

## Assessment Schedule – 2020

## Scholarship Chemistry (93102)

## Evidence Statement

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
ONE (a)	$[\text{HNO}_3] = [\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-1.50} = 3.16 \times 10^{-2} \text{ mol L}^{-1}$ $K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{[\text{NH}_4^+]}$ $\text{NH}_3 + \text{H}_3\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ $[\text{NH}_4^+] = [\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]}$ $K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{K_w} \bigg/ \frac{1}{[\text{H}_3\text{O}^+]}$ $K_a = \frac{[\text{H}_3\text{O}^+]^2 [\text{NH}_3]}{K_w}$ $[\text{NH}_3] = \frac{K_a \times K_w}{[\text{H}_3\text{O}^+]^2} = \frac{10^{-9.24} \times 10^{-14}}{(10^{-11})^2} = 5.75 \times 10^{-2} \text{ mol L}^{-1}$ <p>OR</p> $[\text{NH}_3] = \frac{[\text{OH}^-]^2}{K_b} = \frac{(10^{-(14-11.00)})^2}{10^{-(14-9.24)}} = 5.75 \times 10^{-2} \text{ mol L}^{-1}$ <p>Upon mixing: Weak base more concentrated than acid. Partial neutralisation of base will occur. pH will be dependent on ratio of base : conjugate acid.</p> $n(\text{NH}_3) = 5.75 \times 10^{-2} \text{ mol L}^{-1} \times 0.05 \text{ L} = 2.87 \times 10^{-3} \text{ mol}$ $n(\text{HNO}_3) = 3.16 \times 10^{-2} \text{ mol} \times 0.05 \text{ L} = 1.58 \times 10^{-3} \text{ mol}$ $n(\text{NH}_3)_{\text{remaining}} = 2.87 \times 10^{-3} \text{ mol} - 1.58 \times 10^{-3} \text{ mol} = 1.29 \times 10^{-3} \text{ mol}$ $n(\text{NH}_4^+)_{\text{formed}} = 1.58 \times 10^{-3} \text{ mol}$	<p>Any of the following:</p> <ul style="list-style-type: none"> <li>concentration of <math>\text{NH}_3</math> or <math>\text{NH}_4^+</math> species in final solution</li> <li>pH of final solution</li> <li>enthalpy changes described</li> <li>entropy changes described</li> <li>awareness shown of total entropy and spontaneity</li> <li>compares ionisation of Mg to Na</li> <li>compares ionisation of Mg to <math>\text{Mg}^+</math></li> <li>shows awareness of electron orbitals and nuclear charge.</li> </ul>	<p>Calculates the pH and concentration of some species present in the final solution.</p> <p>AND</p> <p>Explanation given for the enthalpy and entropy changes occurring in the dissolving of oxygen gas, or the reaction to form HCl gas.</p> <p>AND</p> <p>Explanation given of the factors that contribute to ionisation energy, with comparisons made between the ionisation of different species.</p>	<p>Correctly calculates the pH and concentration of all species present in the final solution.</p> <p>AND</p> <p>Comprehensively discusses the entropy and enthalpy changes involved in the dissolving of oxygen gas in water and the reaction to form HCl gas.</p> <p>AND</p> <p>Comprehensive discussion given of the factors that contribute to ionisation energy, with the correct order provided and justified.</p>

$$[\text{NH}_3] = \frac{1.29 \times 10^{-3} \text{ mol}}{0.10 \text{ L}} = 1.29 \times 10^{-2} \text{ mol L}^{-1}$$

$$[\text{NH}_4^+] = \frac{1.58 \times 10^{-3} \text{ mol}}{0.10 \text{ L}} = 1.58 \times 10^{-2} \text{ mol L}^{-1}$$

$$\begin{aligned} [\text{H}_3\text{O}^+] &= \frac{K_a \times [\text{NH}_4^+]}{[\text{NH}_3]} \\ &= \frac{5.75 \times 10^{-10} \times 1.58 \times 10^{-2} \text{ mol L}^{-1}}{1.29 \times 10^{-2} \text{ mol L}^{-1}} \\ &= 7.01 \times 10^{-10} \text{ mol L}^{-1} \end{aligned}$$

$$[\text{OH}^-] = \frac{K_w}{[\text{H}_3\text{O}^+]} = \frac{1.00 \times 10^{-14}}{7.01 \times 10^{-10} \text{ mol L}^{-1}} = 1.42 \times 10^{-5} \text{ mol L}^{-1}$$

$$[\text{NO}_3^-] = 3.16 \times 10^{-2} \text{ mol L}^{-1} \times \frac{0.05 \text{ L}}{0.10 \text{ L}} = 1.58 \times 10^{-2} \text{ mol L}^{-1}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+] = 9.15$$

