cases, as the chance of two unrelated persons having the same DNA profile is less than 1 in  $10^{10}$ .

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(f) (6 marks)

**Outcomes Assessed: H3, H4**

**Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"><li>Evaluates the use of TWO instrumental techniques in providing forensic evidence</li><li>Discusses thoroughly how BOTH techniques are used by forensic scientists</li><li>Uses appropriate examples to illustrate the use of BOTH techniques</li></ul>	5-6
<ul style="list-style-type: none"><li>Discusses thoroughly how TWO techniques are used by forensic scientists</li><li>Uses appropriate examples to illustrate the use of BOTH techniques</li></ul> OR <ul style="list-style-type: none"><li>Evaluates the use of ONE instrumental technique in providing forensic evidence</li><li>Discusses thoroughly how ONE technique is used by forensic scientists</li><li>Uses an appropriate example to illustrate the use of ONE technique</li></ul>	3-4
<ul style="list-style-type: none"><li>Discusses thoroughly how ONE technique is used by forensic scientists</li></ul> AND <ul style="list-style-type: none"><li>Uses an appropriate example to illustrate the use of ONE technique</li></ul>	2
<ul style="list-style-type: none"><li>Discusses thoroughly how ONE technique is used by forensic scientists</li></ul> OR <ul style="list-style-type: none"><li>Uses an appropriate example to illustrate the use of ONE technique</li></ul>	1

**Sample answer:**

Gas-liquid chromatography (GLC) and mass spectrometry (MS) are two sensitive analytical techniques which are used to provide evidence for forensic investigations.

**Gas-liquid chromatography (GLC)** can measure quantities of the material in parts per million or billion. GLC uses only small amounts of a sample to complete each test. GLC separates substances on the basis of their different solubilities in the stationary liquid phase coating the walls of the chromatography column. The different components of the mixture to be analysed vaporise in the hot column and the different gases move through the column (which can be up to 100 m in length) at different rates. The more soluble the substance is in the stationary liquid film, the slower the movement through the column. The gases leaving the end of the column are detected by an electric current which flows when the component of the mixture ionises in a hot flame as it leaves the column. Compounds are identified by the time taken after injection to reach the detector. The samples are identified by comparison of the test result with results for samples of known substances under identical conditions. The chromatogram (the plot of detector signal versus time) can give a quantitative measure of the amount of substance in the sample.

GLC is widely used by forensic chemists to identify illegal drugs and steroids in urine samples taken from elite athletes. It is also used to identify pesticide residues in foods and in water supplies and to identify a wide variety of substances found at crime scenes. It is quick and easy to perform, but the instrumentation is expensive. Its use is limited in that the sample tested must vaporise at temperatures below 250°C (the operating temperature of the column). Great care is needed to avoid contamination of the sample, and the tests are usually repeated with new samples and (in the case of athletes) over a period of time.

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### Evaluation

GLC is a powerful instrumental technique for detection of minute quantities of substances in a mixture. It is limited by the need for the substance to vaporise below 250°C. The results are invalid if minute quantities of contaminants are allowed to enter the test sample in collection or testing. In drug testing, limitations also include false negatives that may occur when other drugs are present in the urine at high concentrations and when more than one drug is eluted from the column in the same fraction or if the drug is converted into a different substance and hence destroyed by the vaporisation process.

In **mass spectrometry (MS)**, 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.

### Evaluation

MS is a powerful instrumental technique for detection and identification of pure substances. It is commonly used for molecular substances which are carbon compounds. It is sensitive and quantitative and provides a unique fingerprint for each molecule. Contamination must be avoided for the technique to retain its validity. A restriction on the use of MS is that MS is not helpful in identifying the components of a mixture as the individual components are destroyed by the ionisation process. If coupled with GLC, the mixture can be separated using GLC, then the pure compound identified using MS. Performance-enhancing drugs in urine of athletes are commonly detected in this way.

### Overall evaluation

Both GLC and MS are destructive techniques, in that the sample analysed is broken up into fragments or vaporised 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 GLC and MS can be justified since only a small percentage of the sample needs to be used.

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