



**General Certificate of Education (A-level)
January 2011**

Chemistry

CHEM5

(Specification 2420)

**Unit 5: Energetics, Redox and Inorganic
Chemistry**

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)	<p><u>Enthalpy change</u> for the formation of <u>1 mol</u> of <u>gaseous atoms</u></p> <p>From the <u>element</u> (in its standard state)</p> <p>Enthalpy change to separate <u>1 mol</u> of an <u>ionic</u> lattice/solid/compound</p> <p>Into (its component) <u>gaseous ions</u></p>	1 1 1 1	<p>allow <u>heat energy change</u> for <u>enthalpy change</u></p> <p>ignore reference to conditions</p> <p>enthalpy change not required but penalise energy</p> <p>mark all points independently</p>
1(b)	$\Delta H_L = -\Delta H_f + \Delta H_a + \text{I.E.} + 1/2E(\text{Cl-Cl}) + \text{EA}$ $= +411 + 109 + 494 + 121 - 364$ $= +771 \text{ (kJ mol}^{-1}\text{)}$	1 1 1	<p>Or correct Born-Haber cycle drawn out</p> <p>-771 scores 2/3</p> <p>+892 scores 1/3</p> <p>-51 scores 1/3</p> <p>-892 scores zero</p> <p>+51 scores zero ignore units</p>
1(c)(i)	<p>Ions are perfect spheres (or point charges)</p> <p><u>Only</u> electrostatic attraction/no covalent interaction</p>	1 1	<p>mention of molecules/intermolecular forces/covalent bonds CE = 0</p> <p>allow ionic bonding <u>only</u></p> <p>If mention of atoms CE = 0 for M2</p>
1(c)(ii)	Ionic	1	Allow no covalent character/bonding

1(c)(iii)	Ionic with additional covalent bonding	1	Or has covalent character/partially covalent Allow mention of polarisation of ions or description of polarisation
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Question	Marking Guidance	Mark	Comments
2(a)	Because it is a <u>gas</u> compared with <u>solid</u> carbon Nitrogen is more disordered/random/chaotic/free to move	1 1	Mark independently
2(b)	0 K / -273 C / absolute zero	1	
2(c)	$\Delta G = \Delta H - T\Delta S$	1	Allow $\Delta H = \Delta G - T\Delta S$ $T\Delta S = \Delta H - \Delta G$ $\Delta S = (\Delta H - \Delta G)/T$ Ignore θ in ΔG^θ
2(d)	ΔG is less than or equal to zero ($\Delta G \leq 0$)	1	Allow ΔG is less than zero ($\Delta G < 0$) Allow ΔG is equal to zero ($\Delta G = 0$) Allow ΔG is negative
2(e)	When $\Delta G = 0$ $T = \frac{\Delta H}{\Delta S}$ $\Delta H = +90.4$ $\Delta S = \sum S(\text{products}) - \sum S(\text{reactants})$ $\Delta S = 211.1 - 205.3/2 - 192.2/2 = \underline{12.35}$ $T = (90.4 \times 1000)/12.35 = 7320 \text{ K} / 7319.8 \text{ K}$	1 1 1 1 1	Allow $\Delta H = +90$ Allow 7230 to 7350 <u>K</u> (Note 7.32 K scores 4 marks) Units of temperature essential to score the mark

2(g)	$\Delta H = 1.9 \text{ (kJ mol}^{-1}\text{)}$ $\Delta S = 2.4 - 5.7 = -3.3 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ ΔG is always positive	1 1 1	for M1 and M2 allow no units, penalise wrong units This mark can only be scored if ΔH is +ve and ΔS is -ve
2(f)	Activation energy is high	1	Allow chemical explanation of activation energy Allow needs route with lower activation energy Allow catalyst lowers activation energy

Question	Marking Guidance	Mark	Comments
3(a)	<p>Na₂O ionic</p> <p>Strong forces between ions/strong ionic bonding</p> <p>SiO₂ macromolecular</p> <p>Strong <u>covalent bonds</u> (between atoms)</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>mention of molecules/intermolecular forces/delocalised electrons, CE = 0</p> <p>Allow lots of energy to break bonds provided M1 scored</p> <p>Allow giant molecular/giant covalent.</p> <p>If ions mentioned, CE = 0</p> <p>Allow lots of energy to break <u>covalent</u> bonds</p> <p>If breaking intermolecular forces are mentioned, CE = 0 for M4</p>
3(b)	<p>Higher</p> <p>Li⁺ (or Li ion) smaller than Na⁺</p> <p>Attracts O²⁻ ion more strongly</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Must imply Li⁺ ion</p> <p>Allow Li⁺ has higher charge/size ratio not charge/mass</p> <p>Allow stronger ionic bonding</p> <p>Allow additional attraction due to polarisation in Li₂O</p> <p>M3 can only be scored if M2 gained</p>
3(c)(i)	<p>Molecular</p> <p>Covalent bonds (between P and O)</p>	<p>1</p> <p>1</p>	<p>Do not allow simple covalent BUT simple covalent molecule scores M1 and M2</p> <p>Ignore reference to van der Waals" or dipole-dipole</p>

