Assessment Schedule – 2022

Scholarship Chemistry (93102)

Evidence Statement

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
ONE (a)(i)	Solution A: $2Br^- \rightarrow Br_2 + 2e^-$ Solution B: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ -- $(5 \times A + 2 \times B)$: $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ $E^o_{cell} = E^o_{red} - E^o_{ox}$ $= E^o(MnO_4^- / Mn^{2+}) - E^o(Br_2 / Br^-)$ $= +1.51\ V - +1.10\ V$ $= +0.41\ V$ E^o_{cell} is positive, indicating the reaction is spontaneous and will progress without outside intervention, and causes the light bulb to illuminate. Solution A became darker in colour. Colourless Br^- ions reacted to form orange Br_2 solution. Solution B became lighter in colour. Purple MnO_4^- ions reacted to form colourless Mn^{2+} ions in the solution. Electrons flowed from Solution A in the left-hand beaker, to Solution B in the right-hand beaker.	Any of the following: • Balanced chemical equation. • E^o_{cell} for apparatus. • Explanation for observations. • Movement of electrons described. • HCl use described. • E^o_{cell} for HCl. • Description of state change in sections B–C and D–E. • Description of kinetic energy changes or formation of attractive forces. • Shows understanding of specific head capacity units or needs for calculation. • Shows understanding of calculation process but with errors.	A range of the following: • Correctly accounts for three of: the E^o_{cell} for the process, the balanced chemical equation, an explanation of the observations occurring, or the movement of electrons in the apparatus. • Explains why using HCl as the acid to acidify the MnO_4^- / Mn^{2+} solution is not appropriate. • Discusses the gradient of lines in sections B-C and D-E with reference to state change and either kinetic energy of particles or the formation of attractive forces.	A range of the following: • Correctly determines the E^o_{cell} for the process, completes the balanced chemical equation, justifies the observations in the process in relation to the changes occurring to the species in each beaker, and the movement of electrons in the apparatus. • Justifies why using HCl as the acid to acidify the MnO_4^- / Mn^{2+} solution is not appropriate. • Justifies the gradient of lines in sections B–C and D–E with reference to state change, kinetic energy of particles, and the formation of attractive forces. • Explains how the specific heat capacity can be determined using the graph, with links to the need for mass of the
(ii)	Consider the reaction between Cl^- ions and MnO_4^- ions: $E^o_{cell} = E^o_{red} - E^o_{ox}$ $= E^o(MnO_4^- / Mn^{2+}) - E^o(Cl_2 / Cl^-)$ $= +1.51\ V - +1.36\ V$ $= +0.15\ V$ E^o_{cell} is positive, indicating a spontaneous reaction in standard conditions. Hydrochloric acid contains Cl^- ions which would react spontaneously with the MnO_4^- ions in Solution B, producing Cl_2 and Mn^{2+} ions before the cell is set up, making it an inappropriate acid to use for this electrochemical cell.			

(b)(i)	During the period of time represented by sections B–C and D–E of the diagram, **intermolecular attractive forces** are forming between the butanoic acid molecules. The formation of these intermolecular attractive forces is an exothermic process, and the energy released counteracts the energy being removed from the sample, hence the gradient of the line is zero.		• Explains how the specific heat capacity can be determined using the graph, with links to some other data required to solve.	sample and rate or amount of energy loss.
	The sample is changing state from gas to liquid during section B–C, with the formation of new intermolecular attractive forces. The gradient of the line is zero, as the energy released due to the formation of the intermolecular attractive forces (which would otherwise increase the temperature) is equivalent to the energy being removed from the sample. There is no change in temperature, so there is no change in the kinetic energy of the particles.		• Correctly calculates the % of Cu or Ag in the silver sample, with clearly detailed working, and attempts to calculate the other with minor errors.	• Correctly calculates the % of Cu and Ag in the silver sample, with clearly detailed working, and concludes that the alloy does not meet the standards required.
	Similarly the sample is changing state from liquid to solid during section D-E, and the release of energy in the formation of more intermolecular attractive forces between particles counteracts the energy being removed from the system.			
	Section B–C is longer than D–E as there is more energy released per particle as the substance changes from gas state to liquid state, than what is released when the substance transitions from a liquid state to a solid state			
(ii)	The gradient of the line between points C and D in the diagram is related to the rate in which energy is lost from the liquid sample. In this section of the curve, the removal of heat slows the particle movement down, which means the temperature of the substance decreases. The gradient is temperature change per second.			
	To be able to determine the value of the (specific / molar) heat capacity you would need to know the mass (or moles) of butanoic acid in the sample, and the energy in joules being removed from the sample.			

