Neap

HSC Trial Examination 2010

Chemistry

Solutions and marking guidelines

Section I

Part A

Answer and explanation	Syllabus content and course outcomes
Question 1 **B** The double bond of ethylene allows it to be easily transformed into other products.	9.2.1 H9
Question 2 **A** Cracking is the name of the industrial chemical process in which long chain hydrocarbons are transformed into shorter hydrocarbon chains. Usually a mix of saturated and unsaturated compounds is produced.	9.2.1 H9
Question 3 **C** The dehydration of ethanol into ethane requires concentrated acid as a catalyst. (Option **B** is incorrect as the addition of water would not favour the dehydration reaction).	9.2.3 H7, H8, H9
Question 4 **A** The structural diagram shows the polar nature of the OH functional group and the non-polar nature of the hydrocarbon chain. (δ = slight difference in charge) This representation would best explain the ability of ethanol to dissolve both polar and non-polar substances.	9.2.3 H9
Question 5 **D** Molecular mass of propanol = 60.064 amu Moles of $C_3H_7OH = 1.47 \div 60.064 = 0.0245$ mole $\Delta H_{Comb}(C_3H_7OH) =$ heat change $\div$ moles of C_3H_7OH $\Delta H_{Comb}(C_3H_7OH) = -36.4 \div 0.0245 = -1487$ kJ mol^{-1}	9.2.3 H7, H9, H10, H12
Question 6 **C** The more active metal will displace the less active metal from solution. Magnesium metal is more electropositive and is hence the more active metal and will displace copper from solutions containing copper ions. $Mg(s) + Cu^{2+}(aq) \rightarrow Mg^{2+}(aq) + Cu(s)$	9.2.4 H8
Question 7 **A** The nuclei of all isotopes with an atomic number greater than 83 are unstable (uranium and americium) and undergo nuclear decay. Carbon-14 is also unstable, hence option **A** is correct. Chlorine and oxygen are stable. All three isotopes in options **B** and **D** are stable.	9.2.5 H6
Question 8 **B** Metallic oxides react with acid (hence with Li), therefore the only possible correct answer is **B**. (In general, oxides of metals are bases and oxides of non-metals area acids.)	9.3.2 H6, H8, H10, H14
Question 9 **B** $n(NO) = \dfrac{2}{3} \times n(Cu) = \dfrac{2}{3} \times 0.100 = 0.0667$ mol $n(NO) = \dfrac{\textbf{Volume of NO}}{\textbf{molar volume of gas}} = \dfrac{\textbf{Volume of NO}}{24.79} = 0.0667$ Volume of NO = 1.65 L	9.3.2 H10, H14

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes	
Question 10 **A** The conical flask should be rinsed with water before use. Using standard sodium carbonate solution would increase the concentration.	9.3.4	H11, H12
Question 11 **A** A buffer must contain a weak acid–base conjugate pair. Only option **A** meets this criteria – it contains the weak acid ammonium ion (NH_4^+) and the weak base ammonia (NH_3). Options **B** and **D** involve adding a strong acid to a strong base, producing a salt NaCl, which is not a buffer. Option **C** also involves adding a strong acid to a strong base, producing a salt Na_2SO_4, which is not a buffer.	9.3.4	H8, H14
Question 12 **D** $NaNO_3$ is a neutral salt and does not react with HCl. This is a simple dilution problem, in which 100 mL of 0.100 mol L^{-1} HCl is diluted to 500.0 mL. $\quad 100.0 \times 0.100 = 500.0 \times$ final concentration final concentration = 0.0200 mol L^{-1} $pH = -\log_{10}[H^+] = -\log_{10}[0.0200] = 1.70$	9.3.3	H10, H12, H13
Question 13 **D** The proton is transferred from the acid (H_2CO_3) to the base (OH^-).	9.3.4	H8, H14
Question 14 **C** Copper can be either green or blue in the flame.	9.4.3	H6
Question 15 **D** Haber's contribution was the development of a catalyst system that enabled the economic production of ammonia directly from the elements hydrogen and nitrogen. Carl Bosch later developed the process to be used industrially.	9.4.2	H1
Question 16 **A** Option **A** is correct. Ozone and oxygen are both colourless gases at room temperature and pressure. The chemical reactivity of ozone is much greater than the chemical reactivity of oxygen, hence option **B** is incorrect. Oxygen is a linear molecule (as are all diatomics) whilst ozone is bent, hence option **C** is incorrect. The molar mass of oxygen is 32 whilst the molar mass of ozone is 48, hence option **D** is incorrect.	9.4.4	H6

Part A (Continued)

Answer and explanation	Syllabus content and course outcomes
Question 17 **C** Increasing the temperature (whilst keeping the pressure constant) results in an increase in the % yield hence the reaction is endothermic. Therefore options **A** and **B** are incorrect. Increasing the pressure (whilst keeping the temperature constant) results in an increased % yield, hence there must be more gas molecules (greater volume) on the reactant side than on the product side. Option **C** correctly shows an endothermic reaction with greater volume than product.	9.4.2 H7, H10, H14
Question 18 **B** Option **B** is the correct answer. The addition reaction of bromine and ethane (reaction I) is the only reaction that will produce only one product.	9.2.1, 9.4.1 H8, H14
Question 19 **B** Ammonia makes a coordinate bond (both electrons in a new bond come from nitrogen) when it reacts with a proton to form an ammonium ion. The rest form standard covalent bonds.	9.4.4 H8
Question 20 **C** AAS is a useful technique for measuring the concentration of metal ions in samples, and hence is useful for monitoring heavy metal pollution within the environment, such as lead pollution. Only option **C** is consistent with the use of AAS, as the other forms of pollution do not involve heavy metals.	9.4.3 H3, H4

