

HSC Trial Examination 2003

# Chemistry

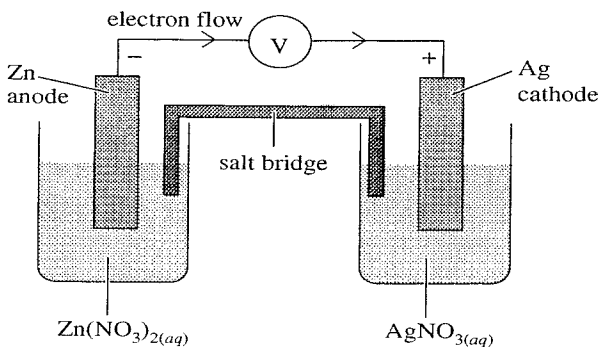
## Solutions and marking guidelines

## Section I

## Part A

Answer and explanation	Syllabus content and course outcomes
<b>Question 1</b> D By definition, the molar heat of combustion is for one mole of fuel, therefore B is unacceptable. The fuel in A is not a compound (as requested by the question). C is an incorrect equation.	9.2.3 H7, H9
<b>Question 2</b> D Yeast enzymes are used in fermentation, dilute acid is used in hydrolysis, high pressure is not a catalyst.	9.2.3, 9.3.5, 9.4.2 H8, H9
<b>Question 3</b> A The $\text{Mn}^{2+}$ changes its oxidation state from +2 to +4. Therefore it is oxidised, i.e. it acts as a reducing agent.	9.2.4 H6, H8
<b>Question 4</b> A A is the only beta decay equation. B is showing alpha decay, C is nonsense and D shows fission.	9.2.5 H6
<b>Question 5</b> D At a pH of 3, the concentration of $\text{H}^+$ is equal to $10^{-3} \text{ mol L}^{-1}$ . At a pH of 5, the concentration of $\text{H}^+$ is equal to $10^{-5} \text{ mol L}^{-1}$ . Therefore, the solution is now more dilute, because the concentration of $\text{H}^+$ has decreased by a factor of $10^{-3}/10^{-5} = 100$ .	9.3.3 H8, H10
<b>Question 6</b> D Acid strength is measured by the extent of ionisation of the acid. Weak acids ionise less than stronger acids.	9.3.3 H8, H14
<b>Question 7</b> C Reaction II is not an Arrhenius or Lowry–Brønsted acid base reaction; $\text{Fe}^{3+}/\text{FeSCN}^{2+}$ are not a conjugate pair; $\text{HSO}_3^-$ acting as a base.	9.3.4 H8
<b>Question 8</b> B Since the equivalence point is at a $\text{pH} > 7$ the mixture is alkaline. This means there must be more $\text{OH}^-$ than $\text{H}^+$ present.	9.3.4 H13
<b>Question 9</b> A According to Lavoisier, oxygen in compounds formed with nonmetals causes acidity.	9.3.4 H1, H8
<b>Question 10</b> C Hydrogen is produced by reacting methane with steam using a nickel catalyst.	9.4.2 H3, H8
<b>Question 11</b> D $\text{PbCl}_2$ and $\text{Fe}(\text{OH})_3$ are the solids formed.	9.4.3 H8, H11
<b>Question 12</b> A Halons are also ozone-depleting gases; in statement III, stratosphere and troposphere should be interchanged.	9.4.4 H4, H9
<b>Question 13</b> C Both structural formulae represent the same compound.	9.4.4 H9
<b>Question 14</b> B	9.4.5 H3, H4, H9
<b>Question 15</b> B Flowing water will have the most dissolved oxygen. Runoff from the dairy farm will provide nutrients for organisms from increased nitrate, and lowering DO.	9.4.5 H11, H14

## Part B

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 16</b> Chloroethene. Polychloroethene or polyvinyl chloride can be produced in rigid and flexible forms. It is used to make pipes and fittings including windows as well as bottles because of its resistance to grease, oil and other chemicals and its great strength. It is also used to insulate wires, as it is a nonconductor.	9.2.1 H3, H4, H9 • Systematic name and two uses related to different properties. . . . . 2–3 OR • Systematic name • only one use . . . . . 1
<b>Question 17</b> Cellulose is a long chain condensation polymer with repeating units of D-glucose, a simple sugar. The C <sub>1</sub> atom of one ring is joined through a single oxygen to the C <sub>4</sub> atom of the next, with water being eliminated. The polymer chains are held near each other by hydrogen bonding, giving the fibres strength. Cellulose is found in almost pure form in cotton fibre and is a major component of biomass. As a raw material it can be used to make cellulose fibres and other fibres based on chemicals made from cellulose. It is also converted to ethanol by enzymes, making it a fuel source that is renewable.	9.2.2 H3, H9 • Describes cellulose structure and two or more uses. . . . . 3–4 OR • Some description and one use • Two uses. . . . . 1–2
<b>Question 18</b> (a) 	9.2.4 H7, H13 • Correctly labelled diagram, anode on left, electron flow from anode to cathode . . . 2
(b) $\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+}_{(aq)} + 2\text{e}^- \quad E^\circ = 0.76 \text{ V}$ $2 \times \text{Ag}^+_{(aq)} + \text{e}^- \rightarrow \text{Ag}_{(s)} \quad E^\circ = 0.80 \text{ V}$ Overall $2\text{Ag}^+_{(aq)} + \text{Zn}_{(s)} \rightarrow 2\text{Ag}_{(s)} + \text{Zn}^{2+}_{(aq)}$ Cell voltage = 0.76 + 0.8 = 1.56 V	9.2.4 H7 • Equations, with states and correct cell voltage . . . . . 2 OR • Overall equation with no voltage • Two correct half equations. . . . . 1
(c) The reaction is an equilibrium process, so adding extra Zn <sup>2+</sup> will reduce the voltage, as less oxidation will occur.	9.2.4 H7, H8 • Correctly explains drop in voltage using equilibrium principles . . . . . 2 OR • Predicts drop in voltage but with poor explanation. . . . . 1

