



HSC Trial Examination 2020

## Chemistry

### Solutions and marking guidelines

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## Section I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
<p><b>Question 1</b>      <b>A</b></p> <p>The procedure shows a reversible reaction, as loss of water can be reversed. It is not an equilibrium reaction because it is an open system, so <b>B</b> is incorrect. There is no information given about bonding, so <b>C</b> is incorrect. As there is no decomposition occurring, <b>D</b> is also incorrect.</p>	<p>Mod 5 Static and Dynamic Equilibrium CH12–5, CH12–12      Bands 2–3</p>
<p><b>Question 2</b>      <b>B</b></p> <p>Conjugate acid–base pairs only differ by a proton (<math>H^+</math>). In the reaction going left to right: <math>CH_3COOH</math> (ethanoic acid) has donated a proton to <math>H_2O</math> (water), so ethanoic acid is an acid and water is a base. In the reaction going right to left: <math>H_3O^+</math> (the hydronium ion) is an acid because it has donated a proton to <math>CH_3COO^-</math> (the ethanoate ion).</p> <p><math>CH_3COOH</math> and <math>CH_3COO^-</math> are a conjugate acid–base pair, acid 1 and base 1 respectively. The other conjugate acid–base pair is <math>H_3O^+/H_2O</math>, acid 2 and base 2 respectively.</p>	<p>Mod 6 Using Brønsted–Lowry Theory CH12–6, CH12–12      Bands 3–4</p>
<p><b>Question 3</b>      <b>D</b></p> <p>Ethanoic acid is a weak acid, and hydrochloric acid is a strong acid. Hydrochloric acid is more dissociated than ethanoic acid; hence, it will have a greater concentration of <math>H_3O^+</math> ions, so <b>C</b> is incorrect. Because of this, hydrochloric acid will react faster with magnesium ribbon and will also have a higher conductivity; <b>A</b> and <b>B</b> are incorrect. Each solution has the same number of moles of acid needed for neutralisation:</p> $\frac{25}{1000} \times 0.1$	<p>Mod 6 Using Brønsted–Lowry Theory CH12–5, CH12–12      Bands 3–4</p>
<p><b>Question 4</b>      <b>C</b></p> <p>Entropy can be thought of as randomness or disorder. In combustion reactions, a system becomes more disordered; hence, entropy increases. In photosynthesis, a system becomes more ordered; hence, entropy decreases.</p> <p>Enthalpy is the heat content of a system. If a system loses/gives out heat, it is described as exothermic. If a system gains/takes in heat, it is endothermic. Combustion causes an increase in entropy and is exothermic. Photosynthesis causes a decrease in entropy and is endothermic.</p>	<p>Mod 5 Static and Dynamic Equilibrium CH12–12      Bands 3–4</p>
<p><b>Question 5</b>      <b>B</b></p> <p>The ratios in the equation mean that 0.5 mol of hydrogen and 0.5 mol of chlorine will be formed, and 1 mol of hydrogen chloride will remain. Therefore, 2 moles of gas are present in the equilibrium mixture in total.</p>	<p>Mod 5 Calculating the Equilibrium Constant CH12–12      Bands 3–4</p>
<p><b>Question 6</b>      <b>C</b></p> <p>The statement ‘the rate of exchange between reactants and products is steady’ only applies to dynamic equilibrium reactions.</p>	<p>Mod 5 Static and Dynamic Equilibrium CH12–12      Band 3</p>
<p><b>Question 7</b>      <b>C</b></p> <p>As the bromophenol blue turned blue, the pH is 4.5 or higher. Methyl red turned yellow, so the pH is 6.3 or higher. The alizarin is yellow, so the pH is 10.2 or lower. Distilled water is the only option with a pH between 6.3 and 10.2.</p>	<p>Mod 6 Properties of Acids and Bases CH12–6, CH12–13      Band 4</p>

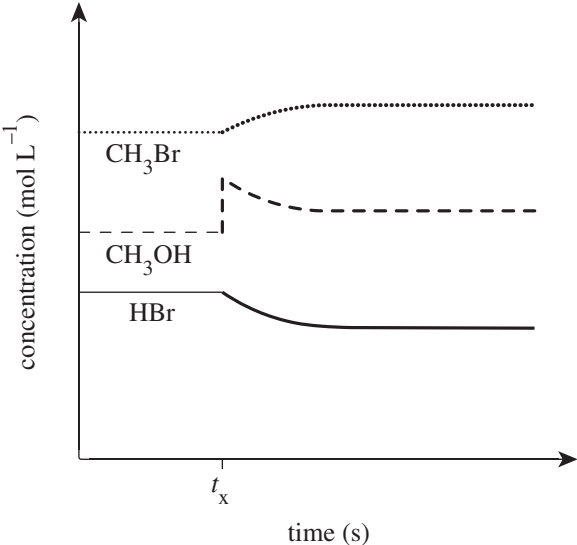
Answer and explanation	Syllabus content, outcomes and targeted performance bands
<p><b>Question 8</b>      <b>A</b></p> <p>Buffers can be made from a weak acid and its salt or a weak base and its salt. Buffer solutions are not necessarily neutral; they can be formulated to a wide variety of pHs. Buffer solutions resist changes in pH when small amounts of acids (<math>\text{H}^+</math>) or bases (<math>\text{OH}^-</math>) are added.</p>	<p>Mod 6 Quantitative Analysis CH12–13      Band 3</p>
<p><b>Question 9</b>      <b>D</b></p> <p>The equilibrium expression is a mathematical ratio that shows the concentrations (in moles per litre) of the products over the reactants at equilibrium, all raised to their stoichiometric powers.</p> <p>The balanced equation described in the question is</p> $\text{Fe}^{3+}(\text{aq}) + \text{SCN}^{-}(\text{aq}) \rightleftharpoons \text{Fe}(\text{SCN})^{2+}(\text{aq}).$ <p>The resulting equilibrium constant is <math>\frac{[\text{Fe}(\text{SCN})^{2+}(\text{aq})]}{[\text{Fe}^{3+}(\text{aq})] \times [\text{SCN}^{-}(\text{aq})]}</math>.</p>	<p>Mod 5 Calculating the Equilibrium Constant CH12–16, CH12–12      Bands 3–4</p>
<p><b>Question 10</b>      <b>D</b></p> $\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ <p>mol of <math>\text{OH}^-</math> added:</p> $\frac{250}{1000} \times 0.1 = 0.025$ <p>mol of <math>\text{H}^+</math> added:</p> $\frac{100}{1000} \times 0.4 = 0.04$ <p>Hence, there is <math>0.040 - 0.025 = 0.015</math> mol of <math>\text{H}^+</math> in excess.</p> <p>There is 350 mL of solution in total.</p> <p>molarity:</p> $\frac{0.015}{350} \times 1000 = 0.043$ <p><math>\text{pH} = -\log_{10}[0.43]</math></p> $= 1.4$ <p><math>\text{pOH} = 14 - 1.4 = 12.6</math></p>	<p>Mod 6 Using Brønsted–Lowry Theory CH12–6, CH12–13      Band 6</p>
