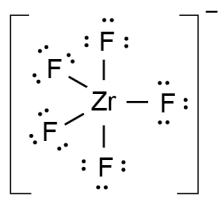
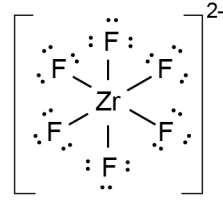
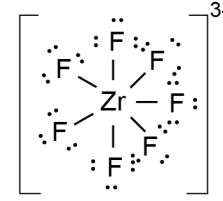
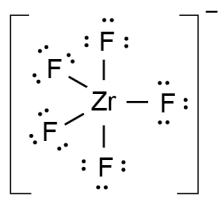
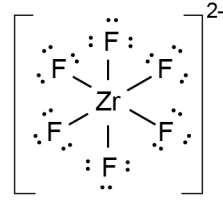
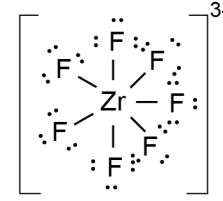
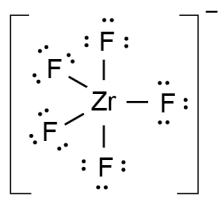
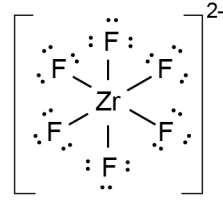
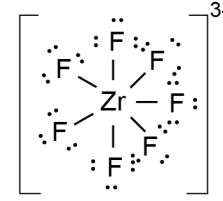


Assessment Schedule – 2023

Scholarship Chemistry (93102)

Evidence Statement

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
ONE (a)(i)	$c(\text{I}^-) = 0.00167 \text{ mol L}^{-1} \times \frac{0.025 \text{ L}}{0.060 \text{ L}} = 6.9583 \times 10^{-4} \text{ mol L}^{-1}$ $c(\text{Pb}^{2+}) = 0.0225 \text{ mol L}^{-1} \times \frac{0.035 \text{ L}}{0.060 \text{ L}} = 1.3125 \times 10^{-2} \text{ mol L}^{-1}$ $c(\text{Ag}^+) = 0.0143 \text{ mol L}^{-1} \times \frac{0.035 \text{ L}}{0.060 \text{ L}} = 8.3416 \times 10^{-3} \text{ mol L}^{-1}$ $Q(\text{PbI}_2) = 6.35 \times 10^{-9}$ <p>No precipitate will be observed in the first beaker.</p> <p>OR</p> <p>If the assumption is made that $[\text{OH}^-] = 10^{-7}$ in the mixture, then $Q(\text{Pb}(\text{OH})_2) = 1.31 \times 10^{-16}$</p> <p>As $Q > K_s(\text{Pb}(\text{OH})_2)$ and a precipitate of $\text{Pb}(\text{OH})_2$ will form in the first beaker,</p> $Q(\text{AgI}) = 5.80 \times 10^{-6}$ <p>A yellow precipitate will be observed in the second beaker.</p>	<p>Any of the following:</p> <ul style="list-style-type: none"> Calculates Q value. Compares Q to K_s to justify one beaker observation. Explains acidification of lead(II) nitrate solution. Identifies Co^{3+} ions as catalyst. Explains temperature effects on rate. Draws correct Lewis diagram. Assigns correct bond angles to molecular shape. <p>Explains bond angles for one shape.</p>	<p>A range of the following:</p> <ul style="list-style-type: none"> Calculates Q values and compares to K_s values to justify beaker observations, but with limited justification of acidification of lead(II) nitrate solution. Discusses the role of Co^{3+} ions and temperature in increasing the rate of reaction for the demonstration, with some links to particle collision theory. Draws correct Lewis diagrams, with associated bond angles and shapes, for two of the three ions, and explains the bond angles in one shape. 	<p>A range of the following:</p> <ul style="list-style-type: none"> Correctly calculates Q values and compares to K_s values to justify beaker observations, and fully explains why acidification of lead(II) nitrate solution is required. Comprehensively discusses the role of Co^{3+} ions as a catalyst and elaborates on the temperature requirements with clear references to particle collision theory. Draws correct Lewis diagrams for all three ions, proposes logical shapes and bond angles, and explains axial and equatorial bond angles for one shape.
(ii)	<p>If $[\text{OH}^-] = 10^{-7}$ in water, then $Q(\text{Pb}(\text{OH})_2) = 2.25 \times 10^{-16}$</p> <p>If only distilled water is used instead of dilute nitric acid, then $[\text{OH}^-]$ will be close to 10^{-7}, and a precipitate of $\text{Pb}(\text{OH})_2$ will be possible. $Q > K_s(\text{Pb}(\text{OH})_2)$. The use of dilute nitric acid lowers $[\text{OH}^-]$, and thus prevents the formation of a precipitate in the $\text{Pb}(\text{NO}_3)_2$ solution.</p>			