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<b>Question 19</b> Ethanol can be manufactured using fermentation of solutions of starch and glucose gained from biomass by yeast enzymes. $\text{C}_6\text{H}_{12}\text{O}_{6(aq)} \xrightarrow[\text{by yeast}]{\text{fermentation}} 2\text{C}_2\text{H}_5\text{OH}_{(l)} + 2\text{CO}_{2(g)}$ Ethanol derived using this method is a renewable resource, which is one of its main advantages over fossil fuels. Ethanol can also be manufactured using the hydration of ethylene with a concentrated sulfuric acid catalyst. $\text{C}_2\text{H}_{4(g)} + \text{H}_2\text{O}_{(l)} \xrightarrow[\text{H}_2\text{SO}_4]{\text{conc.}} \text{C}_2\text{H}_5\text{OH}_{(l)}$ A disadvantage of this method of ethanol production is that it uses a non-renewable resource; the ethylene from which the ethanol is derived is obtained from catalytic or thermal cracking of oil, which means that a finite fossil fuel resource is being used. The other advantages of using ethanol as a fuel in its own right or as part of a petrol/ethanol mix are that the combustion of ethanol produces less greenhouse gases than petrol and other fossil fuels by themselves. The energy cost in producing ethanol from biomass is much less than producing fossil fuels. Pure ethanol can be used as a fuel if engines are designed for it. It can also be used up to 10% in an ethanol/petrol mix without having to modify the fuel system of the engine. Higher concentrations may damage the engine, as will distilled ethanol containing any water. The advantages of using ethanol appear to outweigh its disadvantages.	9.2.3 H3, H4, H9, H13 • Assesses potential and describes two methods of production (including catalysts) and discusses advantages. Must have renewable resource; less greenhouse gases or cheaper energy cost and disadvantages (modification of engines, use of fossil fuel if ethylene is used) of ethanol use as a fuel ..... 6–7 • Good description of methods but less detail in assessment or discussion OR • Potential well assessed but lack of detail in production methods ..... 4–5 • Some description of methods related to use of ethanol as a fuel OR • Reasons why ethanol is a useful fuel .. 2–3 • Naming a method OR • An advantage or disadvantage ..... 1
<b>Question 20</b> (a) It is amphiprotic, acting as a base in I by accepting a proton and as an acid in II by donating a proton to water. (b) Dissolve a small quantity of $\text{NaHCO}_3$ in water and add some universal indicator or litmus. If I is more likely then the indicator will be blue or violet or red litmus will turn blue. If II is more likely then the indicator will be yellow or red, and blue litmus will turn red.	9.3.4 H8 • Names amphiprotic, no description necessary ..... 1 9.3.1 H8, H11 • Describes a suitable test and gives the appropriate result ..... 2 • Describes a test OR • Gives a result ..... 1
<b>Question 21</b> (a) The addition of the acid to food is as a preservative. The acidic condition inhibits the growth of microorganisms. (b) Acetic acid is a weak acid. Therefore the acid molecules do not fully ionise, leaving the $[\text{H}^+]$ lower than expected, resulting in a higher pH. Hydrochloric acid is a strong acid. Therefore it completely ionises, making the $[\text{H}^+]$ high and so the pH is lower.	9.3.3 H3, H4, H8 • Identifies and explains use as preservatives. .... 2 • Identifies use as preservatives ..... 1 9.3.3 H8, H13, H14 • Correctly relates strengths of the acids to $[\text{H}^+]$ and correctly relates $[\text{H}^+]$ to pH. ... 2 • Correctly relates strengths of the acids to $[\text{H}^+]$ OR • Correctly relates $[\text{H}^+]$ to pH. .... 1

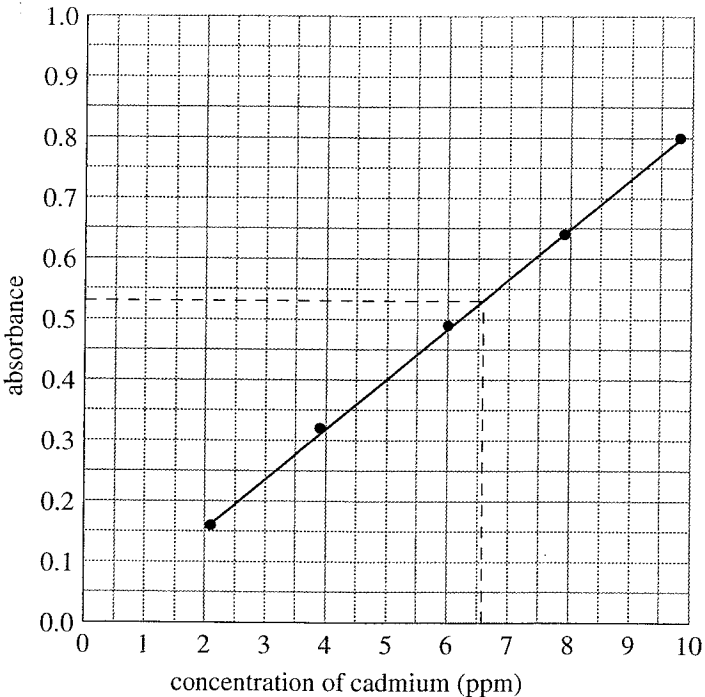
## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p><b>Question 22</b></p> <p>Oxides of sulfur and nitrogen are found in the atmosphere as a result of a number of natural processes, notably volcanic action and decomposition of organic wastes in the case of <math>\text{SO}_2</math>, and lightning in the case of oxides of nitrogen. Since the beginning of the industrial revolution, processes associated with industrialisation and increased human population have added greatly to these natural sources of these oxides. These manmade sources include the processing of sulfide ores to extract metals and production of sulfuric acid, which increase concentration of <math>\text{SO}_2</math>, and combustion of fossil fuels in power plants, car engines and jet engines, which have increased concentrations of the oxides of sulfur and nitrogen.</p> <p>The increased concentrations of these oxides has been evident by the formation of acid rain, which has resulted in damage to waterways, forests, crops and buildings over many years. Other evidence for the increased concentration of these oxides has come from atmospheric pollution, with nitrogen oxides contributing to photochemical smog. Higher levels of these oxides have also contributed to high rates of breathing difficulties often seen in large cities.</p> <p>Over the last few decades, anti-pollution measures have been introduced to reduce industrial <math>\text{SO}_2</math> output and catalytic converters have been a compulsory part of the pollution control equipment of new cars to reduce oxides of nitrogen. Together with standards requiring lower levels of sulfur in fuels, these measures have resulted in many industrial countries experiencing a decrease in the level of these oxides.</p>	<p>9.3.2 H3, H4, H8, H13, H14</p> <ul style="list-style-type: none"> <li>Assesses evidence relating to increases in concentrations of the oxides of nitrogen and sulfur . . . . . 5–6</li> <li>Describes evidence that the concentrations of oxides of nitrogen and sulfur have increased due to human causes . . . . . 5–6</li> <li>Describes effects of the oxides of nitrogen and sulfur . . . . . 1–2</li> </ul>
<p><b>Question 23</b></p> <p>Esterification is an equilibrium reaction with the equilibrium position well to the left. It is also a slow reaction. The reaction to produce ammonia is also slow, although its equilibrium position is well to the right. In each case reaction rate is increased through the use of higher temperatures and a catalyst (concentrated acid for esterification, iron for ammonia). Increasing the temperature also shifts the equilibrium position to the right in the case of esters, increasing yield, but to the left for ammonia, decreasing yield. High pressure (up to 350 atmospheres) is used to increase rate and yield in the Haber process, which is a gas phase reaction, whereas esterification proceeds at atmospheric pressure. Each process removes a product, ammonia is liquefied so that the equilibrium shifts further to the right, and water is removed in esterification so that the equilibrium also shifts to the right.</p>	<p>9.3.5, 9.4.2 H3, H8, H13</p> <ul style="list-style-type: none"> <li>Compares the processes in terms of how rate and position of equilibrium are controlled . . . . . 4–5</li> <li>Compares rate factors</li> <li>OR</li> <li>Equilibrium factors only</li> <li>OR</li> <li>Superficial treatment of both . . . . . 2–3</li> <li>An understanding of rate or equilibrium. . . . . 1</li> </ul>
<p><b>Question 24</b></p> <p>Carbon monoxide is highly toxic to humans, while both substances contribute to environmental pollution. Monitoring the level of these oxides helps the car's computer to adjust settings to ensure complete combustion of fuel takes place, minimising the level of these oxides.</p>	<p>9.4.1 H4, H8</p> <ul style="list-style-type: none"> <li>States a reason for monitoring . . . . . 1</li> </ul>
<p><b>Question 25</b></p> <p>(a) Equilibrium was achieved fastest at <math>400^\circ\text{C}</math>. At this temperature, the concentration of hydrogen gas reached a constant value in the least amount of time.</p>	<p>9.4.2 H8, H13</p> <ul style="list-style-type: none"> <li>Correct explanation and temperature . . . 1–2</li> </ul>

