

HSC Trial Examination 2004

Chemistry

Solutions and marking guidelines

Section I

Part A

Answer and explanation		Syllabus content and course outcomes	
Question 1	B A buffer solution will resist a change in pH, but will not prevent it.	9.3.4	H8
Question 2	B Since metal Q displaces R it would then also displace any metal that R displaces, which include X, Y and Z. Therefore, Q is the more reactive metal, making it suitable to be the anode. Z displaces none of the metals, and so is most suitable to be the cathode. Electrons always move from anode to cathode.	9.2.4	H6, H7, H8
Question 3	D Since both acids have the same pH, their respective $[H^+]$ must be the same. However, acid A is of a lower concentration and so must be a stronger acid.	9.3.3	H8, H10
Question 4	D	9.2.1	H9
Question 5	A Each monomer has two functional groups.	9.2.2	H9
Question 6	C Equation (i) shows the HCl ionising. Equation (iv) shows the NaOH dissociating. In equation (ii), HCl is acting as a proton donor. In equation (iii), H_2O is acting as a proton donor.	9.3.3	H6
Question 7	A The formation of ammonia is exothermic, and so its yield will increase at lower temperatures. According to Le Chatelier's Principle, in this case the equilibrium will shift to the right as pressure is increased.	9.3.2, 9.4.2	H10, H14
Question 8	D The equation for the reaction is $A + B \rightleftharpoons 2C$. Since one mole of each A and B are consumed to form 2 moles of C, there are 2 moles of gas on each side of the equation. Therefore the ratio of moles is unaffected by the change in pressure.	9.3.2, 9.4.2	H10, H14
Question 9	C An increase in a value of pH of 1 means that the dilution factor was 10. Therefore, the total new volume of the acid solution became 100 mL. This would have been achieved by adding 90 mL to the original solution.	9.3.3	H10
Question 10	B The reaction of an acid with a base is exothermic, and so the temperature would have increased. However, in this case, the acid is in excess and so the final pH is still acidic.	9.3.3	H8, H10
Question 11	C Concentration is a quantity, therefore titration is the best method.	9.4.3	H11
Question 12	B Mg^{2+} and Ca^{2+} are associated with hard water.	9.4.5	H11


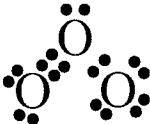
Part A (Continued)

Answer and explanation	Syllabus content and course outcomes	
Question 13 D Option D is the only alternative for a mole of fuel. $\Delta H = \frac{400 \times 4.18 \times 10.1}{1000} \text{ kJ for 1.16 g ethanol}$ $= 16.887 \times \frac{46}{1.16} = 670 \text{ kJ mol}^{-1}$	9.2.3	H10
Question 14 B The method is invalid as there are too many variables uncontrolled. The results are not reliable, as no repetition has occurred.	9.2.3	H12
Question 15 B $\text{mol (BaSO}_4\text{)} = \frac{1.6}{233} = 0.007$ $\text{mol (SO}_4\text{)}^{2-} = 0.007$ $m(\text{SO}_4)^{2-} = 0.007 \times 96$ $\% = \frac{0.66}{1} \times 100$ $= 66\%$	9.4.3	H10