(b)	<p>When the temperature is increased, this increases the kinetic energy of the particles so that there are more collisions per second of sufficient energy for reaction to occur.</p> <p>The Co^{3+} ions act as a catalyst. The catalyst makes available an alternative pathway for the reaction to occur, with a lower activation energy requirement.</p> <p>The combination of heating and use of a catalyst increases the number of successful collisions per second between the reactant particles to a rate that enables the demonstration to work.</p> <p>If either of these two conditions are not met, either by not forming the Co^{3+} catalyst, or not heating to the required temperature, then there will not be a sufficient enough number of successful reactant particle collisions per second occurring for the demonstration to go to plan.</p>											
(c)(i)	<table border="1" data-bbox="255 603 1093 874"> <thead> <tr> <th data-bbox="255 603 367 644">Ion</th> <th data-bbox="367 603 607 644">ZrF_5^-</th> <th data-bbox="607 603 846 644">ZrF_6^{2-}</th> <th data-bbox="846 603 1093 644">ZrF_7^{3-}</th> </tr> </thead> <tbody> <tr> <td data-bbox="255 644 367 874">Lewis structure</td> <td data-bbox="367 644 607 874">  </td> <td data-bbox="607 644 846 874">  </td> <td data-bbox="846 644 1093 874">  </td> </tr> </tbody> </table>	Ion	ZrF_5^-	ZrF_6^{2-}	ZrF_7^{3-}	Lewis structure						
Ion	ZrF_5^-	ZrF_6^{2-}	ZrF_7^{3-}									
Lewis structure												
(ii)	<p>ZrF_5^- is trigonal bipyramidal. Three regions of electron density around the equatorial plane will be distributed equally with bond angles of 120°. There will be bond angles of 90° between the equatorial and axial planes.</p> <p>ZrF_6^{2-} is octahedral. Four regions of electron density around the equatorial plane will be distributed equally with bond angles of 90°. There will be bond angles of 90° between the equatorial and axial planes.</p> <p>ZrF_7^{3-} is pentagonal bipyramidal. Five regions of electron density around the equatorial plane will be distributed equally with bond angles of $\sim 72^\circ$. There will be bond angles of 90° between the equatorial and axial planes.</p>											

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship								
TWO (a)(i)	<table border="1"> <thead> <tr> <th>propan-1-ol</th> <th>1-fluoropropane</th> <th>1-aminopropane</th> <th>2-aminopropane</th> </tr> </thead> <tbody> <tr> <td>97.2 °C</td> <td>-2.50 °C</td> <td>48.5 °C</td> <td>31.7 °C</td> </tr> </tbody> </table> <p>All four compounds have roughly similar molar masses and electron clouds, and thus interact through temporary dipole (TD) forces to a similar extent. Three molecules are polar and can form hydrogen bonds where a polarised H atom bonded to an O / N / F atom on one molecule forms strong interactions with a lone pair of electrons on a nearby O / N / F atom.</p> <p>1-fluoropropane has TD forces, as well as a polar C–F bond which has the potential to enable permanent dipole (PD) interactions between molecules. As there is no H atom bonded to an O / N / F atom, there is no hydrogen bonding present, and it will have the lowest boiling point.</p> <p>Propan-1-ol has TD forces, is polar and has PD forces, and has an O–H bond present, which enables the molecules to form hydrogen bonds with other nearby molecules. The hydrogen bonding will be stronger than in the amines as the O–H bond is more polar than an N–H bond, owing to oxygen being more electronegative than nitrogen. It will have the highest boiling point.</p> <p>The two amines both have similar TD and PD forces and form similar hydrogen bonds between molecules due to the N–H bonds present in both compounds. 1-aminopropane molecules, however, have a more linear shape than 2-aminopropane molecules and can pack / interact more closely with nearby molecules, increasing the strength of the TD forces. This gives 1-aminopropane a higher boiling point than 2-aminopropane.</p>	propan-1-ol	1-fluoropropane	1-aminopropane	2-aminopropane	97.2 °C	-2.50 °C	48.5 °C	31.7 °C	<p>Any of the following:</p> <ul style="list-style-type: none"> • Assigns correct boiling points to compounds. • Description of attractive forces between particles. • Describes hydrogen bonding. • Describes temporary dipole forces in heptane. • Identifies any of Compounds A–C. • Proposes one of Compound X or Y. • Explains hydrolysis products. • Calculates moles of NH₃ produced. • Calculates q. • Calculates temperature change. • Identifies enthalpy or entropy changes in reaction. 	<p>A range of the following:</p> <ul style="list-style-type: none"> • Justifies the boiling points for three of the five compounds with clear links to the intermolecular forces present. • Identifies the name and structure for Compounds A – C and proposes logical structures for Compounds X and Y, with limited justification of hydrolysis products. • Calculates the temperature change with minor error and explains some enthalpy or entropy changes that affect the spontaneity of the reaction. 	<p>A range of the following:</p> <ul style="list-style-type: none"> • Justifies the boiling points for all five compounds with clear links to the intermolecular forces present between particles in each substance. • Correctly identifies the name and structure for Compounds A – C, the structure for Compounds X and Y, and justifies why only two molecular products are distilled in each hydrolysis process. • Correctly calculates the temperature change of the beaker and elaborates clearly on the enthalpy and entropy changes that affect the overall spontaneity of the reaction.
propan-1-ol	1-fluoropropane	1-aminopropane	2-aminopropane									
97.2 °C	-2.50 °C	48.5 °C	31.7 °C									
(ii)	<p>Heptane molecules are non-polar and unable to form any permanent dipole forces or hydrogen bonds between molecules. The size of the molecules is large, and thus electron cloud size is large, enabling heptane molecules to form stronger temporary dipole (TD) forces between molecules.</p> <p>While TD forces are the only forces of attraction present in heptane, the total intermolecular forces present are stronger overall than any of the combinations of intermolecular forces present in the four compounds in (i). The attractive forces in heptane thus require the greatest amount of energy to overcome, causing heptane to have the highest boiling point.</p>											

