



HSC Trial Examination 2006

# Chemistry

## Solutions and marking guidelines

## Section I

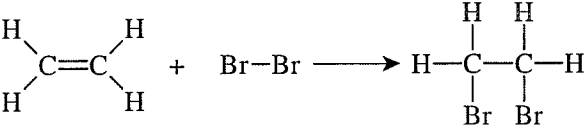
## Part A

Answer and explanation	Syllabus content and course outcomes
<b>Question 1 A</b> The systematic name for the monomer from which polyvinyl chloride is built is chloroethene. Vinyl chloride is the common name for this species, and answers <b>B</b> and <b>C</b> give names for structures containing two Cl atoms (not one).	9.2.1 H9
<b>Question 2 A</b> The strongest reducing agent is most easily oxidised and therefore most difficult to reduce (lowest reduction potential on the table).	9.2.4 H7, H8, H14
<b>Question 3 B</b> The oxidation state of nitrogen in <b>A</b> is +5, in <b>C</b> it is +1 and in <b>D</b> it is -3. Only in $\text{NO}_2$ is it +4.	9.2.4 H6
<b>Question 4 D</b> The reactions occurring in this cell are: $\text{Ni} \rightarrow \text{Ni}^{2+} + 2\text{e}^-$ at the anode (nickel electrode); $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$ at the cathode (platinum electrode). Thus, over time the Ni electrode decreases in mass and the concentration of $\text{Ni}^{2+}$ ions increases. The concentration of $\text{Cl}_2$ decreases and the concentration of $\text{Cl}^-$ increases. The platinum electrode is unaffected.	9.2.4 H7, H8, H14
<b>Question 5 D</b> A beta particle is an $\text{e}^-$ . The decay process occurring is: ${}^{14}_6\text{C} \rightarrow {}^0_{-1}\text{e} + {}^{14}_7\text{N}$ So the product is nitrogen-14.	9.2.5 H6
<b>Question 6 A</b> The production of ethyl propanoate occurs as follows: $\text{ethanol} + \text{propanoic acid} \xrightleftharpoons{\text{conc. H}_2\text{SO}_4} \text{ethyl propanoate} + \text{water}$	9.3.5 H9
<b>Question 7 C</b> MO indicates that the solution has $\text{pH} > 4.4$ BB indicates that the solution has $6.0 < \text{pH} < 7.6$ PR indicates that the solution has $6.4 < \text{pH} < 8.0$ Ph indicates that the solution has $\text{pH} < 8.3$ Altogether, it can be determined that $6.4 < \text{pH} < 7.6$	9.3.1 H10, H13, H14
<b>Question 8 C</b> Amphiprotic substances have the ability to donate a proton (act as acid) and to accept a proton (act as base): $\text{H}_2\text{PO}_4^- + \text{HCl} \rightleftharpoons \text{H}_3\text{PO}_4 + \text{Cl}^-$ $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_2\text{O}$ $\text{HNO}_3$ can only donate a proton, $\text{NH}_2^-$ and $\text{CH}_3\text{COO}^-$ can only accept a proton.	9.3.4 H8, H10

**Part A (Continued)**

Answer and explanation	Syllabus content and course outcomes
<b>Question 9 D</b> A burette is always rinsed with the solution it is going to dispense. A pipette is always rinsed with the solution it is going to dispense. A conical flask is always rinsed with water before use (or is clean and dry).	9.3.4 H11, H12
<b>Question 10 B</b> HCl is monoprotic, citric acid is triprotic. HCl is a strong acid, citric acid is a weak acid. Concentration of $0.01 \text{ mol L}^{-1}$ is the same for each. pH of 2 for HCl implies $[\text{H}^+] = 0.01 \text{ mol L}^{-1}$ pH of 3.6 for citric acid implies $[\text{H}^+] = 2.5 \times 10^{-4} \text{ mol L}^{-1}$ A higher pH means fewer $\text{H}^+$ ions in solution and less ionisation of the acid. Less ionisation means a weaker acid.	9.3.3 H8, H10, H13
<b>Question 11 C</b> AAS is most suited to ions of metallic elements. Nitrogen is the only non-metal in the list.	9.4.3 H4, H6
<b>Question 12 D</b> The $\text{SO}_4^{2-}$ ions in the lawn food solution need to be precipitated out as $\text{BaSO}_4$ . A solution of $\text{Ba}^{2+}$ ions needs to be added. The compounds in A and B don't contain barium at all. Barium carbonate is insoluble and cannot be added as a solution.	9.4.3 H8, H11, H13
<b>Question 13 B</b> Gaseous oxygen is $\text{O}_2$ . It is molecular and relatively less reactive than monatomic O atoms (oxygen free radicals), which contain reactive unpaired electrons.	9.4.4 H7, H8
<b>Question 14 D</b> Microscopic membrane filters are very fine-pored to remove microscopic-sized impurities (microorganisms). They are not suitable for large particulate matter. The pores are not small enough to trap ions such as fluoride and chloride or heavy metals effectively. Also, clean water at the end of the treatment process should still contain fluoride and chloride since they were additives included for specific purposes.	9.4.5 H3, H4, H5
<b>Question 15 B</b> An absorbance reading of 1 corresponds (approximately) to a Zn concentration of 4 ppm. The sample tested is one-tenth the concentration of river water, so the Zn concentration in river water is (approximately) 40 ppm.	9.4.3 H10, H13, H14

## Part B

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 16</b>	
(a) The amount of heat released when one mole of a substance is completely combusted (burnt in sufficient oxygen) at constant temperature and pressure to produce carbon dioxide and water.	9.2.3 H7, H8, H13 • Correctly defines the molar heat of combustion. . . . . 1
(b) $\text{C}_2\text{H}_5\text{OH}_{(l)} + 3\text{O}_{2(g)} \rightarrow 2\text{CO}_{2(g)} + 3\text{H}_2\text{O}_{(g)}$	9.2.3 H9, H10, H13 • Correctly writes the balanced equation . . 1
(c) $q = m \times C \times \Delta T$ $= 100 \times 4.18 \times 40 = 0.1 \times 4.18 \times 10^3 \times 40$ $= 16720 \text{ J}$ $\Delta H = -q \div \frac{m}{M}$ $= -16720 \div \frac{0.76}{46.068}$ $= -1013496 \text{ J/mol}$ $= -1013.5 \text{ kJ/mol}$	9.2.3 H8, H10, H13 • Correctly calculates the heat transferred to water • Correctly calculates the molar heat of combustion of ethanol (with negative sign) . . . . . 2  • Correctly calculates the heat transferred to water and the molar heat of combustion <b>without</b> negative sign OR • Correctly calculates the heat transferred to water only OR • Correctly calculates the molar heat of combustion of ethanol (with negative sign) . . . . . 1
(d) The calculated value is probably lower than the theoretical value. Heat could be lost to the container and/or the surrounding environment; combustion may be incomplete (indicated by a build-up of soot on the base of the container); or some heat may have also been used to evaporate the water in the container.	9.2.3 H7, H8 • States that the calculated value would be lower than the theoretical value • Provides a clear explanation to account for this difference. . . . . 2  • States that the calculated value would be lower than the theoretical value OR • Provides a clear explanation to account for this difference OR • States that the calculated value would be lower than the theoretical value and gives a vague explanation . . . . . 1
<b>Question 17</b>	
(a) 	9.2.1 H9 • Draws a correct structural equation . . . . 1
(b) The purpose of the catalyst is to speed up the rate of reaction (conversion of reactants to products) by lowering the activation energy. The catalyst remains in (or returns to) its original form at the end of the reaction.	9.2.1 H7, H8 • States a clear reason for the presence of the catalyst . . . . . 1

**Part B (Continued)**

Sample answer	Syllabus content, course outcomes and marking guide														
<p>(c) Cling films are made from low-density polyethylene (LDPE).</p> <table border="1"> <thead> <tr> <th>Property of LDPE</th><th>Suitability of property to use</th></tr> </thead> <tbody> <tr> <td>Very flexible</td><td>Allows for it to be easily wrapped around items</td></tr> <tr> <td>Excellent cling properties</td><td>It can easily cling to itself</td></tr> <tr> <td>Transparent (fewer crystalline regions)</td><td>Better visibility of items that have been wrapped</td></tr> <tr> <td>Impermeable to water and resistant to most chemicals (including oil and grease)</td><td>Useful for sealing – keeps food crisp, prevents leakage, etc.</td></tr> <tr> <td>Melting point of approximately 115°C</td><td>Can be used to cover food that requires defrosting</td></tr> <tr> <td>Good elastic recovery and puncture resistance</td><td>Resistant to handling – retains toughness and pliability over a wide temperature range</td></tr> </tbody> </table>	Property of LDPE	Suitability of property to use	Very flexible	Allows for it to be easily wrapped around items	Excellent cling properties	It can easily cling to itself	Transparent (fewer crystalline regions)	Better visibility of items that have been wrapped	Impermeable to water and resistant to most chemicals (including oil and grease)	Useful for sealing – keeps food crisp, prevents leakage, etc.	Melting point of approximately 115°C	Can be used to cover food that requires defrosting	Good elastic recovery and puncture resistance	Resistant to handling – retains toughness and pliability over a wide temperature range	<p>9.2.1 H3, H4, H13</p> <ul style="list-style-type: none"> <li>Identifies several properties of LDPE</li> <li>Clearly relates two or more properties to the use of the product. .... 2</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Identifies some properties of LDPE</li> <li>Clearly relates one property to the use of the product ..... 1</li> </ul>
Property of LDPE	Suitability of property to use														
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<p><b>Question 18</b></p> <p>Transuranic elements can be made by bombarding heavy nuclei such as uranium, plutonium, americium or lead, with high speed particles such as electrons, neutrons, small nuclei (helium or carbon nuclei) or even ions.</p> <p>Ununtrium (<math>Z = 113</math>) and ununpentium (<math>Z = 115</math>) were made by bombarding americium-243 with calcium-48 ions in a cyclotron.</p> <p>Safe practices:</p> <ul style="list-style-type: none"> <li>Radioactive materials must always be stored in containers that are well shielded. You must never handle these materials with bare hands.</li> <li>People who use radioactive materials must be well-trained to handle such things in a safe manner.</li> <li>People must wear appropriate safety clothing which, depending in the radioactive isotope in use, may vary from gloves and face mask to specially laundered laboratory coats and overshoes, lead-lined aprons and, in the extreme, full protective suits.</li> <li>People working in an around radiation facilities must wear radiation monitors (badges) that records the total amount of radiation they receive.</li> <li>Proper procedures for safe storage and disposal of radioactive wastes must be established.</li> <li>Clear signs must be displayed in any location where radiation equipment or materials are being used or stored.</li> </ul>	<p>9.2.5 H1, H3, H6, H13</p> <ul style="list-style-type: none"> <li>Correctly describes how transuranic elements may be synthesised and identifies ONE safe practice that must be adopted when working with them. .... 3</li> <li>Partially describes how transuranic elements may be synthesised and identifies ONE safe practice that must be adopted when working with them. .... 2</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Partially describes how transuranic elements may be synthesised</li> <li>Identifies ONE safe practice that must be adopted when working with them..... 1</li> </ul>														

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 19</b> There are numerous advantages and disadvantages to using ethanol as a fuel, such as: <b>ADVANTAGES:</b> <ul style="list-style-type: none"> <li>it is a renewable resource;</li> <li>it is transportable;</li> <li>it has a low ignition temperature and therefore is readily combustible;</li> <li>it requires less oxygen than octane to completely burn, so it produces less soot and/or carbon monoxide;</li> <li>it doesn't contribute to greenhouse gases because the carbon dioxide that it releases is essentially re-used in growing more plants (CO<sub>2</sub> neutral);</li> <li>it does not produce sulfur dioxide and nitrogen oxides which are evident when other fossil fuels are combusted;</li> <li>it can be mixed with other fuels (such as petrol);</li> <li>it reduces our dependence on foreign fuel.</li> </ul> <b>DISADVANTAGES:</b> <ul style="list-style-type: none"> <li>vast areas of land are necessary to supply enough plants to produce the quantity of ethanol required (monoculture, land degradation);</li> <li>fossil-fuel energy is required to prepare and fertilise the land needed for growing the crops and for the fermentation and distillation processes;</li> <li>the waste products from fermentation can be very smelly and difficult to dispose of;</li> <li>it is currently still cheaper to produce fuel from fossil fuels than from ethanol;</li> <li>vehicles presently on the road will require engine modifications if more than 10% ethanol is used;</li> <li>it has a lower heat content than octane (46.0 kJ/g for octane and 30.6 kJ/g for ethanol) so there is a need to re-fuel more often;</li> <li>it may be difficult to scale up production of ethanol to the quantities required for widespread use.</li> </ul> <b>CRITERIA TO BE CONSIDERED:</b> <ul style="list-style-type: none"> <li>the cost of production, distillation etc. and the cost of altering infrastructure, designing and building new engines, etc.;</li> <li>the energy content of ethanol compared with octane;</li> <li>renewability and potential for long term use;</li> <li>polluting emissions;</li> <li>compatibility with technology.</li> </ul>	9.2.3 H1, H3, H4, H5, H13, H16 <ul style="list-style-type: none"> <li>Demonstrates an extensive knowledge of ethanol's potential as an alternative fuel</li> <li>Provides a comprehensive list describing the advantages and disadvantages of ethanol</li> <li>Provides a suitable evaluation based on specific criteria. . . . . 5</li> </ul> <ul style="list-style-type: none"> <li>Demonstrates a thorough knowledge of ethanol's potential as an alternative fuel</li> <li>Provides a basic list outlining advantages and disadvantages</li> <li>Provides a judgement. . . . . 4</li> </ul> <ul style="list-style-type: none"> <li>Demonstrates a sound knowledge of ethanol's potential as an alternative fuel</li> <li>Outlines several advantages and disadvantages of its use</li> </ul> OR <ul style="list-style-type: none"> <li>Provides a judgement. . . . . 3</li> </ul> <ul style="list-style-type: none"> <li>Demonstrates a limited knowledge of ethanol's potential as an alternative fuel</li> </ul> OR <ul style="list-style-type: none"> <li>Outlines several advantages and disadvantages of its use . . . . . 2</li> </ul> <ul style="list-style-type: none"> <li>Identifies some advantages and disadvantages of its use . . . . . 1</li> </ul>

combustion of EtOH equation (2)  
 INTO (1/2)