Part B

Sample answer	Syllabus content, course outcomes and marking guide
Question 16	9.2.3 H6, H9, H13
(a) Water.	<ul style="list-style-type: none"> Identifies water as compound X 1
(b) Dilute sulfuric acid.	<ul style="list-style-type: none"> Identifies dilute acid as compound Y. . . . 1
<p>(c) The structure of ethanol consists of a polar hydroxyl end and a non-polar alkyl end. The polar end allows for the production of dipole-dipole interactions, such as hydrogen bonding, between itself and other polar substances, and so these substances can readily mix with the ethanol.</p> <p>The non-polar alkyl end only allows for weak dispersion forces which can occur with other non-polar molecules, and so these substances can readily mix with the ethanol. Due to the relatively small size of the ethanol molecule, it is neither excessively polar or non-polar, allowing it to readily mix with both types of substances.</p>	<ul style="list-style-type: none"> Identifies the polar and non-polar nature of ethanol and relates these to the intermolecular forces it has with both polar and non-polar molecules of other species 3
	<ul style="list-style-type: none"> Identifies the polar and non-polar nature of ethanol and relates one of these to the intermolecular forces it has with either polar or non-polar molecules of other species 2
	<ul style="list-style-type: none"> Identifies polarity in the ethanol molecule. 1
Question 17	9.2.5 H4
<p>In medicine, radioisotopes are widely used in a beneficial manner in the prevention, diagnosis and treatment of disease. In terms of prevention, hospital supplies such as surgical instruments can be irradiated to destroy microorganisms. Being a cold process, this permits the sterilisation of heat-sensitive substances without compromising their structure.</p> <p>In terms of diagnosis, very small doses of radioisotopes can be used to detect the presence of diseased cells and analyse how well organs function. Such diagnosis procedures can eliminate the use of invasive surgery.</p> <p>In terms of treatment, radiation can either be projected onto or injected into a diseased person. Such procedures are usually performed post surgery, and are used to eliminate the need for further invasive procedures.</p> <p>OR</p> <p>In industry, radioisotopes are often used as tracers to detect leaks in water and gas pipes. Only small amount of radioisotope are needed. Their use in this manner eliminates the need to excavate and remove entire pipelines to identify the site of a leak.</p> <p>Radioisotopes can also be mixed with sewage at ocean outflows. The detection of the radioisotopes can then be used to analyse the dispersion of this sewage.</p> <p>The ability of gamma radiation to penetrate materials can also be used to measure the thickness of materials manufactured in sheets. The amount of radiation which passes through the material is proportional to that material's thickness. This method allows for very accurate measurements to be made.</p>	<ul style="list-style-type: none"> Identifies at least two uses in either industry or medicine and provides benefits for these uses. 2–3
	<ul style="list-style-type: none"> Identifies a use and provides its benefit. . . 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 18	9.3.4 H6, H8
(a) ammonium chloride	<ul style="list-style-type: none"> Identifies ammonium chloride as the salt 1
(b) $\text{NH}_4\text{Cl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- + \text{NH}_3$ The H_3O^+ produced in this reaction lowers the pH.	<ul style="list-style-type: none"> Identifies that the formation of H_3O^+ lowers the pH and provides a suitable equation 2 Identifies that the formation of H_3O^+ lowers the pH or provides a suitable equation 1
Question 19	9.3.1 H4, H13
(a) (i) Chop red cabbage into thin pieces. (ii) Grind the cabbage in a mortar and pestle. (iii) Add some methylated spirits to the cabbage. (iv) Drain the coloured liquid.	<ul style="list-style-type: none"> Clearly presents procedure used to prepare a natural indicator 1–2
(b) Indicators can be used to determine the pH of an aquarium. The pH needs to be monitored because the marine life can only survive if the pH is within a specific range.	<ul style="list-style-type: none"> Identifies an everyday situation in which an indicator is used and explains why it is necessary to use the indicator 2 Identifies an everyday situation in which an indicator is used OR Explains why it is necessary to use the indicator 1
Question 20	9.4.4 H6, H13
(a) Troposphere.	<ul style="list-style-type: none"> Identifies the troposphere as the layer in the atmosphere in which oxygen is most abundant. 1
(b) Stratosphere.	<ul style="list-style-type: none"> Identifies the stratosphere as the layer in the atmosphere in which ozone is most abundant. 1
(c) The Lewis electron dot structure for oxygen is  The Lewis dot structure for ozone is 	<ul style="list-style-type: none"> Provides correct Lewis dot structure for both ozone and oxygen Provides correct Lewis dot structure for either ozone or oxygen 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(d) Ozone and water are both polar molecules while oxygen is non-polar. Therefore the attraction between ozone and water is greater due to dipole-dipole interactions. Oxygen is only attracted to water by weak dispersion forces. This results in a greater relative solubility between ozone and water when contrasted with oxygen in water.	<ul style="list-style-type: none"> Identifies that ozone is polar and oxygen is non-polar Identifies that polarity of ozone creates attraction with polar water molecules Identifies that oxygen is only attracted to water due to weak dispersion forces 3 <hr/> <ul style="list-style-type: none"> Identifies that ozone is polar and oxygen is non-polar Identifies that polarity of ozone creates attraction with polar water molecules . . . 2 <hr/> <ul style="list-style-type: none"> Identifies that ozone is polar and oxygen is non-polar 1
Question 21	9.4.5 H4, H8, H14
(a) Turbidity; biochemical oxygen demand.	<ul style="list-style-type: none"> Identifies any two other factors used to determine water quality 2 <hr/> <ul style="list-style-type: none"> Identifies any factor used to determine water quality 1
(b) Two of the following lists: pH is affected by natural factors such as minerals in the water, dust in the air, acid rain and photosynthesis, as well as human activities, such as overloading of nutrients from farms or sewage causing algal blooms, industrialisation leading to greater than normal levels of acid rain due to increased oxides of carbon, sulfur and nitrogen in the air, and mining.	<ul style="list-style-type: none"> Any two factors 2 <hr/> <ul style="list-style-type: none"> Any one factor 1
(c) Water bodies are tested regularly using a pH meter and are in danger of becoming polluted when the range of pH values changes too much. Indicators of polluted water would include changes in aquatic life.	<ul style="list-style-type: none"> Relates pH to water pollution and gives one monitoring method. 2 <hr/> <ul style="list-style-type: none"> Some knowledge of pH and water quality 1
Question 22	9.3.3 H6, H13
(a) citric acid: acetic acid: $ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{COOH} \\ \\ \text{HO}-\text{C}-\text{COOH} \\ \\ \text{H}-\text{C}-\text{COOH} \\ \\ \text{H} \end{array} \quad \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C} \\ \quad \diagup \quad \diagdown \\ \text{H} \quad \text{O} \quad \text{OH} \end{array} $	<ul style="list-style-type: none"> Draws two correct structural formulae . . 2 <hr/> <ul style="list-style-type: none"> Draws one correct structural formulae. . . 1
(b) Citric acid ionises more than acetic acid, hence it is a stronger acid. <i>Note: not acceptable to state that citric acid is triprotic.</i>	<ul style="list-style-type: none"> States a correct reason 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide																								
Question 23	9.3.3 H10, H12																								
(a)	<ul style="list-style-type: none">Correct calculation justifying average titre used 3Correct calculation using average of all values 2Correct equation. <p>OR</p> <ul style="list-style-type: none">Some correct working 1																								
<table><tr><th>Run</th><th>1 (rough)</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>Initial burette volume (mL)</td><td>0.5</td><td>23.6</td><td>0.7</td><td>23.5</td><td>0.2</td></tr><tr><td>Final burette volume (mL)</td><td>23.5</td><td>45.8</td><td>23.0</td><td>46.2</td><td>22.4</td></tr><tr><td>Volume used</td><td>23.0</td><td>22.2</td><td>22.3</td><td>22.7</td><td>22.2</td></tr></table> <p>Ignore the first (rough) titration and the fourth as they are too far away from the other readings. Therefore, the average volume of the concordant readings is 22.23 mL.</p> $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_{2(\text{g})} + \text{H}_2\text{O}_{(\text{l})}$ $\text{Mol Na}_2\text{CO}_3 = \frac{1}{2}\text{mol}(\text{HCl})$ $cV(\text{Na}_2\text{CO}_3) = \frac{1}{2}cV(\text{HCl})$ $0.25 \times C = \frac{1}{2} \times 0.0246 \times 0.02223$ $\text{Na}_2\text{CO}_3 = 0.109 \text{ mol L}^{-1}$	Run	1 (rough)	2	3	4	5	Initial burette volume (mL)	0.5	23.6	0.7	23.5	0.2	Final burette volume (mL)	23.5	45.8	23.0	46.2	22.4	Volume used	23.0	22.2	22.3	22.7	22.2	
Run	1 (rough)	2	3	4	5																				
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Volume used	23.0	22.2	22.3	22.7	22.2																				
(b) Reaction between a strong acid and a weak base will produce an acidic solution, so methyl orange will be suitable.	<ul style="list-style-type: none">Chooses correct indicator and provides appropriate reason 2																								
Question 24	9.2.4 H7, H10, H13																								
(a)	<ul style="list-style-type: none">Correct diagram showing electron and ion movement. 3Correct diagram showing electron movement. 2Diagram but no movement. 1																								
(b) $0.96 - 0.52 = 0.44 \text{ V}$, hence the equation is: $\text{X}_{(\text{s})} \rightleftharpoons \text{X}^{2+}_{(\text{aq})} + 2\text{e}^- \quad \text{voltage} = +0.44 \text{ V}$	<ul style="list-style-type: none">Correct half equation and voltage 2Correct half-equation ORCorrect voltage. 1																								
(c) Cell voltage will increase once more Y^+ is available for reduction, pushing the system to produce more $\text{Y}_{(\text{s})}$ $\text{X}_{(\text{s})} + 2\text{Y}^+ \rightleftharpoons 2\text{Y}_{(\text{s})} + \text{X}^{2+}$	<ul style="list-style-type: none">Predicts effect on cell voltage based on Le Chatelier's principle. 2																								

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 25	9.3.2 H10, H13
<p>(a)</p> <p>mass (g)</p> <p>time (hours)</p> <p>water</p> <p>soda water</p>	<ul style="list-style-type: none"> Correctly plots points and draws lines for two data sets. 2 Correctly plots points but draws incorrect lines. OR Plots points. 1
<p>(b) The water graph shows the loss of mass due to evaporation. The soda water graph shows the loss of mass due to water evaporation AND carbon dioxide gas. When no more CO₂ remains the line parallels the water graph.</p>	<ul style="list-style-type: none"> Interprets each graph and forms relationship between them. 2
<p>(c) From the graph, the mass of carbon dioxide gas lost is 3.0 g. Volume of gas is mol × molar volume:</p> $V_{\text{CO}_2} = \frac{3.0 \times 24.79}{44} = 1.69 \text{ L}$	<ul style="list-style-type: none"> Correct calculation using mass of carbon dioxide from graph. 2

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide	
Question 26	9.2.3	H1, H4, H8, H9
<p>The proposed legislation was intended to:</p> <ul style="list-style-type: none">• conserve non renewable fossil fuels and• reduce the production of products of combustion which may harm the environment or human health. <p>Ethanol can be produced from fermentation of sugar cane, a renewable resource. It therefore has the potential to conserve or replace fossil fuels. Ethanol burns more cleanly than petrol because less oxygen is required. The reaction is also more likely to go to completion and not produce pollutants such as $C_{(s)}$ and $CO_{(g)}$. $C_{(s)}$ is harmful to the environment and $CO_{(g)}$ is fatal to humans because it combines irreversibly with haemoglobin and prevents it from carrying oxygen.</p> <p>The proposal was rejected for three reasons.</p> <ul style="list-style-type: none">• At present the cost of producing ethanol in terms of energy inputs in the form of fertiliser and fossil fuels used in harvesting and transport is greater than the cost of using fossil fuels in car engines. Large tracts of land would also have to be converted to sugar cane production, replacing the present land use of farming or conservation.• Car manufacturers recognise that ethanol is a polar molecule that will attract water and is corrosive in car engines. New engines would have to be designed that were resistant to the effects of water on components.• The energy produced by burning ethanol is less than petrol and car engines using ethanol would produce less power and require adjustment for the fuel to air ratio. This would result in the consumption of more materials that are at present uneconomic to produce and the increased cost to adjust engines.	<ul style="list-style-type: none">• Provides two reasons for and against inclusion of ethanol in petrol, including a discussion of:<ul style="list-style-type: none">• renewable resources;• production of pollutants;• energy consumption comparison;• the corrosive nature of ethanol in engines 4	
	<ul style="list-style-type: none">• Provides two reasons for and against inclusion of ethanol in petrol, including a limited discussion of:<ul style="list-style-type: none">• renewable resources;• production of pollutants;• energy consumption comparison;• the corrosive nature of ethanol in engines 2–3	
	<ul style="list-style-type: none">• Identifies or discusses at least one reason for or against 1	