(b)(i)	<p>Compound A 2-aminopropane</p> $\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{NH}_2 \end{array}$ <p>Compound B cyclobutanol</p> $\begin{array}{c} \text{CH}_2 - \text{CH}_2 \\ \quad \\ \text{CH}_2 - \text{CH} - \text{OH} \end{array}$ <p>Compound C methylpropanoic acid</p> $\begin{array}{c} \text{CH}_3 - \text{CH} - \text{COOH} \\ \\ \text{CH}_3 \end{array}$ <p>Compound X</p> $\begin{array}{c} \text{CH}_3 - \text{CH} - \text{C} - \text{O} - \text{CH} - \text{CH}_2 \\ \quad \quad \quad \\ \text{CH}_3 \quad \text{O} \quad \text{CH}_2 - \text{CH}_2 \end{array}$ <p>Compound Y</p> $\begin{array}{c} \text{CH}_3 - \text{CH} - \text{C} - \text{N} - \text{CH} - \text{CH}_3 \\ \quad \quad \quad \\ \text{CH}_3 \quad \text{O} \quad \text{H} \quad \text{CH}_3 \end{array}$			
(ii)	<p>Both compounds in the mixture undergo hydrolysis when heated in acidic and basic conditions. The amide is hydrolysed into a carboxylic acid and amine, while the ester is hydrolysed into a carboxylic acid and alcohol. Due to proton-transfer, the carboxylic acid and alkyl ammonium ions are formed after acidic hydrolysis, while under basic conditions, the amine and carboxylate anions are formed following hydrolysis. The alcohol functional group does not change when the conditions change.</p> <p>When the carboxylic acid is deprotonated, it exists as a carboxylate anion which does not distill from the reaction mixture when heated, due to the strong ion-water attractions that exist. Therefore, under basic conditions, only the alcohol and amine are distilled off as the two molecular products.</p> <p>When the amine is protonated, it exists as an ammonium cation, which again does not distill from the reaction mixture when heated, due to the strong ion-water attractions that exist. Therefore, under acidic conditions, only the alcohol and carboxylic acid are distilled off as the two molecular products.</p>			