(c)	$n\left(\text{SCN}^-\right)$ $= 0.02213 \text{ L} \times 0.1450 \text{ mol L}^{-1}$ $= 0.00320885 \text{ mol}$ $n\left(\text{Ag}^+\right)_{\text{aliquot}} = 0.00320885 \text{ mol}$ $n\left(\text{Ag}^+\right)_{\text{flask}} = 0.00320885 \text{ mol} \times \dfrac{250 \text{ mL}}{20 \text{ mL}}$ $= 0.040110625 \text{ mol}$ $m\left(\text{Ag}\right) = 0.040110625 \text{ mol} \times 108 \text{ g mol}^{-1}$ $= 4.3319 \text{ g}$ $\%\left(\text{Ag}\right) = \dfrac{4.3319 \text{ g}}{4.824 \text{ g}} \times 100\%$ $= \textbf{89.80\%}$ $n\left(\text{S}_2\text{O}_3{}^{2-}\right) = 0.01258 \text{ L} \times 0.0237 \text{ mol L}^{-1}$ $= 2.98146 \times 10^{-4} \text{ mol}$ $n\left(\text{I}_2\right) = \dfrac{2.98146 \times 10^{-4} \text{ mol}}{2}$ $= 1.49703 \times 10^{-4} \text{ mol}$ $n\left(\text{Cu}^{2+}\right)_{\text{aliquot}} = 1.49703 \times 10^{-4} \text{ mol} \times 2$ $= 2.98146 \times 10^{-4} \text{ mol}$ $n\left(\text{Cu}^{2+}\right)_{\text{flask}} = 2.98146 \times 10^{-4} \text{ mol} \times \dfrac{250 \text{ mL}}{10 \text{ mL}}$ $= 7.453 \times 10^{-3} \text{ mol}$ $m\left(\text{Cu}\right) = 7.453 \times 10^{-3} \text{ mol} \times 63.6 \text{ g mol}^{-1}$ $= 0.4740 \text{ g}$ $\%\text{Cu} = \dfrac{0.4740 \text{ g}}{4.824 \text{ g}} \times 100\%$ $= \textbf{9.827\%}$ This alloy does not meet the standards required as the mass percentage of Ag is determined to be 89.80%, which is below 92.5%.			

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
TWO (a)(i)	**Triglyceride X** $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3$ $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3$ $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_{16}CH_3$ Triglyceride X is saturated, so all three fatty acids used to make the tri-ester must be saturated. Butter is a solid at room temperature, indicating strong forces of attraction between molecules. The linear nature of the fatty acids and therefore the triglyceride enables close packing of the molecules, and thus strong intermolecular attractions, and a solid state at room temperature. **Triglyceride Y** $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_7-C=C-(CH_2)_7CH_3$ $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_7-C=C-(CH_2)_7CH_3$ $H-C-O-\overset{O}{\overset{\|}{C}}-(CH_2)_7-C=C-(CH_2)_7CH_3$ Triglyceride Y is unsaturated, so the fatty acids in the molecule must be unsaturated. Olive oil is a liquid at room temperature, indicating weak forces of attraction between molecules. As an oil, the unsaturated fatty acids are likely to be in the *cis* arrangement, leading to bends / kinks in the molecule, and a less linear structure than other fatty acids. This will prevent close packing of the molecules, which will lead to weaker intermolecular attractions than those seen in other triglycerides, meaning olive oil is a liquid at room temperature.	Any of the following: • Triglyceride structure drawn. • Cis-trans isomerism identified. • Melting points compared with reasons. • Molecular shapes and packing of molecules described. • Description of attractions between surfactants and water or oil. • Correct equilibrium equation written for precipitation. • Correct equilibrium equation written for complex ion formation. • Explanation for precipitation formation. • Explanation for complex ion formation. • Explanation for the impact of addition of HCl to the solution on either precipitation or complex ion formation.	A range of the following: • Correctly draws structures for two of triglycerides X, Y, and Z. • Explains the variation in melting points of saturated and unsaturated structures with consideration of the effect of the $C=C$ on the molecular shape and resulting intermolecular attractions between the molecules. • Explains the use of sodium dodecanoate as an anionic surfactant, with reference to the interactions between the surfactant ions and oil / water molecules. • Accounts for the formation of the precipitate and complex ions on addition of NH_3 solution to the $CuSO_4$ solution, using equilibrium concepts and some links between observations and species. • Accounts for the loss	A range of the following: • Correctly draws structures and identifies stereochemistry for triglycerides X, Y, and Z. • Discusses the variation in melting points of the triglycerides with account of the effect that stereochemistry has on the shapes and resulting intermolecular attractions between the molecules as they pack together. • Justifies the use of sodium dodecanoate as an anionic surfactant, with reference to the interactions of the non-polar end with non-polar fats and oils, and the charged end with polar water molecules. • Accounts for the formation of the precipitate and complex ions on addition of NH_3 solution to the $CuSO_4$ solution, with use of correct equilibrium equations and links between observations and species. • Accounts for the loss of complex ions, and formation and loss of the precipitate on addition of HCl solution to the complex ion solution,