<p><b>Question 11</b>      <b>B</b></p> <p>Hexan-3-one contains six carbons and a carbonyl group (<math>\text{C}=\text{O}</math>) on the third carbon from the end, as in <b>B</b>. The structural formula in <b>C</b> represents pentan-3-ol. The structural formula in <b>A</b> represents 1-propyl propanoate. The structural formula in <b>D</b> represents heptan-4-one.</p>	<p>Mod 7 Nomenclature CH12–7, CH12–14      Bands 2–3</p>

Answer and explanation	Syllabus content, outcomes and targeted performance bands
<p><b>Question 12</b>      <b>A</b></p> <p>The Beer–Lambert law relates absorbance and concentration:</p> $A = \epsilon lc$ $c = \frac{A}{\epsilon l}$ $= \frac{0.552}{(3.91 \times 10^3 \times 1)}$ $= 1.41 \times 10^{-4} \text{ mol L}^{-1}$ <p>The tablet was dissolved into 10.0 mL, so there was <math>1.41 \times 10^{-4} \times 0.0100 = 1.41 \times 10^{-6}</math> mol of sodium penicillin G in the tablet.</p>	<p>Mod 8 Analysis of Inorganic Substances CH12–17      Band 3</p>
<p><b>Question 13</b>      <b>B</b></p> <p><math>\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}</math> is butan-1-ol.</p> <p>molar mass of butan-1-ol:</p> $4 \times 12.01 + 10 \times 1.008 + 16.00 = 74.12$ $\Delta T = 100.0 - 25.00 = 75.0^\circ\text{C}$ $q_{\text{water}} = mC\Delta T$ $= 1.00 \times 4.18 \times 10^3 \times (75.0)$ $= 313\,500 \text{ J}$ $n_{\text{butan-1-ol}} = -\frac{q}{\Delta H}$ $= \frac{-313\,500 \text{ J}}{-2670 \times 10^3 \text{ J mol}^{-1}}$ $= 0.1174 \text{ mol}$ <p>mass of butan-1-ol = <math>0.1174 \times 74.12</math></p> $= 8.70 \text{ g}$	<p>Mod 7 Alcohols CH12–5, CH12–4      Bands 5–6</p>
<p><b>Question 14</b>      <b>A</b></p> <p><math>\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}</math> is butan-1-ol. Acid-catalysed dehydration of butan-1-ol yields but-1-ene, X. Esterification of butan-1-ol with acetic acid yields the ester (1-butyl) ethanoate (also named butyl acetate), Y. Oxidation of primary alcohols with acidified permanganate yields acids, so Z is butanoic acid.</p>	<p>Mod 7 Reactions of Organic Acids and Bases CH12–5, 6, 7, 14      Bands 5–6</p>
<p><b>Question 15</b>      <b>C</b></p> <p>Atomic absorption spectroscopy allows the analysis of many metal ions in complex mixtures with minimal interference from other metal ions or organic compounds.</p>	<p>Mod 8 Analysis of Inorganic Substances CH12–4, 5, 6, 7, 14      Band 4</p>
<p><b>Question 16</b>      <b>B</b></p> <p>A precipitate with sulfate ion is likely for calcium or barium ions. Barium gives a green flame, and calcium gives an orange/red flame.</p>	<p>Mod 8 Analysis of Inorganic Substances CH12–3, CH12–5, CH12–6      Band 3</p>

Answer and explanation	Syllabus content, outcomes and targeted performance bands
<p><b>Question 17</b>      <b>C</b></p> <p>Tertiary alcohols are alcohols in which the OH functional group is attached to a carbon that is directly attached to three other carbon atoms.</p>	<p>Mod 7 Alcohols CH12-5, CH12-15      Bands 2-3</p>
<p><b>Question 18</b>      <b>C</b></p> <p><math>A = \log \frac{I_o}{I}</math> where <math>I_o</math> is the intensity of the incident radiation at the measured wavelength (<math>I_b</math> in the diagram) and <math>I</math> is the intensity of the transmitted radiation through the flame (<math>I_c</math> in the diagram).</p>	<p>Mod 7 Polymers CH12-6, CH12-15      Bands 3-4</p>
<p><b>Question 19</b>      <b>D</b></p> <p>The number of peaks in a signal equals <math>n + 1</math> where <math>n</math> is the number of hydrogens on adjacent carbons.</p> <p>Protons for <math>z</math> (<math>\text{CH}_2\text{-CH(OCH}_3)_2</math>) have two hydrogens on the adjacent carbon and will appear as a triplet. <b>D</b> is correct.</p> <p>Protons for <math>w</math> (<math>\text{CH}_3\text{-C=O}</math>) have no hydrogens on the adjacent carbons and will appear as a singlet. <b>A</b> is incorrect.</p> <p>Protons for <math>x</math> (<math>\text{O=C-CH}_2\text{-CH}</math>) have a single hydrogen on the adjacent carbons and will appear as a doublet. <b>B</b> is incorrect.</p> <p>Protons for <math>y</math> (<math>\text{CH}_3\text{-O}</math>) have no hydrogens on adjacent carbons and will appear as a singlet. <b>C</b> is incorrect.</p>	<p>Mod 8 Analysis of Organic Substances CH12-4, CH12-7, CH12-15      Bands 3-4</p>
<p><b>Question 20</b>      <b>A</b></p> <p>The strong peak at 1780 indicates the presence of a carbonyl group; hence, the unknown sample is most likely either butanoic acid or butanal. The lack of a broad OH absorbance between <math>3200\text{-}3500\text{ cm}^{-1}</math> rules out butanoic acid, leaving butanal as the only option that would fit this IR spectrum.</p>	<p>Mod 8 Analysis of Organic Substances CH12-6, CH12-15      Bands 4-5</p>

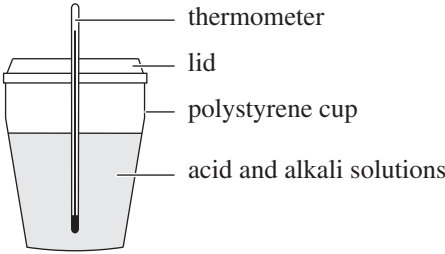
## Section II

Sample answer			Syllabus content, outcomes, targeted performance bands and marking guide