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>Question 27</p> <p>Chlorofluorocarbons (or CFCs) are carbon compounds that contain chlorine and fluorine, e.g. CF_3Cl. CFCs were developed to replace ammonia as a refrigerant because they were thought to be less harmful. They were also used as solvents, propellants and blowing agents in foams because they were viewed as inert.</p> <p>CFC gases were released to the atmosphere while being used in these commercial applications. While they did not react in the troposphere, when they make their way to the stratosphere the UV energy present breaks C–Cl bonds, releasing Cl free radicals. Chlorine and other free radicals like bromine from halons deplete the ozone layer according to the following equations:</p> $\text{CF}_3\text{Cl} \rightarrow \text{CF}_3 + \text{Cl}$ $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$ $\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$ <p>The continual generation of the chlorine radical means that the damage caused by CFCs could last for 150 years. The depletion of the ozone layer allows more UV radiation to reach Earth, which increases the chances of cancer in living things (including humans). It also creates an increase in the enhanced greenhouse effect. The enhanced greenhouse effect is caused by greenhouse gases absorbing heat rays that come from the Earth's surface and emitting them back to the Earth's surface, raising the temperature of the atmosphere.</p> <p>There have been two main steps taken to reduce the breakdown of ozone in the stratosphere. These are:</p> <ul style="list-style-type: none"> The Montreal Protocol, a treaty to achieve global control of production and use of CFCs. Global commitment to the reduction of the production and use of CFCs and halons is needed. Poorer countries will need assistance to achieve targets and if industrialised nations governments do not sign and adhere to the Protocol, CFC levels will not be reduced and the ozone layer will continue to be damaged. At present, although most countries have signed the Protocol, Australia and the United States have not. Both nations, however, have phased out CFCs and halons. China is thought to be still producing significant amounts of both substances and consequently the effectiveness of the Montreal Protocol as a global management system is reduced. The identification and introduction of alternative chemicals, such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). The effectiveness of these compounds has been mixed. Although HCFCs contain hydrogen atoms and fewer chlorine atoms they can still undergo reactions with OH free radicals in the troposphere. This reaction is slow, but HCFCs will still reach the stratosphere and produce chlorine radicals. HFCs, which contain no chlorine, promise to be more effective. They react readily with OH in the troposphere but because they do not contain chlorine, undesirable radicals should not be produced. 	<p>9.4.4 H1, H4, H13, H14</p> <ul style="list-style-type: none"> Demonstrated ability to: <ul style="list-style-type: none"> Define CFCs and identify at least one example; Identify and describe problems associated with the use of CFCs; Explain the need to develop alternatives; Identify and describe alternatives; Assess effectiveness of alternatives; Includes relevant equations 7 Demonstrated knowledge and understanding of: <ul style="list-style-type: none"> A definition of CFCs and at least one example; Problems associated with the use of CFCs; The need to develop alternatives; The type of alternatives available; Assess effectiveness of alternatives . . . 5–6 Demonstrated knowledge and understanding of: <ul style="list-style-type: none"> A definition of CFCs; Problems associated with the use of CFCs; The need to develop alternatives; AND/OR The type of alternatives available 3–4 Demonstrated knowledge of: <ul style="list-style-type: none"> A definition of CFCs; Problems associated with the use of CFCs; AND/OR The need to develop alternatives. AND/OR The type of alternatives available 1–2

Section II

Question 28

Industrial Chemistry

Sample answer		Syllabus content, course outcomes and marking guide	
(a)	(i) Sodium carbonate.	9.5.6	H3
		<ul style="list-style-type: none"> Correctly identifies sodium carbonate (Na_2CO_3) 	1
	(ii) The hydrogen carbonate ion is produced as an aqueous sodium salt. Carbon dioxide from the roasting of calcium carbonate is bubbled into ammoniated brine. $\text{NH}_{3(aq)} + \text{CO}_{2(g)} + \text{NaCl}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightarrow \text{NaHCO}_{3(aq)} + \text{NH}_4\text{Cl}_{(aq)}$ CO ₂ does not normally react to a great extent with water. The brine (saturated sodium chloride solution) has ammonia (a base) dissolved in it to ensure the reaction of the acidic CO ₂ .	9.5.6	H3, H4
		<ul style="list-style-type: none"> Correct equation and explanation of the importance of ammoniated brine 	3
		<ul style="list-style-type: none"> Correct equation (reactants and products) 	2
		<ul style="list-style-type: none"> Understanding that CO₂ reacts with water 	1
(b)	(i) Wear safety glasses to protect eyes from caustic effects of concentrated sodium hydroxide. OR Wear gloves to protect skin from caustic effects of concentrated sodium hydroxide.	9.5.5	H11
		<ul style="list-style-type: none"> Correct 	1
	(ii) Soap is produced by saponification. To produce soap a long chain fatty acid is heated with concentrated sodium hydroxide solution. The soap is separated from the reaction solution and glycerol by-product by the addition of a concentrated sodium hydroxide solution. The soap forms a solid layer on top of the brine while the very polar glycerol molecule remains dissolved in the aqueous solution. An example method could be: <ul style="list-style-type: none"> 5 mL of coconut oil in large test tube. Add 10 mL of 4 M sodium hydroxide . Boil gently in a water bath for 20 – 30 minutes. It is important that the aqueous and oil layers mix, so it is important to shake the mixture every couple of minutes. <ul style="list-style-type: none"> Pour the mixture into beaker containing cold, saturated sodium chloride (beaker in an ice bath). As the solution cools, it should set into a soap – this takes a few minutes. <ul style="list-style-type: none"> Test the 'soap' to see if it lathers in hot water; that is with hot water in a test tube, not on hands. The 'soap' is highly alkaline and should not be handled.	9.5.5	H11, H13, H14
		<ul style="list-style-type: none"> Correctly explains procedure and a test of the soap 	3
		<ul style="list-style-type: none"> Correctly explains a procedure 	2
		<ul style="list-style-type: none"> Names reactants OR Names a test of the soap 	1

Question 28

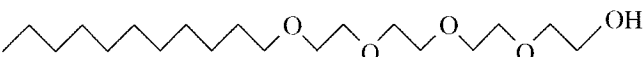
Industrial Chemistry (Continued)

	Sample answer	Syllabus content, course outcomes and marking guide
(e)	<p>The mercury and the diaphragm cells both produce sodium hydroxide, chlorine and hydrogen by electrolytic processes. Both cells have an anode that is made of an inert material, typically graphite, at which chlorine is produced. Chlorine is produced in preference to oxygen due to the use of brine, a highly concentrated sodium chloride solution in which chloride ions are preferentially oxidised over water.</p> $2\text{Cl}^-_{(aq)} \rightarrow \text{Cl}_{2(g)} + 2\text{e}^-$ <p>The two cells differ in their cathode materials.</p> <p>The mercury cell uses a flowing mercury cathode to reduce sodium ions to sodium to an amalgam.</p> $2\text{Na}^+_{(aq)} + 2\text{e}^- + \text{Hg}_{(l)} \rightarrow 2\text{Na(Hg)}$ <p>The amalgam is then sprayed with water. The water reacts with the sodium to produce sodium hydroxide and hydrogen. The remaining mercury is reused in the cathode.</p> $2\text{Na(Hg)} + 2\text{H}_2\text{O}_{(l)} \rightarrow 2\text{NaOH}_{(aq)} + \text{H}_{2(g)} + 2\text{Hg}_{(l)}$ <p>The diaphragm cell has a steel cathode at which the following occurs:</p> $2\text{H}_2\text{O}_{(l)} + 2\text{e}^- \rightarrow \text{H}_{2(g)} + 2\text{OH}^-_{(aq)}$ <p>The sodium ions are already present in the brine thus sodium hydroxide is produced.</p> <p>The mercury cell produces higher purity sodium hydroxide as the diaphragm cells' product is contaminated with sodium chloride and needs purification before it can be used.</p> <p>The mercury cell has caused serious environmental problems due to the release of mercury into the environment.</p> <p>The diaphragm cell uses an asbestos diaphragm between fresh brine and the steel cathode. Asbestos is a known carcinogen.</p> <p>The membrane cell was developed to overcome the environmental and product purity issues. It utilises an ion selective membrane to separate the cathode and anode compartments. It is safe and ensures a high purity product since the membrane only allows Na^+ ions to pass into the cathode compartment where water is reduced to hydroxide ions and hydrogen gas. The equations are the same as those of the diaphragm cell.</p>	<p>9.5.4 H3, H4, H7</p> <ul style="list-style-type: none"> • Correctly describes both cells. • Correctly describes one advantage and one disadvantage that relates to the membrane cell 5 • Describes the two cells and one advantage and one disadvantage. OR • Describes all three cells but does not analyse 4 • Describes the two cells 3 • Describes one cell well 2 • Mentions problems without description 1