OR

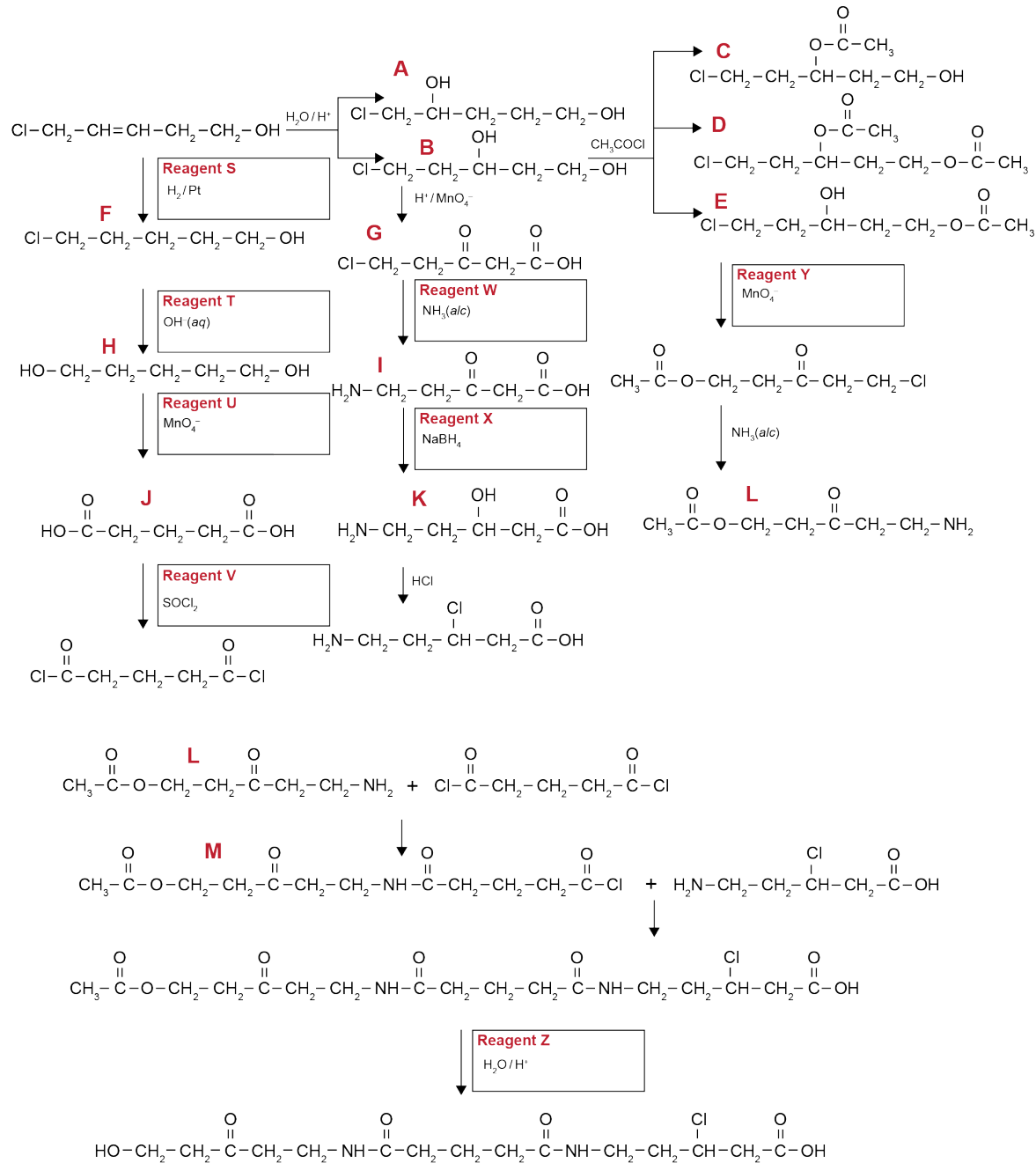
$$\begin{aligned} \text{pH} &= \text{p}K_a + \log \frac{n(\text{NH}_3)}{n(\text{NH}_4^+)} \\ &= 9.24 + \log \frac{1.29 \times 10^{-3} \text{ mol}}{1.58 \times 10^{-3} \text{ mol}} = 9.15 \end{aligned}$$