**Part B (Continued)**

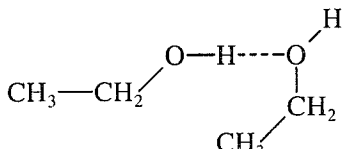
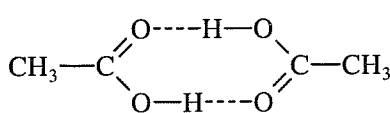
Sample answer	Syllabus content, course outcomes and marking guide
<p><b>Question 19 (continued)</b></p> <p><b>EVALUATION:</b></p> <p>There are several problems associated with the use of ethanol as a fuel (as seen above), but its advantages are ultimately more important. It is sensible to attempt to overcome the issues.</p> <p>Fossil fuel reserves will eventually be depleted and so a renewable alternative (such as ethanol) is crucial.</p> <p>As costs of dwindling fossil fuels continue to rise, the relative cost of ethanol will fall. Better production processes and suitable engines need to be developed so it can become economically viable, energy efficient and widely available.</p> <p>Our environmental wellbeing is of vast importance and ethanol's lower levels of polluting emissions make it a desirable energy source. In order to become a market reality in the future, ethanol will have to prove to be environmentally better than current fuels.</p> <p>In conclusion, it seems likely that ethanol will become a workable alternative fuel in the future as long as production processes are adapted.</p>	

## Part B. (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 20</b>	
<p>(a) The major source of <math>\text{NO}_x</math> is motor vehicle exhaust (combustion engine).</p> <p>The other significant source is the burning of fossil fuels such as coal, oil and natural gas (for purposes such as generating electricity in coal-fired power stations or during primary metal production).</p> <p>Increasing use and number of cars and increased burning of fossil fuels over time has lead to higher levels of <math>\text{NO}_x</math> being released into the atmosphere.</p>	<p>9.3.2 H4, H13</p> <ul style="list-style-type: none"> <li>Gives at least one correct source of <math>\text{NO}_x</math> emissions</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>identifies an increase in the source which leads to greater volumes of <math>\text{NO}_x</math> being released. .... 2</li> </ul> <p>Gives at least one correct source of <math>\text{NO}_x</math> emissions</p> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies an increase in the sources of <math>\text{NO}_x</math> which leads to greater volumes being released ..... 1</li> </ul>
<p>(b) Formation of acidic solution from <math>\text{NO}_x</math> occurs when the nitrogen oxides dissolve in water to form an aqueous solution of nitric acid and/or nitrous acid. The reactions occurring are:</p> $2\text{NO}_2(g) + \text{H}_2\text{O}(l) \rightleftharpoons \text{HNO}_2(aq) + \text{HNO}_3(aq)$ <p>OR</p> $4\text{NO}_2(g) + 2\text{H}_2\text{O}(l) + \text{O}_2(g) \rightleftharpoons 4\text{HNO}_3(aq)$ $\text{HNO}_3(aq) \rightarrow \text{H}^+(aq) + \text{NO}_3^-(aq) \text{ (H}^+ \text{ result in low pH!)}$ <p>Reasons for concern about production of acid rain include:</p> <ul style="list-style-type: none"> <li>It contributes to acidification of lakes and other aquatic environments. Aquatic organisms can die as water acidity drops below pH 5. This disrupts the food web resulting in further deaths.</li> <li>It can cause soil pH to drop, making it difficult for plants to absorb sufficient calcium or potassium. Growth is hindered and death of plants may result.</li> <li>Changes in soil chemistry can also lead to the death of important micro-organisms and can release normally insoluble aluminium and mercury into soil water causing plants to absorb toxic levels of these and other heavy metals.</li> <li>Protective waxes can be lost from leaves, causing leaf damage and thus substantial losses of trees and crops.</li> <li>Buildings, statues and monuments made of carbonates (such as concrete, mortar, limestone and marble) can be gradually dissolved away:</li> </ul> $\text{CaCO}_3(s) + 2\text{HNO}_3(aq) \rightarrow \text{Ca}(\text{NO}_3)_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O}$ <ul style="list-style-type: none"> <li>Acidic rain can also promote corrosion of metals, fade fabrics and degrade rubber.</li> <li>Smog and acid rain can combine to form a "killer fog".</li> </ul> <p>JUDGEMENT:</p> <p>(1) Damage to the natural and man-made environmental is both costly in a monetary sense as well as in cultural and ecological senses. For this reason, concerns about the effects of acid rain are warranted.</p>	<p>9.3.2 H4, H8, H13, H16</p> <ul style="list-style-type: none"> <li>Clearly explains the formation of acid solutions by dissolution of <math>\text{NO}_x</math> including the use of appropriate balanced equations.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Identifies and explains several and varied problems associated with acid rain. Demonstrates a thorough knowledge of the issues and implications and makes a clear judgement/evaluation about the value of these concerns. .... 4</li> </ul> <p>Outlines the formation of acid solutions by dissolution of <math>\text{NO}_x</math>. Includes appropriate equation.</p> <p>AND</p> <ul style="list-style-type: none"> <li>Identifies several problems associated with acid rain and demonstrates a sound knowledge of the issues. A judgement/evaluation is made. .... 3</li> </ul> <p>Identifies need for dissolving of gases for formation of acid rain but little detail or no equations given.</p> <p>AND</p> <ul style="list-style-type: none"> <li>Identifies some problems associated with acid rain. No evaluation. .... 2</li> </ul> <p>Identifies need for dissolving of gases for formation of acid rain but little detail and no equations given.</p> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies some problems with acid rain. No evaluation. .... 1</li> </ul>



## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide									
<b>Question 21</b>	9.3.4	H11, H13								
<table border="1"><thead><tr><th>Salt</th><th>pH nature</th><th>Explanation or equations</th></tr></thead><tbody><tr><td>NH<sub>4</sub>Cl</td><td>acidic (pH &lt; 7)</td><td>NH<sub>4</sub><sup>+</sup> ions react with water (as follows) to form an excess of H<sub>3</sub>O<sup>+</sup> ions, thus lowering pH. NH<sub>4</sub><sup>+</sup> + H<sub>2</sub>O ⇌ NH<sub>3</sub> + H<sub>3</sub>O<sup>+</sup> Cl<sup>-</sup> ion does not react with water.</td></tr><tr><td>Na<sub>2</sub>CO<sub>3</sub></td><td>basic (pH &gt; 7)</td><td>CO<sub>3</sub><sup>2-</sup> ions react with water (as follows) to form an excess of OH<sup>-</sup> ions, thus raising pH. CO<sub>3</sub><sup>2-</sup> + H<sub>2</sub>O ⇌ HCO<sub>3</sub><sup>-</sup> + OH<sup>-</sup> Na<sup>+</sup> ion does not react with water.</td></tr></tbody></table>	Salt	pH nature	Explanation or equations	NH <sub>4</sub> Cl	acidic (pH < 7)	NH <sub>4</sub> <sup>+</sup> ions react with water (as follows) to form an excess of H <sub>3</sub> O <sup>+</sup> ions, thus lowering pH. NH <sub>4</sub> <sup>+</sup> + H <sub>2</sub> O ⇌ NH <sub>3</sub> + H <sub>3</sub> O <sup>+</sup> Cl <sup>-</sup> ion does not react with water.	Na <sub>2</sub> CO <sub>3</sub>	basic (pH > 7)	CO <sub>3</sub> <sup>2-</sup> ions react with water (as follows) to form an excess of OH <sup>-</sup> ions, thus raising pH. CO <sub>3</sub> <sup>2-</sup> + H <sub>2</sub> O ⇌ HCO <sub>3</sub> <sup>-</sup> + OH <sup>-</sup> Na <sup>+</sup> ion does not react with water.	<ul style="list-style-type: none"><li>Clearly states the correct pH nature for NH<sub>4</sub>Cl, and Na<sub>2</sub>CO<sub>3</sub></li><li>Provides a thorough explanation for the pH nature of both salts, including correct ionic equations ..... 3</li></ul> <p>OR</p> <ul style="list-style-type: none"><li>States the correct pH nature of each salt and provides a sound explanation of the pH nature of all both salts, including equations ..... 2</li><li>Provides a thorough explanation of the pH nature of one salt only, including equations ..... 2</li></ul> <p>OR</p> <ul style="list-style-type: none"><li>States the correct pH nature of each salt with no explanation ..... 1</li><li>Provides limited explanation of the pH nature of the salts ..... 1</li></ul>
Salt	pH nature	Explanation or equations								
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Na <sub>2</sub> CO <sub>3</sub>	basic (pH > 7)	CO <sub>3</sub> <sup>2-</sup> ions react with water (as follows) to form an excess of OH <sup>-</sup> ions, thus raising pH. CO <sub>3</sub> <sup>2-</sup> + H <sub>2</sub> O ⇌ HCO <sub>3</sub> <sup>-</sup> + OH <sup>-</sup> Na <sup>+</sup> ion does not react with water.								
<b>Question 22</b>	9.3.5	H2, H9								
<p>(a) The observed trend is that for molecules of the same MM, alkanolic acids have a higher boiling point than the corresponding alkanol.</p> <p>Alkanols and alkanolic acids of the same MM exhibit dispersion forces of equivalent strength. If these were the only forces present then alkanols and alkanolic acids of the same MM would have the same boiling point.</p> <p>Alkanols also contain hydrogen bonding between neighbouring molecules (as seen in diagram). The δ+ on H from the —OH group of one molecule is attracted to the non-bonding electrons on the O of a neighbouring molecule.</p> <div><p>Ethanol</p></div> <p>Alkanolic acid molecules can be involved in two sites of hydrogen bonding with a neighbouring molecule. The δ+ on the H from the —OH group of each molecule is hydrogen bonded to the non-bonding electrons on the O from the C=O group of the neighbouring molecule. This attraction is able to occur at two sites between each pair of molecules due to the shape of the molecules and orientation of the bonds (as can be seen in the diagram below).</p> <p>The additional hydrogen bond that can occur between each pair of alkanolic acid molecules results in greater energy (higher temperatures) being needed to overcome intermolecular forces during boiling (hence higher boiling point).</p> <div><p>Ethanoic acid</p></div>	<ul style="list-style-type: none"><li>Identifies the trend.</li><li>Relates strength of intermolecular forces to boiling point.</li><li>Thoroughly describes intermolecular forces in both alkanols and alkanolic acids.</li><li>Identifies the presence of hydrogen bonding in both substances and clearly explains the reason for the alkanolic acids exhibiting more hydrogen bonds than the corresponding alkanol.</li><li>Provides a clear and complete explanation for difference in boiling point..... 3</li></ul> <p>OR</p> <ul style="list-style-type: none"><li>Identifies the trend.</li><li>Relates strength of intermolecular forces to boiling point.</li><li>Identifies the presence of hydrogen bonding in both substances.</li><li>Provides a sound explanation for the difference in boiling point..... 2</li></ul> <p>OR</p> <ul style="list-style-type: none"><li>Identifies the trend.</li><li>Identifies the relationship between boiling point and intermolecular forces and identifies hydrogen bonding as a strong intermolecular force..... 1</li></ul>									

