

# A-level Chemistry

Paper 1 (7405/1): Inorganic and Physical Chemistry  
Mark scheme

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7405  
Specimen paper

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Version 0.5

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| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                 | Mark | AO                         | Comments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 01.1     | <p>This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.</p> <p>Level 3<br/>5–6 marks</p> <p>All stages are covered and the explanation of each stage is generally correct and virtually complete.</p> <p>Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.</p> | 6    | 2 AO1a<br>2 AO2a<br>2 AO2b | <p><b>Indicative chemistry content</b></p> <p><b>Stage 1:</b> Electrons round P</p> <ul style="list-style-type: none"> <li>P has 5 electrons in the outside shell</li> <li>With 3 electrons from 3 fluorine, there are a total of 8 electrons in outside shell</li> <li>so 3 bond pairs, 1 non-bond pair</li> </ul> <p><b>Stage 2:</b> Electron pair repulsion theory</p> <ul style="list-style-type: none"> <li>Electron pairs repel as far as possible</li> <li>Lone pair repels more than bonding pairs</li> </ul> <p><b>Stage 3:</b> Conclusions</p> <ul style="list-style-type: none"> <li>Therefore, tetrahedral / trigonal pyramidal shape</li> <li>With angle of 109(.5)° decreased to 107°</li> </ul> |
|          | <p>Level 2<br/>3–4 marks</p> <p>All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.</p> <p>Answer is mainly coherent and shows progression from stage 1 to stage 3.</p>                                                                                          |      |                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|          | <p>Level 1<br/>1–2 marks</p> <p>Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.</p> <p>Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.</p>                                                  |      |                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|          | <p>Level 0<br/>0 marks</p> <p>Insufficient correct chemistry to gain a mark.</p>                                                                                                                                                                                                                                                                                                                                 |      |                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

|      |                                              |   |        |                                                  |
|------|----------------------------------------------|---|--------|--------------------------------------------------|
| 01.2 | $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$              | 1 | AO1a   | Allow correct numbers that are not superscripted |
| 01.3 | Too many electrons in d sub-shell / orbitals | 1 | AO3 1b |                                                  |
| 01.4 | Tetrahedral (shape)<br>109.5°                | 1 | AO2a   | Allow 109°                                       |
|      |                                              | 1 | AO2a   |                                                  |

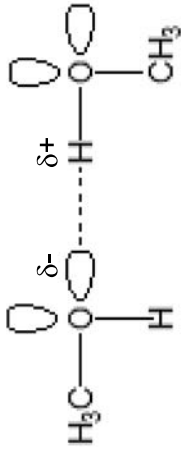
| Question | Marking guidance                                                                                                                                                    | Mark | AO   | Comments                                                                               |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|----------------------------------------------------------------------------------------|
| 02.1     | The number of protons increases (across the period) / nuclear charge increases                                                                                      | 1    | AO1a |                                                                                        |
|          | Therefore, the attraction between the nucleus and electrons increases                                                                                               | 1    | AO1a | Can only score M2 if M1 is correct                                                     |
| 02.2     | S <sub>8</sub> molecules are bigger than P <sub>4</sub> molecules<br>Therefore, van der Waals / dispersion / London forces between molecules are stronger in sulfur | 1    | AO1a | Allow sulfur molecules have bigger surface area and sulfur molecules have bigger $M_r$ |
|          |                                                                                                                                                                     | 1    | AO1a |                                                                                        |
| 02.3     | Sodium oxide contains O <sup>2-</sup> ions<br>These O <sup>2-</sup> ions react with water forming OH <sup>-</sup> ions                                              | 1    | AO2c | O <sup>2-</sup> + H <sub>2</sub> O → 2OH <sup>-</sup> scores M1 and M2                 |
|          |                                                                                                                                                                     | 1    | AO2c |                                                                                        |
| 02.4     | P <sub>4</sub> O <sub>10</sub> + 12OH <sup>-</sup> → 4PO <sub>4</sub> <sup>3-</sup> + 6H <sub>2</sub> O                                                             | 1    | AO2d |                                                                                        |