Question 28	Industrial Chemistry (Continued)	
	Sample answer	Syllabus content, course outcomes and marking guide
(d) (i)	Production of ammonium sulfate fertiliser.	9.5.3 H3 • Correct use 1
(ii)	<p>The conversion of $\text{SO}_{2(g)}$ to $\text{SO}_{3(g)}$ is an exothermic equilibrium process.</p> $2\text{SO}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{SO}_{3(g)} + \text{heat}$ <p>the extent of which is favoured by:</p> <ul style="list-style-type: none"> • lower reaction temperatures as heat is produced; • increased pressure as there are fewer product molecules than reactant molecules; • an excess of one reactant. <p>However, the reaction rate is favoured by:</p> <ul style="list-style-type: none"> • high temperatures and high pressures both of which promote the collision of reactant molecules; • the use of a catalyst that reduces the activation energy for the reaction. <p>In practise a compromise temperature (660°C) is used in conjunction with a catalyst and excess oxygen to achieve an acceptable yield in an acceptable time.</p>	<p>9.5.2 H8</p> <ul style="list-style-type: none"> • Discusses all aspects 3 <hr/> <ul style="list-style-type: none"> • Discusses extent factors not rate or vice versa OR • Only discusses two factors for extent and one for rate 2 <hr/> <ul style="list-style-type: none"> • Mentions equilibrium and compromise . . . 1
(iii)	<p>Oleum ($\text{H}_2\text{S}_2\text{O}_7$) is the product of the dissolution of SO_3 into concentrated H_2SO_4.</p> $\text{SO}_{3(g)} + \text{H}_2\text{SO}_{4(l)} \rightarrow \text{H}_2\text{S}_2\text{O}_{7(l)}$ <p>Water is then added to the oleum to produce sulfuric acid:</p> $\text{H}_2\text{S}_2\text{O}_{7(l)} + \text{H}_2\text{O}_{(l)} \rightarrow 2\text{H}_2\text{SO}_{4(l)}$ <p>The sulfuric acid is produced in this stepwise procedure as adsorption of SO_3 in water is a highly exothermic process. It would normally produce a fog of H_2SO_4 that is very difficult to dissolve in water.</p>	<p>9.5.3 H7, H8</p> <ul style="list-style-type: none"> • Discusses formation of oleum using equation and why it is used as an intermediary 2 <hr/> <ul style="list-style-type: none"> • Only shows the formation of oleum. 1

Question 28

Industrial Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(e) The three types of detergents are anionic, cationic and neutral. They are classed as such due to the type of hydrophilic head group that is attached to the long hydrocarbon chain.</p> <p>Anionic detergents have a negatively charged head group. An alkylbenzene sulfonate is a common example of this type of detergent.</p> $\text{CH}_3(\text{CH}_2)_n\text{CH}_2-\text{C}_6\text{H}_4-\text{SO}_3^-\text{Na}^+ \quad \text{where } n = 10 - 12$ <p>These are the most widely used detergents and are found in dishwashing and laundry detergents, bathroom soap and even toothpaste. The negative head group is not attracted to glass or china as both of these materials tend to gain a negative surface charge. This makes it an excellent choice for the removal of dirt and grease from these materials.</p> <p>Cationic detergents have a positively charged head group. An alkylquaternary ammonium salt is a common example of this type of detergent, e.g.</p> <p style="text-align: center;">Cetyl trimethyl ammonium bromide</p> $[\text{C}_{14}\text{H}_{29}\text{N}(\text{CH}_3)_3]^+\text{Br}^-$ <p>These are often found in domestic disinfectants and nappy wash detergents as the quaternary ammonium is a mild antiseptic. It is not especially useful for glass or china as its positive head charge causes it to adhere to the material leaving a greasy smear. It is this property that makes them useful with some materials such as some fabrics and even human hair that also acquire a negative surface charge. The detergent adsorbs onto the surface giving a waxy coating that allows a softer feel and easier untangling. Thus cationic detergents are often used in fabric and hair conditioners.</p> <p>Non-ionic detergents have polar head groups and often contain ether (oxygen) linkages between hydrocarbon chains, e.g.</p>  <p>These detergents are often used in front-loading washing machines and in dishwashers as they do not form as much froth as the other detergents.</p> <p>Early detergents contained branched hydrocarbon chains that were non-biodegradable and caused significant pollution in the waterways. This problem has been largely overcome by the use of straight chain hydrocarbons that are biodegradable.</p> <p>The ionic head group detergents worked better in solutions with higher alkalinity and to increase the alkalinity phosphates were added as builders. These phosphates also helped to soften the water (remove cations such as Ca^{2+}). However, the phosphates were a major problem in the environment as they contributed to excessive algae growth that depleted aquatic oxygen and led to eutrophication. Non-ionic detergents do not require the same amount of phosphates.</p> <p>The three types of detergent thus have their specific uses and the choice of detergent will be determined by the application. Detergents have been a significant pollution threat but the worst of that problem has been overcome by ensuring the carbon chain is biodegradable. The detergents have wide application in modern society and are among our most useful chemicals.</p>	<p>9.5.5 H3, H4, H6, H9</p> <ul style="list-style-type: none"> Evaluates the effectiveness of detergents using the information below 6 Demonstrates a knowledge of the structure of anionic, cationic and non-ionic detergents. Compares the applicability of different detergents. Discusses the generational change of detergents and the effect on the detergents' biodegradability. Discusses the problem of increased phosphate in waterways and explains eutrophication 5 Describes the three types of detergent. Discusses the use of detergents. Discusses the environmental impact of detergents 4 Describes two types of detergent. Discusses and compares the application of each detergent 3 Describes a detergent. Identifies an environmental issue 2 Describes a detergent. OR Identifies an environmental issue with detergents 1