(b)	<ul style="list-style-type: none"><li>• For a process to be spontaneous there must be an overall increase in the total entropy of the system and the surroundings (<math>\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}</math>).</li><li>• The dissolution of oxygen gas in water is an exothermic process due to the formation of intermolecular attractions between the water molecules and oxygen molecules. There is a decrease in entropy as the dispersed gas mixes with the water to form a more ordered aqueous solution. While the dissolving process has a reduction in system entropy, the dispersal of energy from the system to the surroundings increases the surroundings entropy to a greater extent. Overall the total entropy increases, so the process is spontaneous.</li><li>• In the reaction between hydrogen gas and chlorine gas there is no significant change in the system entropy as there is equivalent moles of reactant and product particles, and all particles are in the gaseous state. <math display="block">\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})</math><p>The reaction however is spontaneous, so it can be inferred that there must be an increase in the entropy of the surroundings for there to be an increase in total entropy. This will be due to the release of thermal energy to the surroundings from the reaction being exothermic. This implies that the energy released in the formation of the H–Cl bonds will be greater than the energy required to break the H–H and Cl–Cl bonds.</p></li></ul>			
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(c)	<p><b>Ionisation of Na v Mg</b></p> <ul style="list-style-type: none"> <li>• In both atoms an electron is removed from the 3s valence orbital.</li> <li>• While Mg and Na atoms have the same number of inner shell electrons which can shield the nuclear charge to the same extent, Mg atoms have a greater number of protons in the nucleus, and therefore the valence electrons in Mg atoms experience a greater effective nuclear charge.</li> <li>• While there is additional electron-electron repulsion between the two valence electrons in Mg atoms, this has less effect on the energy required to ionise the atoms than the increased nuclear charge.</li> <li>• More energy will be required to ionise Mg to <math>\text{Mg}^+</math> compared to Na to <math>\text{Na}^+</math>.</li> </ul> <p><b>Ionisation of Mg v <math>\text{Mg}^+</math></b></p> <ul style="list-style-type: none"> <li>• More energy is required to remove a negatively charged electron from a positively charged ion than is required to remove a negatively charged electron from a neutral atom.</li> <li>• The second ionisation energy of each element will always be greater than the first ionisation energy of each element.</li> </ul> <p><b>Ionisation of <math>\text{Na}^+</math> v <math>\text{Mg}^+</math></b></p> <ul style="list-style-type: none"> <li>• The electron removed from the <math>\text{Mg}^+</math> ion is in the 3s orbital. The electron removed from the <math>\text{Na}^+</math> ion is in the 2p orbital.</li> <li>• It will require greater amounts of energy to remove an electron from a 2p orbital which is closer to the nucleus and experiences a greater effective nuclear charge acting on it.</li> <li>• More energy will be required to ionise <math>\text{Na}^+</math> to <math>\text{Na}^{2+}</math> compared to <math>\text{Mg}^+</math> to <math>\text{Mg}^{2+}</math>.</li> </ul> <p><b>Overall Order</b></p> <ul style="list-style-type: none"> <li>• <math>\text{Na}^+</math> to <math>\text{Na}^{2+}</math> will require the greatest amount of energy.</li> <li>• Mg to <math>\text{Mg}^+</math> will require less energy than <math>\text{Mg}^+</math> to <math>\text{Mg}^{2+}</math>.</li> <li>• Na to <math>\text{Na}^+</math> will require less energy than Mg to <math>\text{Mg}^+</math>, therefore has the lowest ionisation enthalpy.</li> <li>• Therefore, the overall order of increasing ionisation enthalpies is: Na &lt; Mg &lt; <math>\text{Mg}^+</math> &lt; <math>\text{Na}^+</math>.</li> </ul>			