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(b) The formation of ammonia is maximised when the final concentration of hydrogen gas is at a minimum.  This occurs at the lower temperature of the two, showing that lower temperatures favour the formation of ammonia; therefore, the reaction is exothermic.	9.4.2 H3, H7, H8, H13, H14 • Correctly relates temperature to ammonia formation ..... 1–2
(c) The catalyst is magnetite.	9.4.2 H3, H8 • Catalyst is magnetite or iron oxide ..... 1
(d) <div data-bbox="359 577 805 1003" data-label="Figure"> </div> <p>The curve drawn by the students needs to show that the time taken to reach equilibrium is less than the time taken on the graph supplied in the question book for that temperature, but the concentration of hydrogen gas at equilibrium is exactly the same value as that on the graph supplied in the question book for that temperature.</p>	9.4.2 H8, H13 • Correct relationship between time and $[H^+]$ ..... 1–2
<b>Question 26</b>  Student A has performed a gravimetric analysis. Adding dilute acid allows hydroxide and carbonate ions to be removed as water and carbon dioxide gas. Adding excess barium chloride ensures all the sulfate ions are precipitated, so the method so far is very good. The filtration resulted in the loss of some precipitate, which means the results will be inaccurate and hence invalid. The student needs to refine the method to ensure all the $BaSO_4$ is collected. Student B has used volumetric analysis. Errors in the method relate to accuracy of measurements in weighing, volume readings and detecting the end point. Repetition is required to eliminate random errors and produce more valid results.  $n(SO_4^{2-})$ in fertiliser sample = $n(BaCl_2)$ added from burette. $n(BaCl_2) = cV$ $\therefore n(SO_4^{2-}) = 0.2 \times 0.044 = 0.0088$ $m(SO_4^{2-}) = n \times M$ $= 0.0088 \times 96 = 0.845 \text{ g}$ $\%(SO_4^{2-}) = \frac{0.845}{2} \times 100 = 42\%$	9.4.3 H3, H8, H10, H11, H12, H13, H14 • Evaluates each method for procedure and comments on validity of results • Correct calculation with method and units ..... 6–7  • Some evaluation shown or comment on validity of results AND • Correct calculation with method and units ..... 4–5  • Some evaluation shown or comment on validity of results AND • Correct answer and no method ..... 2–3  • Some evaluation shown or comment on validity of results OR • Correct answer and no method ..... 1

## Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p><b>Question 27</b></p>  <p>From the graph, concentration is 6.6 ppm, so sample of soil contains <math>6.6 \times 100 = 660</math> ppm.</p>	<p>9.4.3 H6, H13</p> <ul style="list-style-type: none"> <li>Graph with correctly labelled axis, and appropriate scale</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Concentration read correctly from graph, correct answer ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Graph with correctly labelled axis, and appropriate scale</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Concentration read correctly from graph. 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Graph with correctly labelled axis, and appropriate scale</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Concentration read correctly from graph. 1</li> </ul>
<p><b>Question 28</b></p> <p>(a) Turbidity will increase as more undissolved solids enter the waterway and become suspended.</p> <p>(b) Total dissolved solids will increase due to runoff.</p> <p>(c) Nitrogen:phosphorus ratio will increase as sewage and garden runoff adds nutrients.</p> <p>(d) pH will probably be unaffected or slightly lower since rain is slightly acidic.</p>	<p>9.4.5 H4, H8, H14</p> <ul style="list-style-type: none"> <li>Correct description of each effect ..... 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Correct description of 3 effects ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Correct description of 2 effects ..... 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Correct description of 1 effect ..... 1</li> </ul>