Triglyceride Z

Triglyceride Z is unsaturated, so the fatty acids in the molecule must be unsaturated. Margarine is a solid at room temperature, indicating strong forces of attraction between molecules. The unsaturated fatty acids are likely to be in a *trans* arrangement, leading to chains that are more linear (similar to that seen in saturated fatty acids). This means molecules can still pack closely together, yielding strong intermolecular attractions, and a solid state at room temperature.

| (ii) | Fats and oils contain triglyceride molecules, which are triesters that are predominantly non-polar. These molecules cannot form sufficient attractions to polar water molecules to overcome the network of hydrogen bonds between water molecules, thus preventing the mixing / dissolving of fats and oils in water.

Sodium dodecanoate dissolves in water to form the dodecanoate ion, $CH_3(CH_2)_{10}COO^-$. The charged ionic head of this ion forms sufficient attractions to polar water molecules to enable this solubility in water, while the non-polar chain end of the molecule is able to form attractions with non-polar fat / oil molecules. This means these surfactant ions can bind to both the triglyceride molecules in oils and fats, as well as the water molecules nearby, acting as a bridge between them and enabling them to mix. This then enables water to be used to remove oils and fats from the surface of the cutlery, skin, etc. |

of complex ions, and formation and loss of the precipitate on addition of HCl solution to the complex ion solution, using equilibrium concepts and some links between observations and species.

with use of correct equilibrium equations and links between observations and species.

(b)	Initially the CuSO$_4$ solution is pale blue due to the presence of Cu^{2+} ions in solution.			
	$CuSO_4(aq) \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$			
	The two equilibriums responsible for all the observations during the mixing of the solutions are:			
	$Cu^{2+}(aq) + 2OH^-(aq) \leftrightharpoons Cu(OH)_2(s)$ (1)			
	$Cu^{2+}(aq) + 4NH_3(aq) \leftrightharpoons [Cu(NH_3)_4]^{2+}(aq)$ (2)			
	NH$_3$ solution is basic (contains OH$^-$ ions).			
	$NH_3(aq) + H_2O \leftrightharpoons NH_4^+(aq) + OH^-(aq)$			
	Addition of OH$^-$ ions caused the forwards reaction in equilibrium (1) to occur predominantly, forming a pale blue precipitate of Cu(OH)$_2$.			
	On addition of excess NH$_3$ solution, the Cu^{2+} ions then formed complex ions as per equilibrium (2), due to the high concentration of NH$_3$ molecules in solution. The copper ammonia complex, $[Cu(NH_3)_4]^{2+}(aq)$, has a deep royal blue colour.			
	Equilibrium (2) removes Cu^{2+} ions from solution, causing more Cu^{2+} ions to be produced by the reverse reaction of equilibrium (1). This results in the Cu(OH)$_2$ dissolving.			
	On addition of HCl(aq), an acid-base reaction occurs, converting NH$_3$ molecules into NH$_4^+$ ions.			
	$NH_3(aq) + H_3O^+(aq) \leftrightharpoons NH_4^+(aq) + H_2O(l)$			
	The decrease in the concentration of the concentration of NH$_3$ molecules in the solution results in equilibrium (2) reversing to produce more NH$_3$ and Cu^{2+}, causing the solution to lose the deep royal blue colour as the complex ions reduce in concentration.			
	The pH is above 7, with a sufficiently high [OH$^-$] for the reaction with the Cu^{2+} ions to occur again and reproduce the Cu(OH)$_2$ precipitate.			
	As further HCl(aq) was added, all the NH$_3$ is converted to NH$_4^+$, and the pH drops sharply. The drop in [OH$^-$] causes the Cu(OH)$_2$ to dissolve, leaving the pale blue solution of Cu^{2+} ions.			