3(c)(ii)	Weak van der Waals" forces and/or dipole-dipole forces <u>between molecules</u>	1	Allow weak <u>inter-molecular</u> forces – can score "between" molecules in (c)(i) CE = 0 if ionic or macromolecular mentioned in (c)(i) Must state van der Waals" forces are weak OR low energy needed to break van der Waals" forces
3(d)	Allow –1 to +2 $P_4O_{10} + 6H_2O \rightarrow 12H^+ + 4PO_4^{3-}$ (or $4H_3PO_4$) Allow 12 to 14 $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$	1 1 1 1	Allow balanced equations to form HPO_4^{2-} or $H_2PO_4^-$ ignore state symbols Allow $2Na^+ + O^{2-}$ on LHS, $2NaOH$ on RHS, ignore s.s. Mark independently
3(e)	$6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$ Acid-base	1 1	Allow neutralisation, mark independently of M1 Do not allow Acid + Base \rightarrow Salt + Water

Question	Marking Guidance	Mark	Comments
4(a)	Incomplete (or partially filled) d orbitals/sub-shells	1	Do not allow d shell
4(b)	Variable oxidation states	1	
4(c)(i)	$[\text{H}_3\text{N}-\text{Ag}-\text{NH}_3]^+$	1	Allow $[\text{Cl}-\text{Ag}-\text{Cl}]^-$ or similar Cu(I) ion Allow compounds in (i), (ii) and (iii) (eg Cl-Be-Cl) Allow no charge shown, penalise wrong charge(s)
4(c)(ii)	Cis platin drawn out as square planar	1	Allow NiX_4^{2-} etc
4(c)(iii)	$[\text{CuCl}_4]^{2-}$ drawn out as tetrahedral ion	1	Or $[\text{CoCl}_4]^{2-}$ drawn out
4(d)(i)	$\text{SO}_2 + 1/2\text{O}_2 \rightarrow \text{SO}_3$	1	Allow multiples Allow $\text{SO}_2 + 1/2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ ignore state symbols
4(d)(ii)	In a different phase/state (from the reactants)	1	
4(d)(iii)	$\text{V}_2\text{O}_5 + \text{SO}_2 \rightarrow \text{V}_2\text{O}_4 + \text{SO}_3$ $\text{V}_2\text{O}_4 + 1/2\text{O}_2 \rightarrow \text{V}_2\text{O}_5$	1 1	can be in either order allow multiples
4(d)(iv)	Surface area is increased By use of powder or granules or finely divided	1 1	Allow suspending/spreading out onto a mesh or support

4(e)(i)	Forms two or more co-ordinate bonds	1	Allow more than one co-ordinate bond or <u>donates</u> more than 1 electron pair. Do not allow “has more than one electron pair” Allow uses more than one atom to bond (to TM)
4(e)(ii)	Number of product particles > Number of reactant particles Disorder increases or entropy increases (or entropy change is positive)	1 1	Allow molecules/entities instead of particles Penalise incorrect numbers (should be 2→5) Allow ΔG must be negative because $\Delta H = 0$ and ΔS is +ve
4(e)(iii)	6 Cyanide strongly bound to Co (by co-ordinate/covalent bond)	1 1	

Question	Marking Guidance	Mark	Comments
5(a)(i)	Co/Cobalt	1	If Co or Cobalt not given CE = 0
	(+) 4	1	ignore case in symbol for Co
	(+) 3	1	Allow 4 and 3 in either order
5(a)(ii)	$\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$	1	Ignore state symbols Allow e without -ve sign Do not allow equilibrium sign
5(a)(iii)	Platinum is a conductor (Platinum is) unreactive/inert	1	Ignore mention of surface area or catalyst
		1	Allow 2 marks if two properties given on one answer line Apply list principle to contradictions/wrong answers Do not allow platinum resists corrosion
5(a)(iv)	<u>Li</u> reacts with <u>water</u> /forms lithium hydroxide	1	Allow water breaks down (or is electrolysed) on re-charge