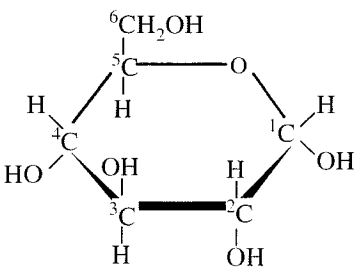
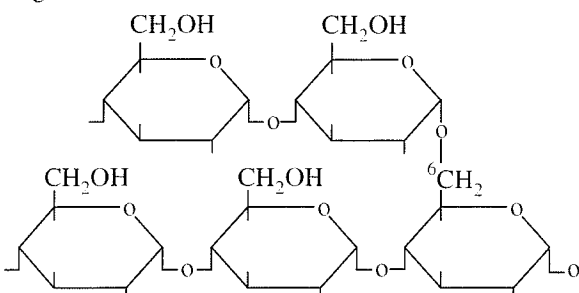
Question 29	Shipwrecks, Corrosion and Conservation	Syllabus content, course outcomes and marking guide
	Sample answer	
(a)	<p>(i) Take two pieces of cast iron. Ensure that both pieces are cleaned and free of surface corrosion. Immerse one of the pieces in oil and leave overnight. Place each piece of iron in a beaker. Pour over and cover each piece with 1 M NaCl solution. Compare the amount of the corrosion on each piece over several days.</p>	<p>9.6.4 H7, H8, H11</p> <ul style="list-style-type: none"> • Outlines an appropriate procedure that compares the corrosion rate of the coated and uncoated samples of the same metal placed in the same solution 1–2
	<p>(ii) The oil acted as a impermeable barrier, preventing water from coming into contact with the surface of the iron.</p>	<ul style="list-style-type: none"> • Identifies that the coating prevents oxygen and/or water from coming into contact with the surface of the metal 1
(b)	<p>PEG method: Waterlogged timber artefacts must not be allowed to dry. If they do, salt crystals would form which would destroy the structure of the wood.</p> <p>To retain this structure in a dried state, the timber needs to be immersed in a synthetic wax known as PEG. The artefact is immersed in PEG and boric acid is usually added as a fungicide.</p> <p>As the timber absorbs the PEG, water and dissolved salts are removed from it. The PEG gives the structure support and prevents it from being brittle when it dries.</p>	<p>9.6.7 H13</p> <ul style="list-style-type: none"> • Identifies an appropriate method used in the preservation of a non-metallic artefact. • Provides details about how the procedure is performed. • Identifies how the process restores the artefact 3 <hr/> <ul style="list-style-type: none"> • Identifies an appropriate method used in the preservation of a non-metallic artefact. • Provides some detail about how the procedure is performed 1–2
(c)	<p>(i) By placing the iron into contact with the copper a potential difference was created. The metal with the greater potential is the iron:</p> $\text{Fe}_{(s)} \rightarrow \text{Fe}_{2+}^{+}(\text{aq}) + 2\text{e}^{-} \quad E^0 = 0.41 \text{ V}$ $\text{Cu}_{(s)} \rightarrow \text{Cu}_{2+}^{+}(\text{aq}) + 2\text{e}^{-} \quad E^0 = -0.35 \text{ V}$ <p>The Statue was erected near a marine environment. The presence of moist air would provide water for the reduction process:</p> $\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4\text{e}^{-} \rightarrow 4\text{OH}^{-}(\text{aq}) \quad E^0 = 0.40 \text{ V}$ <p>In addition to this, the marine environment provides salt. The increased concentration of aqueous ions leads to an acceleration of redox processes.</p>	<p>9.5.2, 9.5.4 H8, H13</p> <ul style="list-style-type: none"> • Identifies that iron has a greater potential than copper, providing half-equations and relevant E^0 values to support argument. • Identifies presence of water and oxygen, providing half-equations to support argument. • Identifies that the presence of ions from salt water accelerates the formation of rust . . 4 <hr/> <ul style="list-style-type: none"> • Identifies that iron has a greater potential than copper. • Identifies that oxygen and water are present. • Some half-equations are given to support argument 2–3 <hr/> <ul style="list-style-type: none"> • Identifies that iron has a greater potential than copper. 1

Question 29 Shipwrecks, Corrosion and Conservation

Sample answer	Syllabus content, course outcomes and marking guide
(d) (i) Extremely cold temperatures greatly decrease the rate of a reaction. Therefore it would be expected that the corrosion of metal structures over a long period of time at such temperatures should not be extensive.	9.6.5, 9.6.1, 9.6.2, 9.6.4 H8, H13 <ul style="list-style-type: none"> Identifies that reaction rate decreases with lowering temperatures. Identifies that this means it would be expected that the amount of corrosion of iron would not be great 1–2
(ii) 1. The presence of H^+ allows for the reduction of the sulfate ions by bacteria: $SO_4^{2-}(aq) + 10H^+(aq) + 8e^- \rightarrow H_2S(aq) + 4H_2O$ 2. H^+ oxidises iron: $Fe_{(s)} + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2$	<ul style="list-style-type: none"> Identifies that H^+ are needed by bacteria to reduce SO_4^{2-}. Identifies that H^+ oxidises iron. Includes relevant half-equations 3 <ul style="list-style-type: none"> Identifies that H^+ are needed by bacteria to reduce SO_4^{2-}. Identifies that H^+ oxidises iron 1–2
(iii) These anaerobic bacteria rely on the reduction of sulfate to respire. The sulfate is present in the sea water. This process produces hydrogen sulfide, H_2S . The electrons required for this reduction come from the oxidation of iron to form iron(II) ions. The iron(II) ions react with the H_2S to form insoluble iron(II) sulfide, Fe_2S .	<ul style="list-style-type: none"> Identifies that sulfate is reduced by bacteria during respiration. Identifies H_2S as a by-product. Identifies that iron provides electrons for this reduction. Identifies that the iron(II) ions formed by the oxidation of iron react with the H_2S to form Fe_2S 3 <ul style="list-style-type: none"> Identifies that sulfate is needed by bacteria for respiration. Identifies H_2S as a by-product. Identifies that iron(II) ions formed by the oxidation of iron react with the H_2S to form Fe_2S 1–2
(e) 1. This prediction is correct. $Cu^{2+} + 2e^- \rightarrow Cu_{(s)}$ $E^0 = 0.35\text{ V}$ $2Cl^- \rightarrow Cl_{2(g)} + 2e^-$ $E^0 = -1.36\text{ V}$ Total $E^0 = -1.01\text{ V}$, therefore voltage supplied by the battery is insufficient as predicted.	9.6.3 H7, H13, H14 <ul style="list-style-type: none"> Provides half-equations and E^0 data to confirm voltage is greater than that supplied by the battery and identifies prediction is correct 2 Uses E^0 data to confirm voltage required is greater than that supplied by the battery 1
2. This prediction is incorrect. The formation of the copper is a reduction process. This occurs at the cathode.	<ul style="list-style-type: none"> Identifies prediction is incorrect because the wrong electrode was identified 1
3. The prediction is correct. $2H_2O(l) \rightarrow O_{2(g)} + 4H^+ + 4e^-$ $E^0 = -1.23\text{ V}$ The oxidation of water occurs. The gas predicted is oxygen.	<ul style="list-style-type: none"> Provides half-equation identifying reduction of water and identifies oxygen as the gas formed 2 Identifies oxygen as the gas formed. 1
4. This prediction is incorrect. According to the half-equation $2H_2O(l) \rightarrow O_{2(g)} + 4H^+ + 4e^-$ $E^0 = -1.23\text{ V}$ The oxidation process shows that H^+ are produced. Since the concentration of the H^+ increases during the electrolysis, the pH of the solution will drop.	<ul style="list-style-type: none"> Uses half-equation to identify production of H^+ and relates changing H^+ concentration to the pH change in solution 2 Identifies that H^+ concentration will change during electrolysis 1

Question 30	The Biochemistry of Movement	Syllabus content, course outcomes and marking guide	
	Sample answer		
(a)	<p data-bbox="272 387 619 418">(i) amino acid structure</p> <div data-bbox="331 423 686 685"> <p data-bbox="502 443 663 474">acid group</p> <p data-bbox="502 539 663 571">side group</p> <p data-bbox="502 613 686 645">amine group</p> </div>	9.7.4	H9
		<ul style="list-style-type: none"> Correct drawing with acid, amino and 'R' side chain groups clearly labelled. 2 	
		<ul style="list-style-type: none"> Drawing with 2 groups labelled. 1 	
	(ii) The binding site results from the folding of the primary sequence of amino acids. Hydrogen bonds, dispersion forces and dipole-dipole interactions occurs between the different amino acids and their side chains, resulting in a secondary structure. This folds again, using the same interactions, to form the tertiary structure and to create the binding site as a 'pocket' that holds the substrate.	9.7.4	H9
		<ul style="list-style-type: none"> Demonstrated understanding of the formation of the binding site by interactions between amino acids in the primary sequence. 2 	
		<ul style="list-style-type: none"> Mention of types of bonding OR Understanding of specificity of enzyme for substrates 1 	

Question 30 The Biochemistry of Movement (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(b) (i) Using <i>Google</i> search engine and the search words <u>glucose</u> and <u>glycogen</u> and <u>structure</u> several websites were reviewed for suitable information and diagrams of both structures. The relevant information was then downloaded and used to write a report comparing the two structures.	9.7.2 H12 • Demonstrated knowledge of the processes involved in collecting the information required 2 • Demonstrated knowledge of one process involved in collecting the information required 1
(ii) Glucose is a single molecule whereas glycogen is a polymer of several thousand glucose molecules. Glucose is a six carbon molecule with the formula $C_6H_{12}O_6$.  Glycogen molecules form when glycoside linkages form between the 1C and 4C atoms, removing water in the process. Other linkages form between 1C and 6C , forming a branched chain polymer of many thousands of glucose molecules. 	9.7.2 H6, H12, H13 • Compares structure of glucose and glycogen including identifying the monomer and polymer, and a description of both compounds (diagram acceptable) 2 • Identifies the monomer and polymer OR • Describes the structures of both compounds 1