| Question | Marking Guidance                                                                                                                                                       | Mark | AO     | Comments                                                                                                                                  |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 03.1     | The ions in the ionic substance in the salt bridge move through the salt bridge<br>To maintain charge balance / complete the circuit                                   | 1    | AO1b   |                                                                                                                                           |
|          |                                                                                                                                                                        | 1    | AO1b   |                                                                                                                                           |
| 03.2     | F <sup>-</sup>                                                                                                                                                         | 1    | AO3 1a |                                                                                                                                           |
| 03.3     | $E^{\ominus} \text{SO}_4^{2-} / \text{SO}_2 < E^{\ominus} \text{Br}_2 / \text{Br}^-$                                                                                   | 1    | AO3 1a | Allow correct answer expressed in words, eg electrode potential for sulfate ions / sulfur dioxide is less than that for bromine / bromide |
| 03.4     | 1.23 (V)                                                                                                                                                               | 1    | AO2d   |                                                                                                                                           |
| 03.5     | A fuel cell converts more of the available energy from combustion of hydrogen into kinetic energy of the car / an internal combustion engine wastes more (heat) energy | 1    | AO3 1b |                                                                                                                                           |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Mark | AO     | Comments                |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------|-------------------------|
| 04.1     | Bonds broken = $2(\text{C}=\text{O}) + 3(\text{H}-\text{H}) = 2 \times 743 + 3 \times \text{H}-\text{H}$<br>Bonds formed = $3(\text{C}-\text{H}) + (\text{C}-\text{O}) + 3(\text{O}-\text{H}) = 3 \times 412 + 360 + 3 \times 463$<br>$-49 = [2 \times 743 + 3 \times (\text{H}-\text{H})] - [3 \times 412 + 360 + 3 \times 463]$<br>$3(\text{H}-\text{H}) = -49 - 2 \times 743 + [3 \times 412 + 360 + 3 \times 463] = 1450$<br>$\text{H}-\text{H} = 483 \text{ (kJ mol}^{-1}\text{)}$ | 1    | AO1b   | Both required           |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1    | AO1b   | Both required           |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1    | AO1b   | Allow 483.3(3)          |
| 04.2     | Mean bond enthalpies are not the same as the actual bond enthalpies in $\text{CO}_2$ (and/or methanol and/or water)                                                                                                                                                                                                                                                                                                                                                                     | 1    | AO1b   |                         |
| 04.3     | The carbon dioxide (produced on burning methanol) is used up in this reaction                                                                                                                                                                                                                                                                                                                                                                                                           | 1    | AO3 1b |                         |
| 04.4     | 4 mol of gas form 2 mol<br>At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure<br>This increases the yield of methanol                                                                                                                                                                                                                                                                                                     | 1    | AO2f   |                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1    | AO3 1b |                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1    | AO3 1b |                         |
| 04.5     | Impurities (or sulfur compounds) block the active sites                                                                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO1b   | Allow catalyst poisoned |

