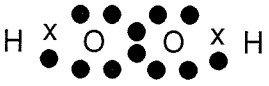
| Abbreviations, annotations and conventions used in the Mark Scheme | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | | |
|---|---|---|---|
| **Question** | **Expected answers** | **Marks** | **Additional guidance** |
| 2 (a) | Oxidation because oxidation state of Hg changes from 0 to +2 so oxidation (1)<br>Reduction because oxidation number of O changes from -1 to -2 (1)<br><br>Or<br><br>Correct identification of all the oxidation numbers (1)<br>Correct identification of oxidation and reduction (1) | 2 | **Allow** ecf for the identification of oxidation and reduction from wrong oxidation numbers |
| (b) | Does not have an incomplete set of d electrons / does not have a partially filled d orbital / does not have a partially filled d sub-shell / ora (1) | 1 | **Allow** use of 3d |
| (c) (i) | Correct 'dot and cross' diagram (1)<br><br>  <br> | 1 | **Ignore** inner shell of oxygen atoms |
| (ii) | Idea that lone pair repulsion is greater than bond pair repulsion / 2 bonded pairs and two lone pairs (1)<br>Bond angle of 104° – 105° (1) | 2 | **Allow** any bond angle between 95 to 106° (1)<br>**Allow** ecf from wrong 'dot and cross' diagram |
| | | **Total = 6** | |

| Abbreviations, annotations and conventions used in the Mark Scheme | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | | |
|---|---|---|---|
| **Question** | **Expected answers** | **Marks** | **Additional guidance** |
| 3 (a) | Mole ratio Fe : Cl = 2.99 : 9.01 (1);<br>Empirical formula = $FeCl_3$ (1);<br>Molecular formula = $Fe_2Cl_6$ (1)<br><br>Alternatively<br><br>Mole ratio of Fe to compound is 2.99 : 1.44 (1)<br>So formula of compound is $Fe_2Cl_x$ (1)<br>Molecular formula = $Fe_2Cl_6$ (1) | 3 | |
| (b) | Simple molecular / simple covalent (1)<br>Idea that if giant structure then it would have a high melting point / idea that simple structure because it melts easily / idea that covalent or molecular chlorides are hydrolysed to give an acidic solution (1) | 2 | **Not** ionic bonding |
| (c) (i) | $(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^6$ (1) | 1 | |
| (ii) | Octahedral shape with some indication of three dimensions (1);<br><br>Bond angle 90° (1) | 2 | **Allow** use of wedges and dotted lines to indicate three dimensions<br>**Allow** three dimensions if at least two bond angles of 90° are shown that clearly demonstrate 3D<br>**If two different bond angles** do not award bond angle mark |
| (iii) | Green / olive green / dark-green / green-blue ppt (1)<br><br>$Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$ (1) | 2 | **Allow** solid instead of precipitate<br>Allow solid or precipitate to be awarded from the state symbol in $Fe(OH)_2(s)$ |

| Abbreviations, annotations and conventions used in the Mark Scheme | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | | |
|---|---|---|---|
| **Question** | **Expected answers** | **Marks** | **Additional guidance** |
| 3 (d) (i) | $Fe(H_2O)_6^{3+} + SCN^- \rightarrow [Fe(H_2O)_5(SCN)]^{2+} + H_2O$ (1) | 1 | |
| (ii) | **Any five from**<br>Known amounts or volumes of $FeCl_3$ and KSCN (and water) are mixed together (1)<br><br>Absorbance of solution is measured (1)<br><br>Idea of a fair test (same overall volume and changing the volumes of the other reagents in a logical way) (1)<br><br>Volumes or amounts of reagents that give maximum absorbance are determined (1)<br><br>Molar ratio of reagents calculated / moles of substances must be calculated (1)<br><br>The molar ratio should be one to one (1) | 5 | **Allow** marks from an appropriate graph |
| (e) (i) | $MnO_2 + 4H^+ + 2Fe^{2+} \rightarrow Mn^{2+} + 2H_2O + 2Fe^{3+}$ (1) | 1 | **Ignore** state symbols |
| (ii) | Moles of $Fe^{2+}$ that reacted with $MnO_2$ = 0.02 – 0.0123 = 0.0077 (1)<br>Mass of $MnO_2$ = 0.00385 x 86.9 = 0.335 (1)<br>% purity = 66.4% (1)<br><br>Alternatively<br><br>Moles of $MnO_2$ in 0.504 = 0.00580<br>So moles of $Fe^{2+}$ that should react with this is 0.0116 (1)<br>Moles of $Fe^{2+}$ that reacted with $MnO_2$ = 0.02 – 0.0123 = 0.0077 (1)<br>% purity = 66.4% (1) | 3 | **Allow** ecf within question<br><br>**Allow** 66.4 – 66.5 |
| | | **Total = 20** | |

