

A-LEVEL CHEMISTRY

CHEM5 Energetics, Redox and Inorganic Chemistry
Mark scheme

2420
June 2014

Version 1.1 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from aqa.org.uk

| Question | Marking Guidance | | Comments |
|----------|--|---------------------|--|
| 1(a) | $\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-\text{(g)}$ | 1 | State symbols essential Allow e with no charge This and all subsequent equations must be balanced |
| 1(b) | There is an <u>attraction</u> between the <u>nucleus / protons</u> and (the added) electron(s) Energy is released (when the electron is gained) | 1 1 | Allow product more stable / product has lower energy Allow reaction exothermic / heat released Allow reference to chlorine rather than fluorine Wrong process eg ionisation, boiling CE = 0 |
| 1(c)(i) | Top line: $+ \text{e}^- + \text{F(g)}$ Second line from top : $+ \text{e}^- + \frac{1}{2}\text{F}_2\text{(g)}$ Bottom two lines: $+ \frac{1}{2}\text{F}_2\text{(g)}$ | 1 1 1 | Penalise missing / wrong state symbols one mark only Penalise F1 or Cl one mark only Mark independently Allow e with no charge Penalise each lack of an electron in M1 and M2 each time |

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| 1(c)(ii) | $\frac{1}{2}E(\text{F-F}) + 732 + 289 + +203 = 348 + 955$ $\frac{1}{2}E(\text{F-F}) = 79$ $E(\text{F-F}) = 158 \text{ (kJ mol}^{-1}\text{)}$ | 1 1 | <p>Award one mark (M2) if M1 wrong but answer = M1 × 2 Ignore no units, penalise wrong units but allow kJ mol⁻¹ Any negative answer, CE = 0</p> |
| 1(d)(i) | <p>Experimental lattice enthalpy value allows for / includes covalent interaction / non-spherical ions / distorted ions / polarisation OR AgF has covalent character</p> <p>Theoretical lattice enthalpy value assumes only ionic interaction / point charges / no covalent / perfect spheres / perfectly ionic OR AgF is not perfectly ionic</p> | 1 1 | <p>Allow discussion of AgCl instead of AgF CE = 0 for mention of molecules, atoms, macromolecular, mean bond enthalpy, intermolecular forces (imf), electronegativity</p> |

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| 1(d)(ii) | <p>Chloride ion larger (than fluoride ion) / fluoride ion smaller (than chloride ion)</p> <p>Attraction between Ag^+ and Cl^- weaker / attraction between Ag^+ and F^- stronger</p> | 1 | <p>Penalise chlorine ion once only</p> <p>Allow Cl^- and F^- instead of names of ions</p> <p>Allow chloride ion has smaller charge density / smaller charge to size ratio but penalise mass to charge ratio</p> |
| | | 1 | <p>For M2 Cl^- and F^- can be implied from an answer to M1</p> <p>Mark M1 and M2 independently provided no contradiction</p> <p>CE = 0 for mention of chlorine not chloride ion, molecules, atoms, macromolecular, mean bond enthalpy, intermolecular forces (imf), electronegativity</p> |

| Question | Marking Guidance | Mark | Comments |
|----------|--|------------|---|
| 2(a) | Enthalpy change/ ΔH when 1 mol of a gaseous ion forms aqueous ions | 1 1 | Enthalpy change for $X^{+/-}(g) \rightarrow X^{+/-}(aq)$ scores M1 and M2 Allow heat energy change instead of enthalpy change Allow 1 mol applied to aqueous or gaseous ions If substance / atoms in M1 CE = 0 If wrong process (eg boiling) CE = 0 |
| 2(b) | $\Delta H(\text{solution}) = \Delta H(\text{lattice}) + \sum(\Delta H_{\text{hydration}})$ OR $+77 = +905 - 464 + \Delta H(\text{hydration, Cl}^-)$ OR $\Delta H(\text{hydration, Cl}^-) = +77 - 905 + 464$ $= -364 \text{ (kJ mol}^{-1}\text{)}$ | 1 1 | Allow any one of these three for M1 even if one is incorrect Allow no units, penalise incorrect units, allow kJ mol^{-1} Allow lower case j for J (Joules) +364 does not score M2 but look back for correct M1 |