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TWO (a)(i)	<p><b>Reduction will occur at the cathode.</b></p> <p>There are three possible oxidants. They are <math>\text{Sn}^{2+}</math>, <math>\text{H}_2\text{O}</math>, and <math>\text{Zn}^{2+}</math>. The strongest oxidant, and the species most likely to undergo reduction, will be <math>\text{Sn}^{2+}</math> with the most positive reduction potential (<math>-0.14\text{ V}</math>). Grey Sn metal will be observed depositing on the outside of the cathode.</p> $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$ <p><b>Oxidation will occur at the anode.</b></p> <p>There are three possible reductants. They are <math>\text{Cl}^-</math>, <math>\text{SO}_4^{2-}</math>, and <math>\text{H}_2\text{O}</math>. The strongest reductant, and the species most likely to undergo oxidation, will be <math>\text{H}_2\text{O}</math> with the least positive reduction potential (<math>+1.23\text{ V}</math>). Bubbles of colourless gas will be observed forming around the electrode.</p> $2\text{H}_2\text{O}(\ell) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$ <p><b>The overall reaction that will occur when the current is applied is:</b></p> $2\text{H}_2\text{O}(\ell) + 2\text{Sn}^{2+}(\text{aq}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 2\text{Sn}(\text{s})$ <p>The cell potential this reaction is: <math>E^\circ_{\text{cell}} = -0.14\text{ V} - +1.23\text{ V} = -1.37\text{ V}</math></p> <p>The cell potential is negative, indicating the reaction as written is non-spontaneous, and a voltage greater than <math>1.37\text{ V}</math> will need to be provided to drive the reaction in a spontaneous direction.</p> <p>(ii) <b>Inert electrodes are replaced with zinc electrodes.</b></p> <ul style="list-style-type: none"> <li>Zinc is a more reactive metal than tin and will spontaneously displace it from solution once the electrodes are inserted, and before the electrolysis can be carried out. A dark grey solid (Sn) will form on the electrodes.</li> </ul> $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s}) \quad E^\circ = -0.76\text{ V} \quad \text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s}) \quad E^\circ = -0.14\text{ V}$ $\text{Zn}(\text{s}) + \text{Sn}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Sn}(\text{s})$ $E^\circ_{\text{cell}} = -0.14\text{ V} - -0.76\text{ V} = +0.62\text{ V}$ <p><b>Tin(II) sulfate is replaced with iron(II) sulfate.</b></p> <ul style="list-style-type: none"> <li>Iron(II) ions will be both the strongest oxidant and strongest reductant in the solution when electrolysis is carried out. Therefore, at one electrode the pale green <math>\text{Fe}^{2+}</math> ions in the solution will slowly form pale orange <math>\text{Fe}^{3+}</math> ions which will lead to an observable change in the colour of the solution. At the other electrode, Fe metal will be observed forming on the surface of the electrode.</li> </ul> $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s}) \quad E^\circ = -0.44\text{ V} \quad \text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq}) \quad E^\circ = +0.77\text{ V}$ $3\text{Fe}^{3+}(\text{aq}) \rightarrow 2\text{Fe}^{2+}(\text{aq}) + \text{Fe}(\text{s})$ $E^\circ_{\text{cell}} = -0.44\text{ V} - +0.77\text{ V} = -1.21\text{ V}$	<p>Any of the following:</p> <ul style="list-style-type: none"> <li>correct oxidant species</li> <li>correct reductant species</li> <li>cell potential calculated</li> <li>observations linked to species</li> <li>energy requirements identified</li> <li>identifies displacement of tin with zinc</li> <li>identifies disproportionation of <math>\text{Fe}^{2+}</math> ions</li> <li>correct observations for altered processes</li> <li>selection of compounds <b>A-M</b> identified</li> <li>selection of reagents <b>S-Z</b> identified.</li> </ul>	<p>Determines and justifies one correct oxidant or reductant species, the observations of the electrolysis process, and the energy requirements.</p> <p>AND</p> <p>Discusses the differences in reactions and observations when either the inert electrodes are replaced with zinc electrodes, or the tin(II) sulfate is replaced with iron(II) sulfate.</p> <p>AND</p> <p>Determines some of compounds <b>A-M</b> and reagents <b>S-Z</b>.</p>	<p>Gives a complete account of the changes occurring in the electrolysis of the solution, including all observations, balanced equation, and the energy requirements of the process.</p> <p>AND</p> <p>Comprehensively discusses the differences in reactions and observations when the inert electrodes are replaced with zinc electrodes, and the tin(II) sulfate is replaced with iron(II) sulfate.</p> <p>AND</p> <p>Correctly determines all of the structures of majority of compounds <b>A-M</b> and reagents <b>S-Z</b>.</p>