<p>(c)(i)</p>	<p> $c(\text{H}_3\text{O}^+) \text{ initial} = 10^{-0.50} = 0.31622 \text{ mol L}^{-1} \times 0.100 \text{ L} = 0.03162 \text{ mol}$ $c(\text{H}_3\text{O}^+) \text{ after reaction} = 10^{-1.21} = 0.061660 \text{ mol L}^{-1} \times 0.100 \text{ L} = 0.006166 \text{ mol}$ $n(\text{H}_3\text{O}^+) \text{ consumed} = 0.03162 \text{ mol} - 0.006166 \text{ mol}$ $= 0.02545 \text{ mol}$ $= n(\text{NH}_3)$ $n(\text{reaction}) = \frac{n(\text{NH}_3)}{2} = \frac{0.02545 \text{ mol}}{2} = 0.01273 \text{ mol}$ $\Delta H = \frac{-q}{n}$ $q = 0.01273 \text{ mol} \times 90.66 \text{ kJ mol}^{-1} = -1.154 \text{ kJ}$ $q = mc\Delta T$ $-1154 \text{ J} = 90.72 \text{ g} \times 0.753 \text{ J }^\circ\text{C}^{-1} \text{ g}^{-1} \times \Delta T$ $\Delta T = \frac{-1154 \text{ J}}{90.72 \text{ g} \times 0.753 \text{ J }^\circ\text{C}^{-1} \text{ g}^{-1}}$ $\Delta T = -16.89 \text{ }^\circ\text{C}$ </p>			
<p>(ii)</p>	<p> The enthalpy change is positive, indicating an endothermic reaction, with heat energy transferred from the surroundings, resulting in a decrease in the entropy of the surroundings. There is a significant difference in state between the solid reactants and the gaseous, liquid, and aqueous products. These changes result in an increase in the entropy of the system, which is favourable. The reaction is spontaneous, thus the positive entropy change for the system must outweigh the negative entropy change for the surroundings. </p>			

Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
THREE (a)	<p> F: $\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\text{Cl}$ G: $\text{HO}-\text{CH}=\text{CH}-\overset{\text{CH}_3}{\underset{\text{CH}_3}{\text{C}}}$ </p> <p> Synthesis of W: $\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\text{Cl} \xrightarrow{\text{NaOH(aq)}} \text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\text{OH}$ $\downarrow \text{H}^+ / \text{MnO}_4^-(\text{aq})$ $\text{CH}_3-\overset{\text{O}}{\parallel}{\text{C}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$ $\xleftarrow{\text{NaBH}_4}$ W: $\text{CH}_3-\underset{\text{OH}}{\text{CH}}-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH}$ </p> <p> Synthesis of X, Y, Z: $\text{HO}-\text{CH}=\text{CH}-\overset{\text{CH}_3}{\underset{\text{CH}_3}{\text{C}}} \xrightarrow{\text{HCl(conc)}} \underset{\text{OH}}{\text{CH}_2}-\underset{\text{Cl}}{\text{CH}}-\text{CH}(\text{CH}_3)_2 + \text{H}-\overset{\text{Cl}}{\text{C}}-\text{CH}_2-\text{CH}(\text{CH}_3)_2$ $\downarrow \text{H}^+ / \text{MnO}_4^-(\text{aq})$ $\underset{\text{O}}{\parallel}{\text{C}}-\underset{\text{Cl}}{\text{CH}}-\text{CH}(\text{CH}_3)_2 \xleftarrow{\text{NaOH(aq)}}$ X: $\text{HO}-\overset{\text{O}}{\parallel}{\text{C}}-\underset{\text{OH}}{\text{CH}}-\text{CH}(\text{CH}_3)_2$ $\downarrow \text{NH}_3(\text{conc})$ Y and Z (enantiomers): $\text{HO}-\overset{\text{O}}{\parallel}{\text{C}}-\underset{\text{NH}_2}{\text{CH}}-\text{CH}(\text{CH}_3)_2$ </p>	<p>Any of the following:</p> <ul style="list-style-type: none"> Compound F identified. Compound G identified. Scheme attempted with some correct reagents / compounds. Concentration of thiosulfate solution. Calculates mass of Vitamin C in original drink powder. Vitamin C after 24 hours calculated with errors. Balanced redox half and full equations for permanganate reaction. Correct oxidant and reductant for one reaction. Assigns correct oxidation numbers to elements. 	<p>A range of the following:</p> <ul style="list-style-type: none"> Determines the identity of compounds F and G and proposes reaction schemes for the synthesis of two of compounds W–Z. Calculates the percentage of Vitamin C remaining after 24 hours with minor error. Correctly identifies the oxidant and reductant in one oxidation-reduction reaction, with clear links to oxidation number changes and balanced half and full equations. 	<p>A range of the following:</p> <ul style="list-style-type: none"> Correctly determines the identity of compounds F and G and proposes a set of reaction schemes, with correct reagents, that would enable synthesis of compounds W–Z. Correctly calculates the concentration of sodium thiosulfate, the mass of Vitamin C in the original drink powder, and the percentage of Vitamin C remaining after 24 hours. Justifies the oxidants and reductants in both oxidation-reduction reactions with clear links to oxidation number changes and balanced half and full equations.