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| 2(c) | <p>Water is polar / water has Hδ^+</p> <p>(Chloride ion) attracts (the H in) water molecules (note chloride ion can be implied from the question stem)</p> | 1 | |
| 2(d) | <p>$\Delta G = \Delta H - T\Delta S$</p> <p>($\Delta G = 0$ so) $T = \Delta H / \Delta S$</p> <p>$T = 77 \times 1000 / 33 = 2333 \text{ K}$ (allow range 2300 to 2333.3)</p> <p>Above the boiling point of water (therefore too high to be sensible) / water would evaporate</p> | 1 1 1 1 | <p>Look for this equation in 2(d) and/or 2(e); equation can be stated or implied by correct use. Record the mark in 2(d)</p> <p>Units essential, allow lower case k for K (Kelvin) Correct answer with units scores M1, M2 and M3 2.3 (K) scores M1 and M2 but not M3</p> <p>Can only score this mark if M3 >373 K</p> |

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| 2(e) | $\Delta S = (\Delta H - \Delta G)/T \text{ OR } \Delta S = (\Delta G - \Delta H)/-T$ $= ((-15 + 9) \times 1000)/298 \text{ OR } (-15 + 9)/298$ $= -20 \text{ J K}^{-1} \text{ mol}^{-1} \quad \text{OR} \quad -0.020 \text{ kJ K}^{-1} \text{ mol}^{-1}$ <p>(allow -20 to -20.2) (allow -0.020 to -0.0202)</p> | 1 1 1 | <p>Answer with units must be linked to correct M2 For M3, <u>units must be correct</u></p> <p>Correct answer with appropriate units scores M1, M2 and M3 and possibly M1 in 2(d) if not already given</p> <p>Correct answer without units scores M1 and M2 and possibly M1 in 2(d) if not already given</p> <p>Answer of -240 / -0.24 means temperature of 25 used instead of 298 so scores M1 only</p> <p>If ans = +20 / +0.020 assume AE and look back to see if M1 and possibly M2 are scored</p> |
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| Question | Marking Guidance | Mark | Comments |
|----------|--|----------------------------|--|
| 3(a) | <p><u>White</u> powder / solid / ash / smoke</p> <p>Bright / white light / flame</p> <p>$\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$</p> | <p>1</p> <p>1</p> <p>1</p> | <p>Ignore ppt / fumes</p> <p>Allow glows white / glows bright</p> <p>Ignore state symbols</p> <p>Ignore reference to effervescence or gas produced</p> |
| 3(b) | <p>Mg^{2+} / magnesium ion has higher charge than Na^+</p> <p>Attracts <u>delocalised</u> / <u>free</u> / <u>sea of</u> electrons more strongly / metal–metal bonding stronger / metallic bonding stronger</p> | <p>1</p> <p>1</p> | <p>Allow Mg^{2+} ions smaller / greater charge density than Na^+ ions</p> <p>Allow Mg atoms smaller than Na (atoms)</p> <p>Allow magnesium has more delocalised electrons</p> <p>Must be a comparison</p> <p>Ignore reference to nuclear charge</p> <p>Wrong type of bonding (vdW, imf), mention of molecules CE = 0</p> |

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| 3(e) | $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{HSO}_3^-$ | 1 | Products must be ions Allow $\text{SO}_2 + \text{H}_2\text{O} \rightarrow 2\text{H}^+ + \text{SO}_3^{2-}$ Allow two equations showing intermediate formation of H_2SO_3 that ends up as ions Ignore state symbols Allow multiples |
| 3(f) | $\text{P}_4\text{O}_{10} + 6\text{MgO} \rightarrow 2\text{Mg}_3(\text{PO}_4)_2$ OR $\text{P}_4\text{O}_{10} + 6\text{MgO} \rightarrow 6\text{Mg}^{2+} + 4\text{PO}_4^{3-}$ OR $\text{P}_2\text{O}_5 + 3\text{MgO} \rightarrow \text{Mg}_3(\text{PO}_4)_2 \text{ etc}$ | 1 | Ignore state symbols Allow multiples |