**Part B** (Continued)

Sample answer	Syllabus content, course outcomes and marking guide																				
<p>(b)</p> <table border="1"> <thead> <tr> <th>Sample acids used in processed foods</th><th>Purpose of acid</th></tr> </thead> <tbody> <tr> <td>Acetic acid, citric acid, tartaric acid, malic acid, fumaric acid or lactic acid</td><td>Preservative in pickles and other processed food</td></tr> <tr> <td>Phosphoric acid</td><td>Preservative in cola drinks</td></tr> <tr> <td>Sulfur dioxide (as sulfurous acid)</td><td>Preservative in dried fruits and wine</td></tr> <tr> <td>Ascorbic acid (vitamin C)</td><td>Antioxidant to protect soft drinks, jams, condensed milk and sausage</td></tr> </tbody> </table> <p>Acids are mostly used as preservatives in processed foods. Presence of the acid destroys most microbes present (that would cause food to spoil or go off) and prevents them multiplying, so over long periods the food material is conserved.</p> <table border="1"> <thead> <tr> <th>Sample esters used in processed foods</th><th>Purpose of ester</th></tr> </thead> <tbody> <tr> <td>Isoamyl acetate</td><td>Artificial banana flavouring</td></tr> <tr> <td>Octyl gallate</td><td>Antioxidant in fats and oils for frying oils, seasoning, dehydrated soups, chewing gum</td></tr> <tr> <td>Polyglycerol esters and lactic acid esters</td><td>Emulsifiers in mayonnaise, margarine, creamy sauces</td></tr> <tr> <td>Triethyl citrate</td><td>Thickener in desserts, foam stabiliser</td></tr> </tbody> </table> <p>Esters can be used as flavour additives due to their strong scent and resulting effect on taste.</p> <p>Emulsifiers allow water and oils to remain mixed together in an emulsion. The ester molecules stabilise emulsions in food products, preventing them from separating.</p> <p>As an antioxidant, esters prevent oxidation of food in air. They help foodstuffs keep their taste and colour and remain edible over a longer period. They stop fats turning rancid.</p>	Sample acids used in processed foods	Purpose of acid	Acetic acid, citric acid, tartaric acid, malic acid, fumaric acid or lactic acid	Preservative in pickles and other processed food	Phosphoric acid	Preservative in cola drinks	Sulfur dioxide (as sulfurous acid)	Preservative in dried fruits and wine	Ascorbic acid (vitamin C)	Antioxidant to protect soft drinks, jams, condensed milk and sausage	Sample esters used in processed foods	Purpose of ester	Isoamyl acetate	Artificial banana flavouring	Octyl gallate	Antioxidant in fats and oils for frying oils, seasoning, dehydrated soups, chewing gum	Polyglycerol esters and lactic acid esters	Emulsifiers in mayonnaise, margarine, creamy sauces	Triethyl citrate	Thickener in desserts, foam stabiliser	<p>9.3.3, 9.3.5 H3, H4</p> <ul style="list-style-type: none"> <li>Names an example of an acid and an example of an ester used in food production and outlines the use of both . . . . . 2</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Names an example of both an acid and an ester</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Outlines the use of a specific, named acid</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Outlines the use of a specific, named ester . . . . . 1</li> </ul>
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## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 23</b>	
<p>(a) Bottle B:</p> $n = \frac{m}{MM} = \frac{0.7}{44.01} = 1.59 \times 10^{-2}$ $V = n \times MV = 1.591 \times 10^{-2} \times 24.79$ $= 0.394 \text{ L or } 394 \text{ mL of CO}_2 \text{ was released.}$	<p>9.3.2 H10, H13</p> <ul style="list-style-type: none"> <li>Correctly calculates the volume of CO<sub>2</sub> released from Bottle B . . . . . 1</li> </ul>
<p>(b) A greater amount of CO<sub>2</sub> gas was released in the warmer room. According to Le Chatelier, when the equilibrium system below is disturbed, the reaction will minimise the change while re-establishing equilibrium.</p> $\text{CO}_{2(g)} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_{3(aq)} + \text{heat}$ <p>At both temperatures, when the lid of the bottle is removed, the pressure of the system is reduced and the equilibrium balance is shifted to the left, releasing CO<sub>2</sub> gas.</p> <p>At the higher temperature of the warm room, there is a greater amount of heat in the system. According to Le Chatelier's Principle, the equilibrium system minimises the greater amount of heat by favouring the endothermic reverse process (to absorb some of the heat). This shifts the equilibrium further to the left than the equilibrium in the colder room.</p> <p>Since the reverse process releases CO<sub>2</sub> gas, a shift further to the left results in a greater volume of CO<sub>2</sub> being released at the higher temperature.</p>	<p>9.3.2 H8, H10, H13, H14</p> <ul style="list-style-type: none"> <li>Provides a thorough explanation of the effect of temperature change on the position of the equilibrium in the bottle</li> <li>Relates the shift in equilibrium to Le Chatelier's principle</li> <li>Correlates the relative equilibrium position to the amount of CO<sub>2</sub> gas released. . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Provides a sound explanation of the effect of temperature change on the position of the equilibrium in the bottle</li> <li>Relates the shift in equilibrium to Le Chatelier's principle</li> <li>Correlates the relative equilibrium position to the amount of CO<sub>2</sub> gas released. . . . . 2</li> </ul> <hr/> <p>OR</p> <ul style="list-style-type: none"> <li>Correlates the amount of CO<sub>2</sub> gas released to the relative equilibrium position</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Provides a limited explanation of the effect of temperature change on the position of the equilibrium in the bottle. . . . . 1</li> </ul>

## Part B (Continued)

Sample answer		Syllabus content, course outcomes and marking guide	
<b>Question 24</b>		9.3.4	H4, H11
<b>Usefulness of advice</b>	<b>Drawbacks of advice</b>	<ul style="list-style-type: none"> <li>Demonstrates a thorough knowledge of the risks involved with acid spills and the use of neutralisation reactions to minimise the risk</li> <li>Thoroughly considers the advantages and disadvantages of using the recommended method</li> <li>Provides a detailed assessment or judgement of the problems and benefits of the method . . . . . 4</li> </ul>	
Adding $\text{CaCO}_3$ neutralises (increases the pH of) the spilt liquid. It reduces the risk of corrosive reaction between skin or eyes or equipment and the acid.	The base being used to neutralise acid could be mildly hazardous in its own right. Avoiding contact of lime with eyes, airways etc. would be necessary.  $\text{NaHCO}_3$ (bicarb soda) is possibly a better choice of base to use since it is slightly less hazardous than $\text{CaCO}_3$ while serving the same purpose.	<ul style="list-style-type: none"> <li>Demonstrates a sound knowledge of the risks involved with acid spills and the use of neutralisation reactions to minimise the risk</li> </ul> OR <ul style="list-style-type: none"> <li>Outlines some of the advantages and disadvantages of using the recommended method</li> <li>Provides an overall judgement of the method . . . . . 3</li> </ul>	
Fizzing of $\text{CaCO}_3$ when added clearly indicates a reaction with the acid. When the fizzing ceases, it can be assumed that all acid is neutralised. Continue to add lime until fizzing ceases. The area can then be washed up or hosed down safely.	Heat is released during the neutralisation process. There would be a need for caution of large amounts of heat posing a burn or heat hazard during the clean-up.	<ul style="list-style-type: none"> <li>Demonstrates a limited knowledge of the risks involved with acid spills and the use of neutralisation reactions to minimise the risk</li> </ul> OR <ul style="list-style-type: none"> <li>Identifies an advantage and a disadvantage of using the recommended method</li> </ul> OR <ul style="list-style-type: none"> <li>Provides an explanation of a problem or benefit of the method . . . . . 2</li> </ul>	
The base used is not strong or soluble and thus poses minimal risk, so it provides a neutralising action with minimal risk from the base itself.	The spill could be contained from spreading first by adding sand or vermiculite to the puddle of liquid. Once this has absorbed the spill, it can then be swept up. This may be less expensive than $\text{CaCO}_3$ and larger quantities may be readily available.	<ul style="list-style-type: none"> <li>Identifies one advantage of using the method</li> </ul> OR <ul style="list-style-type: none"> <li>Identifies one disadvantage of using the method . . . . . 1</li> </ul>	
The powdered sample will absorb some of the liquid of the spill, thus preventing the spread of the liquid (into drains etc.)	It's not mentioned that the area will still need to be washed down with detergent and water after the bulk of the spill is cleared away.		
The advice is suitable for small or large spills of acid and for spills of strong, weak, concentrated or dilute acid.	Apart from goggles, no safety gear is specifically mentioned. Also there is no mention of the need to ventilate the area.		
Lime is readily available.			

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p><b>Question 24 (continued)</b></p> <p><b>JUDGEMENT:</b></p> <p>The method selected is essentially very useful and safe and gives the key information necessary to safely clear up a spill.</p> <p>It minimises the risk from the acid spilt (neutralises it) and the base used in the clean-up (weak, solid form), while allowing the spill to be dealt with adequately (soaked-up liquid, fizzing as evidence of neutralisation, straightforward mop-up to finish).</p> <p>However, more detail about how to go about the clean-up procedure could have been given, including working slowly from the edge of the spill inwards, adding more lime when fizzing subsides until no more fizzing occurs, and listing necessary protective gear to be worn.</p> <p>Other weak base substances could be used apart from lime; however, it should be specified that the neutralising material be solid.</p>	
<p><b>Question 25</b></p> <p>(a) 'Good up high' refers to ozone in the stratosphere which acts as a filter for high-energy UVB radiation. The radiation is absorbed by the ozone, which decomposes into oxygen and a free radical.</p> <p>'Bad down low' refers to ozone in the troposphere being a strong oxidant which acts as a respiratory irritant, can damage vegetation and is both an indicator of and contributor to photochemical smog.</p> <p>(b) Ozone can be thought of as forming from molecular oxygen and an oxygen free radical.</p> $:\ddot{\text{O}}\cdot + :\ddot{\text{O}}::\ddot{\text{O}}: \rightarrow :\ddot{\text{O}}::\ddot{\text{O}}::\ddot{\text{O}}:$ <p style="text-align: center;">oxygen      molecular      ozone free radical      oxygen      molecule</p> <p>The oxygen molecule provides both of the shared electrons for the coordinate covalent bond. The two unpaired electrons on the free radical become a lone pair.</p>	<p>9.4.4 H4, H13</p> <ul style="list-style-type: none"> <li>Recognises that ozone exists in the stratosphere and the troposphere</li> <li>Ozone is a UV filter in the stratosphere</li> <li>Ozone is a pollutant in the troposphere . . . 3</li> </ul> <p>• States the two roles ozone may play in the atmosphere . . . . . 2</p> <p>• States a role that ozone plays in the atmosphere . . . . . 1</p> <p>9.4.4 H6, H13</p> <ul style="list-style-type: none"> <li>Correctly shows the formation of ozone, including all lone pairs, and indicates the source of the bonding electrons for the coordinate bond . . . . . 2</li> <li>Correctly draws molecular oxygen and an oxygen free radical. . . . . 1</li> </ul>

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 26</b>	9.4.3 H8, H11, H13
<p>To identify barium:</p> <ol style="list-style-type: none"> <li>1. A small sample of the unknown salt should be dissolved in water in a test-tube.</li> <li>2. Add 2 mL of HCl and filter.</li> <li>3. Add 2 mL of H<sub>2</sub>SO<sub>4</sub> to the filtrate.</li> <li>4. A white precipitate should form.</li> <li>5. The presence of barium needs to be confirmed with a flame test.</li> <li>6. Dip a platinum wire in concentrated HCl and then heat to red-hot in a non-luminous bunsen burner flame.</li> <li>7. Dip the cleaned platinum wire into the sample and heat in the flame.</li> <li>8. If Ba<sup>2+</sup> ions are present, an apple-green flame will be produced.</li> </ol> <p>A risk-minimising precaution that must be taken is the wearing of safety glasses to ensure that acid splashes cannot reach the eyes.</p>	<ul style="list-style-type: none"> <li>• Outlines an appropriate method with all steps defined that would unambiguously identify the metal ion as barium</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes an appropriate risk minimisation technique . . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Outlines an appropriate method with most steps defined that would identify the metal ion as barium</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes an appropriate risk minimisation technique . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Outlines a method with most steps defined that may identify the metal ion</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes an appropriate risk minimisation technique . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Outlines a method with most steps defined that may identify the metal ion</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>• Includes an appropriate risk minimisation technique . . . . . 1</li> </ul>
<b>Question 27</b>	9.4.5 H4, H8, H11
<ul style="list-style-type: none"> <li>• The low DO reading could be due to eutrophication, addition of organic waste material or an elevated water temperature.</li> <li>• The steel factory could be using the lake's water for cooling of plant machinery and as such cause the temperature of the lake to increase. The solubility of oxygen decreases with temperature and this could explain the low DO reading.</li> <li>• Farmers often use fertilizers to promote the growth of their crops. If fertilizer was applied a short time before rain or heavy watering there may have been run off into Upyjumpa which included dissolved fertilizer. The fertilizer would be rich in nitrates and phosphates. These nutrients would encourage growth of aquatic plants which would lead to a high value for BOD and consequently a low DO.</li> <li>• Any number of people could be dumping organic waste in the lake if there was no other way to dispose of the material. The organic material would begin to decompose and would use up dissolved oxygen.</li> </ul>	<ul style="list-style-type: none"> <li>• Proposes the possible role of the factory AND the farmers. Two or more valid reasons for the low DO/high BOD readings should be included with thorough explanations to link possible sources of contamination to the quality of the water and the test results given. . . . . 4–5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Proposes the possible role of the factory AND</li> <li>• the farmers by briefly outlining two possible sources of contamination, with specific reference to the DO and BOD tests. . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Proposes the possible role of the factory OR</li> <li>• the farmers by outlining one possible reason for the lake's measurements. . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Proposes the possible role of the factory OR</li> <li>• the farmers by identifying one possible reason for the lake's measurements. . . . . 1</li> </ul>