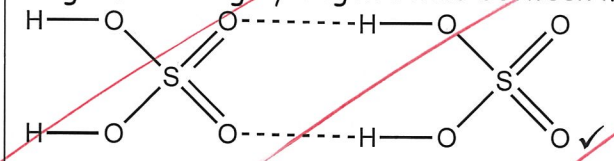
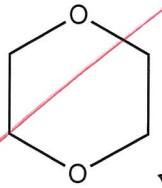
| Abbreviations, annotations and conventions used in the Mark Scheme | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | | |
|---|---|---|---|
| **Question** | **Expected answers** | **Marks** | **Additional guidance** |
| 4 | **Definition – maximum 3 marks**<br><br>$Mg^{2+}(g) + 2Cl^-(g) \rightarrow MgCl_2(s)$ (1)<br>The enthalpy change that accompanies the formation of one mole of a solid (compound) (1);<br>from its constituent gaseous ions (1)<br><br>**Born-Haber cycle – maximum 5 marks**<br><br>Correct formulae on cycle (1)<br>Correct state symbols (1)<br>Use of 2 moles of Cl(g) ie 246 (1)<br>Use of 2 moles of $Cl^-(g)$ 1.e. 698 (1)<br>-2526 kJ $mol^{-1}$ (1)<br><br>**Comparison – maximum 3 marks**<br><br>**Any three from**<br>$Na^+$ has a larger radius than $Mg^{2+}$ / ora (1)<br>$Br^-$ has a larger radius than $Cl^-$ / ora (1)<br>$Na^+$ has a lower charge than $Mg^{2+}$ / ora (1)<br>Strongest attraction is between $Mg^{2+}$ and $Cl^-$ / $MgCl_2$ has the strongest attraction between its ions / ora (1)<br><br>**Or**<br><br>$Na^+$ has a lower charge density than $Mg^{2+}$ / ora (1)<br>$Br^-$ has a lower charge density than $Cl^-$ / ora (1)<br>Strongest attraction between ions which have the highest charge density / $MgCl_2$ has the strongest attraction between its ions / ora (1)<br><br>**And QWC**<br><br>One mark for correct spelling, punctuation and grammar in at least two sentences (1) | 12 | **Allow** marks from an equation<br>**Allow** energy released / energy change<br>**Not** energy required<br>**Allow** ionic compound / salt<br><br>Every formula must have the correct state symbol at least once<br>**Allow** -2403 / -2875 (2)<br>**Allow** -2752 (1)<br>Unit **required**<br><br>Penalise the use of incorrect particle only once within the answer. Penalise it the first time an incorrect particle is mentioned |

| | | |
|---|---|---|
| **Abbreviations, annotations and conventions used in the Mark Scheme** | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | |
| | | |
| **Question** | **Expected Answers** | **Marks** |
| 1 (a) (i) | $H_2$: Exp 2 has 2.5 times $[H_2]$ as Exp 1<br>and rate increases by 2.5 ✓,<br><br>so order = 1 with respect to $H_2$ ✓ | **[2]** |
| | NO: Exp 3 has 3 x [NO] as Exp 2;<br>and rate has increased by $9 = 3^2$ ✓,<br><br>so order = 2 with respect to NO ✓ | **[2]** |
| QWC | At least two complete sentences where the meaning is clear. | **[1]** |
| (ii) | rate = $k[NO]^2 [H_2]$ ✓ | **[1]** |
| (iii) | $k = \frac{\text{rate}}{[NO]^2 [H_2]} / \frac{2.6}{0.10^2 \times 0.20}$ ✓<br><br>= 1300 ✓ units: $dm^6 mol^{-2} s^{-1}$ ✓<br>allow 1 mark for $7.69 \times 10^{-4}$ or $1.3 \times 10^x$ (x not 3) | **[3]** |
| (b) (i) | $1\frac{1}{2}O_2(g) \longrightarrow O_3(g)$/<br>$O_2(g) + \frac{1}{2}O_2(g) \longrightarrow O_3(g)$✓<br><br>NO is a catalyst ✓ as it is (used up in step 1 and) regenerated in step 2/<br>not used up in the overall reaction✓<br>allow 1 mark for '$O/NO_2$ with explanation of regeneration.' | **[3]** |
| (ii) | Rate = $k[NO] [O_3]$ ✓<br>Species in rate equation match those reactants in the slow step / rate determining step ✓ | **[2]** |
| | | **Total: 14** |