<b>Question 21</b>			
	<i>Colour</i>	<i>Justification</i>	Mod 5 Factors that Affect Equilibrium CH12–5, CH12–6, CH12–12 Band 5
X	light brown	A mixture of colourless $\text{N}_2\text{O}_4$ and brown $\text{NO}_2$ gives a light brown equilibrium mixture.	<ul style="list-style-type: none"> <li>Correctly completes all SIX cells of the table . . . . . 6</li> </ul>
Y	lighter brown (lighter than X)	The system has shifted to the right (fewer gas molecules), decreasing the amount of brown $\text{NO}_2$ in the resulting equilibrium mixture (Le Châtelier's principle).	<ul style="list-style-type: none"> <li>Correctly completes FIVE cells of the table . . . . . 5</li> <li>Correctly completes FOUR cells of the table . . . . . 4</li> <li>Correctly completes THREE cells of the table. . . . . 3</li> </ul>
Z	brown (darker than X)	The forward reaction is exothermic. Increasing temperature shifts the reaction to the left, increasing the amount of brown $\text{NO}_2$ in the resulting equilibrium mixture.	<ul style="list-style-type: none"> <li>Correctly completes TWO cells of the table . . . . . 2</li> <li>Correctly completes ONE cell of the table . . . . . 1</li> </ul>
<b>Question 22</b>			
(a)	The rate of production of bromomethane would increase. The system would compensate for the removal of product by increasing the forward reaction (production of $\text{CH}_3\text{Br}$ ), as in Le Châtelier's principle.		Mod 5 Factors that Affect Equilibrium CH12–6, CH12–12 Bands 3–4
			<ul style="list-style-type: none"> <li>Gives the correct prediction.</li> </ul> AND <ul style="list-style-type: none"> <li>Gives a suitable justification. . . . . 2</li> </ul>
			<ul style="list-style-type: none"> <li>Gives the correct prediction . . . . . 1</li> </ul>
(b)	The rate of production of bromomethane would increase. Collision theory tells us that increasing the temperature increases the average kinetic energy of reactant molecules. This results in more collisions that have energy greater than the activation energy needed, so the proportion of collisions that are successful increases.		Mod 5 Static and Dynamic Equilibrium Mod 5 Factors that Affect Equilibrium CH12–12 Bands 3–4
			<ul style="list-style-type: none"> <li>Gives the correct prediction.</li> </ul> AND <ul style="list-style-type: none"> <li>Gives a suitable explanation using collision theory . . . . . 2</li> </ul>
			<ul style="list-style-type: none"> <li>Gives the correct prediction . . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<p>(c)</p>  <p><i>Note: All three lines should level out at the same time, and the three concentration changes should be the same. The CH<sub>3</sub>Br line should rise gradually and level out. The CH<sub>3</sub>OH line should rise sharply vertically, fall gradually, then level out higher than its original concentration. The HBr line should fall gradually and level out.</i></p>	<p>Mod 5 Factors that Affect Equilibrium CH12–6, CH12–12 Bands 4–5</p> <ul style="list-style-type: none"> <li>• Correctly shows changes over time for all THREE species . . . . . 3</li> <li>• Correctly shows changes over time for TWO species . . . . . 2</li> <li>• Correctly shows changes over time for ONE species . . . . . 1</li> </ul>
<p><b>Question 23</b></p>	
<p>(a) The two compounds are relatively insoluble (low solubility constants). The solubility constant for calcium sulfate is related to its molar solubility by the following equation:</p> $K_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}]$ $= 4.93 \times 10^{-5}$ <p>The solubility constant for calcium carbonate is related to its molar solubility by the following equation:</p> $K_{sp} = [\text{Ca}^{2+}][\text{CO}_3^{2-}]$ $= 3.39 \times 10^{-9}$ <p>It therefore follows that calcium sulfate is more soluble because it has a higher solubility constant than calcium carbonate.</p>	<p>Mod 5 Calculating the Equilibrium Constant CH12–5, CH12–12 Band 3</p> <ul style="list-style-type: none"> <li>• Discusses the solubilities of each compound. AND</li> <li>• Links the discussion to the solubility constant . . . . . 2</li> <li>• Gives details of solubilities . . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) $\text{CaSO}_4(s) \xrightleftharpoons{\text{H}_2\text{O}} \text{Ca}^{2+}(aq) + \text{SO}_4^{2-}(aq)$ $K_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}]$ $= 4.93 \times 10^{-5}$ $\sqrt{K_{sp}} = \sqrt{4.93 \times 10^{-5}}$ $= 7.02 \times 10^{-3} \text{ mol L}^{-1}$	Mod 5 Calculating the Equilibrium Constant CH12–6, CH12–12 Bands 4–5 • Derives correct equilibrium expression. AND • Calculates solubility . . . . . 2 <hr/> • Derives correct equilibrium expression . . . 1
(c) Some Aboriginal and Torres Strait Islander groups in northern Australia use the seeds of cycad plants as a food source. These seeds contain toxins and are poisonous if eaten untreated. The solubility of these toxins in water is much greater than the solubility of the nutrients in the cycad seeds. Prolonged soaking of the cycad seeds in water leaches (removes) the toxins. This process depends upon the toxins being more soluble than the non-toxic nutrients.	Mod 5 Solution Equilibria CH12–3, CH12–12 Band 4 • Gives an appropriate example. AND • Gives an outline with at least THREE relevant points. . . . . 3 <hr/> • Gives an appropriate example. AND • Gives an outline with at least TWO relevant points . . . . . 2 <hr/> • Gives an outline with some relevant information . . . . . 1