## Part B, (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p><b>Question 28</b></p> <p>The temperature and pressure must be monitored in both the reaction chamber and the condenser chamber for the following reasons.</p> <p>The reaction chamber is where the hot mixture of nitrogen and hydrogen gases are passed over a catalyst and react to form ammonia.</p> $\text{N}_{2(g)} + 3\text{H}_{2(g)} \xrightleftharpoons{\text{Fe/FeO}} 2\text{NH}_{3(g)} \quad \Delta H = -92 \text{ kJ}$ <p>Temperature: the reaction is exothermic and the equilibrium (forward reaction) is favoured by low temperature. The rate of reaction is too slow at low temperatures and so a compromise temperature of around 500°C is used. The exothermic nature of the reaction means that the reaction must be carefully monitored to maintain this temperature.</p> <p>Pressure: the equilibrium (forward reaction) is favoured by high pressures as 4 mole of reactant gas produces only 2 mole of product gas. The pressure used is around 350 atmospheres which must be carefully monitored to maintain yield, by not dropping too low, and to ensure safety, by not going too high.</p> <p>The condenser chamber is where the ammonia is liquefied and collected.</p> $\text{NH}_{3(g)} \rightleftharpoons \text{NH}_{3(l)}$ <p>Pressure: the pressure of the gas mixture needs to be kept quite high to make it easier to liquefy the ammonia.</p> <p>Temperature: the gases are cooled and the liquid ammonia collected while the nitrogen and hydrogen are recycled to the reactor chamber.</p> <p>The pressure and temperature must be monitored to ensure that all of the ammonia is collected to ensure efficient conversion by further driving the equilibrium to replace the removed ammonia.</p>	<p>9.4.2 H7, H8</p> <ul style="list-style-type: none"> <li>Examines both the reactor and the condenser</li> <li>Specifically addresses pressure and temperature</li> <li>Specifically relates the need to monitor each to the equilibrium process</li> <li>Addresses the extent of the reaction and the rate in the reactor</li> <li>Addresses safety specifically with pressure</li> <li>Addresses the temperature decrease while maintaining pressure in the condenser</li> <li>Includes appropriate equations . . . . . 6</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Examines both the reactor and the condenser</li> <li>Specifically addresses pressure and temperature</li> <li>Relates the need to monitor each to the equilibrium process</li> <li>Addresses the temperature decrease while maintaining pressure in the condenser</li> <li>Addresses safety specifically with pressure</li> <li>Includes an appropriate equation . . . . . 5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Examines both the reactor and the condenser</li> <li>Specifically addresses pressure and temperature</li> <li>Addresses the extent of the reaction and the rate in the reactor</li> <li>Addresses the temperature decrease while maintaining pressure in the condenser</li> <li>Includes an appropriate equation . . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Mentions one of the two vessels <b>and</b> describes correctly the monitoring for both pressure and temperature conditions . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Mentions one of the two vessels <b>and</b> describes correctly the monitoring for one condition</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Writes two correct equations . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Mentions one of the two vessels and the need to monitor conditions for the equilibrium</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Writes one correct equation . . . . . 1</li> </ul>

## Section II

## Question 29

## Industrial Chemistry

Sample answer		Syllabus content, course outcomes and marking guide	
(a)	(i) The products of the Solvay process are sodium carbonate and calcium chloride.	9.5.6	H3 • Correctly identifies the products $\text{Na}_2\text{CO}_3$ and $\text{CaCl}_2$ . . . . . 1
	(ii) Ammonia plays a vital role in the Solvay process, as it allows the formation of the hydrogen carbonate ion. In the process, carbon dioxide is bubbled through ammoniated brine. $\text{CO}_{2(g)} + \text{NH}_{3(aq)} + \text{NaCl}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightarrow \text{NaHCO}_{3(s)} + \text{NH}_4\text{Cl}_{(aq)}$ The reaction is carried out at $0^\circ\text{C}$ , and the sodium hydrogen carbonate crystallises. The ammonia is vital as carbon dioxide reacts with water only to a small extent, forming carbonic acid. $\text{CO}_{2(g)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_2\text{CO}_{3(aq)}$ The ammonia acts as a base, accepting a proton from the carbonic acid, which produces the hydrogen carbonate ion and drives the equilibrium to the right. $\text{NH}_{3(aq)} + \text{H}_2\text{CO}_{3(aq)} \rightleftharpoons \text{NH}_4^+_{(aq)} + \text{HCO}_3^-_{(aq)}$	9.5.6	H3, H4, H13 • Recognises that $\text{CO}_2$ is bubbled through ammoniated brine • Explains that $\text{CO}_2$ reacts with brine only to a small extent • Explains that ammonia shifts the $\text{CO}_2/\text{H}_2\text{CO}_3$ to the right . . . . . 3 • Two of the above . . . . . 2 • One of the above . . . . . 1



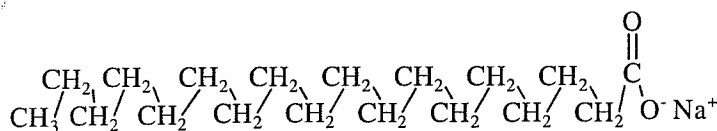
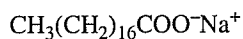
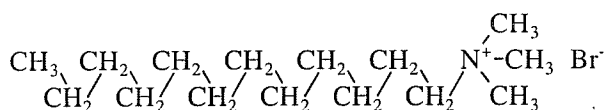
## Question 29

## Industrial Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(b) The chlor-alkali industry uses brine to produce sodium hydroxide and chlorine gas by electrolysis. A number of factors lead to the use of brine.</p> <p>The possible reactants are molten sodium chloride, dilute sodium chloride solution and brine.</p> <p>Molten sodium chloride:</p> <p>Electrolysis yields sodium and chlorine according to</p> $2\text{NaCl}_{(l)} \rightarrow 2\text{Na}_{(l)} + \text{Cl}_{2(g)}$ <p>thus no sodium hydroxide is produced directly, but could be produced by reacting the molten sodium with water.</p> $2\text{Na}_{(l)} + 2\text{H}_2\text{O}_{(l)} \rightarrow 2\text{NaOH}_{(aq)} + 2\text{H}_{2(g)}$ <p>This would be dangerous and expensive, as the sodium chloride must be molten to allow electrolysis and the reaction of sodium and water is highly exothermic and constitutes a severe explosive risk.</p> <p>Dilute sodium chloride solution:</p> <p>The electrolysis of these solutions produces oxygen, hydrogen and sodium hydroxide but not chlorine. This is due to the reduction potentials of the possible reactants.</p> <p>At the cathode the two possible reactants are <math>\text{Na}^+</math> ions and water molecules.</p> $\text{Na}^+_{(aq)} + \text{e}^- \rightarrow \text{Na}_{(s)} \quad E^\circ = -2.76 \text{ V}$ $2\text{H}_2\text{O}_{(l)} + 2\text{e}^- \rightarrow \text{H}_{2(g)} + 2\text{OH}^-_{(aq)} \quad E^\circ = -0.83 \text{ V}$ <p>The reduction of water takes less energy, and hydrogen is produced.</p> <p>At the anode the two possible reactants are <math>\text{Cl}^-</math> ions and water molecules.</p> $2\text{Cl}^-_{(aq)} \rightarrow \text{Cl}_{2(g)} + 2\text{e}^- \quad E = -1.36 \text{ V}$ $2\text{H}_2\text{O}_{(l)} \rightarrow \text{O}_{2(g)} + 4\text{H}^+_{(aq)} + 4\text{e}^- \quad E = -1.23 \text{ V}$ <p>Under near-standard conditions oxygen is produced.</p> <p>Brine is a concentrated sodium chloride solution. Standard conditions no longer apply and while the same reactions as for dilute sodium chloride are possible at each electrode, chlorine ions are oxidised in preference to water and chlorine gas is produced at the anode. Concentration has a direct bearing on the product.</p> <p>The chlor-alkali industry uses brine as it is the safest and cheapest of the three possible reactants that produces the desired products.</p>	<p>9.5.4 H3, H8, H14</p> <ul style="list-style-type: none"> <li>Addresses the three possible reactants: molten NaCl, dilute NaCl solution and brine</li> <li>Explains predicted products using equations for NaCl</li> <li>Explains why molten NaCl is not used</li> <li>Explains predicted and actual products from aqueous solutions using equations and <math>E^\circ</math> values</li> <li>Explains the concentration dependence of the production of chlorine ..... 6–7</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Addresses the three possible reactants</li> <li>Shows products from molten NaCl using equations but does not extend to production of NaOH</li> <li>Explains predicted products using equations</li> <li>Explains the concentration dependence of the production of chlorine ..... 4–5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Addresses two of the possible reactants</li> <li>For this pair, shows predicted products using equations</li> <li>Explains the advantages of one over the other ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Addresses any pair of reactants using equations ..... 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Addresses any pair of reactants ..... 1</li> </ul>

### Sample answer

(c) (i) Sodium stearate, a common soap.


$$\text{CH}_3(\text{CH}_2)_{11}\text{N}^+(\text{CH}_3)_3\text{Br}^-$$


(ii) Soaps are used as cleaning agents for a wide range of applications, from personal bath soaps to laundry soaps. They are used to clean grease from many surfaces.

Most cationic detergents are powerful broad-spectrum biocides and form the basis of household and industrial disinfectant and sanitiser formulations.

Their cationic nature causes them to adhere to negatively-charged surfaces such as glass, hair, fibre, metals and many plastics. They are not good cleaners of these materials but are used as antistatic agents, corrosion inhibitors, fabric softeners, hair conditioners, leather softeners, pigment wetting and dispersing agents and water and sewage treatment flocculants.

### 9.5.5

H9

- Both structures correct..... 2

- One structure correct . . . . . 1

### 9.5.2

H4, H9

- Lists appropriate uses for soap and cationic detergent. . . . . 2

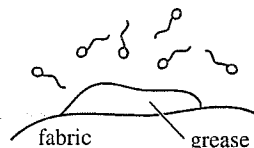
- Lists appropriate uses for soap or cationic detergent. . . . . 1

## Question 29

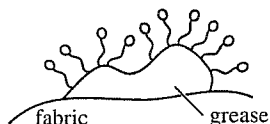
## Industrial Chemistry (Continued)

## Sample answer

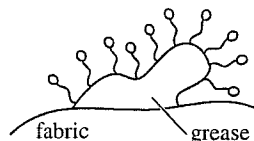
- (iii) Soap cleans materials by the dual nature of its structure. It has a hydrophobic tail, the hydrocarbon chain, and the charged carboxyl group acts as a hydrophilic head. The soap is dissolved in water:



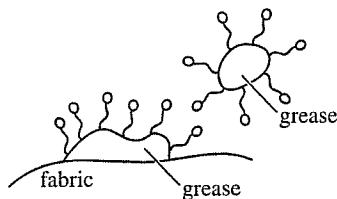
The hydrophobic tail buries itself in the grease on the plate while the hydrophilic head remains in the water:



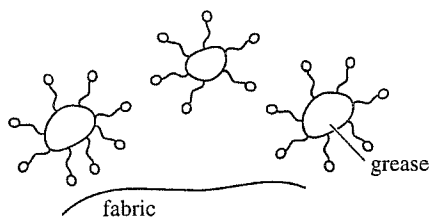
The grease begins to be pulled from the fabric with the help of some agitation of the water:



As more grease is exposed more soap molecules attach and the grease breaks into globules:



The globules are stabilised by the soap which has its hydrophilic head forming a layer over the surface of the grease, keeping it away from other globules and dissolved in the water. This is an example of emulsification:



## Syllabus content, course outcomes and marking guide

9.5.2

H8, H9

- Explains the dual nature of a surfactant with reference to hydrophilic and hydrophobic sections correctly
- Explains how the surfactant attaches to the surface by one end, leaving the other end 'free'
- Explains the formation of the emulsion or the function of the hydrocarbon tail for cationic detergent. . . . . 3
- Explains the dual nature of a surfactant
- Describes in general terms the cleaning action. . . . . 2
- Describes the parts of a surfactant. . . . . 1