(b)

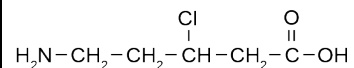


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THREE (a)(i)	$n(\text{PbCl}_2) = \frac{0.225 \text{ g}}{278 \text{ g mol}^{-1}} = 8.09 \times 10^{-4} \text{ mol}$ $s(\text{PbCl}_2) = \frac{8.09 \times 10^{-4} \text{ mol}}{0.050 \text{ L}} = 0.0161 \text{ mol L}^{-1}$ $K_s(\text{PbCl}_2) = 4s^3 = 4(0.0161 \text{ mol L}^{-1})^3 = 1.69 \times 10^{-5}$ $[\text{PbCl}_2]_{250 \text{ mL}} = 0.0161 \text{ mol L}^{-1} \times \frac{50 \text{ mL}}{250 \text{ mL}} = 3.23 \times 10^{-3} \text{ mol L}^{-1}$ $[\text{Pb}^{2+}] = 3.23 \times 10^{-3} \text{ mol L}^{-1} \times \frac{0.05 \text{ L}}{0.075 \text{ L}} = 2.15 \times 10^{-3} \text{ mol L}^{-1}$ $[\text{Cl}^-]_{\text{lead chloride}} = 2 \times 3.23 \times 10^{-3} \text{ mol L}^{-1} \times \frac{0.05 \text{ L}}{0.075 \text{ L}} = 4.31 \times 10^{-3} \text{ mol L}^{-1}$ $[\text{Cl}^-]_{\text{hydrochloric acid}} = 2.35 \times 10^{-3} \text{ mol L}^{-1} \times \frac{0.025 \text{ L}}{0.075 \text{ L}} = 7.83 \times 10^{-4} \text{ mol L}^{-1}$ $[\text{Cl}^-]_{\text{total}} = [\text{Cl}^-]_{\text{lead chloride}} + [\text{Cl}^-]_{\text{hydrochloric acid}}$ $= 4.31 \times 10^{-3} \text{ mol L}^{-1} + 7.83 \times 10^{-4} \text{ mol L}^{-1} = 5.09 \times 10^{-3} \text{ mol L}^{-1}$ $Q(\text{PbCl}_2) = 2.15 \times 10^{-3} \text{ mol L}^{-1} \times (5.09 \times 10^{-3} \text{ mol L}^{-1})^2 = 5.61 \times 10^{-8}$ $Q(\text{PbCl}_2) < K_s(\text{PbCl}_2), \text{ therefore there will not be a precipitate present.}$	<p>Any of the following:</p> <ul style="list-style-type: none"> <li>• <math>K_s(\text{PbCl}_2)</math></li> <li>• Q(mixture)</li> <li>• description of factors contributing to precipitation</li> <li>• nitric acid linked to <math>\text{H}_3\text{O}^+</math> ions</li> <li>• formation of <math>\text{Pb}(\text{OH})_2</math> precipitate explained</li> <li>• hydrolysis of methyl benzoate</li> <li>• Protonation of benzoate ions</li> <li>• description of attractive forces between particles</li> <li>• identifies carbon environments</li> <li>• describes position of peaks in relation to carbon environments</li> <li>• accounts for unique attributes of spectra.</li> </ul>	<p>Determines values for <math>K_s(\text{PbCl}_2)</math>, and Q(mixture), with minor error, and compares them to determine whether a precipitate forms.</p> <p>AND</p> <p>Explains the need for nitric acid in the original solution, with use of balanced chemical equations and equilibrium principles.</p> <p>AND</p> <p>Discussion of the hydrolysis of methyl benzoate, protonation of benzoate ions, with some links given between particle attractions and observed miscibility / solubility of the different substances.</p> <p>AND</p> <p>Predicts attributes of the <math>^{13}\text{C}</math> NMR spectra for all three compounds.</p>	<p>Correctly determines values for <math>K_s(\text{PbCl}_2)</math>, and Q(mixture), and compares them to justify the lack of precipitate formation.</p> <p>AND</p> <p>Justifies the need for nitric acid in the original solution, with use of balanced chemical equations and solubility calculations.</p> <p>AND</p> <p>Comprehensive discussion of the hydrolysis of methyl benzoate, protonation of benzoate ions, and the links between particle attractions and observed miscibility / solubility of all substances.</p> <p>AND</p> <p>Correctly predicts the unique attributes of the <math>^{13}\text{C}</math> NMR spectra for all three compounds and gives an account of how these could be used to identify each hydrolysis product.</p>