## Section II

## Question 29

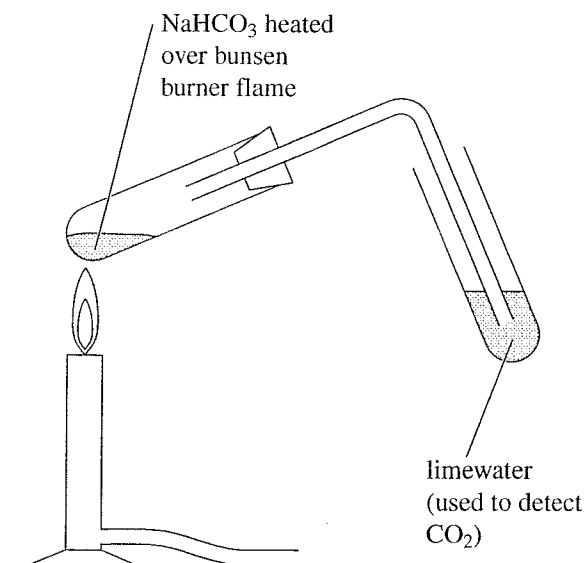
## Industrial Chemistry

Sample answer		Syllabus content, course outcomes and marking guide	
(a)	(i) Oleum is $\text{H}_2\text{S}_2\text{O}_7$ . It is the product of absorption of $\text{SO}_3$ into concentrated $\text{H}_2\text{SO}_4$ .	9.5.3	H3, H8 • Correct definition ..... 1
	(ii) Safety factors: • Wear safety glasses and protective clothing. • Slowly add acid to water with mixing. Explanation: • It is a highly exothermic reaction. • Concentrated sulfuric acid is highly corrosive. • Concentrated sulfuric acid acts as dehydrating agent.	9.5.3	H3, H4, H7, H11 • Correctly identifies safety factors and explains why they are needed ..... 3 • Identifies several safety factors but only explains one ..... 2 • Identifies safety factors without explanation ..... 1
	(b) (i) Electrolysis of dilute NaCl solution Products: hydrogen and oxygen Anode: $2\text{H}_2\text{O}_{(l)} \rightarrow \text{O}_{2(g)} + 4\text{H}^+_{(aq)} + 4\text{e}^-$ Cathode: $2\text{H}_2\text{O}_{(l)} + 2\text{e}^- \rightarrow \text{H}_{2(g)} + 2\text{OH}^-_{(aq)}$ Overall: $2\text{H}_2\text{O}_{(l)} \rightarrow 2\text{H}_{2(g)} + \text{O}_{2(g)}$  Electrolysis of concentrated NaCl solution Products: chlorine and hydrogen Anode: $2\text{Cl}^-_{(aq)} \rightarrow \text{Cl}_{2(g)} + 2\text{e}^-$ Cathode: $2\text{H}_2\text{O}_{(l)} + 2\text{e}^- \rightarrow \text{H}_{2(g)} + 2\text{OH}^-_{(aq)}$ Overall: $2\text{H}_2\text{O}_{(l)} + 2\text{Cl}^-_{(aq)} \rightarrow \text{H}_{2(g)} + 2\text{OH}^-_{(aq)} + \text{Cl}_{2(g)}$	9.5.4	H3, H7, H13 • Provides correct chemical equations for both processes ..... 2 • Provides correct chemical equation for one process ..... 1
	(ii) From the data sheet, $\frac{1}{2} \text{Cl}_{2(g)} + \text{e}^- \rightleftharpoons \text{Cl}^-_{(aq)} \quad 1.36 \text{ V}$ $\frac{1}{2} \text{O}_{2(g)} + 2\text{H}^+_{(aq)} + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_{(l)} \quad 1.23 \text{ V}$ Under dilute conditions, the production of $\text{O}_2$ is favoured as it requires less energy than the production of $\text{Cl}_2$ . When the concentration of $\text{Cl}^-$ increases, the $E^\circ$ value for the production of $\text{Cl}_2$ changes (no longer under standard conditions) and the production of $\text{Cl}_2$ is favoured.	9.5.4	H7, H14 • Correctly identifies the possible oxidants and reductants present in the electrolysis and identifies that concentration of possible reductants affect the products of electrolysis ..... 2 • Correctly identifies the possible oxidants and reductants present in the electrolysis OR • Identifies that concentration of possible reductants affect the products of electrolysis ..... 1



## Question 29

## Industrial Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(c) (i) Decomposition of sodium hydrogen carbonate.</p>  <p>NaHCO<sub>3</sub> heated over bunsen burner flame</p> <p>limewater (used to detect CO<sub>2</sub>)</p>	<p>9.5.6 H3, H8, H11</p> <ul style="list-style-type: none"> <li>Identifies the equipment and describes the process ..... 2</li> <li>Identifies the equipment OR Describes the reaction ..... 1</li> </ul>
<p>(ii) The decomposition of sodium hydrogen carbonate produces the final product of the Solvay process, sodium carbonate.</p> $2\text{NaHCO}_{3(s)} \rightarrow \text{Na}_2\text{CO}_{3(s)} + \text{H}_2\text{O}_{(g)} + \text{CO}_{2(g)}$ <p>The carbon dioxide formed in this reaction can be recycled for use in an earlier stage of the Solvay process, formation of hydrogen carbonate ions.</p>	<p>9.5.6 H3, H11, H14</p> <ul style="list-style-type: none"> <li>Discusses the need for the step and the importance of the products ..... 2</li> <li>Identifies the products or the reactants ... 1</li> </ul>
<p>(d) (i) <math>2\text{SO}_{2(g)} + \text{O}_{2(g)} \rightleftharpoons 2\text{SO}_{3(g)}</math></p> $K = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$	<p>9.5.2 H8, H10</p> <ul style="list-style-type: none"> <li>Correct equilibrium expression (no units required)..... 1</li> </ul>
<p>(ii) <math>K = \frac{5^2}{0.4^2(1)}</math></p> <p>= 156</p>	<p>9.5.2 H10</p> <ul style="list-style-type: none"> <li>Correct response ..... 2</li> <li>Calculates equilibrium concentrations but substitutes incorrectly ..... 1</li> </ul>
<p>(iii) Temperature increase leads to equilibrium shifting to the left.</p> <p>The value of <math>K</math> decreases.</p> <p>Pressure increase shifts equilibrium to the right.</p> <p>This does not change the value of <math>K</math>.</p>	<p>9.5.2 H3, H8, H13</p> <ul style="list-style-type: none"> <li>All four statements correct..... 4</li> <li>Three statements correct ..... 3</li> <li>Two statements correct ..... 2</li> <li>One statement correct ..... 1</li> </ul>

Question 29	Industrial Chemistry (Continued)	Syllabus content, course outcomes and marking guide
	Sample answer	
(e)	<p>Soaps manufactured from oils and fats by saponification reactions are biodegradable (able to be decomposed by bacteria or other organisms). Early synthetic detergents contained branched chain molecules and were not biodegradable. As they do not break down rapidly, these detergents have been responsible for producing foam in waterways. More recently developed synthetic detergents which contain straight chain molecules are more readily biodegradable than the earlier ones. Phosphates have often been added to soaps and detergents. When phosphate from detergent use or other sources enters waterways, it provides nutrients for blue-green algae. When the process of eutrophication occurs, high nutrient levels results in rapid growth of algae, reduced oxygen levels and death of animals in waterways. Because of these environmental problems, phosphate levels in detergents are now regulated by many governments.</p> <p>Due to the use of modern detergents with better biodegradability and lower phosphate levels, the negative impact of detergents on the environment has been greatly reduced.</p>	<p>9.5.5 H3, H4, H9, H13</p> <ul style="list-style-type: none"> <li>• Demonstrates a knowledge of the structure of a soap and a detergent</li> <li>• Compares the biodegradability of soap and detergent</li> <li>• Discusses the generational change of detergents and the affect on the biodegradability of detergents</li> <li>• Discusses the problem of phosphate in waterways and explains eutrophication</li> <li>• Contrasts the effects of soap and detergent in the environment . . . . . 5 –6</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Describes a soap and a detergent</li> <li>• Discusses and compares at least one environmental impact of soap and detergent . . . . . 3–4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Describes either a soap or a detergent</li> <li>• Identifies an environmental issue. . . . . 1–2</li> </ul>