Part B

Sample answer	Syllabus content, course outcomes and marking guide
Question 21	
(a) • A few millilitres of an alkane (e.g. cyclohexene) were placed in a test tube. • A few drops of bromine water (brown) were added. • The test tube was stoppered and shaken. • Any change in colour was noted. • The procedure was repeated with an alkene (e.g. cyclohexene). Safety: no naked flames were present; experiment was carried out in fume-cupboard (or in well-ventilated room); students must wear safety glasses when performing this experiment.	9.2.1 H8, H12, H13 • Gives clear description of the investigation including safety measures, making at least three points. . . . . 3 • Gives description of the investigation including safety measures, making at least two points. . . . . 2 • Gives description of the investigation or safety measures 1
(b) There was no change with the alkane, but the alkene would cause the orange-brown colour of the bromine water to disappear (the alkene would decolourise the bromine solution).	9.2.1 H9 • Notes appropriate colour change 1
(c) cyclohexene + bromine $\rightarrow$ dibromocyclohexane $C_6H_6(l) + Br_2(aq) \rightarrow C_6H_6Br_2(l)$ *Note: Bromocyclohexanol is also a permitted answer.*	9.2.1 H9, H13 • Writes an appropriate equation correctly. 1
Question 22	
(a) Total mass would decrease. Carbon dioxide gas is evolved, which would escape through the cotton wool.	9.2.3 H9, H14 • States decrease in mass and correct explanation. . . . . 2 • States decrease in mass or correct explanation. 1
(b) yeast	9.2.3 H8, H9 • Identifies correct substance 1
(c) $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$	9.2.3 H8, H13 • Writes balanced equation with correct symbols of state 1
Question 23	
(a) The zinc electrode is negative because it is oxidised and loses electrons.	9.2.4 H7, H8 • Correctly identifies charge and gives reason. . . . . 2 • Correctly identifies charge. 1
(b) Stoichiometry shows that one mole of water is produced for every mole of zinc. $\dfrac{2.2}{65.39} = 0.0336$ mol Mass of water $= 18.016 \times 0.0336 = 0.605 = 0.61$ g	9.2.4 H10, H12 • Gives correct answer including units and to correct number of significant figures. . . . 2 • Shows working using correct logic 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 24	
(a) Radioisotopes are unstable as they emit ionising radiation. An industrial use is in nuclear power stations (uranium-235). Gamma Rays are used to take x-ray-type photographs of welded metal joints (cobalt-60). Gamma rays can also be used to sterilise food and to measure the height of substances in containers. The substance being studied can have a radioactive tracer ('labelled') atom added, the path of that substance being followed. Examples include monitoring movement of mud and silt in bodies of water, detecting leaks in pipes, measuring wear on moving surfaces. (technetium-99, caesium-137). Medical uses include measuring the rate and path of biological processes, i.e. how plants absorb minerals from the soil (phosphorus-32) and checking the performance of the thyroid gland (iodine-131). Gamma rays can be used to sterilise medical supplies and kill tumours with much less risk than surgical procedures. Radioisotopes perform roles that are not easily performed by other substances or techniques, however they can pose a health risk and there are problems with their disposal.	9.2.5 H3, H4, H13 • Demonstrates a thorough knowledge of radioisotopes, uses and associated problems. • Mentions at least five major points including named example of radioisotopes . . . . 5 • Demonstrates a thorough knowledge of radioisotopes, uses and associated problems. • Mentions four major points including named examples of radioisotopes . . . . . . 4 • Demonstrates a sound knowledge of radioisotopes, uses and associated problems. • Mentions three major points including named examples of radioisotopes . . . . . . 3 • Demonstrates some knowledge of radioisotopes. • Mentions two major points . . . . 2 • Demonstrates limited knowledge of radioisotopes. • Mentions one major point 1
Question 25	
(a) *Note: Titrations 2, 3 and 5 are concordant. Titrations 1 and 4 are not concordant and should be omitted from any calculation.* Average of concordant titrations = 26.0 mL In the titration (the 25.00 mL aliquot of the diluted vinegar): $CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$ $n(NaOH) = [NaOH] \times Vol_{NaOH} = 0.105 \times 0.0260$ $n(NaOH) = 0.00273$ mol $n(CH_3COOH) = n(NaOH) = 0.00273$ mol $[CH_3COOH] = \dfrac{moles}{volume} = \dfrac{0.00273}{0.02500}$ $\qquad\qquad\quad = 0.109$ mol L^{-1} In the undiluted vinegar sample: 50.00 mL of the NEAP vinegar is diluted to 500.00 mL, representing a $10 \times$ dilution. $[CH_3COOH] = 10 \times 0.109 = 1.09$ mol L^{-1}	9.3.4 H9, H10, H12 • Correctly determines the average of the concordant results. • Determines the number of moles of NaOH used in the titration. • Determines the concentration of the diluted vinegar sample. • Determines the concentration of the concentrated vinegar sample. • The answer is expressed with correct units and an appropriate number of significant figures . . . . 5 • Any four of the above points . . . . 4 • Any three of the above points . . . . 3 • Any two of the above points . . . . 2 • Any one of the above points 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(b) Ethanoic acid is a weak acid that only ionises partially, and so the position of equilibrium lies to the left. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(l)$ Nitric acid is a strong acid and its ionisation can be considered complete. $HNO_3(aq) + H_2O(l) \rightarrow NO_3^-(aq) + H_3O^+(l)$ *Note: Students may state that the equilibrium position of the ionisation of nitric acid lies very much to the right.*	9.3.3 H8 • Correctly describes ionisation of both acids. • Gives balanced equations showing the ionisation of both acids produce H_3O^+. • Describes ethanoic acid as a weak acid and nitric acid as a strong acid . . . . 3 • Gives any two of the above points . . . . . . 2 • Gives only one of the above points 1

Question 26

Sample answer	Syllabus content, course outcomes and marking guide
(a) The structural formula of methyl butanoate is: $$H\!-\!\underset{\underset{H}{\mid}}{\overset{\overset{H}{\mid}}{C}}\!-\!\underset{\underset{H}{\mid}}{\overset{\overset{H}{\mid}}{C}}\!-\!\underset{\underset{H}{\mid}}{\overset{\overset{H}{\mid}}{C}}\!-\!\overset{\overset{O}{\|}}{C}\!-\!O\!-\!\underset{\underset{H}{\mid}}{\overset{\overset{H}{\mid}}{C}}\!-\!H$$	9.3.5 H9 • Correctly uses structural formulae to represent methyl butanoate 1
(b) butanoic acid and methanol	9.3.5 H9 • Correctly identifies both chemicals 1
(c) An acid catalyst is used to increase the rate at which the reaction occurs (the catalyst is not consumed by the reaction) and allows the reaction to reach equilibrium sooner. Refluxing is justified as it increases the rate of reaction (rate is increased by heating) and also ensures that flammable/toxic gases (methanol and butanoic acid) are not released into the laboratory.	9.3.5 H7, H8, H9, H11 • Identifies that an increase in temperature increases the rate of the reaction. AND • Justifies reflux as a safe technique for heating a reaction. OR • Justifies using a catalyst. . . . . 2 • Any one of the above 1