(ii)	<p>The <math>K_s</math> value for <math>\text{Pb}(\text{OH})_2</math> is small, indicating a low solubility. In a neutral or alkaline solution that contains <math>\text{Pb}^{2+}</math> ions there is a high chance that <math>\text{Pb}(\text{OH})_2</math> could form as a solid precipitate. As the <math>\text{PbCl}_2</math> is dissolved, the <math>\text{Pb}^{2+}</math> ions could precipitate out of solution, preventing a saturated solution of <math>\text{PbCl}_2</math> from being achieved.</p> $\text{Pb}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Pb}(\text{OH})_2(\text{s})$ <p>To confirm that a precipitate would form, if the original solution was prepared in water:  <math>[\text{Pb}^{2+}] = 0.0162 \text{ mol L}^{-1}</math>      Assuming <math>\text{pH} = 7</math>, then <math>[\text{OH}^{-}] = 1.00 \times 10^{-7} \text{ mol L}^{-1}</math>  <math>Q(\text{Pb}(\text{OH})_2) = 0.0162 \text{ mol L}^{-1} \times (1.00 \times 10^{-7} \text{ mol L}^{-1})^2 = \mathbf{1.62 \times 10^{-16}}</math>  <math>Q(\text{Pb}(\text{OH})_2) &gt; K_s(\text{Pb}(\text{OH})_2)</math>, therefore <math>\text{Pb}^{2+}</math> ions would precipitate out as <math>\text{Pb}(\text{OH})_2</math> in water at this concentration.</p> <p>Nitric acid is required in the preparation of the <math>\text{PbCl}_2</math> solution as the presence of <math>\text{H}_3\text{O}^{+}</math> ions in the solution prevents the formation of the hydroxide precipitate. Nitrate compounds are soluble, making nitric acid the most appropriate acid to use to prevent any other potential precipitates from forming as well.</p> $\text{HNO}_3(\text{aq}) + \text{H}_2\text{O}(\ell) \rightarrow \text{H}_3\text{O}^{+}(\text{aq}) + \text{NO}_3^{-}(\text{aq})$ $\text{H}_3\text{O}^{+}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\ell)$			
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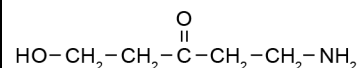
(b) Complete hydrolysis of the compound would produce three products:



This structure would produce **five** distinct peaks on a  $^{13}\text{C}$  NMR spectrum.

- Two peaks around 20 ppm for the C atoms in the  $\text{CH}_2$  groups.
- One peak around 20–40 ppm for the C atom attached to the Cl group.
- One peak around 40–60 ppm for the C atom attached to the  $\text{NH}_2$  group.
- One peak around 180 ppm for the C atom of the  $\text{COOH}$  group.

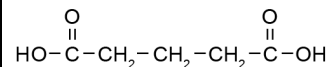
This compound could be uniquely identified by the presence of five peaks on the spectra, with one peak located around 180 ppm indicating a carbon atom as part of a carboxylic acid functional group.



This structure would produce **five** distinct peaks on a  $^{13}\text{C}$  NMR spectrum.

- Two peaks around 20 ppm for the C atoms in the  $\text{CH}_2$  groups.
- One peak around 40–60 ppm for the C atom attached to the  $\text{NH}_2$  group.
- One peak around 60–80 ppm for the C atom attached to the OH group.
- One peak around 200–220 ppm for the C atom of the  $\text{C}=\text{O}$  group.

This compound could be uniquely identified by the presence of five peaks on the spectra, the presence of a peak around 60-80 ppm due to the C atom bonded to the -OH group, and the peak above 200 ppm indicating a carbon atom that is in a  $\text{C}=\text{O}$  bonding environment.



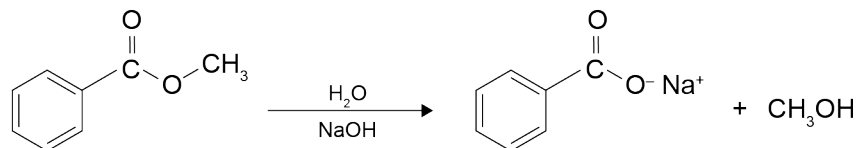
This structure would produce only **three** distinct peaks on a  $^{13}\text{C}$  NMR spectrum, due to symmetry in the structure.

- Two peaks around 20 ppm for the C atoms in the  $\text{CH}_2$  groups.
- One peak around 180 ppm for the C atoms of the  $\text{COOH}$  groups.

This compound could be uniquely identified by the presence of only three peaks on the spectra, indicating symmetry in the molecule which is not present in the other two compounds.