<b>Question 24</b>	
(a) $\text{Na}_2\text{CO}_3(s) + 2\text{HCl}(aq) \rightarrow 2\text{NaCl}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)$	Mod 6 Properties of Acids and Bases CH12–3, CH12–12 Band 5 • Gives correct balanced equation with states . . . . . 1
(b) (i) The enthalpy of neutralisation is the enthalpy change ( $\Delta H_n$ ) that occurs when an acid and a base undergo a neutralisation reaction to form water and a salt. Values are usually given per mole of water formed.	Mod 6 Properties of Acids and Bases CH12–13 Band 3 • Gives an appropriate definition . . . . . 1

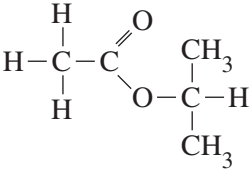
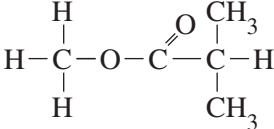


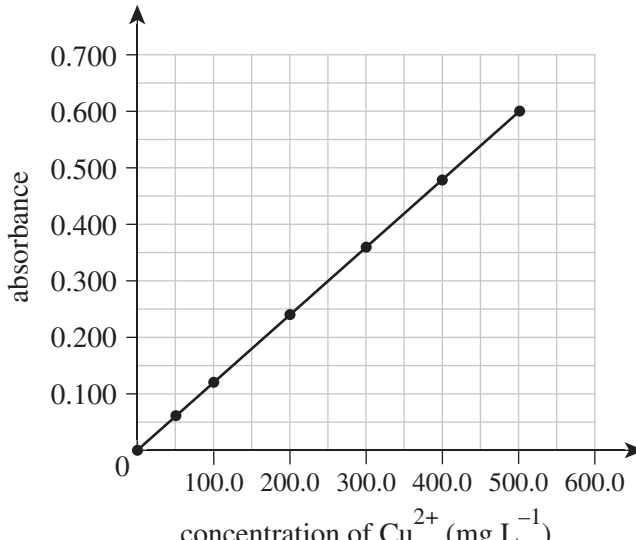
Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<p>(ii) Select appropriate acid and alkali solutions – for example, hydrochloric acid and sodium hydroxide.</p> $\text{HCl}(aq) + \text{NaOH}(aq) \rightarrow \text{NaCl}(aq) + \text{H}_2\text{O}(l)$ <p>There is a 1 : 1 mol ratio.</p> <p>Measure the initial temperature of these solutions. In this example, there is 50 mL of 1.0 mol L<sup>-1</sup> hydrochloric acid solution and 50 mL of 1.0 mol L<sup>-1</sup> sodium hydroxide solution.</p> <p>Place the solutions in a calorimeter, such as a polystyrene cup with a lid, and measure the increase in temperature.</p>  <p>Calculate the enthalpy change involved in this reaction using the equation <math>\Delta H = mCp\Delta T</math>, where <math>\Delta H</math> is the enthalpy change (in J), <math>m</math> is the mass of the mixture (in kg), <math>Cp</math> is the specific heat of the mixture (in J kg<sup>-1</sup>) and <math>\Delta T</math> is the temperature change (in K). Then calculate the enthalpy of neutralisation per mol for the reaction between hydrochloric acid and sodium hydroxide.</p> <p><i>Note: Responses do not require a diagram.</i></p>	<p>Mod 6 Properties of Acids and Bases CH12–3, CH12–7, CH12–13 Band 6</p> <ul style="list-style-type: none"> <li>• Gives a clear description in the correct sequence.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes the materials used.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• States equation/calculations. . . . . 5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives a clear description in the correct sequence.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes the materials used.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Outlines equation/calculations. . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives a clear description in the correct sequence.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes the materials used OR outlines equation/calculations . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives a clear description in the correct sequence. . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives a description with some details . . . 1</li> </ul>
<b>Question 25</b>	
<p>(a) To account for the characteristic properties of acids and bases, Arrhenius suggested that all aqueous solutions of acids contain an excess of H<sup>+</sup> ions and all aqueous solutions of bases (alkalis) contain an excess of hydroxide (hydroxyl) OH<sup>-</sup> ions. His proposals were:</p> <ul style="list-style-type: none"> <li>• Acidic properties are those associated with the H<sup>+</sup> ion.</li> <li>• Basic properties are those associated with the OH<sup>-</sup> ion.</li> <li>• H<sup>+</sup> and OH<sup>-</sup> ions are formed when an acid or base ionises as it dissolves in water.</li> </ul> <p>For nitric acid and sodium hydroxide:</p> $\text{HNO}_3(l) \rightarrow \text{H}^+(aq) + \text{NO}_3^-(aq)$ $\text{NaOH}(s) \rightarrow \text{Na}^+(aq) + \text{OH}^-(aq)$ <p><i>Note: We now know that the H<sup>+</sup> ion (a proton) cannot exist by itself in aqueous solution, but is always combined with a molecule of water to form the hydronium (H<sub>3</sub>O<sup>+</sup>) ion.</i></p>	<p>Mod 6 Properties of Acids and Bases CH12–13 Bands 4–5</p> <ul style="list-style-type: none"> <li>• Gives the principles of the Arrhenius model.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Gives TWO appropriate equations . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives the principles of the Arrhenius model.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Gives ONE appropriate equation. . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives the principles of the Arrhenius model. . . . . 1</li> </ul>
<p>(b) amphiprotic</p>	<p>Mod 6 Using Brønsted–Lowry Theory CH12–13 Band 3</p> <ul style="list-style-type: none"> <li>• Gives the appropriate term. . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<b>Question 26</b>	