| 04.6 | Stage 1: moles of components in the equilibrium mixture<br>$\text{CO}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons \text{CH}_3\text{OH}(\text{g}) + \text{H}_2\text{O}(\text{g})$                                              |   |      | Extended response question                                                                                                                           |
|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|------|------------------------------------------------------------------------------------------------------------------------------------------------------|
|      | Initial moles<br>1.0      3.0      0      0                                                                                                                                                                                              |   |      |                                                                                                                                                      |
|      | Eqm moles<br>(1-0.86)      (3-3×0.86)      0.86      0.86<br>= 0.14      = 0.42                                                                                                                                                          | 1 | AO2f |                                                                                                                                                      |
|      | Stage 2: Partial pressure calculations<br>Total moles of gas = 2.28                                                                                                                                                                      |   |      |                                                                                                                                                      |
|      | Partial pressures = mol fraction × $p_{\text{total}}$                                                                                                                                                                                    |   |      |                                                                                                                                                      |
|      | $p_{\text{CO}_2} = \text{mol fraction} \times p_{\text{total}} = 0.14 \times 500/2.28 = 30.7 \text{ kPa}$<br>$p_{\text{H}_2} = \text{mol fraction} \times p_{\text{total}} = 0.42 \times 500/2.28 = 92.1 \text{ kPa}$                    | 1 | AO2f | M3 is for partial pressures of both reactants<br>Alternative M3 =<br>$pp_{\text{CO}_2} = 0.0614 \times 500$<br>$pp_{\text{H}_2} = 0.1842 \times 500$ |
|      | $p_{\text{CH}_3\text{OH}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500/2.28 = 188.6 \text{ kPa}$<br>$p_{\text{H}_2\text{O}} = \text{mol fraction} \times p_{\text{total}} = 0.86 \times 500/2.28 = 188.6 \text{ kPa}$ | 1 | AO2f | M4 is for partial pressures of both products<br>Alternative M4 =                                                                                     |
|      | Stage 3: Equilibrium constant calculation<br>$K_p = p_{\text{CH}_3\text{OH}} \times p_{\text{H}_2\text{O}} / p_{\text{CO}_2} \times (p_{\text{H}_2})^3$                                                                                  | 1 | AO2f | $pp_{\text{CH}_3\text{OH}} = 0.3772 \times 500$<br>$pp_{\text{H}_2\text{O}} = 0.3772 \times 500$                                                     |
|      | Hence $K_p = 188.6 \times 188.6 / 30.7 \times (92.1)^3 = 1.483 \times 10^{-3} = 1.5 \times 10^{-3}$                                                                                                                                      | 1 | AO1b | Answer must be to 2 significant figures                                                                                                              |
|      | Units = $\text{kPa}^{-2}$                                                                                                                                                                                                                | 1 | AO2f |                                                                                                                                                      |

| Question | Marking guidance                                                                                                                                                                                       | Mark | AO   | Comments                                  |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|-------------------------------------------|
| 05.1     | $\Delta S = 238 + 189 - 214 - 3 \times 131 = -180 \text{ J K}^{-1} \text{ mol}^{-1}$<br>$\Delta G = \Delta H - T\Delta S$<br>$= -49 - \frac{523 \times (-180)}{1000}$<br>$= +45.1 \text{ kJ mol}^{-1}$ | 1    | AO1b | Units essential                           |
|          |                                                                                                                                                                                                        | 1    | AO1a |                                           |
|          |                                                                                                                                                                                                        | 1    | AO1b |                                           |
|          |                                                                                                                                                                                                        | 1    | AO1b |                                           |
| 05.2     | When $\Delta G = 0$ , $\Delta H = T\Delta S$ therefore $T = \Delta H/\Delta S$<br>$= -49 \times 1000/-180 = 272 \text{ (K)}$                                                                           | 1    | AO1b | Mark consequentially to $\Delta S$ in 5.1 |
|          |                                                                                                                                                                                                        | 1    | AO1b |                                           |

|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |   |      |                                                                               |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|------|-------------------------------------------------------------------------------|
| 05.3 | <p>Diagram marks</p>  <p>Diagram of a molecule showing O–H bond and two lone pairs on each oxygen</p> <p>Labels on diagram showing <math>\delta^+</math> and <math>\delta^-</math> charges</p> <p>Diagram showing <math>\delta^+</math> hydrogen on one molecule attracted to lone pair on a second molecule</p> <p>Explanation mark</p> <p>Hydrogen bonding (the name mentioned) is a strong enough force (to hold methanol molecules together in a liquid)</p> | 1 | AO2a | Allow explanation of position of $\delta^+$ and $\delta^-$ charges on H and O |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|------|-------------------------------------------------------------------------------|