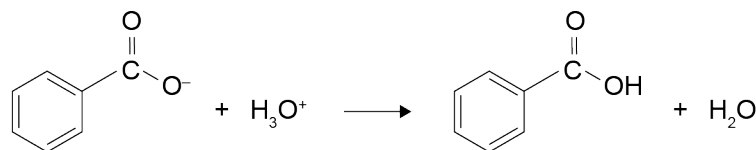
(c) Methyl benzoate is an ester that, when mixed with aqueous base, will be immiscible, due to the inability of the largely non-polar methyl benzoate particles to form sufficient attractions with the water molecules (solute-solvent forces) to overcome the strong network of hydrogen bonding within the water structure (solvent-solvent forces). There are also molecular attractions between the largely non-polar methyl benzoate particles (solute-solute forces), however these forces of attraction do not play a large role in the miscibility in water in comparison to the network of hydrogen bonding between water molecules.

On heating, a hydrolysis reaction occurs, resulting in the formation of methanol, water, and the sodium salt of benzoic acid, sodium benzoate.



Sodium benzoate has increased solubility in water, due to the interactions that can be achieved between the negatively charged carboxylate ions and the polar water molecules. These solute-solvent attractions are strong enough to overcome the hydrogen bonding between the water molecules (solvent-solvent forces). While the high temperature increases the solubility of the salt, even at low temperatures, the sodium benzoate is still appreciably soluble.

When the mixture is acidified with sulfuric acid, any remaining base is neutralised, and then the carboxylate salt particles become protonated to form benzoic acid.



Benzoic acid, while having a polar carboxylic acid group, is less soluble in water than the benzoate salt. The now uncharged molecules, despite being polar and able to form hydrogen bonds, can no longer form the same extent of solute-solvent attractions with the water particles (to overcome the strong solvent-solvent hydrogen bonding between the water molecules, and the new solute-solute attractions between benzoic acid molecules). As a result, the benzoic acid spontaneously precipitates out as a crystalline solid.

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
FOUR (a)	$n(\text{Na}_2\text{CO}_3) = \frac{1.473 \text{ g}}{106.0 \text{ g mol}^{-1}} = 0.01389 \text{ mol}$ $c(\text{Na}_2\text{CO}_3) = \frac{0.01389 \text{ mol}}{0.2500 \text{ L}} = 0.05558 \text{ mol L}^{-1}$ $n(\text{Na}_2\text{CO}_3)_{\text{titration}} = 0.05558 \text{ mol L}^{-1} \times 0.025 \text{ L} = 0.001389 \text{ mol}$ $\text{Na}_2\text{CO}_3(aq) + 2\text{HCl}(aq) \rightarrow 2\text{NaCl}(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(\ell)$ $n(\text{HCl})_{\text{titration}} = 2 \times 0.001389 \text{ mol} = 0.002779 \text{ mol}$ $\text{Average titre, } V(\text{HCl})_{\text{final}} = 0.02574 \text{ L}$ $\text{After reaction, } c(\text{HCl})_{\text{final}} = \frac{0.002779 \text{ mol}}{0.02574 \text{ L}} = 0.1079 \text{ mol L}^{-1}$ $n(\text{HCl})_{\text{final}} = 0.1079 \text{ mol L}^{-1} \times 0.250 \text{ L} = 0.02698 \text{ mol}$ $\text{Before reaction, } n(\text{HCl})_{\text{initial}} = 1.060 \text{ mol L}^{-1} \times 0.100 \text{ L} = 0.1060 \text{ mol}$ $n(\text{HCl})_{\text{reacted}} = n(\text{HCl})_{\text{initial}} - n(\text{HCl})_{\text{final}}$ $= 0.1060 \text{ mol} - 0.02698 \text{ mol} = 0.07901 \text{ mol}$ $\text{CaCO}_3(aq) + 2\text{HCl}(aq) \rightarrow \text{CaCl}_2(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(\ell)$ $n(\text{CaCO}_3) = 0.07901 \text{ mol} \times \frac{1}{2} = 0.03950 \text{ mol}$ $m(\text{CaCO}_3)_{\text{total}} = 0.03950 \text{ mol} \times 100.1 \text{ g mol}^{-1} = 3.954 \text{ g}$ $\text{Average percentage mass CaCO}_3 \text{ in chalk sticks, } \%(\text{CaCO}_3) = \frac{3.954 \text{ g}}{4.017 \text{ g}} \times 100\% = \mathbf{98.45\%}$	<p>Any of the following:</p> <ul style="list-style-type: none"> <li>• <math>n(\text{HCl})_{\text{titration}}</math></li> <li>• <math>n(\text{HCl})_{\text{final}}</math></li> <li>• <math>n(\text{HCl})_{\text{reacted}}</math></li> <li>• determines incorrect percentage mass but shows correct use of stoichiometric principles</li> <li>• determines correct limiting reagent.</li> <li>• determines <math>\Delta H</math> for either reaction</li> <li>• reason for differences in theoretical and actual energy release given.</li> </ul>	<p>Calculates the percentage mass of <math>\text{CaCO}_3</math> in the chalk sticks with minor error.</p> <p>AND</p> <p>Calculates the total energy released in the reaction with error in calculation.</p> <p>AND</p> <p>Describes reasons for the differences between theoretical energy release and actual energy release in the reaction.</p>	<p>Correctly calculates the percentage mass of <math>\text{CaCO}_3</math> in the chalk sticks.</p> <p>AND</p> <p>Correctly calculates the total energy released in the reaction.</p> <p>AND</p> <p>Comprehensively justifies reasons for the differences between theoretical energy release and actual energy release in the reaction.</p>