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
THREE (a)(i)	$s\left(Ca(OH)_2\right) = \sqrt[3]{\dfrac{6.40\times10^{-6}}{4}}$ $= 0.011696 \text{ mol L}^{-1}$ $\left[OH^-\right] = 2\times 0.011696 \text{ mol L}^{-1}$ $= 0.0233921 \text{ mol L}^{-1}$ $n\left(CH_3COOH\right) = 0.0200 \text{ L} \times 0.0308 \text{ mol L}^{-1}$ $= 6.16\times10^{-4} \text{ mol}$ $n\left(OH^-\right)_{equivalence} = 6.16\times10^{-4} \text{ mol}$ $V\left(Ca(OH)_2\right)_{equivalence} = \dfrac{6.16\times10^{-4} \text{ mol}}{0.0233921 \text{ mol L}^{-1}}$ $= 0.02633 \text{ L}$ $= 26.3 \text{ mL}$	Any of the following: • Calculation attempted with correct use of K_s. • pH value calculated with minor error. • Assumption for pH calculations described. • Weak acid and conjugate base pairing related to indicator composition. • Explanation given for variation in indicator colour in different pH values. • Calculated enthalpy change for production of acetylene with minor errors.	A range of the following: • Calculates a volume of $Ca(OH)_2$ solution required to reach the equivalence point in the titration, with minor errors. • Calculates two pH values using correct volume from (i), or all three pH values using the provided volume, and only minor errors. • Explains an assumption related to the calculation of either the initial pH or equivalence pH value. • Discusses the observations of bromothymol blue in solutions of different pH, and accounts for the changes occurring during a titration. • Calculates the energy released when 50.0 kg of acetylene is produced, with minor errors. • Provides a logical reasoned idea for variation in the two enthalpy of formation values.	A range of the following: • Correctly calculates the volume of $Ca(OH)_2$ solution required to reach the equivalence point in the titration, with clearly detailed working. • Correctly calculates the pH values for the start of the titration, using the correct volume from (i), at the equivalence point, and after 35 mL of $Ca(OH)_2$ solution, with clearly detailed working. • Outlines appropriate assumptions related to the calculation of either the initial pH or equivalence pH value. • Discusses the observations of bromothymol blue in solutions of different pH, and accounts for the changes occurring during a titration, with identification that the indicator is not appropriate for the titration in (i) and (ii). • Correctly calculates the energy released when 50.0 kg of acetylene is produced, with clearly detailed working. • Provides logical reasoning for variation in the two enthalpy of formation values.

(ii)	**Initial solution:**			

$K_a \quad = 10^{-4.76} = 1.7378 \times 10^{-5}$

$K_a \quad = \dfrac{\left[H_3O^+\right]\left[CH_3COO^-\right]}{\left[CH_3COOH\right]}$

$\left[H_3O^+\right] = \sqrt{1.7378 \times 10^{-5} \times 0.0308} \text{ mol L}^{-1}$

$\qquad = 7.316 \times 10^{-4} \text{ mol L}^{-1}$

$pH_{initial} \quad = 3.14$

At equivalence:

Total volume $\quad = 0.02000 \text{ L} + 0.02633 \text{ L}$

$\qquad = 0.04633 \text{ L}$

$\left[CH_3COO^-\right]_{equivalence} = \dfrac{6.16 \times 10^{-4} \text{ mol}}{0.04633 \text{ L}}$