| Question | Marking guidance                                                                                                                                                                                                       | Mark        | AO                   | Comments                                                                                                                                   |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 06.1     | Burette<br>Because it can deliver variable volumes                                                                                                                                                                     | 1<br>1      | AO3 1b<br>AO2g       |                                                                                                                                            |
| 06.2     | The change in pH is gradual / not rapid at the end point<br>An indicator would change colour over a range of volumes of sodium hydroxide                                                                               | 1<br>1      | AO3 1a<br>AO3 1a     | Allow indicator would not change colour rapidly / with a few drops of NaOH                                                                 |
| 06.3     | $[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$<br>$K_w = [H^+][OH^-]$ therefore $[OH^-] = K_w / [H^+]$<br>Therefore, $[OH^-] = 1 \times 10^{-14} / 1.58 \times 10^{-12} = 6.33 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$ | 1<br>1<br>1 | AO2h<br>AO2h<br>AO2h | Allow $6.31\text{--}6.33 \times 10^{-3} \text{ (mol dm}^{-3}\text{)}$                                                                      |
| 06.4     | At this point, $[NH_3] = [H^+]$<br>Therefore $K_a = \frac{[H^+]^2}{[NH_4^+]}$<br>$[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$<br>$K_a = (2.51 \times 10^{-5})^2 / 2 = 3.15 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$  | 1<br>1<br>1 | AO2f<br>AO2f<br>AO2f | Allow $3.15\text{--}3.16 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$                                                                     |
| 06.5     | When $[NH_3] = [NH_4^+]$ , $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$<br>Therefore $pH = -\log_{10}(3.15 \times 10^{-10}) = 9.50$                                                                               | 1<br>1      | AO2h<br>AO2h         | Answer using alternative value<br>M2 $pH = -\log_{10}(4.75 \times 10^{-9}) = 8.32$<br>Allow consequential marking based on answer from 6.4 |

| Question | Marking guidance                                                                                                                           | Mark   | AO           | Comments |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------|--------|--------------|----------|
| 07.1     | Y                                                                                                                                          | 1      | AO3 1a       |          |
| 07.2     | X                                                                                                                                          | 1      | AO3 1a       |          |
| 07.3     | Jump in trend of ionisation energies after removal of fifth electron<br>Fits with an element with 5 outer electrons ( $4s^2 3d^3$ ) like V | 1      | AO2b         |          |
| 07.4     | Explanation: Two different colours of solution are observed<br>Because each colour is due to vanadium in a different oxidation state       | 1<br>1 | AO2g<br>AO2g |          |