Question 30	Shipwrecks, Corrosion and Conservation	Syllabus content, course outcomes and marking guide
	Sample answer	
(a)	<p>The oxidation of an active metal produces a compound which does not prevent the reactants from coming into contact with that metal and so it continues to corrode. The product of the oxidation of a passivating metal creates an impermeable layer that prevents reactants coming into contact with that metal; hence the metal does not oxidise further.</p>	<p>9.6.2 H3, H7, H8, H13</p> <ul style="list-style-type: none"> <li>Correctly accounts for the differences between active and passive metals. . . . . 2</li> <li>Correctly describes either active or passivating metals . . . . . 1</li> </ul>
(b)	<p>(i) The iron rusts fastest when it is contact with the tin and slowest when in contact with the zinc.</p> <p>From the table of standard reduction potentials, we can see that iron oxidises according to:</p> $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+}_{(aq)} + 2e^{-} \quad E^{\circ} = 0.41 \text{ V}$ <p>Iron has a higher potential than tin:</p> $\text{Sn}_{(s)} \rightarrow \text{Sn}^{2+}_{(aq)} + 2e^{-} \quad E^{\circ} = 0.14 \text{ V.}$ <p>Iron has a lower potential than zinc:</p> $\text{Zn}_{(s)} \rightarrow \text{Zn}^{2+}_{(aq)} + 2e^{-} \quad E^{\circ} = 0.76 \text{ V}$ <p>and so the corrosion of zinc occurs before the corrosion of iron. There is no potential difference between the two pieces of iron and so the rust formed is not accelerated by a potential difference.</p>	<p>9.6.2 H7, H8, H13, H14</p> <ul style="list-style-type: none"> <li>Correct comparison of rate of rust formation supported by equations . . . . . 3</li> <li>Correct comparison of rate of rust formation without correct use of equations . . . . . 2</li> <li>Correct comparison of some of the experiments OR Writes correct, relevant equations without explanation. . . . . 1</li> </ul>
	<p>(ii) The presence of ions in the sodium chloride solution allows for the accelerated migration of ions from the redox process. The rate of corrosion will be accelerated.</p>	<p>9.6.2 H7, H8, H14</p> <ul style="list-style-type: none"> <li>Correct prediction and explanation . . . . . 2</li> <li>Correct prediction OR Correct explanation . . . . . 1</li> </ul>
(c)	<p>(i) Cathodic protection</p>	<p>9.6.4 H3</p> <ul style="list-style-type: none"> <li>Correct name . . . . . 1</li> </ul>
	<p>(ii) Since the steel wharf is in direct contact with salt water and oxygen, the iron in the steel would oxidise to form <math>\text{Fe}^{2+}</math> ions. However, the DC supply forces electrons to leave the metal hanging in the water and forces electrons back onto the wharf. Any <math>\text{Fe}^{2+}</math> ions formed would have electrons forced back onto them to reform iron.</p>	<p>p.6.4 H3, H7, H8, H13</p> <ul style="list-style-type: none"> <li>Detailed description of process in terms of electron transfer. . . . . 2–3</li> <li>General description of cathodic protection . . . . . 1</li> </ul>
	<p>(iii)</p> <ul style="list-style-type: none"> <li>Painting: Provides a physical barrier between the iron hull and sea water. Limitations are that corrosion can occur at a scratch or other blemish in the paint surface or in nearby parts of the hull which are not scratched. Constant maintenance and frequent repainting are required.</li> <li>Use of a sacrificial anode: A block of reactive metal such as zinc is attached to the hull, effectively creating a galvanic cell in which the zinc is oxidised, and electrons produced in this oxidation reaction flow to the hull, preventing oxidation of the iron. As the anode is corroded in this process, it would need to be periodically replaced.</li> <li>Passivating alloys: Constructing a hull from an alloy containing a passivating metal would result in a protective oxide coating forming over the hull, preventing further erosion.</li> </ul>	<p>9.6.4 H3, H4, H7, H8, H13</p> <ul style="list-style-type: none"> <li>Discussion of a suitable method of protection from erosion . . . . . 1–2</li> </ul>

## Question 30 Shipwrecks, Corrosion and Conservation

Sample answer	Syllabus content, course outcomes and marking guide
(d) (i) Reaction rates are slowed down by the extremely low temperatures at great depths in the ocean. The concentration of oxygen at great depths is very low in the ocean and so rusting of iron should not have occurred to any great extent.	9.6.5 H2, H3, H4, H8, H13 • Two correct reasons ..... 2 • One correct reason ..... 1
(ii) Due to the relatively high concentration of sulfate ions in sea water, sulfate-reducing bacteria are quite active. These bacteria reduce the sulfate to sulfur, which is consequently reduced into hydrogen sulfide. $8\text{H}^+_{(aq)} + \text{SO}_4^{2-}_{(aq)} + 6\text{e}^- \rightarrow \text{S}_{(s)} + 4\text{H}_2\text{O}_{(l)}$ $\text{S}_{(s)} + 2\text{H}^+_{(aq)} + 2\text{e}^- \rightarrow \text{H}_2\text{S}_{(aq)}$ The electrons required for these reductions are supplied by oxidation of solid iron. $\text{Fe}_{(s)} \rightarrow \text{Fe}^{2+}_{(aq)} + 2\text{e}^-$ Finally, the black corrosion formed is iron (II) sulfide. $\text{Fe}^{2+}_{(aq)} + \text{H}_2\text{S}_{(aq)} \rightarrow \text{FeS}_{(s)} + 2\text{H}^+_{(aq)}$	9.6.6 H3, H7, H8, H13 • Gives a description with relevant equations ..... 3–4 • Gives a description without relevant equations OR • Writes relevant equations with little or no written description ..... 1–2
(e) Porous materials such as wood and paper degrade when they are soaking in the water as bacteria eat the cellulose structure. The lost material is replaced by water. As the artefact dries, the water evaporates and salt crystals form. As the salt crystals grow, they expand, destroying the structure that remains. To prevent this damage, the salts must be removed before the object is dried. The first stage is to keep the artefact supported in a bath of distilled water at room temperature to allow the salts to leach out. Then, the artefact is impregnated with a solution of polyethylene glycol (PEG), which penetrates deeply into the cells of the timber and prevents further structural collapse while the artefact gradually dries. This can be applied by immersion or spraying. The length of time each step requires will depend greatly on the size of the artefact. For small wooden objects, 1–2 days in distilled water is followed by 1–2 weeks of spraying with PEG before a slow drying process. For a large artefact such as a ship's hull, the entire process might take 10 or more years to complete.	9.6.7 H3, H4, H8, H11, H12, H13 • Correctly explains how the damage occurs • Discusses a suitable procedure, including name or description, outline of the steps of the process and explanation of how the process maintains the structure of the artefacts ..... 5–6 • Explains how the damage occurs • Discusses a suitable procedure including most important features ..... 3–4 • Explains how the damage occurs • Mentions some features of a suitable procedure ..... 1–2