$\qquad = 0.013295 \text{ mol L}^{-1}$

$K_b \qquad = 10^{-9.24} = 5.7543 \times 10^{-10}$

$K_b \qquad = \dfrac{\left[OH^-\right]\left[CH_3COOH\right]}{\left[CH_3COO^-\right]}$

$\left[OH^-\right] \qquad = \sqrt{5.7543 \times 10^{-10} \times 0.013295} \text{ mol L}^{-1}$

$\qquad = 2.7659 \times 10^{-6} \text{ mol L}^{-1}$

$pOH_{equivalence} \qquad = 5.56$

$pH_{equivalence} \qquad = 8.44$

Or:

$\left[H_3O^+\right] \quad = \sqrt{\dfrac{K_w \times K_a}{\left[CH_3COO^-\right]}}$

$\qquad = \sqrt{\dfrac{10^{-14} \times 1.7378 \times 10^{-5}}{0.013295}} \text{ mol L}^{-1}$

$\qquad = 3.615 \times 10^{-9} \text{ mol L}^{-1}$

$pH_{equivalence} = 8.44$

At 35 mL added:

Total volume $\quad = 0.02000\ L + 0.03500\ L$

$\quad = 0.05500\ L$

Excess $V\left(Ca\left(OH^-\right)_2\right)_{35\,mL}\quad = 35.00\ mL - 26.33\ mL$

$\quad = 8.67\ mL$

Unreacted $n\left(OH^-\right)_{35\,mL}\quad = 0.00867\ L \times 0.0233921\ mol\ L^{-1}$

$\quad = 2.0281\times 10^{-4}\ mol$

$\left[OH^-\right]_{35\,mL}\quad = \dfrac{2.0281\times 10^{-4}\ mol}{0.0550\ L}$

$\quad = 3.687\times 10^{-3}\ mol\ L^{-1}$

$pOH_{35\,mL}\quad = 2.43$

$pH_{35\,mL}\quad = 11.57$

Assumptions:

For initial solution, assume that:

   (1) the amount of dissociation of the acid is negligible compared to the amount of acid originally added (i.e., the $[CH_3COOH]_{0mL} = [CH_3COOH]_{initial}$, and

   (2) that the contribution of $[H_3O^+]$ from water dissociation is negligible and thus $[H_3O^+] = [CH_3COOH^-]$.

OR

For the solution at equivalence, assume that:

   (1) the reaction of the base with water is negligible compared to the amount of base in solution (i.e., the $[CH_3COOH^-] = [CH_3COOH^-]_{equivalence}$, and

   (2) that the contribution of $[OH^-]$ from water self-dissociation is negligible, and thus $[OH^-] = [CH_3COOH]$.

(iii)	pH indicators are weak acids where the colour of the solution of the acid and conjugate base are different. In low pH environments, the protonated form of the indicator, HIn, is present in high concentration, and is a yellow colour. As the pH of the solution rises to near the pK_a of the indicator, the HIn molecules are deprotonated to form In^- ions, which are blue in colour. The colour of the solution becomes green, as blue and yellow mixed appears green. [HIn]=[In$^-$] when the pH of the solution is 7.2 and equals the pK_a(bromothymol blue). When more OH^- is added, the deprotonated form, In^-, becomes the predominant species, and the solution turns blue in colour. The 'effective range' for the indicator during which the colour changes are observed, is ±1 pH unit from the pKa of the indicator. For bromothymol blue that will be between pH 6.2 and 8.2. This indicator would not be appropriate for the titration in (i), as the indicator would start to change colour from yellow to green prior to pH 7.2, and turn blue well before the equivalence point of the titration being reached (at pH 8.44).			
(b)(i)	**Reaction:** $CaC_2(s) + 2H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(aq)$ Thermochemical Data: $CaC_2(s) \rightarrow Ca(s) + 2C(s)$ $\Delta H = -(-60 \text{ kJ mol}^{-1})$ $= +60 \text{ kJ mol}^{-1}$ $Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\Delta H = -635 \text{ kJ mol}^{-1}$ $2CO_2(g) + H_2O(l) \rightarrow C_2H_2(g) + 2\frac{1}{2}O_2(g)$ $\Delta H = -(-1301 \text{ kJ mol}^{-1})$ $= +1301 \text{ kJ mol}^{-1}$ $2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = 2 \times (-394 \text{ kJ mol}^{-1})$ $= -788 \text{ kJ mol}^{-1}$ $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ $\Delta H = -65 \text{ kJ mol}^{-1}$ Total enthalpy change ($\Delta_r H$) **$= -127 \text{ kJ mol}^{-1}$** $n(C_2H_2) = \dfrac{50\,000 \text{ g}}{26.0 \text{ g mol}^{-1}} = 1923.0769 \text{ mol}$ $\Delta E = 127.0 \text{ kJ mol}^{-1} \times 1923.0769 \text{ mol} = 244\,230 \text{ kJ energy}$ **released**			