Question 27

Sample answer	Syllabus content, course outcomes and marking guide
(a) As the temperature rises, solubility decreases. As pressure rises, solubility decreases.	9.3.2 H8, H9 • Describes both relationships 1
(b) $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$	9.3.2 H13 • Writes a balanced equation with symbols of state and the equilibrium symbol 1
(c) (i) If the conditions of an equilibrium reaction are changed, the system will act in such a manner as to minimise these changes.	9.3.2 H8 • Correctly states le Chatelier's principle . . 1
(ii) It must be an exothermic reaction (ΔH is negative) as it is releasing heat. Heating the system would tend to drive reaction from right to left, making the reaction endothermic as it is taking in heat. This minimises the change in direction of the equilibrium reaction.	9.3.2 H7, H8 • States that system must be exothermic and links to change in the direction of the equilibrium reaction. . . . . 2 • States that system must be exothermic or links to change in direction of equilibrium reaction. 1
(d) Find mass of unopened drink container. Open container and re-weigh. Continue to re-weigh at regular intervals until mass is constant. Final difference in mass is carbon dioxide lost to the atmosphere from the drink.	9.3.2 H11 • Describes the appropriate sequence with at least four relevant points . . . . 2 • Describes appropriate sequence with at least two relevant points 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
Question 28 Excess barium nitrate is added to the sample, the mixture is gently heated and allowed to stand overnight until precipitation reaction is complete. Some more barium nitrate may be added the following day to ensure all of the sulfate ions are precipitated out. The precipitate is filtered, dried and weighed. From the mass of the precipitate ($BaSO_4$) the number of moles of sulfate and then mass of sulfate in the sample can be determined. The procedure relies upon the addition of the barium nitrate, which precipitates with the sulfate present, via the reaction: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	9.4.3 H8, H11, H12 • Describes the procedure, identifies reactants, products or gives an equation . 3 • Describes the procedure, identifies reactants or products or gives an equation . . . . 2 • Describes the procedure. 1
Question 29	
Sydney's drinking water is supplied from a number of catchment areas such as the Warragamba Catchment. Although these areas are located away from major sources of contamination, it is possible for contaminants to enter the water. For example, algal blooms have found their way into dams, and parasites such as *Cryptosporidium* have also been present in the past in high enough levels to cause health concerns. Thus chemical monitoring and treatment play a vital role in ensuring the water is safe to drink. Upon large scale screening and flocculation to remove large amounts of suspended material, water is allowed to settle and then filtered through sand beds. The filtered water at this stage is not suitable for drinking, however, because it has not been chemically treated or monitored adequately for all possible contaminants. Chemical treatments such as the addition of chlorine (to kill any microbes) take place, after which monitoring of any bacteria still present is performed. For example, the water will be tested for the presence of coliforms associated with contamination from animal manure. The pH of water is also monitored to ensure it is at the correct level, i.e. between 6.5–8.5. If the pH lies outside of this range, chemicals such as lime might be used to treat the water (in this case to decrease acidity). Finally, water is also treated by adding small amounts of fluoride, which scientists have found strengthens children's teeth against decay. Although Sydney's water has been contaminated in the past (e.g. with *Cryptosporidium*) the continued use of careful monitoring and chemical treatments ensure the quality of our drinking water remains high.	9.4.5 H4, H8, H13 • Gives a thorough evaluation of the roles of chemical monitoring and treatment, identifying contaminants and how they can be treated. • Mentions at least six relevant points . . . . 6 • Gives a thorough evaluation of the roles of chemical monitoring and treatment, identifying contaminants and how they can be treated. • Mentions five relevant points . . . . 5 • Gives an evaluation of the roles of chemical monitoring and treatment, identifying one contaminant and how it can be treated. Mentions four relevant points . . . . 4 • Gives an evaluation of the roles of chemical monitoring and treatment, identifying one contaminant and how it can be treated. • Mentions three relevant points . . . . 3 • Gives an evaluation of the roles of chemical monitoring or treatment, identifying one contaminant and how it can be treated. • Mentions two relevant points . . . . 2 • Shows limited understanding of the roles of chemical monitoring or treatment and identifies one contaminant and how it can be treated. • Mentions one relevant point. 1
Question 30	

(a) $n(MnO_4) = c\ V = 0.0104 \times 0.0251 = 2.6104 \times 10^{-4}$ mol
       $n(Fe^{2+}) = (2.6104 \times 10^{-4}) \times 5$ (5:1 ratio) $= 1.31 \times 10^{-3}$ mol.
       Stoichiometry gives $5Fe^{2+}$ every MnO_4^- ion.
	9.3.4, 9.4.3 H10, H14
	• Gives correct answer with appropriate units and to correct number of significant figures 2
	
	• Shows working using correct logic 1

Part B (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(b) $n(Fe^{2+}) = (2.6104 \times 10^{-4}) \times 5$ (5:1 ratio) $\qquad = 1.31 \times 10^{-3}$ mol (in one tablet) $m(Fe)$ in one tablet $= 1.31 \times 10^{-3} \times 55.85 = 72.90$ mg $\%Fe = \dfrac{72.90}{500} \times 100 = 14.6\%$	9.3.4, 9.4.3 $\qquad\qquad$ H10, H14 • Gives correct answer with appropriate units and to correct number of significant figures 1

Question 31

(a) $$F\!-\!\underset{\displaystyle Cl}{\overset{\displaystyle Cl}{C}}\!-\!F$$	9.4.4 $\qquad\qquad\qquad$ H9, H13 • Draws the correct structure 1
(b) The graph shows an initial sharp increase in the production of CFC-12 in the early 1930s. This corresponds to the period in time shortly after the discovery that the properties of CFCs could be exploited for uses such as coolants in refrigerants and later propellants in aerosols. These molecules were non-toxic and unreactive and as demand increased for fridges etc., production sharply increased. However, the low reactivity of the molecules meant that they did not break down in the troposphere and found their way into the stratosphere. Although undetected at this time, UV light was reacting with the CFC molecules, causing release of chlorine radicals. $CCl_2F_2 \rightarrow CClF_2 + Cl$ The chlorine radicals produced can react with ozone, an allotrope of oxygen in the stratosphere, causing it to form an oxygen molecule and a chlorine oxide radical. $Cl + O_3 \rightarrow O_2 + OCl$ The chlorine oxide radical can then react with oxygen radicals, forming oxygen atoms and regenerating chlorine radicals. $OCl + O \rightarrow O_2 + Cl$ In this way, chlorine radicals from CFCs were slowly converting ozone in the stratosphere to oxygen, and being regenerated in the process. Ozone plays a significant role in maintaining life on earth, as it absorbs harmful UV light from the sun, reducing the amount that falls onto earth. From the 1970s, scientists were able to measure the levels of ozone in the stratosphere and found levels dropping, particularly over the polar regions. The term 'ozone hole' began to be used to describe this problem and scientists began to suspect the use of CFCs as the culprit. With greater amounts of UV light falling on earth, we began to notice health and environmental problems associated with higher UV levels, including increases in skin cancer, interruption of reproductive processes in aquatic organisms, loss of phytoplankton, to name a few. In 1987, the Montreal Protocol was signed, mandating a reduction in the production of CFCs, which is why levels begin to fall dramatically from the late 80s. Replacement chemicals began to be used, and although production of CFC-12 continued (particularly by developing nations), as the graph shows, levels were greatly reduced beyond the year 2000.	9.4.4 $\qquad$ H4, H8, H13, H14 • Accounts for general trends shown in the graph and uses appropriate chemical equations. • Gives five relevant points. . . . . 5 • Accounts for general trends shown in the graph and uses appropriate chemical equations. • Gives four relevant points . . . . 4 • Accounts for some trends shown in the graph and uses some chemical equations. • Gives three relevant points. . . . . 3 • Accounts for some trends shown in the graph and uses some chemical equations. • Gives two relevant points. . . . . 2 • Accounts for some trends shown in the graph or uses some chemical equations. • Gives one relevant point. 1