<p>(b)(i)</p>	$n(\text{IO}_3^-) = \frac{0.132 \text{ g}}{214 \text{ g mol}^{-1}}$ $= 6.168 \times 10^{-4} \text{ mol}$ $c(\text{IO}_3^-) = 6.168 \times 10^{-4} \text{ mol L}^{-1}$ $n(\text{IO}_3^-)_{\text{blank}} = 6.168 \times 10^{-4} \times 0.02$ $= 1.2336 \times 10^{-5} \text{ mol}$ $n(\text{I}_2)_{\text{blank}} = 1.2336 \times 10^{-5} \text{ mol} \times 3$ $= 3.700 \times 10^{-5} \text{ mol}$ $n(\text{S}_2\text{O}_3^{2-}) = 3.700 \times 10^{-5} \text{ mol} \times 2$ $= 7.401 \times 10^{-5} \text{ mol}$ $c(\text{S}_2\text{O}_3^{2-}) = \frac{7.401 \times 10^{-5} \text{ mol}}{0.0272 \text{ L}}$ $= 2.7213 \times 10^{-3} \text{ mol L}^{-1}$ $n(\text{S}_2\text{O}_3^{2-})_{\text{immediate}} = 2.7213 \times 10^{-3} \text{ mol L}^{-1} \times 0.01610 \text{ L}$ $= 4.3812 \times 10^{-5} \text{ mol}$ $n(\text{I}_2)_{\text{immediate}} = \frac{4.3812 \times 10^{-5} \text{ mol}}{2}$ $= 2.1906 \times 10^{-5} \text{ mol}$ $n(\text{I}_2)_{\text{reacted}} = 3.700 \times 10^{-5} \text{ mol} - 2.1906 \times 10^{-5} \text{ mol}$ $= 1.5093 \times 10^{-5} \text{ mol}$ $n(\text{ascorbic acid})_{20\text{mL}} = 1.5093 \times 10^{-5} \text{ mol}$ $n(\text{ascorbic acid})_{1000\text{mL}} = 1.5093 \times 10^{-5} \text{ mol} \times 50$ $= 7.5468 \times 10^{-4} \text{ mol}$ $m(\text{ascorbic acid})_{1000\text{mL}} = 7.5468 \times 10^{-4} \text{ mol} \times 176.1 \text{ g mol}^{-1}$ $= \mathbf{0.133 \text{ g}}$ <p>Yes, the nutritional information was accurate.</p> $n(\text{S}_2\text{O}_3^{2-})_{24\text{hr}} = 2.7213 \times 10^{-3} \text{ mol L}^{-1} \times 0.01835 \text{ L}$ $= 4.9935 \times 10^{-5} \text{ mol}$ $n(\text{I}_2)_{24\text{hr}} = \frac{4.9935 \times 10^{-5} \text{ mol}}{2}$ $= 2.49677 \times 10^{-5} \text{ mol}$ $n(\text{I}_2)_{\text{reacted}} = 3.700 \times 10^{-5} \text{ mol} - 2.49677 \times 10^{-5} \text{ mol}$ $= 1.2032 \times 10^{-5} \text{ mol}$ $n(\text{ascorbic acid})_{20\text{mL}} = 1.2032 \times 10^{-5} \text{ mol}$			
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(ii)	$\%(\text{ascorbic acid})_{\text{remaining}} = \frac{1.2032 \times 10^{-5} \text{ mol}}{1.5093 \times 10^{-5} \text{ mol}} \times 100\%$ $= 79.7\%$ $12\text{H}^+ + 10\text{e}^- + 2\text{IO}_3^- \rightarrow \text{I}_2 + 6\text{H}_2\text{O}$ $2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$ <hr/> $6\text{H}^+ + 5\text{I}^- + \text{IO}_3^- \rightarrow 3\text{I}_2 + 3\text{H}_2\text{O}$ <p>The oxidant is IO_3^-. The oxidation number of I is decreasing from +5 in IO_3^- to 0 in I_2, indicating a gain of electrons and reduction. As IO_3^- is reduced, it must be the oxidant in the reaction.</p> <p>The reductant is I^-. The oxidation number of I is increasing from -1 in I^- to 0 in I_2, indicating a loss of electrons and oxidation. As I^- is oxidised, it must be the reductant in the reaction.</p> $\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$ $\text{Mn}^{2+} + 2\text{H}_2\text{O} \rightarrow 2\text{e}^- + \text{MnO}_2 + 4\text{H}^+$ <hr/> $2\text{MnO}_4^- + 3\text{Mn}^{2+} + 2\text{H}_2\text{O} \rightarrow 5\text{MnO}_2 + 4\text{H}^+$ <p>The oxidant is MnO_4^-. The oxidation number of Mn is decreasing from +7 in MnO_4^- to +4 in MnO_2, indicating a gain of electrons and reduction. As MnO_4^- is reduced, it must be the oxidant in the reaction.</p> <p>The reductant is Mn^{2+}. The oxidation number of Mn is increasing from +2 in Mn^{2+} to +4 in MnO_2, indicating a loss of electrons and oxidation. As Mn^{2+} is oxidised, it must be the reductant in the reaction.</p>			
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Q	Evidence	Scholarship Not Awarded	Scholarship	Outstanding Scholarship
<p>FOUR (a)(i)</p> <p>(ii)</p>	<p>The first ionisation enthalpy is the enthalpy change that occurs during the removal of one mole of the least tightly bound electrons from one mole of gaseous atoms.</p> <p>Nitrogen and oxygen are both located in period 2, with valence electrons in the same energy level. Nitrogen is a group 15 element with seven protons, two inner shell electrons, five valence electrons, and the electron arrangement $1s^2, 2s^2, 2p^3$. Oxygen is a group 16 element with eight protons, two inner shell electrons, six valence electrons, and the electron arrangement $1s^2, 2s^2, 2p^4$.</p> <p>The outermost electrons for both atoms are in 2p orbitals, with oxygen atoms having one more electron than nitrogen atoms, causing greater electron-electron repulsion between electrons in those orbitals. Oxygen atoms also have one additional proton in the nucleus, causing a greater nuclear charge, and as both have the same degree of shielding by the inner shell electrons, oxygen atoms have a greater effective nuclear charge.</p> <p>Oxygen atoms have a lower first ionisation enthalpy than nitrogen atoms. In nitrogen atoms, all three 2p orbital electrons are in individual orbitals, while in oxygen atoms, two valence electrons are paired in a 2p orbital. This increased electron-electron repulsion within the paired orbital means that they are in a higher energy position, and thus less energy is required to remove one from the atom. While there is a greater attraction by the nucleus on all the 2p electrons, the electron-electron repulsion within the same orbital is the dominant factor in the first ionisation energies of these elements.</p> <p>Nitride ions, N^{3-}, oxide ions, O^{2-}, and neon atoms, Ne, are all isoelectric, with 10 electrons and the same electron arrangement of $1s^2, 2s^2, 2p^6$.</p> <p>Neon atoms ions have 10 protons, while oxide ions comparatively have only 8 protons, and nitride ions have only 7 protons. As neon atoms have the greatest number of protons, the nuclear charge acting on the valence electrons is greatest, drawing them closest to the nucleus of the atom, and yielding the smallest radii. Similarly oxide ions will be smaller than nitride ions, due to having a higher nuclear charge attracting the electrons closer to the nucleus of the ion.</p>	<p>Any of the following:</p> <ul style="list-style-type: none"> • Defines first ionisation enthalpy. • Describes link between protons, electrons, and ionisation enthalpy. • Electron arrangements for nitrogen and oxygen. • Radii for two particles compared. • Cell potential calculation for one beaker correct. • Colour for all three beakers correct. • Calculates points on either titration curve. 	<p>A range of the following:</p> <ul style="list-style-type: none"> • Justifies the first ionisation enthalpies of nitrogen and oxygen, with limited comparison of the radii of the three particles. • Completes cell potential calculations to determine the final oxidation state of vanadium, and colour, for two solutions. • Completes calculations to draw one titration curve correctly. 	<p>A range of the following:</p> <ul style="list-style-type: none"> • Comprehensively justifies the first ionisation enthalpies for nitrogen and oxygen, and compares the radii of N^{3-}, O^{2-}, and Ne. • Determines the correct colour and oxidation number of vanadium in the three final solutions, with support of cell potential calculations. • Draws the correct shape for both titration curves, with key values correctly calculated, with the pH at the point where the two curves intersect correctly determined.