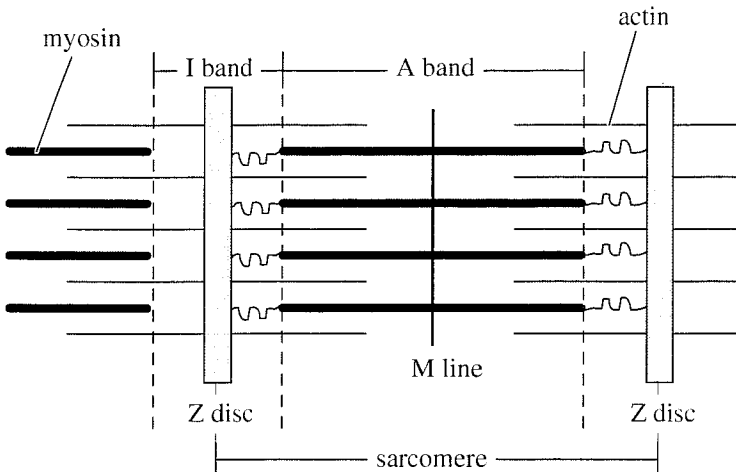
Question 30

The Biochemistry of Movement (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(c) Aerobic respiration is the oxidation of glucose or fat to produce energy in the presence of oxygen. Oxygen is the final acceptor of electrons and is reduced to form water. Electrons produced from the oxidation of glucose and fats reduce the electron carriers FAD and NAD^+ to FADH_2 and NADH.</p> <p>The first process of respiration is glycolysis. It produces 2 molecules of ATP, 2 pyruvate and 2 NADH. Each pyruvate is converted to acetyl CoA, producing a molecule of NADH. Oxidation of fats to produce acetyl CoA also yields NADH and FADH_2. Because fats are more reduced than carbohydrates, their oxidation yields more energy.</p> <p>Acetyl CoA then enters the TCA cycle where it is oxidised completely to carbon dioxide, and electrons are transferred to NAD^+ and FAD.</p> <p>The electrons from NADH and FADH_2 are passed through a series of electron carriers during oxidative phosphorylation. At each step through the chain the energy from the electrons is used to create the proton gradient that produces ATP from ADP and P_i. The electrons are finally used to reduce oxygen to water.</p> <p>The whole process of producing energy from glucose and fats during aerobic respiration is a series of oxidation-reduction reactions in which the glucose and fats are oxidised to CO_2 and their electrons are transferred to FAD and NAD^+. These electron carriers are reduced to FADH_2 and NADH but are regenerated when they transfer their electrons (are oxidised) to the electron transport chain during oxidative phosphorylation. The final oxidation-reduction reaction is the acceptance of the electrons by oxygen to form water.</p>	<p>9.7.6, 9.7.7, 9.7.8, 9.7.9 H1, H7, H9, H13</p> <ul style="list-style-type: none"> • Demonstrated understanding of aerobic respiration as an oxidation-reduction reaction in which fuels are oxidised to form CO_2 and oxygen is reduced to form water. • Analyses the biochemical pathways involved including: <ul style="list-style-type: none"> – glycolysis as an anaerobic reaction that reduces electron carriers; – the TCA cycle as the oxidative decarboxylation of acetyl CoA and the reduction of electron carriers; – oxidation of fatty acids to produce acetyl CoA for the TCA cycle; – oxidative phosphorylation as a process that creates ATP from the oxidation of NADH and FADH_2. • Identifies oxygen as the final acceptor of the electrons from the cytochrome chain to produce water as a final product 5 <hr/> <ul style="list-style-type: none"> • Demonstrated understanding of aerobic respiration as an oxidation-reduction reaction in which fuels are oxidised to form CO_2 and oxygen is reduced to form water. OR • Identifies oxygen as the final acceptor of the electrons from the cytochrome chain to produce water as a final product. • Analyses at least two of the biochemical pathways involved which may include: <ul style="list-style-type: none"> – glycolysis as an anaerobic reaction that reduces electron carriers; – the TCA cycle as the oxidative decarboxylation of acetyl CoA and the reduction of electron carriers; – oxidation of fatty acids to produce acetyl CoA for the TCA cycle; – oxidative phosphorylation as a process that creates ATP from the oxidation of NADH and FADH_2. 3–4 <hr/> <ul style="list-style-type: none"> • Analyses of one the biochemical pathways in involved AND/OR • Identifies oxygen as the final acceptor of the electrons from the cytochrome chain to produce water as a final product 1–2

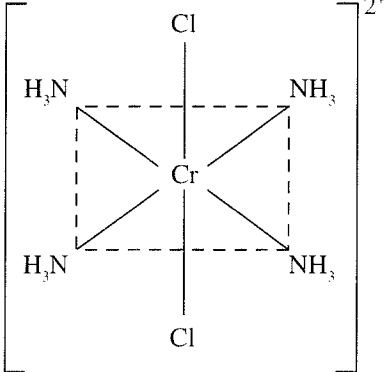
Question 30

The Biochemistry of Movement (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(d) (i) Actin fibres are encircled by strands of tropomyosin with troponin protein molecules blocking the binding site with actin. Calcium ions bind with troponin to expose the binding site so that contraction can occur.</p>	<p>9.7.5 H7</p> <ul style="list-style-type: none"> Correctly explains how calcium exposes the binding site on actin fibres. 1
<p>(ii) Muscle fibrils consist of alternating bands of thick filaments of the protein myosin and thin filaments of the protein actin. Myosin and actin are arranged in the sarcomere so that both are joined to the Z disc. Myosin passes through the M line but actin does not continue through the M line, its ends are free to be pulled forward towards the M line during contraction.</p> 	<p>9.7.5 H7, H8</p> <ul style="list-style-type: none"> Demonstrated knowledge of the arrangement of filaments in skeletal muscle (diagram acceptable) 2 Identifies one correct fact about the arrangement of filaments in skeletal muscle 1
<p>(iii) ATP binds with the myosin heads and is hydrolysed. This raises the head to make contact with the exposed binding site on the actin strand, forming a cross-bridge. The phosphate group of the ATP is then released and the conformation of the head changes. This results in the power stroke, pulling the actin filament towards the M line. When the ADP remaining attached to the myosin head is released, the myosin head returns to its lower conformation and binds with another ATP, repeating the cycle.</p> <p>ATP is consumed in the process because it provides the energy for the conformational changes in the myosin head and so provides the energy for movement.</p>	<p>9.7.5 H7, H8</p> <ul style="list-style-type: none"> Displays thorough knowledge of the process of muscle contraction. Displays thorough knowledge of the role of ATP in changing the conformation of the myosin head. 2–3 Identifies one fact about the process of muscle contraction OR Identifies one fact about the role of ATP in changing the conformation of the myosin head 1