Section II

Question 32   Industrial Chemistry

	Sample answer	Syllabus content, course outcomes and marking guide
(a) (i)	Galvanic cells produce energy whereas electrolytic cells require energy in order to operate.	9.5.4 H7 • Identifies one key difference between galvanic and electrolytic cells 1
(ii)	In the electrolysis of NaCl(l) the only species present are Na^+ and Cl^- ions. Electrolysis can therefore only produce Na(l) and $Cl_2(g)$: $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$. On the other hand, aqueous NaCl contains Na^+, Cl^- and water. Reduction of water occurs preferentially to reduction of Na^+ to produce $H_2(g)$. In dilute NaCl(aq), water is also oxidised to produce $O_2(g)$ and/or $Cl_2(g)$.	9.5.4 H8 • Explains why different products are obtained in the electrolysis of NaCl(l) compared to dilute NaCl(aq) . . . . 2 • Identifies the correct products for the electrolysis of either NaCl(l) or NaCl(aq)1
(iii)	The mercury process for producing NaOH is an electrolytic process, whereby purified brine is pumped into an electrolytic cell containing a flowing mercury cathode, and a graphite anode. At the anode, Cl^- ions are oxidised to Cl_2. $2Cl^- \rightarrow Cl_2(g) + 2e^-$. At the mercury cathode Na^+ ions are reduced to sodium metal, which dissolves in the mercury to form an amalgam. Depleted NaCl(aq) is pumped out of the cell. The flowing mercury cathode, containing dissolved Na, is pumped out of the cell, and sprayed into water. The sodium metal reacts with the water to produce NaOH(aq) of high purity, $H_2(g)$, and the mercury is pumped back into the electrolytic cell. $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$	9.5.4 H3, H8 • Describes the mercury process for producing NaOH, including two relevant chemical equations . . . . 3 • Outlines the mercury process for producing NaOH, including one relevant chemical equation . . . . 2 • Response contains one correct element related to the mercury process for producing NaOH 1
(b) (i)	$K = \dfrac{[CO][H_2]}{[H_2O]}$ $K = \dfrac{1.5 \times 0.96}{2.5} = 0.58$	9.5.2 H10, H14, H12 • Correctly calculates the equilibrium constant for the system . . . . 2 • Correctly calculates the equilibrium constant using an incorrect equilibrium constant expression 1
(ii)	The forward reaction is endothermic. Decreasing the temperature will shift the equilibrium position to the left, and decrease the value of K.	9.5.2 H8, H14 • Outlines the effect on K of decreasing the temperature on the system 1
(c)	Saponification was carried out by heating a mixture of cooking oil, sodium hydroxide and ethanol, for 30 minutes. The product mixture was poured into saturated NaCl solution, and the desired product (soap, the sodium salt of the fatty acids in the oil) was collected by filtration, washed with cold distilled water, and dried in the air. The other product, glycerol, was not collected. Because ethanol is flammable, heating was carried out using an electric hot plate to reduce the risk of a fire.	9.5.5 H12, H13 • Describes a procedure for saponification, including one identified and minimised risk, the reactants and products . . . . 3 • Outlines a procedure for saponification, including one identified and minimised risk. OR • Outlines a procedure for saponification, including one reactant and product . . . . . 2 • Identifies that soap is produced in saponification reactions 1

Question 32   Industrial Chemistry   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(d) (i) $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$ mass Na_2CO_3 required = 135 kg moles $NaHCO_3$ required = $\dfrac{135000}{105.99}$ = 1273.7 mol moles $NaHCO_3$ = 2×1273.3 = 2547.4 mol mass $NaHCO_3$ = 2547.4×84.007 = 214 kg	9.5.6 H10, H14, H12 • Correctly calculates the mass of sodium hydrogen carbonate required . . . . 2 • Calculation contains one error 1
(ii) Ammonia is an essential substance in the Solvay process, even though it does not appear in the overall equation: $CaCO_3(s) + 2NaCl(aq) \rightarrow Na_2CO_3(s) + CaCl_2(s)$. The equation shows that the Solvay process is based on a reaction which usually would occur (in aqueous solution) in the reverse direction. Ammonia is added to brine, to produce ammoniacal brine, into which CO_2 is bubbled. Carbon dioxide reacts with water to generate carbonic acid, and this reacts with ammonia to produce ammonium and hydrogencarbonate ions: $NH_3 + H_2CO_3 \rightarrow NH_4^+ + HCO_3^-$. In the presence of $NaCl(aq)$, when the temperature of the reaction mixture is reduced, $NaHCO_3$ precipitates. This is easy to separate from the reaction mixture by filtration, and heating produces the desired product, $Na_2CO_3(s)$. It is the use of ammonia, a weak base, which facilitates this reaction sequence. The process also produces ammonium chloride, from which ammonia is regenerated so that it can be recycled. This is important because it reduces production costs, and protects the environment from disposal of ammonium chloride which can lead to the release of ammonia into the atmosphere.	9.5.6 H4, H8, H13 • Explains the importance of both the use and recovery of ammonia, giving a thorough account of the chemistry involved, and includes two chemical equations . . . . 4 • Explains the importance of both the use and recovery of ammonia, giving an outline of the chemistry involved, and includes one chemical equation . . . . 3 • Outlines the chemistry of the use of ammonia or reasons for the recovery of ammonia. . . . . 2 • Response includes one correct statement about the use or recovery of ammonia in the Solvay process, or includes one correct chemical equation 1