<p>(b)</p>	<p>With Zinc: $E^\circ_{\text{cell1}} (\text{VO}_2^+ \text{ reduced to } \text{VO}^{2+}) = +1.00 - -0.76 = +1.76 \text{ V} - \text{positive so spontaneous}$ $E^\circ_{\text{cell2}} (\text{VO}^{2+} \text{ reduced to } \text{V}^{3+}) = +0.34 - -0.76 = +1.10 \text{ V} - \text{positive so spontaneous}$ $E^\circ_{\text{cell3}} (\text{V}^{3+} \text{ reduced to } \text{V}^{2+}) = -0.26 - -0.76 = +0.50 \text{ V} - \text{positive so spontaneous}$ Zn can reduce VO_2^+ to V^{2+} meaning the final colour is violet (V^{2+}), and the final oxidation number is +2.</p> <p>With Tin: $E^\circ_{\text{cell1}} (\text{VO}_2^+ \text{ reduced to } \text{VO}^{2+}) = +1.00 - -0.14 = +1.14 \text{ V} - \text{positive so spontaneous}$ $E^\circ_{\text{cell2}} (\text{VO}^{2+} \text{ reduced to } \text{V}^{3+}) = +0.34 - -0.14 = +0.48 \text{ V} - \text{positive so spontaneous}$ $E^\circ_{\text{cell3}} (\text{V}^{3+} \text{ reduced to } \text{V}^{2+}) = -0.26 - -0.14 = -0.12 \text{ V} - \text{negative so not spontaneous}$ Sn can reduce VO_2^+ to V^{3+} meaning the final colour is green (V^{3+}), and the final oxidation number is +3.</p> <p>With Silver: $E^\circ_{\text{cell1}} (\text{VO}_2^+ \text{ reduced to } \text{VO}^{2+}) = +1.00 - +0.80 = +0.20 \text{ V} - \text{positive so spontaneous}$ $E^\circ_{\text{cell2}} (\text{VO}^{2+} \text{ reduced to } \text{V}^{3+}) = +0.34 - +0.80 = -0.46 \text{ V} - \text{negative so not spontaneous}$ Ag can reduce VO_2^+ to VO^{2+} meaning the final colour is blue (VO^{2+}), and the final oxidation number is +4.</p>			
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(c)(i) **NaOH + HCl Titration**