| Question | Marking Guidance | Mark | Comments |
|----------|---|-------------------|---|
| 4(a) | <p>Reaction 1</p> <p>ammonia (NH₃) (solution) / NaOH</p> $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+ /$ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ | <p>1</p> <p>2</p> | <p>General principles in marking this question</p> <p>Square brackets are not essential</p> <p>Penalise charges on individual ligands rather than on the whole complex</p> <p>Reagent and species can be extracted from the equation</p> <p>Ignore conditions such as dilute, concentrated, excess</p> <p>Reagent must be a compound NOT just an ion</p> <p>Equations must start from $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ except in 4(b)</p> <p>Mark reagent, species and equation independently</p> <p>Do not allow OH⁻ for reagent</p> <p>Product 1, balanced equation 1</p> <p>Allow either equation for ammonia</p> |
| 4(b) | <p>Reaction 2</p> <p>Ammonia (conc/xs)</p> $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2] + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-$ | <p>1</p> <p>2</p> | <p>Product 1, balanced equation 1</p> <p>Note that the equation must start from the hydroxide $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2]$</p> |

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| 4(c) | <p>Reaction 3 Na_2CO_3 / any identified soluble carbonate / NaHCO_3</p> <p>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + \text{CO}_3^{2-} \rightarrow \text{CuCO}_3 + 6\text{H}_2\text{O}$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + \text{Na}_2\text{CO}_3 \rightarrow \text{CuCO}_3 + 6\text{H}_2\text{O} + 2\text{Na}^+$ OR $2[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{CO}_3^{2-} \rightarrow \text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3 + 11\text{H}_2\text{O} + \text{CO}_2$ OR with NaHCO_3 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + \text{HCO}_3^- \rightarrow \text{CuCO}_3 + 6\text{H}_2\text{O} + \text{H}^+$</p> | 1 2 | Do not allow NaCO_3 or any insoluble carbonate but mark on Product 1, balanced equation 1 |
| 4(d) | <p>Reaction 4 HCl (conc/xs) / NaCl</p> <p>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$</p> | 1 2 | Allow any identified soluble chloride Product 1, balanced equation 1 |

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|----------|--|-------------------|---|
| 5(a) | <p>Pt H₂ H⁺ Fe²⁺ Fe</p> <p>Note, allow one mark only for correct symbol in reverse: Fe Fe²⁺ H⁺ H₂ Pt</p> | 2 | <p>Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary</p> <p>Allow dashed lines for salt bridge</p> <p>Ignore state symbols</p> <p>Ignore 2 if used before H⁺</p> |
| 5(b) | Electron donor | 1 | <p>Allow (species that) loses electrons</p> <p>Do not allow reference to electron pairs</p> |
| 5(c) | <p>Cl₂ / chlorine</p> <p>(Species on RHS / electron donor) has most positive / largest E^\ominus / has highest potential</p> | <p>1</p> <p>1</p> | <p>If M1 blank or incorrect cannot score M2</p> <p>Do not allow reference to e.m.f. or $E(\text{cell})$</p> |
| 5(d)(i) | Cl / chlorine | 1 | |
| 5(d)(ii) | Chlorine +1 to chlorine 0 | 1 | <p>CE if chlorine not identified in 5(d)(i)</p> <p>Allow chlorine +1 to chlorine –1 (in Cl[–])</p> <p>Allow oxidation state decreases by one OR two</p> <p>Allow oxidation state changes by –1 OR –2</p> |

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| 5(e) | $4\text{HOCl} + 4\text{H}^+ + 4\text{OH}^- \rightarrow 2\text{Cl}_2 + \text{O}_2 + 6\text{H}_2\text{O}$ OR $4\text{HOCl} \rightarrow 2\text{Cl}_2 + \text{O}_2 + 2\text{H}_2\text{O}$ | 2 | Allow one mark for any incorrect equation that shows $\text{HOCl} \rightarrow \text{Cl}_2 + \text{O}_2$ Allow multiples Ignore state symbols Penalise one mark for uncancelled or uncombined species (eg $\text{H}_2\text{O} + \text{H}_2\text{O}$ instead of $2\text{H}_2\text{O}$) |
| 5(f)(i) | e.m.f. = $0.40 - (-1.25) = \underline{1.65} \text{ (V)} / \underline{\pm 1.65} \text{ (V)}$ | 1 | Allow -1.65 (V) |
| 5(f)(ii) | $2\text{Zn} + \text{O}_2 \rightarrow 2\text{ZnO}$ | 1 | Allow multiples Ignore state symbols Do not allow uncancelled species If more than one equation given, choose the best |
| 5(f)(iii) | A / stainless lid <u>O₂</u> (electrode) has a more positive E^\ominus / <u>oxygen</u> (electrode) requires / gains electrons from external circuit OR <u>Zinc</u> (electrode) has more negative E^\ominus | 1 1 | If M1 incorrect or blank CE=0 Or reference to the overall equation and a link to electrons going into A Allow oxygen is reduced and reduction occurs at the positive electrode Do not allow reference to e.m.f. or $E(\text{cell})$ |
| 5(f)(iv) | (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated | 1 | Allow danger from production of gas / oxygen produced / hydrogen produced |