| | | |
|---|---|---|
| **Abbreviations, annotations and conventions used in the Mark Scheme** | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>___ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | |
| | | |
| **Question** | **Expected Answers** | **Marks** |
| 2 (a) | $K_c = \frac{[PCl_3]\,[Cl_2]}{[PCl_5]}$ ✓ | [1] |
| (b) (i) | $PCl_5 > 0.3$ mol $dm^{-3}$ ; $PCl_3$ and $Cl_2 < 0.3$ mol $dm^{-3}$ ✓ | [1] |
| (ii) | At start, system is out of equilibrium with too much $PCl_3$ and $Cl_2$ and not enough $PCL_5$ /<br>$\frac{0.3 \times 0.3}{0.3} = 0.3$ is greater than $K_c = 0.245$ mol $dm^{-3}$ ✓ | [1] |
| (c) (i) | $K_c$ does not change as temperature is the same ✓ | [1] |
| (ii) | Fewer moles on left hand side ✓<br>system moves to the left to compensate for increase in pressure by producing less molecules ✓ | [2] |
| (d) (i) | $K_c$ decreases (as more reactants than products)✓ | [1] |
| (ii) | Forward reaction is exothermic/<br>reverse reaction is endothermic ✓<br>equilibrium ⟶ left to oppose increase in energy/<br>because $K_c$ decreases ✓ | [2] |
| (e) (i) | $4PCl_5 + 10MgO \longrightarrow P_4O_{10} + 10MgCl_2$ ✓ | [1] |
| (ii) | 100g $P_4O_{10} = \frac{100}{284}$ / 0.35(2) mol ✓<br>moles $PCl_5$ needed = $4 \times 0.352 = 1.408/1.4$ mol ✓<br>mass $PCl_5$ = 1.4(08) x 208.5 = 293.568 / 294 g/ 291.9 g ✓<br>✓ for use of 284 for $P_4O_{10}$ and 208.5 for $PCl_5$<br>73.4/72.975/72.3 g scores 3 marks (no use of '4' factor)<br>18.35 g from dividing by 4 scores 3 marks | [4] |
| | | **Total: 14** |

| | | |
|---|---|---|
| **Abbreviations, annotations and conventions used in the Mark Scheme** | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | |
| | | |
| **Question** | **Expected Answers** | **Marks** |
| 3 (a) (i) | Ionic product ✓ | [1] |
| (ii) | $K_w = [H^+(aq)]\,[OH^-(aq)]$ ✓ *state symbols not needed* | [1] |
| (b) | moles of HCl = $\frac{5 \times 10^{-3} \times 21.35}{1000} = 1.067 \times 10^{-4}$ mol ✓<br><br>moles of $Ca(OH)_2 = \frac{1.067 \times 10^{-4}}{2} = 5.34 \times 10^{-5}$ mol ✓<br><br>concentration of $Ca(OH)_2$ $= 40 \times 5.34 \times 10^{-5}$<br>$= 2.136 \times 10^{-3}$ mol $dm^{-3}$ ✓<br>2 marks for $4.27 \times 10^{-3}$/ $8.54 \times 10^{-3}$ mol $dm^{-3}$<br>(no factor of 4) | [3] |
| (c) | $[OH^-] = 2 \times 2.7 \times 10^{-3} = 5.4 \times 10^{-3}$ mol $dm^{-3}$ ✓<br>$[H^+(aq)] = \frac{K_w}{[OH^-(aq)]} = \frac{1.0 \times 10^{-14}}{5.4 \times 10^{-3}} = 1.85 \times 10^{-12}$ mol $dm^{-3}$ ✓<br><br>pH = $-\log (1.85 \times 10^{-12})$ = 11.73/11.7 ✓<br><br>ecf is possible for pH mark providing that the $[H^+]$ value has been derived from $K_w/[OH^-]$<br>If pOH method is used, pOH = 2.27. would get 1st mark,<br>pH = 14 - 2.27 = 11.73 gets 2nd mark.<br>Commonest mistake will be to not double $OH^-$ and to use $2.7 \times 10^{-3}$<br>This gives ecf answer of 11.43/11.4, worth 2 marks.<br>pH = 11.13 from dividing by 2: worth 2 marks | [3] |
| (d) | 8 ✓ | [1] |
| | | **Total: 9** |