$$[\text{H}_3\text{O}^+] = 10^{-1.04} = \mathbf{0.09120 \text{ mol L}^{-1}}$$

$$n(\text{H}_3\text{O}^+) = 0.09120 \text{ mol L}^{-1} \times 0.0300 \text{ L} = 2.736 \times 10^{-3} \text{ mol} = n(\text{NaOH})$$

$$V(\text{NaOH})_{\text{equivalence}} = n/[\text{NaOH}] = \frac{2.736 \times 10^{-3} \text{ mol}}{0.0886 \text{ mol L}^{-1}} = \mathbf{30.88 \text{ mL}}$$

$$[\text{OH}^-]_{\text{past equivalence}} = 0.0886 \text{ mol L}^{-1} \times \frac{10 \text{ mL}}{70.88 \text{ mL}} = 0.0125 \text{ mol L}^{-1}$$

$$\text{pH}_{\text{past equivalence}} = 14 - \log(0.0125 \text{ mol L}^{-1}) = \mathbf{12.10}$$

NaOH + HOCl Titration

$$[\text{H}_3\text{O}^+] = 10^{-4.16} = \mathbf{6.918 \times 10^{-5} \text{ mol L}^{-1}}$$

$$10^{-7.53} = \frac{(6.918 \times 10^{-5})^2}{[\text{HOCl}]}$$

$$[\text{HOCl}] = 0.1622 \text{ mol L}^{-1}$$

$$n(\text{H}_3\text{O}^+) = 0.1622 \text{ mol L}^{-1} \times 0.0300 \text{ L} = 4.865 \times 10^{-3} \text{ mol}$$

$$V(\text{NaOH})_{\text{equivalence}} = \frac{n(\text{NaOH})}{c(\text{NaOH})} = \frac{4.865 \times 10^{-3} \text{ mol}}{0.0886 \text{ mol L}^{-1}} = \mathbf{54.91 \text{ mL}}$$

$$c(\text{OCl}^-)_{\text{equivalence}} = \frac{4.865 \times 10^{-3} \text{ mol}}{(30.00 + 54.91) / 1000 \text{ L}} = 0.05730 \text{ mol L}^{-1}$$

$$\frac{10^{-14}}{10^{-7.53}} = \frac{[\text{OH}^-]^2}{0.05730 \text{ mol L}^{-1}}$$