## Question 29

## Industrial Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(d) (i) <math>K = \frac{[\text{SO}_3]_e^2}{[\text{SO}_2]_e^2 [\text{O}_2]_e}</math></p> <p><math>[\text{SO}_2] = \frac{0.224}{2} \text{M}</math> <math>[\text{O}_2] = \frac{0.136}{2} \text{M}</math> <math>[\text{SO}_3] = \frac{0.414}{2} \text{M}</math></p> <p><math>K_c = \frac{(0.207)^2}{(0.112)^2 (0.068)}</math></p> <p><math>K_c = 50.2</math></p>	<p>9.5.2 H10</p> <ul style="list-style-type: none"> <li>Writes the equation for the equilibrium constant and calculates the correct value. .... 2</li> <li>Writes the equation for the equilibrium constant. .... 1</li> </ul>
<p>(ii) The production of <math>\text{SO}_3</math> gas from <math>\text{SO}_2</math> gas is an equilibrium process. It is at the heart of the contact process for the production of sulphuric acid.</p> <p>The specific conditions for this part of the process are: a temperature of about <math>400\text{--}450^\circ\text{C}</math> at close to 1 atm pressure and the use of a <math>\text{V}_2\text{O}_5</math> catalyst. The reactant gases are mixed with oxygen in excess.</p> <p>The rate of reaction is how quickly equilibrium is established.</p> <p>The rate is favoured by high temperatures.</p> <p>The lower the temperature, the greater the yield, but the time taken to achieve equilibrium is far too great to be economical and vice versa.</p> <p>The temperature used is a compromise between a temperature that produces a very fast rate and one which will produce a reasonable amount of product at equilibrium.</p> <p>The rate is favoured by increased pressures.</p> <p>Increased pressure would increase both the rate and yield of this reaction. However, the reaction is carried out at close to atmospheric pressures. This is because the rate achieved by using the moderate temperature along with the catalyst is quite satisfactory as is the yield due to the use of excess oxygen and the recycling of reactant gases. It is economically less attractive to build expensive high pressure plant for the small gain in overall yield.</p> <p>Thus, rate and equilibrium considerations need to be carefully balanced to achieve a compromise that leads to an acceptable yield within a reasonable time.</p>	<p>9.5.3 H3, H8</p> <ul style="list-style-type: none"> <li>Lists conditions used for the contact process</li> <li>Discusses rate and extent with temperature</li> <li>Discusses rate and extent with pressure</li> <li>Recognises that the conditions used are a compromise between the competing demands of rate and yield ..... 4–5</li> <li>Discusses rate and extent with temperature</li> <li>Discusses rate and extent with pressure</li> <li>Recognises that the conditions used are a compromise between the competing demands of rate and yield ..... 3</li> <li>Discusses one of temperature or pressure with regard to the rate and extent of the reaction. .... 2</li> <li>Mentions that compromise conditions are used ..... 1</li> </ul>

## Question 30

## Shipwrecks, Corrosion and Conservation

Sample answer	Syllabus content, course outcomes and marking guide
(a) (i) Oxygen and carbon dioxide become more soluble in ocean water as depth increases.	9.6.5 H8 <ul style="list-style-type: none"> <li>Identifies that both gases become more soluble at greater depths . . . . . 1</li> </ul>
<p>(ii) Deeper into the ocean, the solubility of O<sub>2</sub> and CO<sub>2</sub> increases due to increased pressure and lower temperatures:</p> $\text{O}_{2(g)} \rightleftharpoons \text{O}_{2(aq)} + \text{energy}$ $\text{CO}_{2(g)} \rightleftharpoons \text{CO}_{2(aq)} + \text{energy}$ <p>The concentration of these gases should increase at depths, given their increasing solubility. This is the case for CO<sub>2</sub> but not for O<sub>2</sub>.</p> <p>O<sub>2</sub> levels in surface water are at saturation point due to direct contact with air and the photosynthetic action of phytoplankton:</p> $6\text{H}_2\text{O} + 6\text{CO}_2 \xrightarrow{\text{sunlight}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$ <p>As the O<sub>2</sub> diffuses into the lower layers of the water, aerobic organisms consume large quantities of it but photosynthesis diminishes due to lack of light. At greater depths the concentration of O<sub>2</sub> is lower than at the surface. So, even though more O<sub>2</sub> could dissolve at greater depths, there isn't enough present in the water to reach these levels.</p> <p>Carbon dioxide reacts with water to form hydrogen carbonate ions and carbonate ions leading to increased solubility when compared with oxygen:</p> $\text{CO}_{2(g)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{energy}$ $\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \rightleftharpoons 2\text{H}^+ + \text{CO}_3^{2-}$ <p>Marine organisms produce CO<sub>2</sub> during respiration, so CO<sub>2</sub> is being produced at a constant rate at all depths</p> $6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy}$ <p>More is able to dissolve in the higher pressure and lower temperature conditions of the deep ocean.</p> <p>Levels of CO<sub>2</sub> are significantly higher at depths than at the surface but they do not reach the point of saturation, as a lot of the CO<sub>2</sub> gas is being precipitated out by Ca<sup>2+</sup> to form insoluble CaCO<sub>3</sub>.</p>	<p>9.6.5 H8</p> <ul style="list-style-type: none"> <li>Provides a brief explanation for the increasing solubility of the gases at depths.</li> <li>Identifies that actual concentrations of the gases may not increase and provides thorough explanation of this for both CO<sub>2</sub> and O<sub>2</sub>.</li> <li>Includes relevant balanced equations. . . . 4</li> </ul> <p>Provides brief explanation for the increasing solubility of the gases at depths</p> <ul style="list-style-type: none"> <li>Identifies that actual concentrations of the gases may not increase and provides a sound explanation of this for both CO<sub>2</sub> and O<sub>2</sub></li> <li>Includes a relevant balanced equation . . . 3</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies that actual concentrations of the gases may not increase and provides a limited explanation of this for CO<sub>2</sub> and O<sub>2</sub></li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Includes a relevant balanced equation . . . 2</li> </ul> <p>Identifies increased solubility but decreased relative concentration</p> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies increased solubility but low availability of CO<sub>2</sub> and O<sub>2</sub> . . . . . 1</li> </ul>

## Question 30

## Shipwrecks, Corrosion and Conservation (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(b) (i) 1. Weigh out six approximately equal masses of the same type of iron nail.  2. Place a single nail into individual test tubes of the same shape and size.  3. Label the test tubes <i>A</i> to <i>F</i>.  4. To test tube <i>A</i>, <i>B</i> and <i>C</i> add 5 mL of distilled water to completely cover the sample.  5. To test tube <i>D</i>, <i>E</i> and <i>F</i> add 5 mL of 0.01 M NaCl, 5 mL of 0.1 M NaCl and 5 mL of 1.0 M NaCl solution, respectively, at room temperature.  6. Seal all six test tubes.  7. Place test tubes <i>A</i>, <i>D</i>, <i>E</i> and <i>F</i> in a cupboard in the laboratory.  8. Place test tube <i>B</i> in a refrigerator (at about 4°C) and test tube <i>C</i> in an incubator set at 40°C.  9. Leave all test tubes for one week then wash and dry all nails.  10. Reweigh nails to determine mass lost through corrosion.  11. Determine whether there's a link between salt concentration and amount of corrosion or between temperature and amount of corrosion.</p>	<p>9.6.5 H8, H13</p> <ul style="list-style-type: none"> <li>Provides a complete sequence of steps in the investigation</li> <li>States how the amount of corrosion is measured</li> <li>Identifies other variables that are controlled and includes a suitable control. . . . . 3</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Provides an incomplete sequence of steps in the investigation including how the amount of corrosion is measured</li> <li>Provides an incomplete sequence of steps in the investigation including stating that other variables are controlled . . . . . 2</li> <li>Identifies a correct aspect of the procedure for investigating the effect of temperature or salt concentration on corrosion . . . . . 1</li> </ul>

## Question 30

## Shipwrecks, Corrosion and Conservation (Continued)

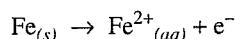
Sample answer	Syllabus content, course outcomes and marking guide
<p>(ii) Conclusion:</p> <p>The procedure is essentially appropriate but accuracy and reliability could be improved by ensuring absolute control over temperatures during the seven days (or by calculating an average temperature during the time).</p> <p>Points supporting conclusion:</p> <p>All variables were controlled except the one(s) being measured (e.g. the same mass and type of steel, the same test tube, the same volume of liquid. Salt solutions were all tested at the same temperature. While varying the temperature, the nails were submerged in the same distilled water).</p> <p>A control (test tube A) was used. The mass of the steel in A at end of the experiment is used as the standard for comparison to determine whether the introduction of NaCl or temperature change cause an effect. If the final mass in B, C, D, E or F is different, then corrosion is affected by salt concentration or temperature.</p> <p>There is a need to monitor the temperature in the cupboard to ensure steadiness or to gain an average. A cupboard has a more constant temperature over seven days than a bench top or window sill, making it a valid choice.</p> <p>All nails will rust to some degree. It is difficult to ascertain by sight whether one rusts more than another, hence the need for a re-weigh. This provides an accurate comparison.</p> <p>A greater variety of temperatures and salt concentrations could have been tested and the final masses plotted. This would provide a broader and more accurate indication of the trend, but the general trend is observed with the set-up outlined.</p> <p>The entire experiment should be repeated several times or several pieces of steel should be set up under each specific set of conditions to maximise reliability (reproducibility).</p>	<p>9.6.5 H8, H13</p> <ul style="list-style-type: none"> <li>Thoroughly supports the procedure with reference to suitable use of a control, careful control of variables (such as type of nail, volume of water), method used to measure amount of corrosion and monitoring of temperature.</li> <li>Explains need for repetition of procedure for reliability/reproducibility</li> <li>Describes the need for more variations in the conditions and explains how this would improve accuracy and hence validity</li> <li>Pinpoints drawback in the procedure (such as inability to maintain constant temperatures, inaccuracies in balance used) . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Describes the suitability of some features of the procedure such as control of variables, method used to measure amount of corrosion and monitoring of temperature.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Explains the need for repetition to ensure reliable results AND explains the need for greater range of temperatures or concentrations being investigated in order to accurately identify a trend . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Identifies that there were controlled variables and/or a control used in the procedure</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies the need for repetition to ensure reliable results</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Identifies the need for greater range of temperatures or concentrations being investigated in order to accurately identify a trend. . . . . 1</li> </ul>

## Question 30

## Shipwrecks, Corrosion and Conservation (Continued)

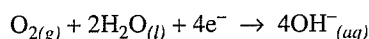
## Sample answer

- (c) Rusting is the corrosion of iron that forms the hydrated iron(III) oxide,  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ . This compound is commonly known as rust.  
Iron will rust only if it is in contact with both oxygen and water.  
Iron is oxidised at the anode. The anode (oxidation) reaction occurs at a point of stress in the metal and/or at a point of lower oxygen concentration:

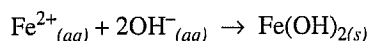


Electrons released flow through the iron until they reach a point of higher oxygen concentration, impurity in the metal or where the iron is in contact with a less active metal.