TENCHEM_SS_10.FM

Question 32   **Industrial Chemistry**   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(e) Sulfuric acid is produced from elemental sulfur, by the Contact Process, in the following way: sulfur (obtained from the Frasch process) is melted, and sprayed into a furnace in an abundant supply of oxygen. Because the sulfur is present as very fine droplets, the reaction rate is very rapid, and the process therefore produces SO_2 in 100% yield: $S(l) + O_2(g) \rightarrow SO_2(g)$. The $SO_2(g)$ is converted to SO_3 by reaction with oxygen: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$. This step involves an equilibrium reaction, and it is here that reaction conditions must be carefully manipulated to maximise both rate and yield. Reaction rates can be increased by increasing the reaction temperature. However, the forward reaction is exothermic, and according to Le Chatelier's principle, increasing the temperature of an exothermic equilibrium reaction will cause the equilibrium position to shift to the left, decreasing the yield of SO_3. A low reaction temperature will increase the yield, but reduce the rate. A compromise temperature of $600\,°C$ is used, which maximises both rate and yield. Furthermore, the rate is increased by using a catalyst, $V_2O_5(s)$. The reaction mixture is passed sequentially over three beds of the catalyst, at successively lower temperatures. This has the effect of increasing the rate, and the yield, since the temperature is reduced with each catalyst bed, shifting the reaction to the right, producing more SO_3. This process results in almost 100% conversion of SO_2 to SO_3. The SO_3 is then added to concentrated sulfuric acid to produce oleum, and the oleum is then carefully diluted with water to produce sulfuric acid: $H_2SO_4(l) + SO_3(g) \rightarrow H_2S_2O_7(l)$, and $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$. The sulfuric acid is produced via oleum because of the dangers and difficulties associated with mixing $SO_3(g)$ directly with water. The reaction is very exothermic, and a fog of sulfuric acid droplets is produced.	9.5.3 H7, H8, H10, H13 • Explains the formation of sulfuric acid from sulfur by thoroughly describing the chemistry involved, including the equilibrium reaction producing SO_3, and includes chemical equations . . . . 7 • Explains the formation of sulfuric acid from sulfur by describing the chemistry involved, including the equilibrium reaction producing SO_3, and includes a chemical equation . . . . 6 • Explains the formation of sulfuric acid from sulfur by describing the chemistry involved, including an outline of the equilibrium reaction producing SO_3, and includes a chemical equation . . . . 5 • Outlines the formation of sulfuric acid from sulfur by giving an outline of the chemistry involved, including the equilibrium reaction producing SO_3, and includes a chemical equation . . . . 4 • Outlines the formation of sulfuric acid from sulfur by giving an outline of some aspects of the chemistry involved. . . . . 3 • Response contains some correct aspects of the production of sulfuric acid . . . . 2 • Response includes a correct aspect of the production of sulfuric acid, or contains a correct, relevant chemical equation 1

Question 33   **Shipwrecks, Corrosion and Conservation**

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	There are two main sources for minerals dissolved in the sea: rainwater leaching of minerals from terrestrial sources; and seawater leaching minerals directly from hydrothermal vents and mid-ocean ridges.	9.6.1 H13, H14 • Correctly identifies at least one source of minerals dissolved in the Earth's ocean 1
	(ii)	The relative rates of corrosion of iron, steel and zinc can only be compared if a number of factors are controlled (kept constant). Factors which must be controlled include temperature, pH, electrolyte concentration, exposed surface area of each metal and exposure to oxygen. A solution of salt water is prepared and air is bubbled through the solution (to ensure that the solution is well oxygenated). The salt water solution is divided into a number of equal portions and each portion placed into a clean test tube. A square of each metal (identical in size) is cut from a thin sheet of metal and each square of metal could be weighed. A piece of iron is added to one test tube containing oxygenated salt water, a piece of zinc into a second test tube and a piece of stainless steel is added to a third test tube. The test tubes are then sealed (with a cork stopper) and placed together. Each day each test tube is inspected for evidence of corrosion (either the changes to the appearance of the surface of the metal or changes in the appearance of the salt solution). After a week (or a month), each test tube could be opened and the metal squares removed, dried and reweighed. Any change in weight would indicate corrosion had occurred. The relative rate of corrosion might be related to the size of the weight change. Concentrated sodium carbonate solution was than added to small samples of each sodium chloride solution. The formation of a precipitate confirms that a corrosion process has occurred and the amount of precipitate indicates how much corrosion has occurred. The reliability of the results could be improved by performing the experiment in triplicate (or repeating the experiment). The accuracy of the conclusions could be tested by designing a second experiment, using different techniques, to compare the rates of corrosion of the metals (for example comparing the corrosion process of bimetallic strips of these metals).	9.6.2 H9, H10 • Identifies control variables. • Describes an experimental procedure that compares the rates of corrosion of these metals and identifies controls. • Indicates the experimental observations that should be recorded . . . . 5 • Describes a suitable experiment in detail. AND • Identifies control variables. OR • Indicates the experimental observations that should be recorded . . . . 4 • Describes a suitable experiment in detail. 3 • Briefly describes a suitable experiment . . 2 • Indicates the data to be recorded OR • Identifies control variables. 1