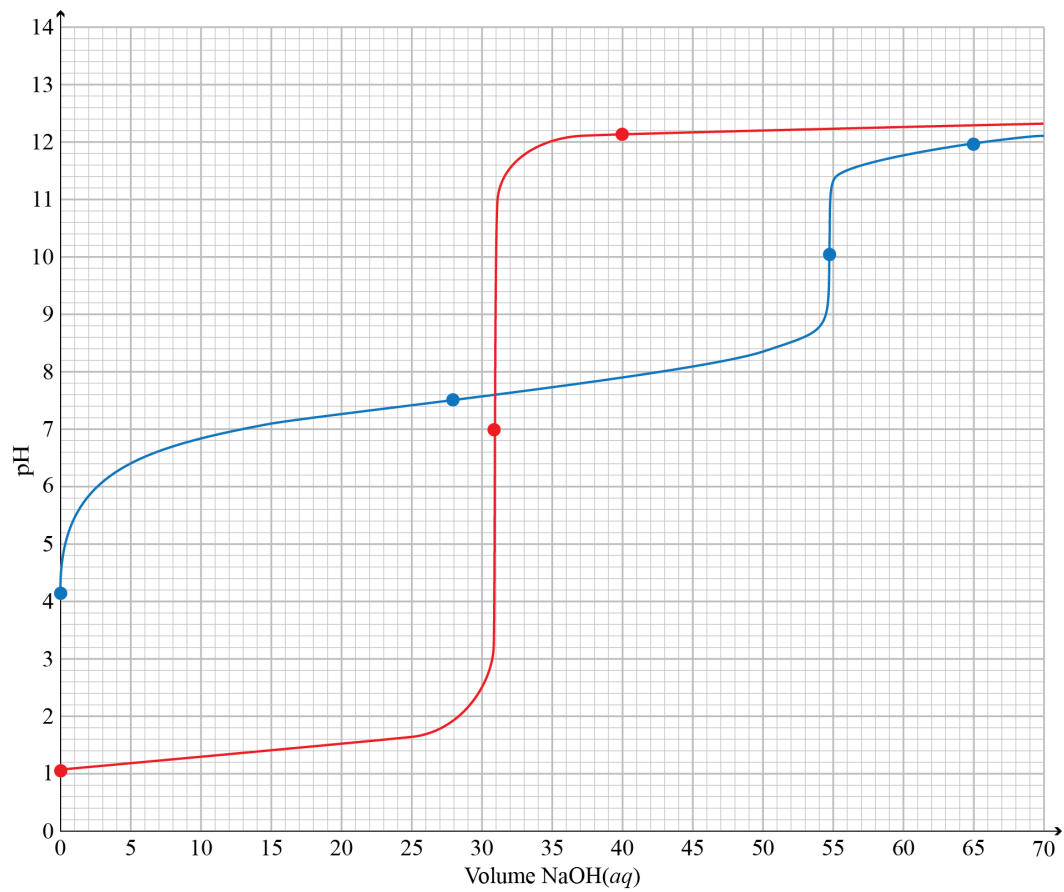
$$[\text{OH}^-] = 1.3933 \times 10^{-4} \text{ mol L}^{-1}$$

$$\text{pH}_{\text{equivalence}} = 14 - \log(1.3933 \times 10^{-4} \text{ mol L}^{-1}) = \mathbf{10.14}$$

$$\text{pH}_{\text{half equivalence}} = \text{p}K_{\text{a}} = \mathbf{7.53}$$

$$[\text{OH}^-]_{\text{past equivalence}} = 0.0886 \text{ mol L}^{-1} \times \frac{10 \text{ mL}}{94.91 \text{ mL}} = 0.00934 \text{ mol L}^{-1}$$

$$\text{pH}_{\text{past equivalence}} = 14 - \log(0.00934 \text{ mol L}^{-1}) = \mathbf{11.97}$$



(ii)	<p>The point of intersection is at 30.88 mL. This is in the buffer region on the weak acid–strong base titration.</p> $n(\text{NaOH}) = cV = 0.0886 \text{ mol L}^{-1} \times 0.03088 \text{ L} = 2.736 \times 10^{-3} \text{ mol}$ $n(\text{HOCl}) = 4.865 \times 10^{-3} \text{ mol} - 2.736 \times 10^{-3} \text{ mol} = 2.129 \times 10^{-3} \text{ mol}$ $n(\text{OCl}^-) = 2.736 \times 10^{-3} \text{ mol}$ $\text{pH} = 7.53 + \log \left(\frac{2.2736 \times 10^{-3}}{2.129 \times 10^{-3}} \right) = \mathbf{7.64}$ <p>OR</p> $10^{-7.53} = \frac{2.736 \times 10^{-3} \text{ mol} \times [\text{H}_3\text{O}^+]}{2.129 \times 10^{-3} \text{ mol}}$ $[\text{H}_3\text{O}^+] = 2.291 \times 10^{-8} \text{ mol L}^{-1}$ <p>pH = 7.64</p>			
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Cut Scores

Scholarship	Outstanding Scholarship
17 – 25	26 – 32