Question 31	The Biochemistry of Movement	Syllabus content, course outcomes and marking guide
	Sample answer	
(a)	(i) Glucose  (ii) Large numbers glucose monomers are joined in a dehydration reaction to form glycogen. A hydrogen atom is removed from the 1 carbon atom of one molecule and an OH is removed from the 4 carbon atom of another molecule to form water and an $\alpha$ (1 $\rightarrow$ 4) glycoside bond between the monomers. Linkages are formed between 1 and 6 carbon atoms in the glucose monomers, $\alpha$ (1 $\rightarrow$ 6) on every fourth glucose to form branched chains.	<p>H9</p> <ul style="list-style-type: none"> <li>Correctly identified monomer (glucose) . 1</li> <li>Demonstrated understanding of the formation of <math>\alpha</math> (1 <math>\rightarrow</math> 4) glycoside bond between the monomers producing water and <math>\alpha</math> (1 <math>\rightarrow</math> 6) glycoside linkages forming branched chains . . . . . 3</li> <li>Demonstrated understanding of the formation of a bond between the monomers producing water and the formation of branched chains . . . . . 2</li> <li>Demonstrated understanding of water formed when monomers join OR The formation of branched chains . . . . . 1</li> </ul>
(b)	<p>Acetyl CoA is the compound that enters the tricarboxylic acid (TCA or Krebs) Cycle to produce ATP, NADH and FADH<sub>2</sub>. Acetyl CoA can be formed from pyruvate produced from glucose by glycolysis or from the oxidation of fatty acids.</p> <p>Fatty acids are long chain hydrocarbons that are oxidised by reaction with enzyme CoA removing two carbons at a time to produce acetyl CoA. Because large numbers of acetyl CoA molecules can be produced from one fatty acid, high levels of fatty acids entering a cell compete with pyruvate for the finite amount of enzyme CoA available.</p>	<p>H7, H8, H9</p> <ul style="list-style-type: none"> <li>Demonstrated knowledge of the importance of acetyl CoA as the entry molecule to the TCA cycle</li> <li>Demonstrated understanding of acetyl CoA formation from either glucose via glycolysis and pyruvate or oxidation of fatty acids</li> <li>Discussion of the relative amounts of acetyl CoA formed to compete for enzyme CoA . . . . . 4</li> <li>Demonstrated knowledge of the importance of acetyl CoA as the entry molecule to the TCA cycle</li> <li>Demonstrated understanding of acetyl CoA formation from either glucose or fatty acids and the relative amounts of acetyl CoA formed . . . . . 2–3</li> <li>Knowledge of acetyl CoA as the entry molecule to the TCA cycle OR Demonstrated understanding that acetyl CoA is produce from either fats or carbohydrates . . . . . 1</li> </ul>
(c)	(i) The cause of contraction movement is the formation of a bridge or temporary bond between the myosin heads and actin fibres in the muscle.	<p>H8</p> <ul style="list-style-type: none"> <li>Correct statement referring to the formation of cross bridges between actin and myosin . . . . . 1</li> </ul>

Question 31	The Biochemistry of Movement (Continued)	Syllabus content, course outcomes and marking guide
	Sample answer	
(ii)	ATP binds with a myosin head and then hydrolyses to ADP and inorganic phosphate ( $P_i$ ). This causes a conformational change (or change in shape) in the myosin head that lifts it upwards to form a cross bridge with the actin filament. When the ADP and $P_i$ are released from the myosin, the actin filament moves towards the sarcomere (the power stroke). The cross bridge is broken when the myosin binds with ATP again.	<p>H7</p> <ul style="list-style-type: none"> <li>An explanation of the role of ATP and ATP hydrolysis in the conformational change in the myosin head causing cross bridge formation and filament sliding. . . . . 3–4</li> <li>An explanation of the role of ATP in the conformational change in the myosin head causing cross bridge formation and/or filament sliding . . . . . 2</li> <li>Knowledge of the role of ATP in cross bridge formation or filament sliding . . . . 1</li> </ul>
(d) (i)	NADH and $FADH_2$ are oxidised and provide the electrons which are passed through a series of electron transport chains (complexes I–IV) until they combine with oxygen to form water. The energy released from this oxidation-reduction reaction is used to drive the synthesis of ATP.	<p>H7, H12, H14</p> <ul style="list-style-type: none"> <li>A description of the oxidation of NADH and <math>FADH_2</math> providing electrons with reference to their transfer to the electron carriers in the membrane and the final reduction of oxygen to form water . . . . . 2</li> <li>Understanding that the oxidation of NADH and <math>FADH_2</math> provides electrons . . . . . 1</li> </ul>
(ii)	The energy produced by the electron transport chains (complexes I–IV) transferring electrons through intermediates to water is used to pump hydrogen ions across the inner mitochondrial membrane from the matrix to the space between the outer and inner membranes. The hydrogen ions accumulate in the space, creating an electrochemical gradient because the membrane is impermeable to ions. Complex V is an enzyme, ATP synthase, which contains a proton channel. Protons flow through the channel along their concentration gradient. The energy produced by the movement of charged particles is used to combine ADP and $P_i$ to produce ATP.	<p>H7, H10, H12, H14</p> <ul style="list-style-type: none"> <li>A well expressed explanation of the formation of the electrochemical gradient produced using the energy from electron transfer reactions to pump hydrogen ions across the membrane with reference to the biochemical flow chart</li> <li>Demonstrated understanding of the movement of hydrogen ions into the matrix to produce ATP . . . . . 4</li> <li>An explanation of the formation of the electrochemical gradient produced and the movement of hydrogen ions across the membrane</li> <li>Demonstrated understanding of the movement of hydrogen ions into the matrix to produce ATP . . . . . 2–3</li> <li>Understanding of the formation of an electrochemical gradient OR Understanding of the movement of hydrogen ions into the matrix to produce ATP . . . . . 1</li> </ul>

Question 31	The Biochemistry of Movement (Continued)	Syllabus content, course outcomes and marking guide
	Sample answer	
(e)	<p>Reducing the intake of carbohydrates while exercising would reduce the amount of glycogen stored in the muscles. If eating carbohydrate three days before the event enhanced the glycogen stores, then athletes involved in both extremes of exercise would benefit.</p> <p>Sprinting and other intense exercises use type 2 muscle cells and anaerobic respiration. Glucose in the blood is quickly depleted during sprinting and glycogen is metabolised to provide glucose for anaerobic respiration. Glucose molecules are split simultaneously from the ends of the branched glycogen. Increased amounts of glycogen in the muscles would make more glucose available at a faster rate and so benefit the athlete.</p> <p>Less intense exercise uses type 1 muscles and aerobic respiration to provide energy over a longer period of time. Aerobic respiration can use carbohydrates, fats and proteins to provide ATP for muscle contraction. In the first minutes of exercise, glucose in the blood is utilised and then glycogen stores are metabolised during the next 30 minutes. After that more fat than carbohydrate is metabolised. Carbohydrate loading would benefit long and middle distance athletes in the anaerobic stage of exercise and then continue to provide glucose in smaller amounts when fat metabolism provided most of the ATP.</p> <p>Carbohydrate loading would be of more use to athletes involved in heavy sprinting exercise using anaerobic respiration to provide energy than to athletes involved in distance exercise relying on aerobic respiration.</p>	<p>H1, H3, H4, H7, H9, H13, H14</p> <ul style="list-style-type: none"> <li>• A well expressed answer demonstrating understanding of the different requirements of both types of exercise for glucose supplied by glycogen</li> <li>• An evaluation of the benefits with reference to the relative importance of aerobic and anaerobic respiration to both types of athletes ..... 5-6</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrated understanding of the different requirements of both types of exercise for glucose supplied by glycogen</li> <li>• An evaluation of the benefits with reference to the aerobic and anaerobic respiration ..... 3-4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Knowledge of aerobic and anaerobic respiration as they apply to the extremes of exercise</li> <li>• Knowledge of the role of glucose from glycogen in providing energy for athletes ..... 1-2</li> </ul>