<p>(a) The ‘equivalence point’ occurs when the reaction has reached a specific stoichiometric ratio of reactants. In acids and bases the equivalence point is reached when the number of <math>H^+</math> ions equals the number of <math>OH^-</math> ions (equal mole ratio).</p> <p>The ‘end point’ is when a physical change can be detected. In this case, it is when the indicator changes colour.</p> <p>The end point is not necessarily exactly the same as the equivalence point. In this case, the end point (colour change) for titration 1 does not match with the end points for the other titrations, suggesting that the end point for titration 1 does not occur at the equivalence point.</p> <p>In an accurate titration, the indicator should change colour as close to the equivalence point as possible.</p>	<p>Mod 6 Quantitative Analysis CH12–13 <span style="float: right;">Band 3</span></p> <ul style="list-style-type: none"> <li>• Clearly explains the difference between the two terms.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Uses the titration as an example . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Clearly explains the difference between the two terms . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Gives some useful information. . . . . 1</li> </ul>
<p>(b) <math>HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)</math></p>	<p>Mod 6 Quantitative Analysis CH12–13 <span style="float: right;">Band 3</span></p> <ul style="list-style-type: none"> <li>• Gives correct equation with states . . . . . 1</li> </ul>
<p>(c) Ignoring titration 1 (rough), the average of titrations 2–4 is 36.1 mL.</p> <p>Stoichiometry is 1 : 1 (acid : base). Hence the number of moles of acid equals the number of moles of base.</p> <p><math>n = cV</math>, where <math>n</math> = number of moles (mol), <math>c</math> = concentration (<math>mol\ L^{-1}</math>) and <math>V</math> = volume (L).</p> $n = 1.01 \times \frac{25.0}{1000}$ $= 0.02525\ mol$ <p>For the concentration of the acid:</p> $0.02525 = x \times \frac{36.1}{1000}$ $x = \frac{0.02525}{36.1} \times 1000$ $= 0.699\ mol\ L^{-1}$ <p><b>OR</b></p> $c_1V_1 = c_2V_2$ $1.01 \times 25.0 = c_2 \times 36.1$ $c_2 = 1.01 \times \frac{25}{36.1}$ $= 0.699\ mol\ L^{-1}$	<p>Mod 6 Quantitative Analysis CH12–4, CH12–6, CH12–13 <span style="float: right;">Bands 5–6</span></p> <ul style="list-style-type: none"> <li>• Obtains correct value for the end point.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Explains how the value was obtained.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Correctly calculates the concentration.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Shows working . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Any THREE of the above points . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Any TWO of the above points . . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<p>(d)</p> <p style="text-align: center;">pH</p> <p style="text-align: center;">14</p> <p style="text-align: center;">7</p> <p style="text-align: center;">0</p> <p style="text-align: center;">volume of acid added (mL)</p> <p><i>Note: The initial pH of the 1.01 M NH<sub>3</sub> solution should be less than 14. The pH of the equivalence point and the pH of the final solution should be less than 7.</i></p>	<p>Mod 6 Quantitative Analysis CH12-3, CH12-13 <span style="float: right;">Band 4</span></p> <ul style="list-style-type: none"> <li>• Draws an appropriate graph showing the correct shape</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Labels axes appropriately . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Draws an appropriate graph showing some relevant details . . . . . 1</li> </ul>
<p><b>Question 27</b></p> <p>The sodium salts of long chain fatty acids consist of two parts: a non-polar hydrophobic ‘tail’ consisting of fatty acids; and a polar, hydrophilic, charged ‘head’ consisting of the sodium salt of the alkanolic acid, as shown below.</p> <div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; padding: 2px; margin-right: 10px;"> <math>\text{CH}_3\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2\text{-CH}_2</math> </div> <div style="text-align: center;"> <p style="font-size: small;">non-polar tail</p> <p style="font-size: small;">polar head</p> </div> </div> <p style="text-align: center;">simplified representation</p> <p>A micelle forms when sodium salts assemble so that the long hydrophobic tails all point inwards and the polar heads all sit on the outside of the micelle.</p> <div style="text-align: center;"> <p style="font-size: small;">polar exterior</p> <p style="font-size: small;">non-polar interior</p> <p style="font-size: small;">micelle</p> </div> <p>The hydrophobic tails embed themselves in the grease. The hydrophilic heads are attracted to the water and lift the grease off the dirty dishes to reform a micelle that then remains suspended in water.</p> <div style="text-align: center;"> </div> <p><i>Note: While the question requires a diagram of only a single micelle, diagrams of micelle formation or action such as those above may help to develop high-quality responses.</i></p>	<p>Mod 7 Reactions of Organic Acids and Bases CH12-6, CH12-7, CH12-13 <span style="float: right;">Band 4</span></p> <ul style="list-style-type: none"> <li>• Provides a detailed explanation of the surfactant properties of the sodium salts of long chained fatty acids.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes a detailed diagram of a micelle . . . . . 3-4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Provides an explanation of the surfactant properties of the sodium salts of long chain fatty acids.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Includes a diagram of a micelle . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Provides some relevant information . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide									
