AQA Qualifications

A-LEVEL
CHEMISTRY

CHEM5 Energetics, Redox and Inorganic Chemistry
Mark scheme

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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.

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Question	Marking Guidance		Comments
1(a)	$Cl(g) + e^- \rightarrow Cl^-(g)$	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)	1	
	Energy is released (when the electron is gained)	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: $+ e^- + F(g)$	1	Penalise missing / wrong state symbols one mark only Penalise Fl or Cl one mark only
	Second line from top : $+ e^- + \frac{1}{2}F_2(g)$	1	Mark independently Allow e with no charge
	Bottom two lines: $+ \frac{1}{2}F_2(g)$	1	Penalise each lack of an electron in M1 and M2 each time

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

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

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)	ΔH(solution) = ΔH(lattice) + $\underline{\Sigma}$(ΔH hydration) OR +77 = +905 – 464 + ΔH(hydration, Cl^-) OR ΔH(hydration, Cl^-) = +77 –905 + 464 = –364 (kJ mol^{-1})	1 1	Allow any one of these three for M1 even if one is incorrect Allow no units, penalise incorrect units, allow kJ mol^- Allow lower case j for J (Joules) +364 does not score M2 but look back for correct M1

2(c)	Water is polar / water has Hδ+	1	
	(Chloride ion) attracts (the H in) water molecules (note chloride ion can be implied from the question stem)	1	Idea that there is a force of <u>attraction</u> between the chloride ion and water Do not allow H bonds / dipole–dipole / vdW / intermolecular but ignore loose mention of bonding Do not allow just chlorine or chlorine atoms / ion Mark independently

2(d)	$\Delta G = \Delta H - T\Delta S$	1	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)
	($\Delta G = 0$ so) $T = \Delta H/\Delta S$	1	
	$T = 77 \times 1000/33 = 2333$ <u>K</u> (allow range 2300 to 2333.3)	1	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
	Above the boiling point of water (therefore too high to be sensible) / water would evaporate	1	Can only score this mark if M3 >373 K

2(e)	$\Delta S = (\Delta H - \Delta G)/T$ OR $\Delta S = (\Delta G - \Delta H)/ -T$	1	
	$= ((-15 + 9) \times 1000)/298$ OR $(-15 + 9)/298$	1	
	$= -20\ \text{J K}^{-1}\ \text{mol}^{-1}$ OR $-0.020\ \text{kJ K}^{-1}\ \text{mol}^{-1}$ (allow –20 to –20.2) (allow –0.020 to –0.0202)	1	Answer with units must be linked to correct M2 For M3, <u>units must be correct</u> Correct answer with appropriate units scores M1, M2 and M3 and possibly M1 in 2(d) if not already given Correct answer without units scores M1 and M2 and possibly M1 in 2(d) if not already given Answer of –240 / –0.24 means temperature of 25 used instead of 298 so scores M1 only If ans = +20 / +0.020 assume AE and look back to see if M1 and possibly M2 are scored

Question	Marking Guidance	Mark	Comments
3(a)	White powder / solid / ash / smoke	1	Ignore ppt / fumes
	Bright / white light / flame	1	Allow glows white / glows bright
	$Mg + H_2O \rightarrow MgO + H_2$	1	Ignore state symbols Ignore reference to effervescence or gas produced
3(b)	Mg^{2+} / magnesium ion has higher charge than Na^+	1	Allow Mg^{2+} ions smaller / greater charge density than Na^+ ions Allow Mg atoms smaller than Na (atoms) Allow magnesium has more delocalised electrons Must be a comparison Ignore reference to nuclear charge
	Attracts delocalised / free / sea of electrons more strongly / metal–metal bonding stronger / metallic bonding stronger	1	Wrong type of bonding (vdW, imf), mention of molecules CE = 0

3(c)	**Structure**: Macromolecular / giant molecule / giant covalent	1	Mark independently
	Bonding: Covalent / giant covalent	1	
	Physical Properties: Any **two** from: Hard Brittle / not malleable Insoluble Non conductor	2	Ignore correct chemical properties Ignore strong, high boiling point, rigid