| (ii) | The enthalpy change for a reaction is a combination of the energy absorbed in breaking the bonds in the reactants and the energy released when new bonds are formed in the products. The enthalpy of formation of calcium oxide is a lot more exothermic than that of carbon monoxide.

 • C(s) is a giant covalent network, where each C is covalently bonded to multiple other C atoms, requiring a large amount of energy to be absorbed in the breaking of these bonds which would be a large positive value. Ca metal is in a giant metallic lattice, but Ca is a soft metal and the metallic bonds could require less energy to break.

 • Both compounds release energy on forming new bonds. When CaO forms, it exists as a solid ionic lattice, with a network of ionic bonds formed between Ca^{2+} and O^{2-} ions. When CO forms, it exists as discrete covalent molecules, with covalent bonds between the atoms, and weak intermolecular attraction between the molecules. The ionic lattice being formed in CaO may release more energy than the covalent bonds being formed in CO, which may account for the more negative enthalpy value. | | | |

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
FOUR (a)(i)	The ^{13}C NMR spectra indicates two unique carbon bonding environments as there are two peaks. The peak at ~205 ppm indicates the presence of a C=O carbonyl group. This C=O group is confirmed by the IR spectrum which has a strong sharp peak at ~1700cm^{-1}, which is likely to be from a C=O carbonyl stretch. The mass spectrum indicates the molar mass of the compound is 58 g mol^{-1}, as the molecular ion peak is at 58 m/z. A molecular formula which matches this molecular mass, and contains a carbonyl group is C_3H_6O. Integrating the above information, there are two possible structural isomers, propanal or propanone. Given the 13C NMR spectra has two peaks, this implies there is some form of **symmetry** in the structure. Propanone is the likely compound, which would give only two peaks due to the two equivalent CH_3 groups. Propanone has a fragment of 43 g mol–1 (CH_3CO^+) represented by the peak at 43 m/z, and a fragment of 15 g mol^{-1} (CH_3^+) represented by the peak at 15 m/z. **Propanone is Compound A**.	A range of the following: • Compound A identified. • Identifies a number of compounds B–L. • Identifies correct functional group changes but with incorrect structures. • Describes entropy changes for NaCl dissolving. • Describes entropy changes for water evaporating and NaCl crystalising. • Links entropy changes together to explain spontaneity of a process.	A range of the following: • Solves the identity of Compound A, with weak justification. • Draws the structural formulae for most of Compounds B–L and Reagents X–Y, without structural errors. • Discusses most of the entropy changes associated with the dissolving of NaCl into water, with explanation for the spontaneity of the overall process. • Discusses most of the entropy changes associated with the evaporation of water and recrystallisation of NaCl in solution, with explanation for the spontaneity of the overall process.	A range of the following: • Solves the identity of Compound A, with justification that integrates data from all three spectra provided. • Draws the structural formulae for all of Compounds B–L and Reagents X–Y, without structural errors. • Discusses the entropy changes associated with the dissolving of NaCl into water, with justification of the spontaneity of the overall process. • Discusses the entropy changes associated with the evaporation of water and recrystallisation of NaCl in solution, with justification of the spontaneity of the overall process.