<b>Question 28</b>										
(a) $  \begin{array}{c}  \text{H} \quad \text{CH}_3 \\    \quad   \\  -[\text{C}-\text{C}]_n- \\    \quad   \\  \text{H} \quad \text{H}  \end{array}  $	Mod 7 Polymers CH12-7, CH12-14 <span style="float: right;">Band 4</span> • Draws structural formula of polypropene ..... 1									
(b) <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th style="text-align: center;"><i>Polymer A</i></th> <th style="text-align: center;"><i>Polymer B</i></th> </tr> </thead> <tbody> <tr> <td style="text-align: center;"><i>Name</i></td> <td style="text-align: center;">low-density polypropylene (LDPP)</td> <td style="text-align: center;">high-density polypropylene (HDPP)</td> </tr> <tr> <td style="text-align: center;"><i>Properties</i></td> <td> <i>Any two of:</i> <ul style="list-style-type: none"> <li>• amorphous polymer</li> <li>• lots of side chains</li> <li>• flexible</li> <li>• lower melting point</li> <li>• weaker</li> <li>• cheaper</li> </ul> </td> <td> <i>Any two of:</i> <ul style="list-style-type: none"> <li>• crystalline polymer</li> <li>• fewer side chains</li> <li>• rigid</li> <li>• higher melting point</li> <li>• stronger</li> <li>• more expensive</li> </ul> </td> </tr> </tbody> </table>		<i>Polymer A</i>	<i>Polymer B</i>	<i>Name</i>	low-density polypropylene (LDPP)	high-density polypropylene (HDPP)	<i>Properties</i>	<i>Any two of:</i> <ul style="list-style-type: none"> <li>• amorphous polymer</li> <li>• lots of side chains</li> <li>• flexible</li> <li>• lower melting point</li> <li>• weaker</li> <li>• cheaper</li> </ul>	<i>Any two of:</i> <ul style="list-style-type: none"> <li>• crystalline polymer</li> <li>• fewer side chains</li> <li>• rigid</li> <li>• higher melting point</li> <li>• stronger</li> <li>• more expensive</li> </ul>	Mod 7 Polymers CH12-7, CH12-14 <span style="float: right;">Band 4</span> • Correctly identifies polymer A as low-density polypropylene and polymer B as high-density polypropene. AND • Lists at least TWO properties of each polymer ..... 3 • Correctly identifies polymer A as low-density polypropylene and polymer B as high-density polypropene. OR • Lists at least TWO properties of each polymer ..... 2 • Provides some relevant information ..... 1
	<i>Polymer A</i>	<i>Polymer B</i>								
<i>Name</i>	low-density polypropylene (LDPP)	high-density polypropylene (HDPP)								
<i>Properties</i>	<i>Any two of:</i> <ul style="list-style-type: none"> <li>• amorphous polymer</li> <li>• lots of side chains</li> <li>• flexible</li> <li>• lower melting point</li> <li>• weaker</li> <li>• cheaper</li> </ul>	<i>Any two of:</i> <ul style="list-style-type: none"> <li>• crystalline polymer</li> <li>• fewer side chains</li> <li>• rigid</li> <li>• higher melting point</li> <li>• stronger</li> <li>• more expensive</li> </ul>								
<b>Question 29</b>										
(a) Propanoic acid and methyl ethanoate have the same molecular formula but different structural formulae and are therefore isomeric. The isomers differ in their functional group (one being an acid and the other an ester). These are their functional group isomers.	Mod 7 Nomenclature CH12-5, CH12-7, CH12-15 <span style="float: right;">Bands 2-3</span> • Identifies isomers as having the same molecular formula but different structural formulae. AND • Identifies the TWO functional groups represented by the two isomers ..... 2 • Any ONE of the above points. .... 1									
(b) There will be no visible change when sodium bicarbonate is added to the solution of methyl ethanoate. Adding sodium bicarbonate to the test tube containing the solution of propanoic acid will produce bubbles of gas. $\text{CH}_3\text{CH}_2\text{COOH}(aq) + \text{HCO}_3^-(aq) \rightarrow \text{CH}_3\text{CH}_2\text{COO}^-(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$	Mod 7 Reactions of Organic Acids and Bases Mod 8 Analysis of Organic Substances CH12-2, 3, 7, 14 <span style="float: right;">Bands 3-4</span> • Describes the observations expected for the methyl ethanoate test tube. AND • Describes the observations expected for the propanoic acid test tube. AND • Provides a net ionic equation ..... 3 • Any TWO of the above points ..... 2 • Any ONE of the above points. .... 1									