3(d)	**Formula**: P_4O_{10}	1	Mention of ionic or metallic, can score M1 only
	Structure: Molecular	1	If macromolecular, can score M1 & M3 only
	Bonding: Covalent / shared electron pair	1	
	van der Waals' / dipole–dipole forces <u>between molecules</u>	1	Allow vdW, imf and dipole–dipole imf but do not allow imf alone

3(e)	$SO_2 + H_2O \rightarrow H^+ + HSO_3^-$	1	Products must be ions Allow $SO_2 + H_2O \rightarrow 2H^+ + SO_3^{2-}$ Allow two equations showing intermediate formation of H_2SO_3 that ends up as ions Ignore state symbols Allow multiples

3(f)	$P_4O_{10} + 6MgO \rightarrow 2Mg_3(PO_4)_2$ OR $P_4O_{10} + 6MgO \rightarrow 6Mg^{2+} + 4PO_4^{3-}$ OR $P_2O_5 + 3MgO \rightarrow Mg_3(PO_4)_2$ etc	1	Ignore state symbols Allow multiples

Question	Marking Guidance	Mark	Comments
4(a)	**Reaction 1**		**General principles in marking this question** Square brackets are not essential Penalise charges on individual ligands rather than on the whole complex Reagent and species can be extracted from the equation Ignore conditions such as dilute, concentrated, excess Reagent must be a compound NOT just an ion Equations must start from $[Cu(H_2O)_6]^{2+}$ except in 4(b) Mark reagent, species and equation independently
	ammonia (NH_3) (solution) / NaOH	1	
	$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$ / $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow [Cu(H_2O)_4(OH)_2] + 2H_2O$	2	Do not allow OH^- for reagent Product 1, balanced equation 1 Allow either equation for ammonia
4(b)	**Reaction 2**		
	Ammonia (conc/xs)	1	
	$[Cu(H_2O)_4(OH)_2] + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2H_2O + 2OH^-$	2	Product 1, balanced equation 1 Note that the equation must start from the hydroxide $[Cu(H_2O)_4(OH)_2]$

4(c)	**Reaction 3** Na_2CO_3 / any identified soluble carbonate / $NaHCO_3$	1	Do not allow $NaCO_3$ or any insoluble carbonate but mark on
	$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$ OR $[Cu(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CuCO_3 + 6H_2O + 2Na^+$ OR $2[Cu(H_2O)_6]^{2+} + 2CO_3^{2-} \rightarrow Cu(OH)_2.CuCO_3 + 11H_2O + CO_2$ OR with $NaHCO_3$ $[Cu(H_2O)_6]^{2+} + HCO_3^- \rightarrow CuCO_3 + 6H_2O + H^+$	2	Product 1, balanced equation 1

4(d)	**Reaction 4** HCl (conc/xs) / NaCl	1	Allow any identified soluble chloride
	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$	2	Product 1, balanced equation 1

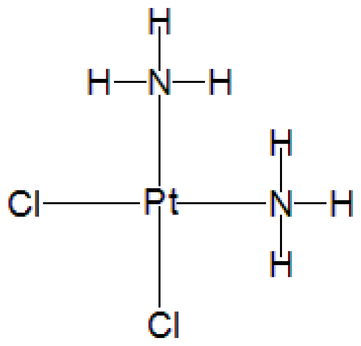
Question	Marking Guidance	Mark	Comments
5(a)	$Pt\|H_2\|H^+\|\|Fe^{2+}\|Fe$ Note, allow one mark only for correct symbol in reverse: $Fe\|Fe^{2+}\|\|H^+\|H_2\|Pt$	2	Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary Allow dashed lines for salt bridge Ignore state symbols Ignore 2 if used before H^+
5(b)	Electron donor	1	Allow (species that) loses electrons Do not allow reference to electron pairs
5(c)	Cl_2 / chlorine (Species on RHS / electron donor) has most positive / largest $E^⦵$ / has highest potential	1 1	If M1 blank or incorrect cannot score M2 Do not allow reference to e.m.f. or *E*(cell)
5(d)(i)	Cl / chlorine	1	
5(d)(ii)	Chlorine +1 to chlorine 0	1	CE if chlorine not identified in 5(d)(i) Allow chlorine +1 to chlorine –1 (in Cl^-) Allow oxidation state decreases by one OR two Allow oxidation state changes by –1 OR –2