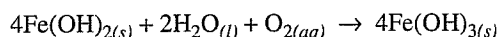
Dissolved oxygen is reduced at this point, which constitutes the cathode:



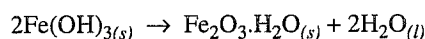
The  $\text{OH}^{-}$  and  $\text{Fe}^{2+}$  ions migrate towards each other through the moisture until they meet. They combine to form a green  $\text{Fe}(\text{OH})_2$  precipitate which forms a layer on the piece of iron:



$\text{Fe}(\text{OH})_2$  is further oxidised to iron(III) oxide:



The  $\text{Fe}(\text{OH})_3$  may then partially dehydrate to form hydrated iron(III) oxide,  $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$  (rust). For example,



Conditions under which rusting occurs	Relationship between components
Oxygen AND water needed (point of reduction)	<ul style="list-style-type: none"> <li>Reduction process involves BOTH species being present for <math>\text{O}_2</math> to be reduced to <math>\text{OH}^{-}</math> ions.</li> <li>Also, water is essential since ions migrate through the droplet or layer of moisture.</li> </ul>
Salt water (electrolyte)	<ul style="list-style-type: none"> <li>Electrolyte is more concentrated, speeds up the flow of ions.</li> </ul>
Mechanical stress (point of oxidation)	<ul style="list-style-type: none"> <li>Individual Fe atoms less strongly bonded together, thus easier to break away from the crystal lattice as <math>\text{Fe}^{2+}</math> ions.</li> </ul>
Impurities (point of reduction)	<ul style="list-style-type: none"> <li>Impurities may act as the cathode. The <math>\text{O}_2</math> is reduced on these impurities.</li> </ul>
Contact with less-active metal (point of reduction)	<ul style="list-style-type: none"> <li>Active metal acts as cathode.</li> </ul>

## Syllabus content, course outcomes and marking guide

9.6.2 H8, H13

- Displays an extensive knowledge of the rusting process including the movement of electrons and the reduction and oxidation processes occurring
- Provides a thorough explanation of the need of oxygen and water for rusting of iron to occur, and outlines other factors which accelerate rusting
- Includes relevant, balanced chemical equations (oxidation process, reduction process, precipitation of  $\text{Fe}(\text{OH})_3$  and formation of rust)
- Analyses conditions required. . . . . 6–7

- Displays a clear knowledge of the rusting process
- Provides a thorough explanation of the need of oxygen and water for rusting to occur
- Includes relevant, balanced chemical equations (oxidation process, reduction process, precipitation of  $\text{Fe}(\text{OH})_3$ ). . . . . 4–5

- Displays a sound knowledge of the rusting process
- Provides a limited description of the need for oxygen and water
- Includes some relevant, balanced chemical equations (oxidation process and reduction process) . . . . . 3

- Displays a limited knowledge of the rusting process
- Outlines the need for oxygen and water OR includes a relevant chemical equation . . . . . 2

- Displays minimal knowledge of the rusting process
- Identifies that oxygen and water are required for rusting to occur. . . . . 1



## Question 30

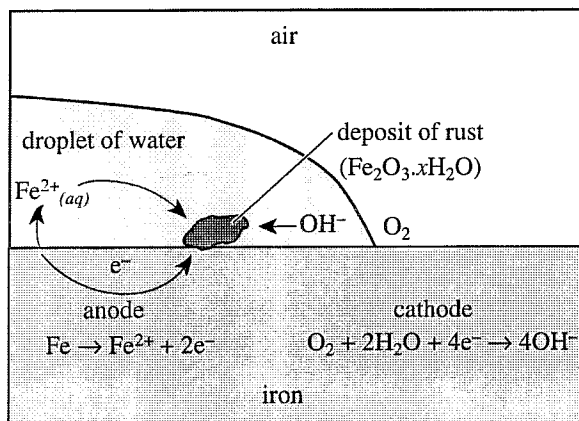
## Shipwrecks, Corrosion and Conservation (Continued)

## Sample answer

## Syllabus content, course outcomes and marking guide

(c) (continued)

The diagram below illustrates this reaction process.



(d) (i) The platinum electrode (B) is the cathode.

9.6.3

H8

- Correctly identifies the platinum electrode (B) as the cathode. .... 1

(ii)  $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}_{(\text{s})}$  $E^\circ = -2.71 \text{ V [R]}$ 

9.6.3

H7, H8, H10, H13

 $\text{H}_2\text{O}_{(\text{l})} + \text{e}^- \rightarrow \frac{1}{2} \text{H}_{2(\text{g})} + \text{OH}^-$  $E^\circ = -0.83 \text{ V [R]} \checkmark$ 

- Calculates the correct voltage
- Writes correct oxidation and reduction half-equations (correctly named). .... 2

 $\text{H}_2\text{O}_{(\text{l})} \rightarrow \frac{1}{2} \text{O}_{2(\text{g})} + 2\text{H}^+ + 2\text{e}^-$  $E^\circ = -1.23 \text{ V [O]}$ 

- Calculates the correct voltage

 $\text{Ag}_{(\text{s})} \rightarrow \text{Ag}^+ + \text{e}^-$  $E^\circ = -0.80 \text{ V [O]} \checkmark$ 

OR

- Writes correct oxidation and reduction half-equations (correctly named). .... 1

 $\text{Br}^- \rightarrow \frac{1}{2} \text{Br}_{2(\text{aq})} + \text{e}^-$  $E^\circ = -1.10 \text{ V [O]}$  $\checkmark$  denotes the highest reduction and oxidation  $E^\circ$ .

Anode:

 $\text{Ag}_{(\text{s})} \rightleftharpoons \text{Ag}^+ + \text{e}^-$  $E^\circ = -0.80 \text{ V}$ 

Cathode:

 $\text{H}_2\text{O}_{(\text{l})} + \text{e}^- \rightleftharpoons \frac{1}{2} \text{H}_{2(\text{g})} + \text{OH}^-$  $E^\circ = -0.83 \text{ V}$ 

Overall:

 $\text{Ag} + \text{H}_2\text{O} \rightarrow \text{Ag}^+ + \frac{1}{2} \text{H}_2 + \text{OH}^-$  $\text{EMF} = -1.63 \text{ V}$ 

The voltage required is greater than 1.63 V.

## Question 30

## Shipwrecks, Corrosion and Conservation (Continued)

Sample answer		Syllabus content, course outcomes and marking guide												
(d)	(iii)	9.6.3 H7, H8, H13												
<table><tr><th>Proposed alteration</th><th>Predicted change in reactions</th></tr><tr><td>Changing anode to Cu</td><td>Cu would be oxidised at anode (not Ag)</td></tr><tr><td>Changing anode to Pt</td><td>Br<sup>-</sup> would be oxidised at the anode (not Ag)</td></tr><tr><td>Using molten or very concentrated NaBr</td><td>Na<sup>+</sup> ions would be reduced at the cathode (not H<sub>2</sub>O)</td></tr><tr><td>Using aqueous NaI (or NaOH) instead of NaBr</td><td>I<sup>-</sup> (or OH<sup>-</sup>) ions will be oxidised at the anode (not Ag)</td></tr><tr><td>Using PbBr<sub>2</sub> (or ZnBr<sub>2</sub> or FeBr<sub>2</sub> or NiBr<sub>2</sub> or SnBr<sub>2</sub>) instead of NaBr</td><td>Pb<sup>2+</sup> (or Zn<sup>2+</sup> or Fe<sup>2+</sup> or Ni<sup>2+</sup> or Sn<sup>2+</sup>) ions will be reduced at cathode (not H<sub>2</sub>O)</td></tr></table>		Proposed alteration	Predicted change in reactions	Changing anode to Cu	Cu would be oxidised at anode (not Ag)	Changing anode to Pt	Br <sup>-</sup> would be oxidised at the anode (not Ag)	Using molten or very concentrated NaBr	Na <sup>+</sup> ions would be reduced at the cathode (not H <sub>2</sub> O)	Using aqueous NaI (or NaOH) instead of NaBr	I <sup>-</sup> (or OH <sup>-</sup> ) ions will be oxidised at the anode (not Ag)	Using PbBr <sub>2</sub> (or ZnBr <sub>2</sub> or FeBr <sub>2</sub> or NiBr <sub>2</sub> or SnBr <sub>2</sub> ) instead of NaBr	Pb <sup>2+</sup> (or Zn <sup>2+</sup> or Fe <sup>2+</sup> or Ni <sup>2+</sup> or Sn <sup>2+</sup> ) ions will be reduced at cathode (not H <sub>2</sub> O)	<ul style="list-style-type: none"><li>• Demonstrates a thorough knowledge of ways to change the process occurring in an electrolytic cell.</li><li>• Describes two specific changes (electrode, nature or concentration of electrolyte)</li><li>• Predicts and gives thorough description of changes (to voltage, reactions occurring, observations) that would occur for each modification</li><li>• Writes correct, relevant half equations and electrode potentials ..... 3</li></ul>
Proposed alteration	Predicted change in reactions													
Changing anode to Cu	Cu would be oxidised at anode (not Ag)													
Changing anode to Pt	Br <sup>-</sup> would be oxidised at the anode (not Ag)													
Using molten or very concentrated NaBr	Na <sup>+</sup> ions would be reduced at the cathode (not H <sub>2</sub> O)													
Using aqueous NaI (or NaOH) instead of NaBr	I <sup>-</sup> (or OH <sup>-</sup> ) ions will be oxidised at the anode (not Ag)													
Using PbBr <sub>2</sub> (or ZnBr <sub>2</sub> or FeBr <sub>2</sub> or NiBr <sub>2</sub> or SnBr <sub>2</sub> ) instead of NaBr	Pb <sup>2+</sup> (or Zn <sup>2+</sup> or Fe <sup>2+</sup> or Ni <sup>2+</sup> or Sn <sup>2+</sup> ) ions will be reduced at cathode (not H <sub>2</sub> O)													
<p>In each case, the new half-reaction that occurs essentially has a higher potential than the one it replaces.</p> <p>For example:</p> $\text{Cu}_{(s)} \rightarrow \text{Cu}^{2+} + 2\text{e}^{-} \quad E^{\circ} = -0.34 \text{ V} \quad [\text{O}]$ $\text{I}^{-} \rightarrow \frac{1}{2} \text{I}_{2(aq)} + \text{e}^{-} \quad E^{\circ} = -0.62 \text{ V} \quad [\text{O}]$ $\text{Pb}^{2+} + 2\text{e}^{-} \rightarrow \text{Pb}_{(s)} \quad E^{\circ} = -0.13 \text{ V} \quad [\text{R}]$ <p>The voltage required for the electrolysis process will be altered in each case.</p>		<ul style="list-style-type: none"><li>• Demonstrates a sound knowledge of ways to change the process occurring in an electrolytic cell.</li><li>• Writes correct, relevant half equations and electrode potentials</li><li>• Describes one alteration in detail and clearly predicts changes that would occur OR states two alterations and outlines changes that would occur for each ..... 2</li></ul>												
(iv)	<p>Electrolysis can be used as a means for removing salt from saturated artefacts.</p> <p>Electrolysis can be used as a means of cleaning and stabilising copper, iron and lead artefacts.</p>	9.6.3 H4 <ul style="list-style-type: none"><li>• Identifies a suitable use of electrolysis in the conservation and restoration process . . . . 1</li></ul>												

## Question 31

## The Biochemistry of Movement

Sample answer	Syllabus content, course outcomes and marking guide
(a) (i) The energy stored in the ATP bonds comes from the food the organism consumes. Ultimately, the energy in food comes from the sun via photosynthesis.	9.7.1 H7 • Correct response – the sun . . . . . 1
(ii) Glycolysis occurs in the cytosol of the cell, outside the mitochondrion.	9.7.1 H7 • Correct response – cytosol . . . . . 1
(b) Muscle fibres consist of layers of myosin (thick filament) and actin (thin filament) fibres. The actin has cross-bridge binding sites for the myosin heads which are blocked until the action of calcium on the tropomyosin reveals them prior to contraction. The myosin heads are bound to ATP in a low-energy configuration until the ATP hydrolyses to ADP and $P_i$ , using the energy released to move the head towards the actin binding site. This forms the cross bridge between the two fibres. When ADP and $P_i$ are released from the head, it moves back to its low-energy position, sliding the actin filament towards the sarcomere. ATP provides the energy to move the myosin head through hydrolysis to form ADP and $P_i$ .	9.7.5 H2, H7, H13 • Detailed description of the formation of cross bridges and explanation of the role of ATP . . . . . 3–4 • Description of the formation of cross bridges OR • an explanation of the role of ATP . . . . 1–2
(c) (i) Glycolysis produces two ATP and two NADH and two molecules of pyruvate per glucose molecule. The TCA cycle produces one ATP, three NADH and one $FADH_2$ for each pyruvate that enters the cycle and twice that number of each molecule per glucose molecule. Production of NADH and $FADH_2$ is important because the compounds go into oxidative phosphorylation to produce ATP.	9.7.7, 9.7.8 H7, H14 • Correct calculation of the number of molecules of ATP and NADH from glycolysis and from the TCA cycle for a molecule of glucose and understanding of the role of oxidation phosphorylation to use NADH and $FADH_2$ to produce ATP . . 3–4 • Correct calculation of the number of molecules of ATP and NADH from glycolysis OR • from the TCA cycle for a molecule of glucose . . . . . 1–2
(ii) When oxygen is not present in animal and plant cells, the pyruvate produced during glycolysis is converted by enzymes to lactic acid. Yeast cells produce ethanol and carbon dioxide from the pyruvate produced in glycolysis but only two molecules of ATP are produced per molecule of glucose in both cases.	9.7.10 H7 • Correct comparison of both processes to produce the same amount of ATP . . . . 2 • Any comparison of both processes . . . . 1