Question 32	The Chemistry of Art	Syllabus content, course outcomes and marking guide
	Sample answer	
(a)	<p>Azurite is a beautiful blue pigment which was used by the Egyptians and also extensively during the Middle Ages and the Renaissance. It is isolated naturally from the mineral azurite by grinding, washing and sifting; coarse particles are dark blue and finer particles are a lighter blue.</p> <p>Zinc white (zinc oxide) is prepared by heating metallic zinc at high temperature and suspending it in poppy oil. It is used for making tints with other colours and can be used by itself in moderate amounts. Large areas of zinc white form a brittle film that cracks.</p>	<p>9.8.1 H3, H13</p> <ul style="list-style-type: none"> <li>Names two pigments and describes preparation method and a use of each ..... 3–4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Names two pigments and describes a use of each</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Describes how one is prepared ..... 1–2</li> </ul>
(b)	<p>(i) Ligands are ions or molecules with a lone pair of electrons which can be used to form coordinate covalent bonds with a central metal ion.</p> <p>(ii) The lone pair of electrons on each ammonia molecule is shared with an empty orbital on the <math>\text{Co}^{3+}</math>, forming coordinate covalent bonds. The arrangement is octahedral.</p>	<p>9.8.5 H6, H13</p> <ul style="list-style-type: none"> <li>Defines ligand ..... 1</li> </ul> <hr/> <p>9.8.5 H6, H13</p> <ul style="list-style-type: none"> <li>Explains coordinate bond between the lone electron pair of each ammonia and the copper ion. .... 1–2</li> </ul>
(c)	<p>An atomic emission spectrum is comprised of lines corresponding to specific frequencies of light emitted by an element after it has been energised. Each element has its own set of spectral lines.</p> <p>Niels Bohr assumed the electron in hydrogen would behave in predictable ways and developed an atomic model that accurately described the expected emission spectrum of hydrogen. He assumed that electron energies were quantised (that is, that electrons could only exist in specific energy levels), and that electrons could make transitions between energy levels by absorbing or emitting photons of specific energy corresponding to the difference in energy levels.</p> <p>The energy difference is shown in the formula <math>E_{\text{photon}} = hf</math>, where <math>f</math> is the frequency of radiation, which can be related to the principal quantum number, <math>n</math>. For the lowest energy level, called the ground state, <math>n = 1</math>, whereas for <math>n &gt; 1</math>, the electrons are said to be in an excited state. Electron transitions from <math>n &gt; 1</math> back to the <math>n = 1</math> (ground state) give rise to the Lyman series; transitions from <math>n &gt; 2</math> back to the <math>n = 2</math> state correspond to the Balmer series; and transitions from <math>n &gt; 3</math> back to the <math>n = 3</math> state correspond to the Lyman series.</p>	<p>9.8.2 H1, H2, H3, H6, H13</p> <ul style="list-style-type: none"> <li>Extensive description of how spectral lines provide information about the energy levels in hydrogen and that shells of electrons contain electrons of similar energy (the Bohr model) ..... 4–5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Thorough description relating electron energies to electron shells and spectral lines ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Basic description of Bohr model ..... 1–2</li> </ul>



Question 32	The Chemistry of Art (Continued)	Syllabus content, course outcomes and marking guide
	Sample answer	
(d)	(i) Chromium was investigated. $\text{Cr}^{6+}$ is orange in the dichromate ion $\text{Cr}_2\text{O}_7^{2-}$ , $\text{Cr}^{3+}$ is green, and $\text{Cr}^{2+}$ is blue.	9.8.4 H6 • Names and gives colour changes for each state ..... 2
	(ii) The colour changes were achieved by adding small pieces of Zn metal in dilute HCl to a solution of $\text{K}_2\text{Cr}_2\text{O}_7$ . The Zn was oxidised and the $\text{Cr}_2\text{O}_7^{2-}$ was reduced to $\text{Cr}^{3+}$ . $\text{Cr}^{6+}$ has the electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6$ . $\text{Cr}^{3+}$ has the electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ . Cr has the electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ . The +6 oxidation state is formed using the $3d^5 4s^1$ electrons and the +3 state forms when two of the 3d electrons and the 4s electrons are used.	9.8.4 H6, H7, H13 • Correctly outlines one method, using appropriate reducing or oxidising agent AND uses electron configurations for oxidised and reduced form. .... 4–5 • Basic description of how oxidation number is changed AND uses electron configurations for oxidised and reduced form ..... 3 • Uses electron configurations OR gives a basic description ..... 1–2
(e)	Radiation produced by a tungsten lamp (UV) or by heating a ceramic SiC rod (IR) is split into two beams. One beam passes through the sample being tested and the other through a solvent reference sample. A photomultiplier tube (for UV) or a thermocouple (for IR) detects the radiation passing through the sample and reference tubes and compares how much radiation has been absorbed. IR spectra provide qualitative data on pigments such as zinc oxide, which changes from white to yellow as it is heated, and copper(I) oxide, which becomes black copper(II) oxide upon heating. A database of spectra is available for comparing results. UV spectra provide quantitative information - a graph of absorbance against wavelength is produced. Comparison with a database of spectra of known pigments allows identification of pigments within paintings as well as revealing how much of a pigment is used, since the absorbance is directly proportional to the concentration.	9.8.2 H3, H6, H7, H13, H14 • Shows extensive knowledge of how each method is used AND provides examples ..... 5–6 • Shows reasonable knowledge of spectroscopy AND provides examples ..... 3–4 • Shows some knowledge OR provides examples ..... 1–2

Question 33	Forensic Chemistry	Syllabus content, course outcomes and marking guide
(a)	<p>(i) <math>\text{CH}_2\text{O}</math></p> <p>(ii) Non-reducing sugars contain a ketone group where the <math>\text{C}=\text{O}</math> group is positioned within the carbon chain and protected from oxidation. Reducing sugars, however, contain an aldehyde group where the <math>\text{C}=\text{O}</math> is at the end of the chain and easily oxidised. This means that non-reducing sugars such as fructose do not reduce a basic solution of <math>\text{Cu}^{2+}</math>, as found in Fehling's and Benedict's reagents. Glucose, a reducing sugar, will reduce Fehling's and Benedict's reagents to form <math>\text{Cu}_2\text{O}</math> as a red-brick precipitate.</p>	<p>9.9.2 H9</p> <ul style="list-style-type: none"> <li>Correctly identifies empirical formula . . 1</li> </ul> <hr/> <p>9.9.2 H8, H9</p> <ul style="list-style-type: none"> <li>Demonstrates understanding of the comparative structure of non-reducing and reducing sugars and the impact on their chemical reactivity</li> <li>Identifies reagents which distinguish between them and the nature of the tests . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Demonstrates understanding of the difference between non-reducing and reducing sugars</li> <li>Identifies a reagent which distinguishes between them . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Demonstrates understanding of a reagent which distinguishes between non-reducing and reducing sugars . . . . . 1</li> </ul>
(b)	<p>Forensic chemistry is used in legal investigations to determine the origin of organic and inorganic samples. Accuracy is extremely important as any results must be reliable and verifiable under the law. Inaccuracies may occur in a number of areas, the most significant of these being the collection and storage of samples and interpretation of forensic data. Care must be taken when collecting samples to ensure that they are properly labelled and that contamination is minimised by using gloves, clean, sterile containers and by collecting duplicate samples if possible. Ethical issues concerning the origin and the proper handling and storage of samples can be minimised by rigorous record keeping and appropriate and secure storage of samples.</p>	<p>9.9.1 H3, H4, H14</p> <ul style="list-style-type: none"> <li>Demonstrates understanding of the application of forensic science</li> <li>Discussion of the importance of accuracy of analysis</li> <li>Identifies possible sources of error in analysis due to contamination and precautions needed</li> <li>Discussion of ethical issues arising . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Demonstrates understanding of importance of accuracy in forensic science</li> <li>Identifies possible sources of error in analysis which may give rise to ethical concerns . . . . . 2-3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Demonstrates understanding that inaccuracies may give rise to ethical concerns . . . . . 1</li> </ul>
(c)	<p>(i) The DNA structure can be described as two long polymer chains twisted around each other to form a double helix. The polymer is made up of chains of nucleotide units. Each nucleotide consists of a phosphate molecule, a sugar molecule and one of four nitrogen bases (thymine, adenosine, guanine or cysteine), and each of these bases lines up with a specific base on the other strand of the DNA molecule.</p>	<p>9.9.4 H8</p> <ul style="list-style-type: none"> <li>Correctly identifies the polymeric structure of DNA and the chemical composition of the monomer . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Identifies the polymeric structure of DNA. . . . . 1</li> </ul>