<p>(b)(i)</p>	$n(\text{KClO}_3) = \frac{12.0 \text{ g}}{122.5 \text{ g mol}^{-1}} = 0.0979 \text{ mol}$ $n(\text{O}_2) = \frac{3}{2} \times 0.0979 \text{ mol} = 0.146 \text{ mol}$ $n(\text{C}_{12}\text{H}_{22}\text{O}_{11})_{\text{combustible}} = \frac{1}{12} \times 0.146 \text{ mol} = 0.0122 \text{ mol}$ $n(\text{C}_{12}\text{H}_{22}\text{O}_{11})_{\text{gummy bear}} = \frac{4.50 \text{ g}}{342.3 \text{ g mol}^{-1}} = 0.0131 \text{ mol}$ <p>Therefore, <math>\text{KClO}_3</math> is the limiting reagent in the reaction, and the <math>\text{C}_{12}\text{H}_{22}\text{O}_{11}</math> is in excess.</p> $2\text{KClO}_3(\text{s}) \rightarrow 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$ $\Delta_r H = \sum \Delta_f H(\text{products}) - \sum \Delta_f H(\text{reactants})$ $= 2(-436.5) - 2(-397.7) = -77.6 \text{ kJ mol}^{-1}$ $\text{Heat released} = \frac{77.6 \text{ kJ mol}^{-1}}{2} \times 0.0979 \text{ mol} = 3.80 \text{ kJ}$ $\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s}) + 12\text{O}_2(\text{g}) \rightarrow 12\text{CO}_2(\text{g}) + 11\text{H}_2\text{O}(\text{g})$ $\Delta_r H = \sum \Delta_f H(\text{products}) - \sum \Delta_f H(\text{reactants})$ $= 12(-393.5) + 11(\frac{1}{2} \times -483.6) - -2226 = -5155.8 \text{ kJ mol}^{-1}$ $\text{Heat released} = 5155.8 \text{ kJ mol}^{-1} \times 0.0122 \text{ mol} = 63.1 \text{ kJ}$ $\text{Total energy released} = 3.80 \text{ kJ} + 63.1 \text{ kJ} = \mathbf{66.9 \text{ kJ}}$			
<p>(ii)</p>	<p>Reasons may include:</p> <ul style="list-style-type: none"> <li>• The amount of oxygen from outside of the test tube, or inside the test tube to start with, is not considered.</li> <li>• Not all of the <math>\text{KClO}_3</math> decomposes in the heat.</li> <li>• Oxygen is lost from the vessel during the reaction, i.e. not all oxygen produced by <math>\text{KClO}_3</math> reacts.</li> <li>• The composition of the gummy bear is not sufficiently close to 100% sucrose.</li> <li>• The energy provided by heating the boiling tube is not included in calculation.</li> <li>• The reagents may not be at <math>25^\circ\text{C}</math> at the start of the reaction.</li> <li>• Some of the sucrose may undergo incomplete combustion, forming <math>\text{CO}</math> or <math>\text{C}</math> instead of <math>\text{CO}_2</math>.</li> <li>• The reaction may eject reagents from the test tube before they have had opportunity to react.</li> </ul>			

**Cut Scores**

<b>Scholarship</b>	<b>Outstanding Scholarship</b>
17 – 24	25 – 32