Question 33   **Shipwrecks, Corrosion and Conservation   (Continued)**

Sample answer	Syllabus content, course outcomes and marking guide
(b) Anaerobic bacteria promote the corrosion of iron through the reduction of sulfate iron to sulfide ion. $SO_4^{2-}(aq) + 10H^+(aq) + 8e^- \rightarrow 4H_2O(l) + H_2S(aq)$ Oxidation of iron to iron(II) provides electrons for the sulfate reducing bacteria. $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ Black corrosion deposits indicate the formation of iron(II) sulfide. $Fe^{2+}(aq) + H_2S(aq) \rightarrow FeS(s) + 2H^+(aq)$ Iron(II) ions are also easily oxidised to iron(III) ions. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$ Red corrosion deposits indicate the formation of iron(III) oxide.	9.6.4, 9.6.5, 9.6.6 H1, H2, H13, H14 • Identifies that reduction of sulfate ion leads to sulfide ion. • Identifies that corrosion of iron always involves the oxidation of metallic iron to iron(II). • Writes at least two equations in support of their answer . . . . 3 • Any two of the above answers . . . . 2 • Any one of the above answers 1
(c) Oxidation occurs at the anode. $2I^-(aq) \rightarrow I_2(aq) + 2e^-$ Reduction occurs at the cathode. $2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$	9.6.3 H1, H3, H11, H13, H14 • Describes oxidation as occurring at the anode and reduction as occurring at the cathode. • Provides the correct half equation for the oxidation of water at the anode. • Provides the correct half equation for the reduction of iodide ion at the cathode . . . 3 • Any two of the above answers . . . . 2 • Any one of the above answers 1
(d) (i) Metals that form strongly adhering oxide layers are called passivating metals.	9.6.4 H8 • Gives correct outline 1
(ii) Zinc is a sacrificial anode and will react before copper and tin or any of the elements in steel (iron, chromium, nickel, vanadium). Zinc is the anode of this corrosion cell and is oxidised: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ The bronze propeller blade and the steel propeller shaft are the cathodes of this corrosion cell. These are the sites where oxygen is reduced to give hydroxide ion: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ Iron is protected from corrosion because zinc (the more active metal) is oxidised in preference to iron. The zinc metal will have to be periodically replaced to ensure continued protection.	9.6.2, 9.6.4 H3, H6, H13 • Identifies zinc as sacrificial anode (either by name or description). • Identifies that zinc is oxidised in preference to iron. • Correctly identifies that oxygen is reduced at the iron cathode. • Indicates that zinc is consumed as it protects the propeller assembly and will have to be periodically replenished . . . . 4 • Any three of the above answers . . . . 3 • Any two of the above answers . . . . 2 • Any one of the above answers 1
(iii) Reduction occurs at the cathode (the propeller). The impressed current provides electrons for the aqueous oxygen demand (rather these electrons being provided by the propeller itself). $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$	9.6.3, 9.6.4 H4, H13 • Identifies that reduction occurs at the cathode of an electrochemical cell. • Writes the correct half-equation for the reduction of water that will occur in this marine environment . . . . 2 • Any one of the above answers 1

Question 33   Shipwrecks, Corrosion and Conservation   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(e) Any artefact recovered from a shipwreck saturated with salt water, is likely to be covered with barnacles, other biological material, calcium carbonate and, in the case of metals, a coating of corroded material. The water starts to evaporate when the artefact is removed from the ocean with the danger that salt crystals will form and damage the artefact. To prevent this damage all artefacts are initially placed into seawater for transport back to the shore for further assessment. Once on shore, surface coatings may be mechanically removed (often using dental tools). Small artefacts (both wood and iron) need to be kept moist. Wooden objects would be placed into distilled water, regularly changed, to leach out salt water and replace it with fresh water. When the wooden artefacts are free of dissolved salts they are further stabilised by replacing the water in their structure with polyethylene glycols, which penetrate into the tissue of the wood and prevent further deterioration. Iron objects are placed into a slightly alkaline bath (either dilute NaOH or alkaline sodium dithionite) to minimise any further corrosion whilst the extent of the damage to the artefact was assessed. This solution neutralises any acid within the iron artefact and also leaches out chloride ion from the iron artefact. The leaching solution would be regularly replaced. The corrosion that has occurred within the iron artefact can be reversed by two methods: either by reduction with hydrogen, or by electrolysis (the iron artefact is the cathode in an electrolysis cell). The electrolysis technique has the added advantage that it removes chloride ions from the artefact in a slow and controlled manner. Alternatively, the corrosion that has occurred within the iron artefact can be reversed by heating the artefact in a reducing atmosphere of hydrogen gas.	9.6.7 H3, H4, H8, H11, H12, H13 • Identifies a need to keep the artefacts moist whilst the appropriate conservation technique is assessed. • Discusses techniques (either mechanical or chemical) for removal of surface coatings • Identifies an appropriate desalination technique for wood. • Describes the use of PEG in stabilizing wooden artefacts. • Identifies that iron artefacts are initially stabilised in slightly alkaline solution to minimise further corrosion. • Describes a suitable desalination technique for iron artefacts. • Describes a suitable technique to reverse the corrosion that may have occurred within the iron artefact . . . . 7 • Any six of the above answers . . . . 6 • Any five of the above answers . . . . 5 • Any four of the above answers . . . . 4 • Any three of the above answers . . . . 3 • Any two of the above answers . . . . 2 • Any one of the above answers 1

TENCHEM_SS_10.FM

Question 34   The Chemistry of Art

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	Electronegativity is a measure of the electron affinity of an element.	9.8.3 H6 • Provides a basic definition of electronegativity. 1
	(ii)	Element Y would have the highest first ionisation energy as it must be a noble gas. Noble gases are not assigned electronegativity values as they rarely form chemical bonds. Ionisation energy (the energy required to remove an outer electron) increases across a period due to increasing nuclear charge, but then it drops sharply as you move to Group 1, which has its valence electron in an outer electron shell, making it much easier to remove. This is why Element Y must have the highest ionisation energy.	9.8.3 H6, H14 • Identifies the correct element with an explanation that relates ionisation energy to electronegativity. 2 • Draws a correct conclusion about electronegativity or ionisation energy of an element from the graph. OR • Relates electronegativity and ionisation energy without identifying the correct element. 1
	(iii)	Elements V to Y are in the same period, corresponding to filling the same valence shell. Since Y is a noble gas (its configuration is s^2p^6), it has a stable configuration which explains its very low reactivity (and thus absent electronegativity). Since the elements are consecutive, this makes V belong to Group 5 (s^2p^3), W to Group 6 (s^2p^4), X is in Group 7 (s^2p^5) and Z must be in Group 1 of the next period (s^1). As you move across the same period, electronegativity increases as you add an extra proton to the nucleus (thus atomic radius decreases) and as it gets closer to a stable s^2p^6 configuration. Thus X has the highest electronegativity as it has a small radius, high nuclear charge and is one electron short of a stable configuration. Y has no value assigned (it is already stable) and Z, a Group 1 metal with a larger radius and a single valence electron, therefore has the smallest electronegativity value.	9.8.3 H6, H13, H14 • Deduces the valence shell configuration of elements V–Z and explains fully the relationship between the electron configurations and electronegativity values. . . . . 3 • Provides a partial explanation to relate the electron configurations of the elements to their electronegativity values. . . . . 2 • Identifies the electron configurations of the elements or their correct group numbers from the periodic table. OR • Identifies a correct feature of the relationship between electron configuration and electronegativity 1
(b)	(i)	Raman spectroscopy is a method used to determine the elemental composition of a paint sample in an artwork. The sample is irradiated with light which is scattered in a manner characteristic of the chemical composition of the paint. A Raman spectrograph is collected and analysed to determine the composition of the paint.	9.8.2 H4 • Provides characteristic features of a technique that would be useful in the analysis of a material used in artwork . . . 2 • Identifies a technique which would be useful in the analysis of a material used in an artwork 1
	(ii)	The technique is non-destructive as it neither requires removal of the sample from the work or changes the chemical composition of the material being analysed in any way.	9.8.2 H4, H11 • Correctly classifies the identified technique including a suitable justification which makes clear the student's understanding of destructive vs non-destructive testing . . . 1