## Question 33

## Forensic Chemistry (Continued)

Question 33	Forensic Chemistry (Continued)	Syllabus content, course outcomes and marking guide
	<b>Sample answer</b>	
(ii)	<p>Electrophoresis is used to analyse DNA. This process is a separation technique that involves applying an electric field to a gel loaded with a solution of the DNA sample. Solute molecules migrate towards either the anode or cathode, their velocity dependent upon the size and shape of the molecule. This technique allows for the identification of the sequence of nucleic acids in a DNA sample.</p> <p>Each individual has DNA with a unique sequence of nucleic acids. By matching sample data from individuals to standard data in a register of DNA, individuals can be identified. Identification can only be made if individuals have submitted their DNA for analysis and recording in the register.</p>	<p>9.9.4 H4, H8, H9, H14</p> <ul style="list-style-type: none"> <li>• An explanation of electrophoresis as a separation technique which can sequence individual DNA samples for comparison with standards</li> <li>• Demonstrates understanding of the uniqueness of an individual's DNA and its use in identification ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• An explanation of electrophoresis as an identification technique for DNA samples</li> <li>• Understanding of the use of DNA data for identification ..... 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Knowledge that electrophoresis is a technique used to identify individuals by their DNA. .... 1</li> </ul>
(d)	(i) Chromatography	<p>9.9.3 H9</p> <ul style="list-style-type: none"> <li>• Identifies a suitable separation technique (chromatography). .... 1</li> </ul>
(ii)	<p>Samples of plant pigments for analysis were prepared by grinding the plants in a mortar. The paste was then dissolved in an organic solvent such as ethanol. Small spots of sample were applied to a base line on a piece of chromatography paper along with samples of known organic compounds. The chromatography paper was placed in a solution of organic solvent which was allowed to diffuse along the paper. Before the solvent reached the end of the paper, the paper was removed and the movement of components in the mixture were compared to the movement of the known samples. Components were identified on the basis of similar migration to known samples.</p>	<p>9.9.3 H11, H13, H14</p> <ul style="list-style-type: none"> <li>• Describes the main steps in the investigation including specific reference to preparation of the sample, use of standards and solvent, apparatus used, progress of the separation and results obtained ..... 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Describes the general procedure used to undertake a chromatographic separation . 1</li> </ul>

## Question 33

## Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(iii) Components of the mixture have different chemical and physical properties. The most important of these in chromatographic separation are the size and shape of the molecule and interactions between the molecule and the solvent. As the solvent moves along the chromatographic paper it carries the components of the mixture with it. Molecules that interact strongly with the solvent will be carried most readily. Unknown components with identical or similar chemical structure to known standards will interact with the solvent in a similar way and therefore migrate along the paper similar distances.</p> <p>This technique can assist forensic chemists to identify samples of organic material in soil, food or biological samples. This, in turn allows identification of the source and nature of a sample providing useful data for evidence.</p>	<p>9.9.3 H4, H8, H9, H11, H13, H14</p> <ul style="list-style-type: none"> <li>• Demonstrates understanding of the physical and chemical properties affecting the behaviour of organic substances in chromatographic separation, including molecular size, shape and solvent interactions</li> <li>• Demonstrates understanding that comparison of components to known standards allows identification of components and determination of the origin and nature of the sample ..... 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrates understanding of the interactions between the sample and the solvent</li> <li>• Identifies the usefulness of determining the components of a mixture.. ..... 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Identifies that components of a mixture have different properties which can be useful in identification ..... 1</li> </ul>
<p>(e) GLC and HPLC are separation techniques that can be of great use in forensic investigations. They are particularly useful for identifying the organic and/or inorganic components of a mixture, quantifying the amount of each mixture and in some cases can be used to isolate components for further analysis. They have particular value when only small samples of a mixture are available.</p> <p>These techniques are faster and more accurate than paper or gravity column chromatography as they use a high-pressure gas or liquid mobile phase to speed up separation. The length of the separating column can be quite long and this provides a more effective separation, particularly of substances with a similar molecular structure. Sample analysis can be repeated quickly to obtain reliable results. Separation information is recorded on a graph chart and can be immediately analysed by computer. The rate of elution of components can be compared to a database of many substances to identify its chemical nature. The preparation of standard concentration curves allows the amount of each component to be calculated.</p> <p>In many investigations, the amount of sample available is very small. GLC and HPLC are of great value in these cases as only very small samples, usually in the order of mL, are needed for analysis. This is due to the sensitivity of the instruments detectors and the reliability provided by being able to quickly perform repetitive analyses.</p> <p>As analytical data provided by a forensic chemist must be valid, reliable and reproducible, GLC and HPLC are able to provide valuable evidence in an investigation. They are of particular value in the analysis of small samples.</p>	<p>9.9.5 H3, H4, H9, H11, H13, H14</p> <ul style="list-style-type: none"> <li>• A well-constructed discussion demonstrating understanding of the instrumentation and principles of separation associated with either GLC or HPLC</li> <li>• Identifies the advantages associated with speed, reproducibility, reliability and interpretation of results and their value in forensic investigations</li> <li>• An explanation of how results are used to identify the nature and origin of samples. ....5-6</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Demonstrates understanding of the technique of either GLC or HPLC, identifying advantages associated with repeatability and small sample analysis</li> <li>• An explanation of the value of the technique in forensic investigations .....3-4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Identifies the basic principles of either GLC or HPLC analysis and their value in small sample analysis .....1-2</li> </ul>