## Question 31

## The Biochemistry of Movement (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(d) NADH and FADH<sub>2</sub> are high-energy electron carriers produced in glycolysis and the TCA cycle. They are essential for the production of ATP in oxidative phosphorylation. These molecules transfer their high-energy electrons to the components of the cytochrome chain.</p> <p>During the transfer of electrons down the chain, the energy produced is used to pump H<sup>+</sup> ions across the membrane of the cristae into the intermembrane space. The H<sup>+</sup> ions are transported against their concentration gradient and can only flow back through the channels provided by ATP synthase. The flow of H<sup>+</sup> ions back into the cristae provides the energy (proton motive force) which drives the synthesis of ATP from ADP and P<sub>i</sub>.</p> <p>The NADH and FADH<sub>2</sub> are oxidised.</p> $\text{NADH} \rightarrow \text{NAD}^+ + 2\text{e}^- + \text{H}^+$ $\text{FADH}_2 \rightarrow \text{FADH}^+ + 2\text{e}^- + \text{H}^+$ <p>The proteins in the cytochrome chain are reduced when they accept the electrons from NADH and FADH<sub>2</sub>. The electrons enter the cytochrome chain and the NAD<sup>+</sup> and FADH<sup>+</sup> is regenerated to be used again.</p>	<p>9.7.9 H7, H9, H14</p> <p>Demonstrated understanding of:</p> <ul style="list-style-type: none"> <li>the link between the production of NADH and FADH<sub>2</sub> in glycolysis and the TCA cycle to the production of ATP in oxidative phosphorylation;</li> <li>AND</li> <li>the oxidation/reduction processes involved;</li> <li>AND</li> <li>the use of the energy from the electrons to provide the proton motive force that produces ATP. . . . . 6–7</li> </ul> <p>Demonstrated understanding of:</p> <ul style="list-style-type: none"> <li>the link between the production of NADH and FADH<sub>2</sub> in glycolysis and the TCA cycle to the production of ATP in oxidative phosphorylation;</li> <li>AND</li> <li>the oxidation/reduction processes involved;</li> <li>OR</li> <li>the use of the energy from the electrons to provide the proton motive force that produces ATP. . . . . 4–5</li> </ul> <ul style="list-style-type: none"> <li>Understanding of the link between the production of NADH and FADH<sub>2</sub> in glycolysis and the TCA cycle to the production of ATP in oxidative phosphorylation . . . . . 1–3</li> </ul>
<p>(e) (i)</p> <pre>       H   H   H                 H — C — C — C — H                       OH  OH  OH           </pre>	<p>9.7.3 H9</p> <ul style="list-style-type: none"> <li>Correct drawing . . . . . 1</li> </ul>
<p>(ii) Glycerol is a small molecule with three polar side chains as OH groups attached to each carbon. Fatty acids are large molecules of 10–20 carbon atoms attached to an acid group. They are a long non-polar hydrocarbon chain with one polar end.</p>	<p>9.7.3 H9</p> <ul style="list-style-type: none"> <li>Correct description and comparison of the structures of glycerol and fatty acids . . 1–2</li> </ul>

## Question 31

## The Biochemistry of Movement (Continued)

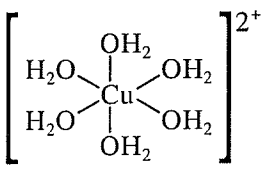
Sample answer	Syllabus content, course outcomes and marking guide
<p>(iii) Glycerol is highly soluble in water and insoluble in oily solvents because of the polar nature of the hydroxyl groups and the small size of the molecule. It forms dipole-dipole interactions and hydrogen bonds with water but is not able to form dispersion forces to mix with non-polar solvents.</p> <p>Although fatty acids have a polar end, it has little effect on solubility because it is dominated by the large numbers of weak dispersion forces formed between the molecules themselves or with solvents.</p> <p>This means that they are not soluble in water but are soluble in oily solvents which also have non-polar molecules.</p> <p>Predictions for viscosity also depend on structure and bonding between the molecules of the substance. Fatty acids would be more viscous than glycerol because, although dispersion forces are weak, there is a large number of them operating between the molecules to hold them together and make them feel smooth but not runny.</p> <p>Glycerol, being polar and smaller in size, will be more runny (viscous) than fatty acids. The number of bonds between molecules, although stronger, is much fewer in number and makes for a silky feel and a runny material.</p>	<p>9.7.3 H6, H12, H14</p> <ul style="list-style-type: none"> <li>• Prediction and demonstrated understanding of the contribution of intermolecular forces to the viscosity and solubility of both substances ..... 2–3</li> <li>• Prediction of the viscosity and solubility of both substances ..... 1</li> </ul>

## Question 32

## The Chemistry of Art

Sample answer		Syllabus content, course outcomes and marking guide	
(a)	(i) Potassium	9.8.2	H6, H7
		<ul style="list-style-type: none"> <li>Correctly identifies the element as potassium (as K, K<sup>+</sup>, potassium, or potassium ions) . . . . .</li> </ul>	1
	(ii) The atoms in the sample absorb a specific quantum of energy from the flame, which causes electrons to be excited. This same quantum of energy is released when the electrons relax back to the ground state, and is observed as a specific wavelength of visible light. This is the characteristic flame colour of the element.	9.8.2	H6, H7
		<ul style="list-style-type: none"> <li>Explains fully, including: the absorption of a specific wavelength (or frequency or quantum) of energy from the flame; the excitation of a ground state electron to an excited energy level; the release of the same energy when the electron relaxes back to the ground state; the released energy observed as a characteristic flame colour (or light of a specific wavelength) . . . . .</li> </ul>	3
		<ul style="list-style-type: none"> <li>Gives an explanation based on the absorption and release of energy that is not as comprehensive as for 3 marks, or with some minor error in understanding . . . . .</li> </ul>	2
		<ul style="list-style-type: none"> <li>Indicates a basic knowledge of either the excitation or relaxation of electrons. . . . .</li> </ul>	1
(b)	(i) Any two of: insolubility in water; readily available in the local environment; coloured.	9.8.1	H1, H3
		<ul style="list-style-type: none"> <li>Identifies two properties . . . . .</li> </ul>	2
		<ul style="list-style-type: none"> <li>Identifies one property . . . . .</li> </ul>	1
	(ii) Cinnabar (HgS) was a red pigment used by the ancient Egyptians as a rouge. Malachite (basic copper carbonate) was used as a green eye shadow. Cinnabar contains mercury, which is a cumulative poison that is harmful by skin contact and can cause serious central nervous system damage. Malachite contains copper, is harmful if swallowed or inhaled, and is an eye irritant. Thus the use of each of these pigments as cosmetics poses serious health hazards. While their use was important in these cultures because it allowed the expression of a social hierarchy including royalty, the use of these pigments as cosmetics today would not be allowed.	9.8.1	H3, H4
		<ul style="list-style-type: none"> <li>Identifies (by name or formula and by colour) and describes the use as cosmetics of two pigments in a named ancient culture AND</li> <li>Discusses (i.e. gives both pros and cons of) their use . . . . .</li> </ul>	4
		<ul style="list-style-type: none"> <li>Identifies and describes the use as cosmetics of two pigments in a named ancient culture AND</li> <li>Outlines the health effects of using these pigments as cosmetics</li> </ul>	AND
		<ul style="list-style-type: none"> <li>Discusses (i.e. gives both pros and cons of) the use of one identified (by name or formula, and colour) pigment as a cosmetic in a named ancient culture . . . . .</li> </ul>	3
		<ul style="list-style-type: none"> <li>Names an ancient culture, outlines the use of one identified pigment as a cosmetic (including its colour), and gives at least one health effect of its use . . . . .</li> </ul>	2
		<ul style="list-style-type: none"> <li>Identifies one ancient culture and one pigment that was used as a cosmetic in that culture . . . . .</li> </ul>	1

## Question 32 The Chemistry of Art (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(c) Green <math>\text{CuCl}_2</math> and white (anhydrous) <math>\text{CuSO}_4</math> are both lattice solids, with different colours because of the different ligands around the <math>\text{Cu}^{2+}</math> ions. However, when either one is dissolved in water, the copper ion is surrounded by water molecules which bond with it. Hence both salts produce the same hydrated complex, <math>[\text{Cu}(\text{H}_2\text{O})_6]^{2+}</math>, which is pale blue. This is an example of a coordination complex, or complex ion. The structure of this complex is:</p> <div style="text-align: center;">  </div> <p>Each water molecule in the complex is a ligand, and each bonds to the copper ion via one of the lone pairs of electrons on the oxygen atom.</p> <p>The copper(II) ion does not have a full third or fourth electron shell, so it acts as a Lewis acid, accepting an electron pair from each water molecule's oxygen atom, which act as Lewis bases. Each covalent bond formed is a coordinate covalent bond because both electrons are donated by the oxygen atom.</p> <p>Note: students should not be penalised for using <math>[\text{Cu}(\text{H}_2\text{O})_4]^{2+}</math>.</p>	<p>9.8.5 H2, H6, H8, H13</p> <ul style="list-style-type: none"> <li>Explains that both salts give the same hydrated complex in solution, draws the correct structure of the complex, and gives a full description of the bonding in the complex ..... 7</li> <li>Explains that both salts give the same hydrated complex in solution AND EITHER</li> <li>Draws the correct structure of the complex and gives a correct but incomplete account of the bonding in the complex OR</li> <li>Draws the correct but incomplete structure of the complex and gives a correct and complete description of the bonding in the complex ..... 5–6</li> <li>Draws a correct but incomplete structural diagram of the complex and gives a correct but incomplete description of the bonding in the complex ..... 3–4</li> <li>An attempt at an explanation of bonding in coordination complexes OR</li> <li>An attempt at a structural drawing of the hydrated ion ..... 1–2</li> </ul>
<p>(d) (i) <math>1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}</math></p>	<p>9.8.4 H6</p> <ul style="list-style-type: none"> <li>Correctly states the electron configuration of <math>\text{Zn}^{2+}</math> using <i>s</i>, <i>p</i>, <i>d</i> notation ..... 1</li> </ul>
<p>(ii) Mn(VII), purple, and Mn(II), colourless (or very pale pink).</p>	<p>9.8.4 H8, H12, H13</p> <ul style="list-style-type: none"> <li>Correctly names two oxidation states of an identified metal and their associated colours ..... 2</li> <li>Correctly identifies the colour of one oxidation state of an identified metal. ... 1</li> </ul>
<p>(iii) 1) One pipette full of an iron(II) solution was transferred to a test tube. 2) Acidified <math>\text{KMnO}_4</math> solution was added drop by drop from a pipette to an iron(II) solution at room temperature. 3) The colour change was observed. As the 5 M <math>\text{H}_2\text{SO}_4</math> is corrosive and could easily come into contact with skin, it was handled with gloves to avoid burns as a result of skin contact. <math>\text{KMnO}_4</math> is moderately toxic if ingested. The likelihood of eating potassium permanganate was extremely low, but to further reduce the risk we wore gloves to prevent skin contact and washed our hands after the experiment.</p>	<p>9.8.4 H12, H13</p> <ul style="list-style-type: none"> <li>Outlines the method used, including reagents and conditions, and gives a risk assessment for two hazards ..... 5</li> <li>Gives correct aspects of the method used, including reagents and/or conditions, and assesses one hazard ..... 3–4</li> <li>Gives correct aspects of the method used, including reagent and/or conditions OR</li> <li>Gives a risk assessment of one or two hazards ..... 1–2</li> </ul>

## Question 33

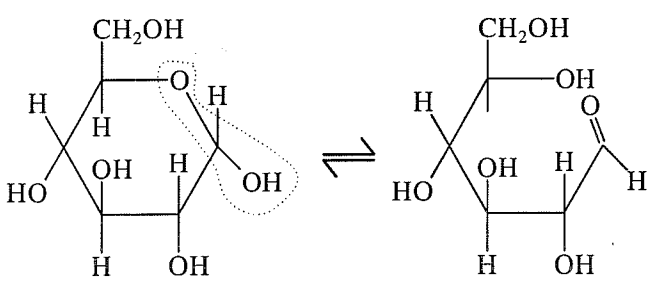
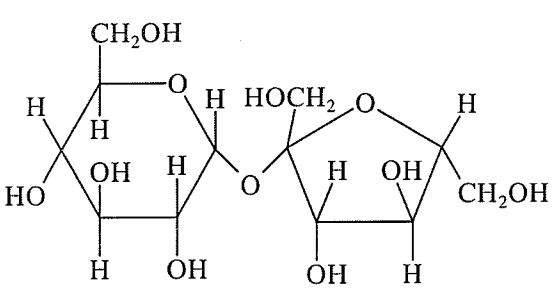
## Forensic Chemistry

Sample answer	Syllabus content, course outcomes and marking guide
<p>(a) Cyclohexene: add drops of bromine water to the sample. It will readily change colour from brown to colourless even in the absence of UV light. Ethanol and ethanoic acid show no (or a very slow) reaction with bromine.</p> <p>Ethanoic acid: add drops of aqueous sodium carbonate to the sample. Bubbles of colourless gas (<math>\text{CO}_2</math>) will form. No reaction observed with cyclohexene or ethanol.</p> <p>Ethanol: dry the sample with calcium chloride and then add small pieces of sodium. Bubbles of colourless gas form (<math>\text{H}_2</math>). Alkanoic acids, however, react in a similar manner but ethanoic acid would have been identified by reaction with sodium carbonate.</p> <p>Alternatively, as ethanol is a primary alcohol a few drops of acidified potassium permanganate solution <math>\text{H}^+/\text{MnO}_4^-</math> or acidified potassium dichromate solution, <math>\text{H}^+/\text{Cr}_2\text{O}_7^{2-}</math> can be added. The purple permanganate solution is decolourised to <math>\text{Mn}^{2+}</math> or the orange dichromate solution turns green. There will be no reaction observed with either test reagent for ethanoic acid and there will be no reaction with the dichromate solution for cyclohexene. Although, when the cyclohexene reacts with the acidified potassium permanganate a brown precipitate of manganese dioxide is formed.</p>	<p>9.9.1 H9, H11</p> <ul style="list-style-type: none"> <li>Correctly describes one test for each of the following organic compounds: cyclohexene, ethanoic acid and ethanol. . . . . 3</li> <li>Correctly describes one test for two of the following organic compounds: cyclohexene, ethanoic acid and ethanol. . . . . 2</li> <li>Correctly describes one test for at least one of the following organic compounds: cyclohexene, ethanoic acid and ethanol. . . 1</li> </ul>