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| 6(a)(i) | $\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ / $\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$ | 1 | Any order |
| | $\text{O}_2 + 4\text{e}^- + 2\text{H}_2\text{O} \rightarrow 4\text{OH}^-$ / $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$ | 1 | |
| 6(a)(ii) | Hydrogen (electrode) produces electrons | 1 | Ignore reference to salt bridge Do not allow at negative / positive electrode – must identify hydrogen and oxygen |
| | Oxygen (electrode) accepts electrons | 1 | Allow electrons flow to the oxygen electrode |
| 6(b) | Hydrogen / the fuel / reactants supplied continuously / fed in | 1 | Do not accept oxygen supplied as the only statement |
| 6(c) | In the fuel cell, a greater proportion of the energy available from the hydrogen–oxygen reaction is converted into useful energy | 1 | Allow less energy wasted / more efficient Do not allow reference to safety |
| 6(d) | Hydrogen is flammable / H^+ corrosive / OH^- corrosive / hydrogen explosive | 1 | |

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| 7(a) | <p>In each of P and Q the oxidation state of Cr is +3 / both contain Cr³⁺</p> <p>In each of P and Q the electron configuration is the same / d³ / 3d³</p> <p>Ligands are different</p> <p>Different energies of (d) electrons / different split of (d) electron energy levels / different energy gap of (d) electrons / different (d) orbital energy</p> <p>Different wavelengths / frequencies / energies of light / colours (of light) are absorbed (by the d electrons)</p> <p>Different wavelengths / frequencies / energies of light / colours (of light) are transmitted / reflected</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> | <p>If oxidation states are different lose M1 and M2</p> <p>Do not allow just same number of electrons</p> <p>Reference to emission and/or uv light but not to visible loses M5 and M6</p> |

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| 7(d) | $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3 / V_2O_5 + SO_2 \rightarrow 2VO_2 + SO_3$ | 1 | Allow multiples |
| | $V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5 / 2VO_2 + \frac{1}{2}O_2 \rightarrow V_2O_5$ | 1 | |
| | Acts as a catalyst / lowers the activation energy | 1 | |
| | Speeds up the (overall) reaction (between SO_2 and oxygen) | 1 | |

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| 8(a) | <p>moles of $\text{Cr}_2\text{O}_7^{2-}$ per titration = $21.3 \times 0.0150/1000 = \underline{3.195 \times 10^{-4}}$</p> <p>$(\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{Fe}^{3+})$ $\text{Cr}_2\text{O}_7^{2-}:\text{Fe}^{2+} = 1:6$</p> <p>moles of $\text{Fe}^{2+} = 6 \times 3.195 \times 10^{-4} = 1.917 \times 10^{-3}$</p> <p>original moles in $250 \text{ cm}^3 = 1.917 \times 10^{-3} \times 10 = 1.917 \times 10^{-2}$</p> <p>mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O} = 1.917 \times 10^{-2} \times 277.9 = 5.33 \text{ (g)}$ (allow 5.30 to 5.40)</p> | <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> | <p>If 1:6 ratio incorrect cannot score M2 or M3</p> <p>Process mark for M1 $\times 6$ (also score M2)</p> <p>Process mark for M3 $\times 10$</p> <p>Mark for answer to M4 $\times 277.9$ Answer must be to at least 3 sig figs Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)</p> |
| 8(b) | <p>(Impurity is a) reducing agent / reacts with dichromate / impurity is a version of FeSO_4 with fewer than 7 waters (not fully hydrated)</p> <p>Such that for a given mass, the impurity would react with more dichromate than a similar mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$</p> <p>OR for equal masses of the impurity and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, the impurity would react with more dichromate.</p> | <p>1</p> <p>1</p> | <p>Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}</p> <p>Must compare mass of impurity with mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$</p> |