|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |   |      |                                                                                                                                                                                     |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 07.5 | <p><b>Stage 1:</b> mole calculations in either order<br/> Moles of vanadium = <math>50.0 \times 0.800/1000 = 4.00 \times 10^{-2}</math><br/> Moles of <math>\text{SO}_2 = pV/RT = (98\,000 \times 506 \times 10^{-6})/(8.31 \times 293)</math><br/> <math>= 2.04 \times 10^{-2}</math></p> <p><b>Stage 2:</b> moles of electrons added to <math>\text{NH}_4\text{VO}_3</math><br/> When <math>\text{SO}_2</math> (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change<br/> Moles of electrons released when <math>\text{SO}_2</math> is oxidised = <math>2.04 \times 10^{-2} \times 2</math><br/> <math>= 4.08 \times 10^{-2}</math></p> <p><b>Stage 3 :</b> conclusion<br/> But in <math>\text{NH}_4\text{VO}_3</math> vanadium is in oxidation state 5<br/> <math>4.00 \times 10^{-2}</math> mol vanadium has gained <math>4.08 \times 10^{-2}</math> mol of electrons<br/> therefore 1 mol vanadium has gained <math>4.08 \times 10^{-2}/4.00 \times 10^{-2} = 1</math> mol of electrons to the nearest integer, so new oxidation state is 5–1=4.</p> | 1 | AO2d | <p>Extended response</p> <p>Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.</p> |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2d |                                                                                                                                                                                     |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2d |                                                                                                                                                                                     |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2d |                                                                                                                                                                                     |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2d |                                                                                                                                                                                     |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2b |                                                                                                                                                                                     |
|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 | AO2d |                                                                                                                                                                                     |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                | Mark | AO     | Comments                                |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|--------|-----------------------------------------|
| 08.1     | An electron pair on the ligand<br>Is donated from the ligand to the central metal ion                                                                                                                                                                                                                                                                                           | 1    | AO1a   |                                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO1a   |                                         |
| 08.2     | Blue precipitate<br>Dissolves to give a dark blue solution<br>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \longrightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$<br>$\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 4\text{NH}_3 \longrightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{OH}^- + 2\text{H}_2\text{O}$ | 1    | AO1b   |                                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO1b   |                                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO2d   |                                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO2d   |                                         |
| 08.3     | $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \longrightarrow$<br>$[\text{Cu}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_2(\text{H}_2\text{O})_2]^{2+} + 4\text{NH}_3$                                                                                                                                              | 1    | AO2b   |                                         |
| 08.4     | Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken<br>And the same number of bonds broken and made                                                                                                                                                                                                                                                           | 1    | AO3 1b |                                         |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO3 1b |                                         |
| 08.5     | 3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive<br>Therefore, the free-energy change is negative                                                                                                                                                                                                               | 1    | AO2e   | M2 can only be awarded if M1 is correct |
|          |                                                                                                                                                                                                                                                                                                                                                                                 | 1    | AO2e   |                                         |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                   | Mark             | AO                                   | Comments                                                                                                        |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------------------------|-----------------------------------------------------------------------------------------------------------------|
| 09.1     | Start a clock when KCl is added to water<br>Record the temperature every subsequent minute for about 5 minutes<br>Plot a graph of temperature vs time<br>Extrapolate back to time of mixing = 0 and determine the temperature                                                                                                                                                                                                      | 1<br>1<br>1<br>1 | AO3 2b<br>AO3 2b<br>AO3 2a<br>AO3 2a | Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2 |
| 09.2     | Heat taken in = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6 \text{ J}$<br>Moles of KCl = $5.00/74.6 = 0.0670$<br>Enthalpy change per mole = $+1128.6/0.0670 = 16\,839 \text{ J mol}^{-1}$<br>= $+16.8 \text{ (kJ mol}^{-1}\text{)}$                                                                                                                                                                           | 1<br>1<br>1<br>1 | AO2h<br>AO2h<br>AO2h<br>AO1b         | Max 2 if $14.6^\circ\text{C}$ used as $\Delta T$<br><br>Answer must be given to this precision                  |
| 09.3     | $\Delta H_{\text{solution}} = \Delta H_{\text{lattice}} + \Delta H(\text{hydration of calcium ions}) + 2 \times \Delta H(\text{hydration of chloride ions})$<br>$\Delta H_{\text{lattice}} = \Delta H_{\text{solution}} - \Delta H(\text{hydration of calcium ions}) - 2 \times \Delta H(\text{hydration of chloride ions})$<br>$\Delta H_{\text{lattice}} = -82.9 - (-1650 + 2 \times -364) = +2295 \text{ (kJ mol}^{-1}\text{)}$ | 1<br>1           | AO2f<br>AO2f                         |                                                                                                                 |
| 09.4     | Magnesium ion is smaller than the calcium ion<br>Therefore, it attracts the chloride ion more strongly / stronger ionic bonding                                                                                                                                                                                                                                                                                                    | 1<br>1           | AO2a<br>AO2a                         |                                                                                                                 |

| Question | Marking guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Mark                                                  | AO                                                                                  | Comments                         |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------|
| 10.1     | <p><b>Q</b> is calcium or magnesium bromide</p> <p><b>R</b> is aluminium chloride</p> <p><b>S</b> is iron(III) sulfate</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> | <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p> <p>AO3 1b</p> | Mark this question independently |
| 10.2     | <p><math>\text{Ba}^{2+} + \text{SO}_4^{2-} \longrightarrow \text{BaSO}_4</math></p> <p><math>[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}</math></p> <p><math>2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \longrightarrow</math></p> <p><math>2\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O} + 3\text{CO}_2</math></p> <p><math>[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 4\text{Cl}^- \longrightarrow [\text{FeCl}_4]^- + 6\text{H}_2\text{O}</math></p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p>                   | <p>AO1a</p> <p>AO1a</p> <p>AO1a</p> <p>AO1a</p>                                     |                                  |