## Question 33

## Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(b) (i) Sugars that have both a <math>\text{-OH}</math> group and a <math>\text{O}</math> attached to the one <math>\text{C}</math> atom in their ring form are referred to as reducing sugars. They can readily isomerise into an open chain structure with a carbonyl group, <math>\text{-C=O}</math>. They are also easily oxidised.</p> <p>Example: Glucose</p> <div style="text-align: center;">  </div> <p style="text-align: center;">ring                                      open chain</p> <p>Sugars that do not have a <math>\text{C}</math> atom that has both a <math>\text{OH}</math> group and an <math>\text{O}</math> atom attached to it in their ring form are referred to as non-reducing sugars. It is not possible to convert this sugar into an open-chain structure in order to form the carbonyl group, <math>\text{-C=O}</math>. They are not easily oxidised.</p> <p>Example: Sucrose</p> <div style="text-align: center;">  </div>	<p>9.9.2 H9</p> <ul style="list-style-type: none"> <li>Correctly describes the chemical structure of a reducing sugar and a non-reducing sugar. .... 2</li> <li>Correctly describes the chemical structure of either a reducing sugar or a non-reducing sugar. .... 1</li> </ul>
<p>(ii) Sucrose is a non-reducing sugar because neither of its rings can be converted to an open chain structure. Therefore it is not possible to form the carbonyl group <math>\text{C=O}</math> because the linkage between the glucose and the fructose units of which sucrose is composed is through both carbonyl carbons.</p>	<p>9.9.2 H9, H10, H11</p> <ul style="list-style-type: none"> <li>Correctly identifies sucrose as a non-reducing sugar .... 1</li> </ul>

## Question 33

## Forensic Chemistry (Continued)

## Sample answer

## Syllabus content, course outcomes and marking guide

(iii)

## Method:

- 1) Add 10 drops of Benedict's solution (or Fehling's reagent) to a small sample of the sugar to be tested.
- 2) Heat the mixture and record colour changes.

## Results:

Reducing sugars	Non-reducing sugars
Brick red precipitate forms	No precipitate. Solution remains unchanged.

9.9.2

H9, H10, H11

- Correctly identifies the use of Benedict's solution (or Fehling's reagent) in order to determine whether the sugar is a reducing or non-reducing sugar and correctly describes the observed results . . . . . 2
- Identifies Benedict's solution (or Fehling's reagent) as a way in which a sugar can be classified as a reducing or non-reducing sugar. . . . . 1

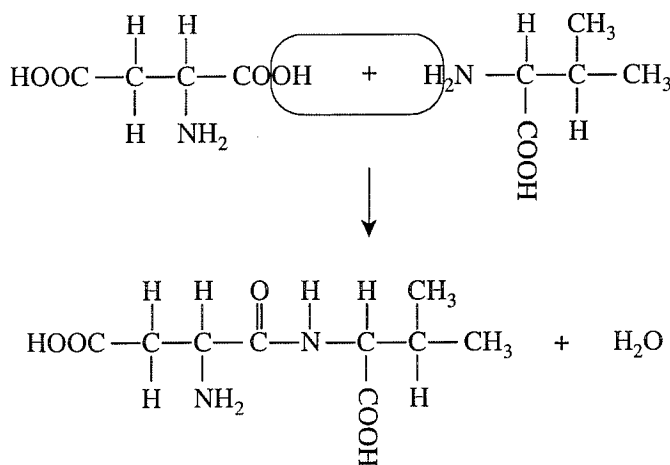
- (c) (i) amine (or amino) functional group ( $-\text{NH}_2$ )  
carboxylic acid (or carboxyl) functional group ( $-\text{COOH}$ )

9.9.3

H9

- Correctly identifies the two major functional groups for an amino acid . . . . . 1

(ii)



9.9.3

H9, H10

- Correctly draws the structural formula of the dipeptide formed from the amino acids valine and aspartic acid . . . . . 1

## Question 33

## Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(iii) Gel electrophoresis can separate a mixture of amino acids according to the charge and size.</p> <ul style="list-style-type: none"> <li>The sign of their charge will determine the direction the amino acid moves in the gel and the rate at which it moves depends on the magnitude of the charge and the friction to their movement.</li> </ul> <p>Changing the pH of the buffer solution will control the charge across an amino acid. If the pH of the buffered solution is lower than the isoelectric point (pI) for that amino acid, then the amino acid will exist as a positively charged species. The amino acid will move towards the negative electrode. If the buffered solution has a pH higher than the iso-electric point for that amino acid then the amino acid exists as a negatively charged species and it will move towards the positive electrode. However, if the buffered solution has a pH that is identical to the isoelectric point for that amino acid then the amino acid won't move at all.</p> <ul style="list-style-type: none"> <li>The size of the R group for the amino acid will determine the distance the amino acid will run in the gel. The larger the R group the more slowly it will move.</li> </ul>	<p>9.9.3 H9, H10, H11</p> <ul style="list-style-type: none"> <li>Provides a detailed explanation for the separation of a mixture of amino acids according to their size and charge. . . . . 3</li> <li>Provides a thorough explanation for the separation of a mixture of amino acids according to their size and charge. . . . . 2</li> <li>Provides a sound explanation for the separation of a mixture of amino acids according to their size and/or charge. . . . 1</li> </ul>
<p>(iv) A – Lysine. Will migrate towards the negative electrode as in a buffer solution of pH 6 lysine exists as a positively charged species.</p> <p>B – Valine. Won't migrate at all as its isoelectric point is the same as the pH of the buffer solution.</p> <p>C – Aspartic acid. Will migrate towards the positive electrode as in a buffer solution of pH 6 aspartic acid exists as a negatively charged species.</p>	<p>9.9.3 H10, H13</p> <ul style="list-style-type: none"> <li>Correctly identifies all three amino acids 1</li> </ul>

## Question 33

## Forensic Chemistry (Continued)

## Sample answer

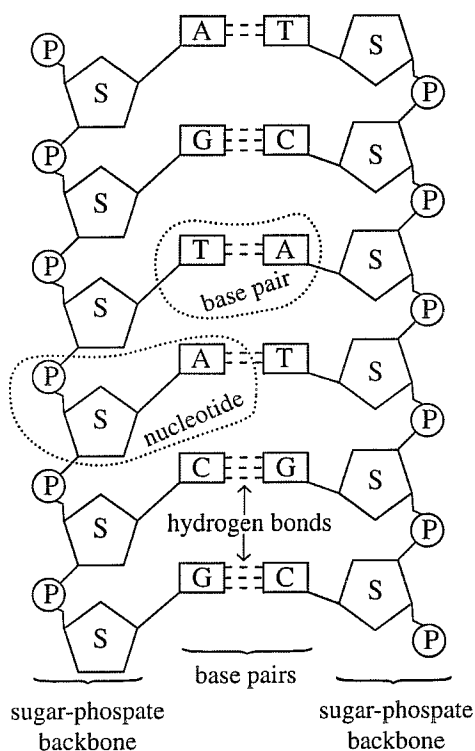
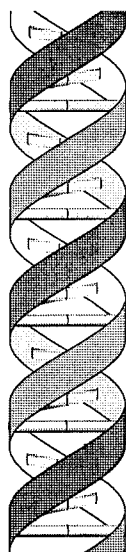
- (d) (i) DNA is a polymeric molecule whose monomer units are called nucleotides. A nucleotide consists of a sugar molecule, deoxyribose, attached to a phosphate and a base unit. There are four bases: adenine (A), guanine (G), cytosine (C) and thymine (T).

DNA occurs as two long chains that are connected by hydrogen bonding between the base pairs. The base pairs are:

adenine and thymine;

cytosine and guanine.

The chains are twisted in a double helix, consisting of two twisted chains. It resembles a spiral staircase.



## Syllabus content, course outcomes and marking guide

9.9.4

H1, H3, H4, H5, H13

- Clearly describes the structure (helical strands which are connected between helices at complementary N bases) and composition (sugar groups, phosphate, four different N bases) of DNA..... 2

- Describes the structure of DNA

OR

- Describes the composition of DNA

OR

- Shows a basic knowledge of both the structure and composition of DNA ..... 1

## Question 33

## Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(ii) The analysis of DNA and the maintenance of a DNA data bank have many advantages and disadvantages.</p> <p><b>Advantages of maintaining a DNA data bank:</b></p> <ul style="list-style-type: none"> <li>• It may help to solve outstanding crimes.</li> <li>• It allows for conclusive identification of a father in a paternity case.</li> <li>• It can provide more accurate identification than fingerprints or blood typing.</li> <li>• It allows for crime scenes to be linked (across state or time) and possibly allows for the identification of serial offenders.</li> <li>• It can exclude certain individuals early on in an investigative process. As occasionally innocent people have been incarcerated for a crime they did not commit.</li> </ul> <p><b>Disadvantages of maintaining a DNA data bank:</b></p> <ul style="list-style-type: none"> <li>• It can lead to discrimination against families with genetic disorders by insurance companies. Discrimination can include higher insurance premiums or denial of insurance coverage for income, travel, superannuation or life insurance.</li> <li>• It may allow for genetic information to become available to employers and this may result in people not being employed on the basis of their genetic information.</li> <li>• It could ignite a potentially dangerous search for a 'criminal gene' and this could lead to unwarranted labelling and mistreatment of criminals and their law-abiding biological relatives.</li> <li>• It could result in a person being said to be guilty of a crime based solely on DNA although DNA alone does not prove guilt.</li> </ul>	<p>9.9.4 H1, H3, H5, H13, H16</p> <ul style="list-style-type: none"> <li>• Demonstrates a thorough knowledge of the issues associated with DNA data banks.</li> <li>• Provides a comprehensive list describing the advantages and disadvantages . . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrates a thorough knowledge of the issues associated with DNA data banks.</li> <li>• Outlines several advantages and disadvantages (at least two of each) . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrates a good knowledge of the issues associated with DNA screening.</li> <li>• Outlines some advantages and disadvantages (one of each) . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrates a limited knowledge of the issues associated with DNA data banks.</li> <li>• Identifies one advantage OR one disadvantage. . . . . 1</li> </ul>

## Question 33

## Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(e) When a sample of an element is given energy in a discharge tube an emission spectrum occurs. Excited electrons jump to higher energy levels but as they fall back from these higher energy levels to their ground state they emit the extra energy as light.</p> <p>The electrons, however, do not necessarily fall back to the ground state in one drop.</p> <p>As a result, a series of coloured lines of differing wavelengths can be seen on a black background when the sample is examined through a spectroscope. Each element has a characteristic emission spectrum of its own, therefore emission spectroscopy is a useful tool for identification of unknown samples.</p> <p>Emission spectroscopy is important to forensic scientists as it can be used to:</p> <ul style="list-style-type: none"> <li>Determine where a soil sample has come from by comparing the concentrations of less common elements in the soil to a known soil sample's composition.</li> <li>Determine where samples of paint found at a crime scene have come from by comparing the paint's composition to known paint samples. For example, emission spectroscopy may indicate that a chip of paint taken from the crime scene has high levels of lead. This could indicate the origin of the paint was from an older house or a paint factory.</li> <li>Determine the origin of metal fragments by comparing the spectrum to spectra from likely sources.</li> <li>Determine suspected contaminants in fertiliser and other products and compare to a known sample for a match.</li> <li>Determine the concentration of heavy metals such as lead, mercury and arsenic in water samples. This information can then be used in conjunction with other evidence to determine the likely source of the water.</li> </ul> <p>Emission spectroscopy is important as it enables the elements of any mixture to be determined from small samples, although the nature of the compounds in which the elements were found cannot be determined using this method. This is because the compounds can be decomposed into gaseous atoms if the compounds are exposed to high temperatures or electrical discharges.</p>	<p>9.9.6 H3, H4, H6, H7, H13</p> <ul style="list-style-type: none"> <li>Demonstrates a thorough knowledge of emission spectra of elements and how they can assist in the identification of the origins of a mixture . . . . . 4–5</li> <li>Demonstrates a good knowledge of emission spectra and how they are used to identify elements . . . . . 2–3</li> <li>Identifies a feature of emission spectra . . . 1</li> </ul>