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<p>(c) Boiling points for both alkanolic acids and their isomeric methyl esters increase with the increasing number of carbon atoms. This is the result of dispersion forces (which act between all molecules) increasing with increasing chain length.</p> <p>Both alkanolic acids and their isomeric methyl esters are polar compounds, and dipole–dipole forces act between these molecules (in addition to dispersion forces). However, only alkanolic acids can form hydrogen bonds (H bonds). The presence of the additional strong intermolecular H bonds means the boiling points of alkanolic acids are always higher than their isomeric methyl esters.</p> <p>The difference between the boiling points of alkanolic acids and their isomeric methyl esters decreases as the chain length (number of carbons in the molecule) increases. This is the result of the dispersion forces (present in both isomers) increasing as the chain length increases.</p>	<p>Mod 7 Reactions of Organic Acids and Bases CH12–5, 6, 7, 14 Bands 5–6</p> <ul style="list-style-type: none"> <li>Comprehensively explains the trends of the boiling points . . . . . 4</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Explains most of the trends of the boiling points . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Describes most of the trends of the boiling points.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Explains ONE pattern of the boiling points . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Provides some relevant information . . . . 1</li> </ul>
<p><b>Question 30</b></p>	
<p>(a)</p> <div style="text-align: center;">  </div> <p><b>OR</b></p> <div style="text-align: center;">  </div> <p>The infrared spectrum shows a strong carbonyl (C=O) band at 1780 cm<sup>-1</sup>. The absence of a broad OH band between 2500–3300 cm<sup>-1</sup> indicates that the compound is not an acid, but could be an aldehyde, ketone or ester.</p> <p>The <sup>13</sup>C NMR shows four different carbon environments, and the peak at 170 ppm confirms the presence of a carbonyl group. The peak at 68 ppm suggests a carbon attached to oxygen or nitrogen, providing evidence of an ester.</p> <p>The <sup>1</sup>H NMR shows a 1H septet, consistent with six neighbouring H atoms (CH<sub>3</sub>CHCH<sub>3</sub>). The 6H doublet is consistent with one neighbouring H atom (CH<sub>3</sub>CHCH<sub>3</sub>). The final <sup>1</sup>H NMR signal is a 3H singlet (CH<sub>3</sub>C). A chemical shift of around 5.0 ppm for the septet suggests the signal is for a H atom on a carbon bonded to an oxygen atom.</p> <p>The singlet at 2.0 for 3H suggests CH<sub>3</sub> adjacent to a carbonyl group. The <sup>1</sup>H NMR suggests 10 H atoms.</p>	<p>Mod 8 Analysis of Organic Substances CH12–4, 5, 6, 7, 15 Bands 4–6</p> <ul style="list-style-type: none"> <li>Draws a correct structure.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Identifies functional group information provided by the IR spectra to justify the chosen structure.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Analyses chemical shift data from BOTH the <sup>13</sup>C and <sup>1</sup>H NMR spectra to justify chosen structure.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>Analyses the splitting pattern of the <sup>1</sup>H NMR spectra to justify the chosen structure . . . . . 6</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Draws a correct structure AND justifies the structure using the chemical reactivity AND refers to BOTH spectra.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Draws a correct structure AND justifies using some spectroscopic data . . . . . 4–5</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Draws a substantially correct structure AND some give correct analysis.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>Gives a substantially correct analysis . . . . . 2–3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>Provides some relevant information. . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<p>(b) The molecular (parent) ion occurs at <math>m/z = 102</math>, in agreement with the formula of <math>C_3H_{10}O_2</math>. The splitting pattern provides further evidence of structure:</p> <ul style="list-style-type: none"> <li>• The peak at <math>M-15 = 87</math> suggests loss of a methyl group.</li> <li>• The peak at <math>M-41 = 59</math> suggests loss of a <math>CH_3CO_2</math> group.</li> <li>• The peak base, <math>m/z = 43</math>, is consistent with a <math>CH_3CHCH_3</math> group.</li> </ul>	<p>Mod 8 Analysis of Organic Substances CH12–2, 6, 15 Bands 3</p> <ul style="list-style-type: none"> <li>• Identifies the molecular ion.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Explains how the splitting pattern provides supporting evidence for structure determination . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Identifies the molecular ion.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>• Provides some relevant information regarding the splitting pattern . . . . . 1</li> </ul>
<b>Question 31</b>	