Question 30	The Biochemistry of Movement (Continued)	Syllabus content, course outcomes and marking guide
	Sample answer	
(e)	<p>There are two types of athletes: those who perform light endurance exercise using aerobic respiration and those who perform high intensity exercise like sprinting using anaerobic respiration.</p> <p>Both types of athletes use the anaerobic biochemical pathway of glycolysis to split 6C glucose to 3C pyruvate, producing 2 ATP per molecule of glucose.</p> <p>The blood vessels cannot maintain the supply of oxygen to strongly exercising muscles and so these muscles then carry out aerobic respiration, converting the pyruvate from glycolysis to lactic acid and 2 ATP. Rising acid levels inhibit the contraction of muscles but athletes who train for high intensity exercise increase their stores of glycogen in the muscle. Glucose can be split from glycogen and produce ATP at a greater rate from glycolysis than ATP production using oxygen and the Tricarboxylic Acid (TCA) Cycle and oxidative phosphorylation.</p> <p>Athletes performing light endurance exercise use aerobic respiration, as supply of oxygen is not a problem. The pyruvate produced from glycolysis is converted to acetyl CoA and transferred to the TCA cycle, producing more ATP, NADH and FADH₂. The NADH and FADH₂ are then passed to the cytochrome chain and the reactions of oxidative phosphorylation to produce 38 molecules of ATP.</p> <p>These athletes can also metabolise fats. Fats are broken down in 2C units and converted to acetyl CoA to enter the TCA cycle and produce 138 molecules of ATP per 16C fatty acid.</p> <p>In the future, understanding of these pathways may change the diets of athletes. Sprinting athletes need stores of glycogen in their muscles to provide fuel for glycolysis while fat stores are of no use during exercise. Methods of improving glycogen storage or availability of glucose will be appropriate. Athletes undertaking lighter exercise may be able to modify fat intake in their diet to make use of their ability to use fats to produce much more ATP than carbohydrates through the TCA cycle and oxidative phosphorylation.</p>	<p>9.7.2, 9.7.6, 9.7.7, 9.7.8, 9.7.9, 9.7.10 H1, H3, H4, H5, H7, H13</p> <ul style="list-style-type: none"> • Displays thorough knowledge of biochemical pathways. • Displays thorough knowledge of the needs of different types of athletes. • Analyses possible future methods of improved performance linked to the needs of different athletes. 5–6 <hr/> <ul style="list-style-type: none"> • Displays thorough knowledge of biochemical pathways AND/OR • Displays thorough knowledge of the needs of different types of athletes 3–4 <hr/> <ul style="list-style-type: none"> • Identifies one fact about biochemical pathways AND/OR • Identifies one fact about the needs of different athletes. 1–2

Question 31. The Chemistry of Art

Sample answer	Syllabus content, course outcomes and marking guide
<p>(a) (i) d-block elements are those in which a valence electron is being added to a d-subshell. Scandium and zinc each have electrons being added to the d-subshell, hence they are d-block elements. They are not transition elements as they do not form at least one ion with a partially filled d-orbital. Scandium and zinc do not form coloured ions and their physical properties differ from the transition elements.</p>	<p>9.8.4 H6, H8</p> <ul style="list-style-type: none"> Explains the difference between d-block and transition elements in terms of d-subshells and partially filled d-orbitals 2–3 Gives a definition of d-block elements OR States where transition elements are found on the periodic table. 1
<p>(ii)</p> 	<p>9.8.5 H6, H13</p> <ul style="list-style-type: none"> Appropriate diagram with two ligands identified 2 Appropriate diagram 1
<p>(b) A destructive technique is laser microspectral analysis in which a small chip of paint is vaporised by laser and the atoms are excited electrically to produce an emission spectrum. This spectrum is then analysed by comparing the inferred pigments to known samples used by the artist, i.e. Cezanne. Other destructive techniques rely on dissolving a small amount of the pigment/binder and performing infrared or ultraviolet-visible spectroscopy on it.</p> <p>A non-destructive technique relies on irradiating the surface of the sample with ultraviolet or visible light and recording and analysing the reflected spectrum. This is then compared to known samples of pigment, since each pigment has a characteristic spectrum.</p>	<p>9.8.2 H1, H2, H3, H11, H14</p> <ul style="list-style-type: none"> Describes two techniques AND States how the identification of the painting could be made 3–4 States two techniques, with some description OR Describes one technique and states how it could be used to identify the painting ... 2 States two techniques. 1
<p>(c) Early pigments were mineral based solids suspended in a medium. Over time advances in technology allowed a wider range of media and pigments to be used and alternatives to be found when the links between some pigments and ill-health caused by them were found.</p> <p>Yellow and red ochre, black from charcoal and white were the earliest colours used. As mining and metallurgical techniques developed so did the range of colours and variety within colours. Yellow pigments, such as orpiment, based on arsenic, were found to be highly poisonous.</p> <p>The use of lead oxide (replacing orpiment) caused lead poisoning (anaemia, convulsion, kidney and brain damage), but not to the same extent. Yellow lead oxide based paints are now only used for applications such as road markings. Modern yellow pigments, including Hansa yellow, Naples yellow or even Saffron (if only small amounts are needed) in white titanium dioxide are not associated with deleterious effects on health.</p>	<p>9.8.1 H1, H4, H13</p> <ul style="list-style-type: none"> Discusses use of named pigments of a specified colour over time with appropriate reason for the changes, e.g. health or improvements in technology 4–5 Describes how pigments change over time with appropriate reason for the changes, e.g. health or improvements in technology 2–3 Names a pigment with a specific colour OR Gives a reason for changing use of pigment 1

Question 31 The Chemistry of Art (Continued)

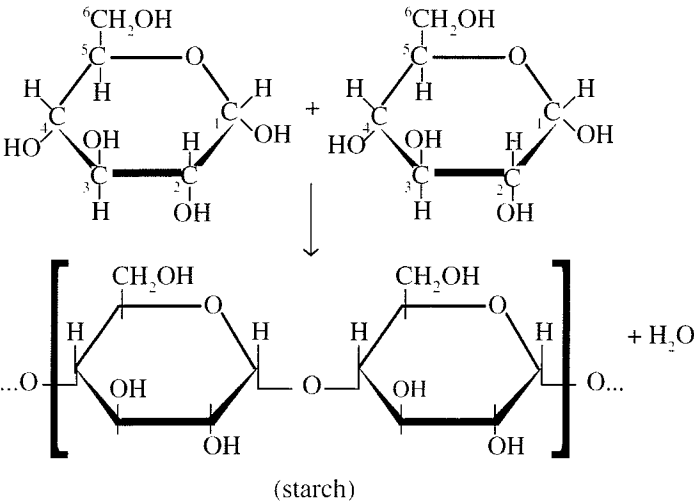
Sample answer	Syllabus content, course outcomes and marking guide
(d) (i) The solution stains skin and is a powerful oxidant, especially in contact with organic materials, hence care needs to be taken to avoid spillages and contact with skin.	9.8.4 H6, H8, H11 • Describes a safety precaution with a reason for it 2 • Describes a safety precaution 1
(ii) The strength of an oxidant is related to its oxidation number. The higher the oxidation number of an element, the stronger its oxidising strength, e.g. manganese(VII) is a stronger oxidant than manganese(II). The electrode potential is also related to oxidising strength. Strong oxidants have a higher (more positive) potential than weak oxidants.	9.8.4 H6, H8, H11 • Relates oxidising strength AND • oxidation number AND • electrode potential using KMnO_4 as an example 3 • Relates two of the factors. 2 • Describes one or two factors 1
(e) The Bohr model describes the electrons in atoms as having discrete amounts of energy, rather than any amount of energy, and that the electrons are able to move from one energy level (or shell) to another if sufficient energy is provided. When an excited electron(s) returns to a lower energy level the energy difference is released as a specific frequency of electromagnetic radiation. For the hydrogen spectrum, this model worked extremely well, but for helium, which had a more complex spectrum, additional levels of energy within shells were needed. This was not accounted for in Bohr's model. Although this model was useful in that it explained some of the lines for the helium spectrum, it was too simple since it could not explain all the lines.	9.8.3 H1, H2, H13, H14 • Explains the Bohr model AND • Emission spectra in terms of electron transitions AND • Evaluates the model for hydrogen and helium 5–6 • Describes the Bohr model AND • Emission spectra in terms of electron transitions hydrogen and helium OR • Evaluates the model in terms of spectra of hydrogen and helium AND gives a basic description of the model 3–4 • Basic description of the Bohr model OR • Description of emission spectra. 1–2