Question 34   The Chemistry of Art   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(c) The ancient Egyptians used many naturally occurring minerals in the materials they widely used for self-decoration. As these minerals often contained heavy metal ions, there were a number of adverse health effects. For example, copper compounds such as azurite ($CuCO_3.2Cu(OH)_2$) were used as blue eye shadows and are now known to act as eye irritants. More dangerous was the use of cinnabar (HgS), a red powder used as rouge. Mercury compounds are neurotoxins and can be absorbed across the skin. They accumulate in the body and over time cause a range of effects on the brain and nervous system, and can eventually lead to brain damage.	9.8.1 H1, H13 • For at least two specific examples (including chemical composition of the named minerals), relates the presence of the metal to a specific health effect . . . . 3 • Describes the use of minerals in cosmetics used by the named culture and gives one specific example of a mineral and its health effect. . . . . 2 • Identifies a mineral (by name or formula) used by the named culture as a cosmetic which has an adverse health effect. 1
(d) (i) Half-equations $$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$ $$Br^-(aq) \rightarrow \tfrac{1}{2}Br_2 + e^-$$ Net ionic equation $$MnO_4^-(aq) + 5Br^- + 8H^+(aq)$$ $$\rightarrow Mn^{2+}(aq) + \frac{5}{2}Br_2(aq) + 4H_2O(l)$$	9.8.4 H8, H13, H14 • Provides both half-equations and the net ionic equation for the reaction . . . . 2 • Provides one correct half-equation. OR • Provides the net ionic equation for the reaction. 1
(ii) The results show that the permanganate ion was able to oxidise the Cl^-, Br^- and I^- halide ions to their respective halogen because the fading of the purple colour shows the permanganate ion is being reduced, hence the halide ions are being oxidised. Since the halide ions (especially the Cl^- ion) are themselves powerful oxidants, the fact that the permanganate can oxidise them is the basis for the student's conclusion. The ion is not, however, able to oxidise the F^- ion, which is a stronger oxidising agent than the permanganate. The strength of the permanganate ion is due to the composition of the MnO_4^- ion. This ion contains Mn in the +VII oxidation state (as it is bonded to the very electronegative oxygen atoms). In this high oxidation state, the species has a strong affinity for electrons from other species, and is therefore able to accept electrons, resulting in the oxidation of the other species.	9.8.4 H6, H8, H13 • Explains how the results relate to the conclusion and correctly accounts for the high oxidising strength of the permanganate ion. . . . . 4 • Relates the results to the conclusion and provides a general reason for the strong oxidising strength of ions such as the permanganate ion . . . . 3 • Outlines how the results relate to the conclusion. OR • Accounts for the high oxidising strength of the permanganate ion . . . . 2 • Makes a correct statement relating to the strong oxidising strength of the permanganate ion 1

TENCHEM_SS_10.FM

Question 34   The Chemistry of Art   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(e) Copper(II) sulfate forms a blue solution due to the presence of copper(II) ions. Copper is a transition metal and compounds of these metals tend to be coloured. The colour is due to the arrangement of electrons within the d-orbitals of the metal ions. In the case of copper, the electron configuration for Cu^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$, and thus this ion has partially filled the d-orbitals, which confers on its compounds their colour. In the presence of molecules or ions known as ligands, the d-orbitals possess different amounts of energy and electrons can move from lower d-orbitals to higher ones by absorbing light from the visible spectrum. When water molecules act as ligands, the energy absorbed corresponds to red-orange wavelengths, and hence the solution appears blue. When different ligands are present (e.g. after adding HCl to the aqueous solution), the d-orbitals are split by different amounts, and hence the solution colour changes (e.g. when Cl^- ligands are present, the blue solution turns green). When the copper solution is added to the Bunsen burner flame, electrons present in the ground state shells may move to higher shells as a result of the absorption of a specific amount of energy (quanta), which is equal to the energy difference between the shells. Upon returning to the more stable lower shells, the electrons release the energy absorbed by emitting light of a wavelength corresponding to the energy difference between the shells. In this case, copper emits blue-green radiation. If a spectroscope is used to view the emission from the flame, the emission spectra of the element can be observed. This is a set of discrete coloured bands on a black background, unique for each element. Each line represents an emission of radiation as excited electrons return to lower shells. In the case of copper, the main emissions lie in the blue and green region of the visible spectrum, hence explaining the blue-green flame colour of copper.	9.8.2 9.8.5 H6, H13, H14 • Explains each observation of copper identified by displaying extensive knowledge of electron arrangement in transition metals and splitting of d-orbitals due to ligands . . . . 7 • Explains three observations of copper identified using sound knowledge of electron arrangement in transition metals and splitting of d-orbitals due to ligands . . . . 6 • Explains two of the observations of copper identified using sound knowledge of electron arrangement and states the correct electron arrangement of Cu or Cu^{2+} . . . . 5 • Provides a satisfactory general explanation of both flame test observations and about emission spectroscopy (may not be specific to copper) . . . . 4 • Explains one of the observations by referring to relevant features of electron arrangement (may be general and not specific to copper) . . . . 3 • Outlines features of electron arrangement in atoms of transition metals . . . . 2 • Identifies one correct feature of electron arrangement of atoms or behaviour of transition metals such as copper 1

Question 35   Forensic Chemistry

		Sample answer	Syllabus content, course outcomes and marking guide
(a)	(i)	Organic compounds are based on the element carbon, with the exception of carbonates, carbon monoxide, carbon dioxide and cyanides. Other elements present (usually in smaller quantities) include hydrogen, oxygen, sulfur and halogens. All other compounds are classified as inorganic.	9.9.1 H9, H11 • Gives correct definition 1
	(ii)	Physical appearance: Organic compounds tend to be liquids and gases or solids with low melting points. Heating organic compounds often causes their decomposition. Organic compounds often have a distinctive smell. Many are flammable and (in sufficient air) burn to form water and carbon dioxide. An example of an inorganic compound is sodium chloride. An example of an organic compound is sucrose. Both of these compounds appear as white solids. To distinguish between the two, both compounds could be heated. Gentle heating will show sucrose to melt, however sodium will not. With strong heating: sucrose melts quickly and will leave a black residue (indicating it is organic); and for sodium chloride, no reaction will occur (note: inorganic carbonates will give off carbon dioxide). By burning: sucrose will burn to give carbon dioxide and water, as per: $C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$ Sodium chloride will not burn. *Note: Students could also include a specific test for chloride, i.e. silver nitrate and precipitate. Other examples could include glucose and magnesium carbonate; ethanol and water.*	9.9.1 H9, H11 • Names two suitable compounds. Gives a clear account of sequence and results, making at least five relevant points . . . . . 5 • Names two suitable compounds. Gives a clear account of sequence and results, making four relevant points . . . . 4 • Names two suitable compounds. Gives a clear account of sequence and results, making three relevant points . . . . 3 • Names two suitable compounds. Gives a clear account of sequence and results, making two relevant points . . . . 2 • Gives an account of sequence and results, making two relevant points 1
(b)	(i)	protein or polypeptide	9.9.3 H6, H7 • Identifies type of compound 1