| | | |
|---|---|---|
| **Abbreviations, annotations and conventions used in the Mark Scheme** | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | |
| | | |
| **Question** | **Expected Answers** | **Marks** |
| 4 (a) | $Ca_3(PO_4)_2 + 2H_2SO_4 \longrightarrow Ca(H_2PO_4)_2 + 2CaSO_4$ ✓ | [1] |
| (b) | $H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$ /<br>$H_2PO_4^-(aq) \rightleftharpoons 2H^+(aq) + PO_4^{3-}(aq)$ ✓<br>(or equivalent with $H_2O$ forming $H_3O^+$) | [1] |
| (c) (i) | $HPO_4^{2-}$ ✓ | [1] |
| (ii) | $H_3PO_4$ ✓ | [1] |
| (iii) | $H_2PO_4^-$ produced $Ca(H_2PO_4)_2$ or on LHS of an attempted equilibrium equation ✓<br>2 equations/equilibria to shown action of buffer ✓✓<br>from:<br>$H_2PO_4^- + H^+ \rightleftharpoons H_3PO_4$ /<br>$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$ /<br>$H_2PO_4^- + OH^- \rightleftharpoons H_2O + HPO_4^{2-}$ /<br>$H^+ + OH^- \rightleftharpoons H_2O$ | [3] |
| | | **Total: 7** |

| | | |
|---|---|---|
| **Abbreviations, annotations and conventions used in the Mark Scheme** | / = alternative and acceptable answers for the same marking point<br>; = separates marking points<br>NOT = answers which are not worthy of credit<br>( ) = words which are not essential to gain credit<br>____ = (underlining) key words which **must** be used to gain credit<br>ecf = error carried forward<br>AW = alternative wording<br>ora = or reverse argument | |
| | | |
| **Question** | **Expected Answers** | **Marks** |
| 5 (a) | Sulphuric acid molecules form hydrogen bonds ✓<br><br>Diagram showing hydrogen bonds between molecules:<br>  <br>or H bond from H-O to O-H (as in water)<br><br>hydrogen bonds break (on boiling) ✓ | [3] |
| (b) | Correct equation for a metal ✓<br>Correct equation for a carbonate ✓<br>Correct equation for a base ✓ | [3] |
| (c) (i) | $SO_4^{2-} \longrightarrow H_2S$: S from +6 to -2 ✓<br>$I^- \longrightarrow I_2$: I from -1 to 0 ✓ | [2] |
| (ii) | $10H^+ + SO_4^{2-} + 8I^- \longrightarrow 4I_2 + H_2S + 4H_2O$ ✓ | [1] |
| (d) | **A**: CO ✓<br>$HCOOH/H_2CO_2 \longrightarrow CO + H_2O$ ✓<br><br>**B**: C ✓<br>$C_{12}H_{22}O_{11} \longrightarrow 12C + 11H_2O$ ✓<br><br>**C**: $C_4H_8O_2$ ✓<br>$2C_2H_6O_2 \longrightarrow C_4H_8O_2 + 2H_2O$ ✓<br><br>Structure:<br>  <br>accept any sensible structure of $C_4H_8O_2$ | [2]<br><br>[2]<br><br>[3] |
| | | **Total: 16** |