(ii)	Compound A: $H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3$ Compound C: $H_3C-\overset{\overset{}{\underset{\underset{\displaystyle Cl}{\|}}{}}}{CH}-CH_3$ Reagent X: PCl_3, PCl_5, $SOCl_2$		
	Compound B: $H_3C-\overset{\underset{\displaystyle OH}{\|}}{CH}-CH_3$ Compound D: $H_3C-\overset{\underset{\displaystyle NH_2}{\|}}{CH}-CH_3$ Reagent Y: $NH_3(alc)$		
	Compound E: $H_3C-\overset{\underset{\displaystyle CH_3}{\|}}{CH}-\overset{\underset{\displaystyle OH}{\|}}{CH}-CH_2-Cl$ Compound I: $H_3C-\overset{\overset{\displaystyle OH}{\|}}{\underset{\underset{\displaystyle CH_3}{\|}}{C}}-\overset{\overset{\displaystyle OH}{\|}}{CH}-CH_2-Cl$		
	Compound F: $H_3C-\overset{\underset{\displaystyle CH_3}{\|}}{C}=CH-CH_2-Cl$ Compound J: $H_3C-\overset{\overset{\displaystyle OH}{\|}}{\underset{\underset{\displaystyle CH_3}{\|}}{C}}-\overset{\overset{\displaystyle OH}{\|}}{CH}-CH_2-OH$		
	Compound G: structure with $C=C$, H and H above, $H_3C-\overset{\underset{\displaystyle CH_3}{\|}}{CH}$ and Cl below. Compound K: $H_3C-\overset{\overset{\displaystyle OH}{\|}}{\underset{\underset{\displaystyle CH_3}{\|}}{C}}-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-OH$		
	Compound H: structure with $C=C$, H and Cl above, $H_3C-\overset{\underset{\displaystyle CH_3}{\|}}{CH}$ and H below. Compound L: $H_3C-\overset{\overset{\displaystyle OH}{\|}}{\underset{\underset{\displaystyle CH_3}{\|}}{C}}-\overset{\overset{\displaystyle O}{\|}}{C}-\overset{\overset{\displaystyle O}{\|}}{C}-O^-$ $H_3\overset{+}{N}-\overset{\underset{\displaystyle CH_3}{}}{CH}-CH_3$		

(b)	$H_2O(l) + NaCl(s) \rightarrow H_2O(l) + NaCl(aq)$			
	As sodium chloride dissolves in water, the ordered ionic lattice in the crystal is disrupted, and the hydrated ions of Na^+ and Cl^- are dispersed throughout the solution, which results in a gain in entropy for the system.			

$H_2O(l) + NaCl(s) \rightarrow H_2O(l) + NaCl(aq)$

As sodium chloride dissolves in water, the ordered ionic lattice in the crystal is disrupted, and the hydrated ions of Na^+ and Cl^- are dispersed throughout the solution, which results in a gain in entropy for the system.

The process is slightly endothermic requiring energy from the surroundings, which reduces the surroundings entropy.

The entropy increase in the system is greater than the entropy decrease in the surrounding, resulting in an overall gain in entropy, making this reaction spontaneous.

$H_2O(l) + NaCl(aq) \rightarrow H_2O(g) + NaCl(s)$

The precipitation of the salt crystals in the warm room is observed to be spontaneous, and this is due to the process resulting in an increase in total entropy overall. This is primarily driven by the increase in entropy **of the system**, due to the **evaporation of water in the warm room**.

The water is changing from a liquid form to a gas form, which is dispersed throughout a much larger volume in the atmosphere, and this leads to a significant increase the entropy of the system.

This process requires intermolecular interactions between the water molecules to be broken, which is endothermic, and will draw energy from the surroundings, reducing the surroundings entropy.

The aqueous sodium ions and chloride ions combine to form a solid lattice of sodium chloride solid. As the less ordered ions combine to form an ordered lattice, the entropy of the ions, and thus the system, decreases.

Forming the crystal is a slightly exothermic process, as there are extended ionic interactions formed throughout the crystal. This means forming the NaCl crystals will release energy into the surroundings, increasing the surroundings' entropy slightly.

The total entropy change for the precipitation process overall will be the sum of all these system and surroundings entropy changes.

Candidates who identified and discussed the spontaneous evaporation of the water in the warm room, and then related this to the increasing concentration of the ions in the solution causing the solution to become saturated, resulting in precipitation of NaCl, were also given reognition of their argument.

Cut Scores

Scholarship	Outstanding Scholarship
17 – 24	25 – 32