Question 35　　Forensic Chemistry　(Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(ii)　Certain enzymes can break polypeptide chains at specific points, giving results unique to each enzyme. Hydrolysis using warm (6 M) hydrochloric acid also breaks these bonds, but this gives a more random mix of products. *Note: Students could also include a diagram:*	9.9.3　　　　　　　　　　　　　H6, H7 • Identifies enzymes as a cause and states that chain is broken at specific points. OR • Identifies hydrochloric acid as a cause and states that chain is broken at random points.. 2

	• Identifies enzymes as a cause. OR • Identifies hydrochloric acid as a cause .. 1
(c)　Carbohydrates contain carbon, hydrogen and oxygen, with a hydrogen-oxygen ratio of 2:1. Plants contain starch and cellulose, and animals possess glycogen. All three are large chains (polysaccharides) with glucose as the monomer. They are joined in different ways; cellulose has β-glucose, whereas starch and glycogen have α-glucose units. Cellulose is relatively unbranched, whereas glycogen is branched. *Note: Students could also include diagrams to illustrate their response.*	9.9.2　　　　　　　　　　　　　　　　H9 • Names three carbohydrates, correctly states their origin and makes at least three relevant observations to compare structure 3
	• Names three carbohydrates, correctly states their origin and makes two relevant observations to compare structure 2
	• Names three carbohydrates, correctly states their origin and makes one relevant observation to compare structure 1
(d)　(i)　DNA is present in all living cells, so it may be used to identify any sample containing cells. DNA can remain intact for many years and samples can be easily found where a person has been present (for example, traces of saliva, skin, hair or semen). This can determine whether a suspect was present at the scene of a crime, or handled a piece of evidence. DNA evidence can be used to link an individual to crimes or eliminate them from investigations if there is not a match. Only small samples of DNA are required. The sequence of amino acids composing DNA (AGTC) can act as a 'fingerprint' because (with the exception of identical twins) the odds of two individuals having the same DNA is billions-to-one. Since children inherit half of each parent's DNA, it can be used to establish paternity or maternity and other familial-links. DNA can also be used to identify bodies from disasters such as aeroplane crashes, bombings and mass graves.	9.9.4　　　　　　　　　　　　　H3, H9 • Gives detailed explanation including why DNA is so useful with at least four other relevant points 4
	• Gives detailed explanation including why DNA is so useful with three other relevant points 3
	• Gives detailed explanation including why DNA is so useful with two other relevant points 2
	• Gives detailed explanation including why DNA is so useful with one relevant point 1
(ii)　Privacy may be an issue, as the database could be accessed by people outside the legal system, or for reasons other than solving crimes. People believe that the database may be misused, for example. to discover someone's genetic diseases, relationships or racial origins. However, precautions are taken. Records are 'de-identified', so no name or other personal identifiers are passed from the database. In addition, the profiles used for criminal identification are obtained from introns (non-coding genes).	9.9.4　　　　　　　　　　　　　H4, H16 • Shows a clear understanding and raises at least two issues. 2
	• Shows understanding and raises one issue. 1

Question 35   Forensic Chemistry   (Continued)

Sample answer	Syllabus content, course outcomes and marking guide
(e) Chromatography is a technique used to separate substances based on the properties that distribute them between stationary and mobile phases (e.g. solubility/attraction between sample and stationary phase). Chromatography is a type of destructive testing, so it is important that only small samples are needed. Since it is used in forensic chemistry, results must be accurate. Originally a simple technique using relatively large samples (more than 0.1 g), it has become more complex and needs smaller samples. As new techniques and improved machinery have been developed, only very small samples are needed and these can be identified with confidence; the most sensitive machines can analyse in the nanogram range. Three types of chromatography are used: thin layer chromatography (TLC), gas-liquid chromatography (GLC), and high-performance liquid chromatography (HPLC). All three involve separating the sample in order to analyse it. TLC is the earliest type of chromatography. It uses the simplest equipment and provides the least resolution. It has a thin layer of adsorbent material on a plate and the solvent mixture is drawn up the plate by capillary action. Early types of chromatography used gravity to cause liquid to move, but now GLC and HPLC use gas under pressure, giving much quicker results. In GLC, a sample is vapourised, injected into the stationary phase (column) and an inert carrier gas takes the sample through the system. The components emerge from the column and are measured. Sensitivity is in the microgram to nanogram ranges. It is used to identify illegal drugs in athletes, blood alcohol levels, pesticides in foods, pollutants in air and water, and a wide variety of substances found at crime scenes, such as accelerants used in arson. Due to the heating process, GLC can decompose some organic compounds. HPLC overcomes this by operating at room temperature and using separation in both stationary and mobile phases. It can differentiate between very similar substances. It can detect very low concentrations of explosives, proteins in food, drugs and contaminants in water and air samples. *Note: Answer should emphasise that with time, improvements in apparatus (which have become more complex and costly) have given quicker, more sensitive, more accurate results.*	9.9.5 H3, H4, H6, H14 • Identifies the three major types of chromatography, demonstrates a thorough knowledge of these techniques, discusses a wide range of improvements and issues and makes at least seven points. . . . . 7 • Identifies the three major types of chromatography, demonstrates a thorough knowledge of these techniques, discusses a wide range of improvements and issues and makes six points. 6 • Identifies the three major types of chromatography, demonstrates a thorough knowledge of these techniques, discusses a wide range of improvements and issues and makes five points. . . . . 5 • Identifies the three major types of chromatography, demonstrates a sound knowledge of these techniques, discusses a wide range of improvements and issues and makes four points. . . . . 4 • Identifies the three major types of chromatography, demonstrates a basic knowledge of these techniques, discusses some improvements and issues and makes three points. . . . . 3 • Identifies two major types of chromatography, demonstrates a basic knowledge of these techniques, discusses some improvements and issues and makes two points. . . . . 2 • Identifies one major type of chromatography, demonstrates a basic knowledge of this technique, discusses an improvement or issue. 1