<p>(a)</p>  <p style="text-align: center;">concentration of <math>Cu^{2+}</math> (<math>mg\ L^{-1}</math>)</p>	<p>Mod 8 Analysis of Inorganic Substances CH12–1, 4, 5, 6, 7, 15 Bands 3–4</p> <ul style="list-style-type: none"> <li>• Plots points.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Labels graph.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Draws line of best fit . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Plots points.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Labels graph OR draws line of best fit . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Plots points.</li> </ul> <p>OR</p> <ul style="list-style-type: none"> <li>• Labels graph . . . . . 1</li> </ul>
<p>(b) From the graph, an absorbance of 0.150 gives a concentration of <math>120\ mg\ L^{-1}</math>. <i>Note: Accept responses in the 110–130 range.</i></p> <p>The brass sample was dissolved in 100 mL; hence, it contains <math>12.0\ mg</math> of <math>Cu^{2+}</math>.</p> $\% \text{ of Cu} = \frac{\text{mass of Cu}}{\text{mass of the sample}} \times 100$ $= \frac{12.0}{19.8} \times 100$ $= 60.6\%$ <p><i>Note: Accept responses in the 55–66% range.</i></p>	<p>Mod 8 Analysis of Inorganic Substances CH12–1, 4, 5, 6, 7, 15 Band 3</p> <ul style="list-style-type: none"> <li>• Accurately reads the graph.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Correctly determines the mass of Cu in the sample.</li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>• Correctly determines the percentage of Cu in the sample . . . . . 3</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Determines the mass of Cu in the sample based on an incorrect reading of the graph. . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Provides some relevant calculations . . . . . 1</li> </ul>
<p>(c) The hollow cathode lamp that is used in the atomic absorption spectrometer (AAS) analysis of copper contains a copper cathode that produces wavelengths of light uniquely characteristic for copper. Zinc does not absorb light at the same wavelengths as copper.</p>	<p>Mod 8 Analysis of Inorganic Substances CH12–2, 4, 6, 15 Bands 4–5</p> <ul style="list-style-type: none"> <li>• Provides a detailed explanation . . . . . 2</li> </ul> <hr/> <ul style="list-style-type: none"> <li>• Provides some relevant information . . . . . 1</li> </ul>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
<b>Question 32</b>	
Step 1: Propan-2-ol can be dehydrated to propene when heated with concentrated sulfuric acid as a catalyst.	Mod 7 Products of Reactions Involving Hydrocarbons
Step 2: Addition of water using dilute sulfuric acid will yield a mixture of isomeric propanols.	Mod 7 Alcohols
Step 3: Propan-1-ol can be oxidised using acidified potassium dichromate.	Mod 7 Reactions of Organic Acids and Bases
Step 4: Propanamide can be obtained through an elimination reaction by heating ammonia and propanoic acid together.	Mod 8 Analysis of Organic Substances
The $^{13}\text{C}$ NMR spectrum for propan-2-ol (compound M) will show two peaks for its two carbon environments. Propan-1-ol (compound O) will show three peaks for its three carbon environments.	CH12–4, 5, 6, 7, 14, 15 Bands 4–6
The $^1\text{H}$ NMR spectrum for each isomeric alcohol will show a broad exchangeable peak for the OH hydrogen. The $^1\text{H}$ NMR for propan-2-ol will show a doublet integrating to 6H for the two methyl groups and a heptet integrating to 1H for the CH hydrogen.	<ul style="list-style-type: none"> <li>Provides a detailed discussion of the appropriate reagents and conditions.</li> </ul>
The $^1\text{H}$ NMR for propan-2-ol will show a triplet integrating to 3H for the methyl group (at around $\delta$ 1.00 ppm), a hexet integrating to 2H for one of the $\text{CH}_2$ groups (at about $\delta$ 2.00 ppm) and a triplet integrating to 2H for the $\text{CH}_2\text{OH}$ group (at around $\delta$ 3.50 ppm).	AND
The mass spectra for both alcohols will have the same molecular ion (at $m/z = 60.0$ ), but the splitting patterns will be different.	<ul style="list-style-type: none"> <li>Provides a detailed explanation of how NMR AND mass spectroscopic techniques could be used for identification . . . . . 7</li> </ul>
Propan-2-ol, $\text{CH}_3\text{CHOHCH}_3$ , will show a strong peak at $M^+ - 15$ for the loss of a $\text{CH}_3$ group. Propan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ , would be expected to show a strong peak at $M^+ - 15$ for the loss of a $\text{CH}_3\text{CH}_2$ group.	<ul style="list-style-type: none"> <li>Outlines the appropriate reagents and conditions.</li> </ul>
	AND
	<ul style="list-style-type: none"> <li>Provides a detailed explanation of how NMR OR mass spectroscopic techniques could be used for identification . . . . . 5–6</li> </ul>
	<ul style="list-style-type: none"> <li>Outlines the appropriate reagents and conditions.</li> </ul>
	AND
	<ul style="list-style-type: none"> <li>Explains some relevant spectroscopic data . . . . . 3–4</li> </ul>
	<ul style="list-style-type: none"> <li>Outlines the appropriate reagents and conditions.</li> </ul>
	OR
	<ul style="list-style-type: none"> <li>Outlines some relevant spectroscopic data . . . . . 2</li> </ul>
	<ul style="list-style-type: none"> <li>Provides some relevant information . . . . 1</li> </ul>