Question 32	Forensic Chemistry	Syllabus content, course outcomes and marking guide	
	Sample answer		
(a)	(i) Contamination of samples can compromise the reliability of results. When collecting samples, contamination can be minimised by wearing gloves and other protective clothing such as facemasks and overalls and using clean, sterile containers which are properly labelled and carefully catalogued.	9.9.1	H3, H4, H12, H14, H16 <ul style="list-style-type: none"> Identified the precautions necessary to prevent contamination during collection of samples for forensic analysis 2 Identified one precaution 1
	(ii) Forensic chemistry is concerned with providing information which 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.	9.9.1	H3, H4, H12, H14, H16 <ul style="list-style-type: none"> Identified the role of forensic chemistry and/or the forensic chemist. Demonstrated understanding of importance of accuracy in forensic science 2 OR <ul style="list-style-type: none"> Identified the role of forensic chemistry Demonstrated understanding of importance of accuracy in forensic science 1
(b)	A mass spectrometer is used to determine the mass/charge ratio of ion fragments from a sample and can be used to identify the molecular formula and % abundance of components of the sample. <ul style="list-style-type: none"> Samples are vaporised, if necessary, to produce a gaseous sample. The vaporised sample is passed into a low-pressure ionising chamber where an electron beam ionises the sample by removing electrons from uncharged atoms or molecules. Positive ions are formed. An electric field, created by charged plates, accelerates the ions to high speed. The ions pass through a magnetic field that is perpendicular to their pathway. This causes the ions to move in a curved path. The radius of the curve depends on the mass-to-charge ratio of the ion. An ion collector traps each ion and the detector identifies its mass based on its movement through the magnetic field. A recorder trace is produced which shows the mass number and relative % abundance of each ion fragment 	9.9.5	H3, H4 <ul style="list-style-type: none"> Correctly identifies the main sequence of events in analysing a sample using mass spectrometry. Identifies the nature of the information obtained on analysis. 2 OR <ul style="list-style-type: none"> Correctly identifies some of the operating sequences or the nature of information obtained 1

Question 32	Forensic Chemistry (Continued)	
	Sample answer	Syllabus content, course outcomes and marking guide
(e) (i)	The major functional groups are an amino group ($-\text{NH}_2$) and an alkanolic acid group ($-\text{COOH}$).	9.9.3 H9 • Correct identification of both functional groups. 1
(ii)	Amino acids are linked by a peptide (or amide) bond. The peptide bond is a covalent bond between the carbon atom from the alkanolic acid functional group of one amino acid (R) and the nitrogen atom from the amino group of another amino acid (R'). The peptide bond forms from a condensation reaction between two amino acids and results in the elimination of water. $\text{R}' - \text{NH}_2 + \text{HOOC} - \text{R} \rightarrow \text{R}' - \text{NHOC} - \text{R} + \text{H}_2\text{O}$	9.9.3 H6, H9 • Correctly identifies the covalent nature of the peptide bond and describes its formation 2 • Correctly identifies the linkage as a peptide bond 1
(iii)	Electrophoresis is an excellent method for the separation and analysis of proteins. It can be used to identify the origin of proteins by comparing separation results to those of known samples. It can be used to identify the nature of other biological molecules and is particularly important in identifying the origin of DNA samples. The technique uses chromatographic separation based on the rate at which molecules migrate through an electric field. Samples are applied to a paper or gel medium. The medium is placed between two electrodes and a current is applied. The rate of migration depends on the size of the molecule and its charge. Adjusting the pH of the gel medium can control the charge on proteins. After separation, proteins are stained and compared to reference standards. Since different organisms contain different proteins, electrophoresis can be used to identify the type of organism from which a sample originated. Different animal species, including different species of fish, have different proteins, so electrophoresis can distinguish between them. A particularly important application is the identification of individuals based on some human proteins which have a number of different forms. If the protein found to be present in analysed samples corresponds with reference samples then identification can be made on the basis of electrophoresis.	9.9.3, 9.9.4 H3, H4, H8, H13 • An explanation of the chemical basis of electrophoresis as a separation technique. • Demonstrates understanding that electrophoresis can be used to identify the origin of proteins and other biological molecules, including DNA. • A description of the importance of the identification of proteins in Forensic Chemistry using examples. • Recognition that DNA is unique to individuals and can be used to identify individuals 3–4 • An explanation of electrophoresis as an identification technique for protein and DNA samples • Understanding of the use of protein and DNA sample data for identification of species and individuals by their DNA 2–3 • Knowledge that electrophoresis is a separation technique used to identify species by their protein and individuals by their DNA 1

Question 32

Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(d) (i) Sample 2 is of animal origin.	9.9.2 H14 • Correctly identifies animal origin of sample 1
(ii) The sample is ground using a mortar and pestle, transferred to a test tube and diluted with approximately 2 mL of water. 2 mL of iodine is added to the sample mixture and also to a comparison sample of water. A deep blue-black colour in the sample mixture indicates the presence of starch. The water sample remains a yellow-orange colour.	9.9.2 H8, H9, H11 • Correct description of experimental procedure and reagent (iodine). • Correct identification of colour change in a positive test result 2 OR • Correct description of experimental procedure and reagent (iodine). • Correct identification of colour change in a positive test result 1
(iii) Starch is produced by a condensation polymerisation reaction in which glucose monomers are polymerised and water is eliminated. The glucose units form a linear structure joined by a $\alpha(1 \rightarrow 4)$ glycoside bond. <div data-bbox="209 943 906 1442">  <p style="text-align: center;">(starch)</p> </div>	9.9.2 H6, H9, H10 • Description of a condensation polymerisation reaction including products and site of water eliminating on glucose. • Identification of glycoside bonding in linear starch molecule. • Correct chemical reaction equation supporting description 3 OR • Description of products of condensation polymerisation reaction • Correct chemical reaction equation supporting description 2 OR • Identification of starch formation from a condensation polymerisation reaction of glucose 1

Question 32 Forensic Chemistry (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
<p>(e) Line emission spectra occur as result of electron movements between an element's electronic levels, or electron shells. Since the electronic configuration of each element is unique, so the allowable or possible electron movements are also unique. As a result, line emission spectra are characteristic for given elements and can be used to identify trace elements in forensic investigations.</p> <p>When sufficient energy is supplied to an atom, electrons will be excited to higher energy electron orbitals. On relaxation, or moving to lower energy orbitals, electrons emit light as a result of energy loss. Some of this light has energy corresponding to the visible region and is seen as a particular and characteristic colour. These colours are a blend of light at different wavelengths and can also be seen with a spectroscope as lines. In this way, line spectra are produced.</p> <p>Placing the sample onto a platinum wire and then heating in a Bunsen burner can excite elements. The sample is vaporised, electrons are excited and characteristic colours can be quickly observed. Samples may also be injected into an atomic emission spectrometer and vaporised in a similar way. Excitation by electrical discharge can also be used. Metals are ideally suited to line emission analysis since they produce emissions in the visible region. Due to its high sensitivity, this technique allows the analysis of small samples which is often necessary in forensic work due to the limited availability of physical evidence.</p> <p>Analyses are easily and quickly repeated which enables the chemist to verify and check results. Detection limits are low so trace amounts can be identified. Atomic emission spectrometers can be used to produce standard intensity vs. concentration data for pure element samples. These can be used to determine the amount of a given element in a sample. This is useful because it is often the amount of substance that is critical in investigations as well as the actual presence of an element, e.g. in the case of metal poisoning or environmental pollution.</p> <p>This technique involves destructive testing and is not suitable in cases where non-destructive testing is required, e.g. with samples of high economic or historical value. Line emission spectra provide a reliable, speedy and simple way to identify and quantify the presence of trace amounts of metals, in particular in small samples, and are extremely useful in forensic investigations.</p>	<p>9.9.6 H3, H4, H6, H12, H13, H14</p> <ul style="list-style-type: none"> • A well-constructed discussion demonstrating understanding of the production and principles associated with line emission spectra, including the concept of fingerprint emission spectra. • Identified the advantages associated with speed, reproducibility, reliability and interpretation of results and their value in forensic investigations. • An explanation of how results are used to identify the nature and origin of samples. • Describes the quantitative applications of atomic emission techniques. • Identifies the disadvantages associated with destructive testing techniques and limitations of line emission 5–6 <hr/> <ul style="list-style-type: none"> • Demonstrated understanding of the technique of atomic emission, identifying advantages associated with repeatability and small sample analysis. • An explanation of the value of the technique in forensic investigations, including disadvantages and limitations 3–4 <hr/> <ul style="list-style-type: none"> • Identified the basic principles of line emission spectra and the advantages and/or limitations of its use. 1–2