5(e)	$4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$ OR $4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$	2	Allow one mark for any incorrect equation that shows $HOCl \rightarrow Cl_2 + O_2$ Allow multiples Ignore state symbols Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ instead of $2H_2O$)
5(f)(i)	e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)	1	Allow –1.65 (V)
5(f)(ii)	$2Zn + O_2 \rightarrow 2ZnO$	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>O_2</u> (electrode) has a more positive <u>$E^\ominus$</u> / <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*(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

Question	Marking Guidance	Mark	Comments
6(a)(i)	$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$ / $H_2 \rightarrow 2H^+ + 2e^-$ $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$ / $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1 1	Any order
6(a)(ii)	Hydrogen (electrode) produces electrons Oxygen (electrode) accepts electrons	1 1	Ignore reference to salt bridge Do not allow at negative / positive electrode – must identify hydrogen and oxygen 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	

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

7(b)	$[Co(NH_3)_6]^{2+}$ + $3NH_2CH_2CH_2NH_2$ $\rightarrow$ $[Co(NH_2CH_2CH_2NH_2)_3]^{2+}$ + $6NH_3$	1	Allow $NH_2C_2H_4NH_2$ and $CH_2NH_2CH_2NH_2$ Allow partial substitution Do not allow en or other formulae for M1 but can score M2
	4 particles form 7 particles / increase in number of particles	1	Allow molecules, entities, ions, moles instead of particles Do not allow atoms Can score M2 if numbers match candidates incorrect equation provided number of particles increases
	disorder / entropy increases / ΔS positive	1	Cannot score M3 if number of particles stated or in equation is the same or decreases
	ΔH is approx. zero / no net change in bond enthalpies	1	Allow same number and type of bonds broken and formed
	ΔG is negative / ΔG <= 0	1	Mark M4 and M5 independently

7(c)(i)		1	Correct displayed structure Must show all three N–H bonds on each N Ignore arrows and lone pairs, attempt to show shape Ignore charges on atoms in structure for M1
	Bond angle 90^o	1	Allow 87 to 93 degrees Allow this angle for any complex with 4 ligands eg if NH_2 or Cl used instead of NH_3
	Charge of zero	1	Award this mark if no charge shown on structure but if charges shown on ligands in M1 must state that overall charge = 0 Allow M3 only if cisplatin is correct OR if trans form OR if NH_3 not displayed OR if NH_2 used instead of NH_3
7(c)(ii)	$(NH_3)_2PtCl_2 + H_2O \rightarrow [(NH_3)_2PtCl(H_2O)]^+ + Cl^-$	1	If formula of cisplatin is incorrect, mark consequentially provided H_2O replaces Cl^- and charge on complex increases by one
7(c)(iii)	Use in small amounts / short bursts / target the application / monitor the patients	1	Allow: Give patient time between doses

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	

Question	Marking Guidance	Mark	Comments
8(a)	moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150/1000 = $\underline{3.195 \times 10^{-4}}$	1	
	($Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$) $Cr_2O_7^{2-}:Fe^{2+}$ = 1:6	1	If 1:6 ratio incorrect cannot score M2 or M3
	moles of Fe^{2+} = 6 × 3.195 × 10^{-4} = 1.917 × 10^{-3}	1	Process mark for M1 × 6 (also score M2)
	original moles in 250 cm^3 = 1.917 × 10^{-3} × 10 = 1.917 × 10^{-2}	1	Process mark for M3 × 10
	mass of $FeSO_4.7H_2O$ = 1.917 × 10^{-2} × 277.9 = 5.33 (g) (allow 5.30 to 5.40)	1	Mark for answer to M4 × 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)
8(b)	(Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)	1	Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}
	Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$ OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.	1	Must compare mass of impurity with mass of $FeSO_4.7H_2O$