5(b)(i)	$\text{Pt} \mid \text{SO}_3^{2-}(\text{aq}), \text{SO}_4^{2-}(\text{aq}) \parallel \text{ClO}_3^{-}(\text{aq}), \text{Cl}^{-}(\text{aq}) \mid \text{Pt}$	2	State symbols and „" not necessary Allow in place of ', ' NOT „," in place of Ignore H^+ and H_2O Deduct one mark for each mistake (e.g. Pt missed twice counts as two mistakes) Allow reverse order for whole cell $\text{Pt} \mid \text{Cl}^{-}, \text{ClO}_3^{-} \parallel \text{SO}_4^{2-}, \text{SO}_3^{2-} \mid \text{Pt}$
5(b)(ii)	$\text{ClO}_3^{-} + 3\text{SO}_3^{2-} \rightarrow \text{Cl}^{-} + 3\text{SO}_4^{2-}$ Oxidising agent ClO_3^{-} Reducing agent SO_3^{2-}	1 1 1	

Question	Marking Guidance	Mark	Comments
6(a)	Brown <u>ppt/solid</u> Gas evolved/effervescence $2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	1 1 2	Must be stated, Allow CO_2 evolved. Do not allow CO_2 alone Correct iron product (1) allow $\text{Fe}(\text{OH})_3$ and in equation Balanced equation (1)
6(b)	White <u>ppt/solid</u> Colourless <u>Solution</u> $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Al}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}$ $\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{OH}^- \rightarrow [\text{Al}(\text{OH})_6]^{3-} + 3\text{H}_2\text{O}$	1 1 1 1	Only award M2 if M1 given or initial ppt mentioned Allow $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Al}(\text{OH})_3 + 6\text{H}_2\text{O}$ Allow formation of $[\text{Al}(\text{H}_2\text{O})_{6-x}(\text{OH})_x]^{(x-3)-}$ where $x=4,5,6$ Allow product without water ligands Allow formation of correct product from $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$
6(c)	Blue <u>ppt/solid</u> (Dissolves to give a) deep blue <u>solution</u> $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$ $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 2\text{OH}^- + 2\text{H}_2\text{O}$	1 1 1 1	Only award M2 if M1 given or initial ppt mentioned Allow $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{OH})_2 + 2\text{NH}_4^+ + 4\text{H}_2\text{O}$ Allow two equations: $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$ then $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2 + 4\text{H}_2\text{O}$ etc Allow $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$
6(d)	Green/yellow <u>solution</u> $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$	1 1	

Question	Marking Guidance	Mark	Comments
7(a)(i)	Ammonia Starts as a pink (solution) Changes to a yellow/straw (solution)	1 1 1	If reagent is missing or incorrect cannot score M3 Allow pale brown Do not allow reference to a precipitate
7(a)(ii)	(dark) brown	1	Do not allow pale/straw/yellow-brown (i.e. these and other shades except for dark brown)
7(b)(i)	Ruby / red-blue / purple / violet / green Green $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{OH}^- \rightarrow [\text{Cr}(\text{OH})_6]^{3-} + 6\text{H}_2\text{O}$ Formula of product	1 1 1 1	Do not allow red or blue If ppt mentioned contradiction/CE =0 If ppt mentioned contradiction/CE =0 Can score this mark in (b) (ii)
7(b)(ii)	$\text{H}_2\text{O}_2 + 2\text{e}^- \rightarrow 2\text{OH}^-$ $2[\text{Cr}(\text{OH})_6]^{3-} + 3\text{H}_2\text{O}_2 \rightarrow 2\text{CrO}_4^{2-} + 8\text{H}_2\text{O} + 2\text{OH}^-$ Yellow	1 2 1	Allow 1 mark out of 2 for a balanced half-equation such as $\text{Cr}(\text{III}) \rightarrow \text{Cr}(\text{VI}) + 3\text{e}^-$ or $\text{Cr}^{3+} + 4\text{H}_2\text{O} \rightarrow \text{CrO}_4^{2-} + 8\text{H}^+ + 3\text{e}^-$ etc also for $2\text{Cr}(\text{III}) + 3\text{H}_2\text{O}_2 \rightarrow 2\text{CrO}_4^{2-}$ (unbalanced) Do not allow orange

7(c)	$2\text{MnO}_4^- + 6\text{H}^+ + 5\text{H}_2\text{O}_2 \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{O}_2$ <p>Moles $\text{MnO}_4^- = (24.35/1000) \times 0.0187 = \underline{4.55 \times 10^{-4}}$</p> <p>Moles $\text{H}_2\text{O}_2 = (4.55 \times 10^{-4}) \times \underline{5/2} = 1.138 \times 10^{-3}$</p> <p>Moles H_2O_2 in 5 cm^3 original $= (1.138 \times 10^{-3}) \times \underline{10} = 0.01138$ Original $[\text{H}_2\text{O}_2] = 0.01138 \times \underline{(1000/5)} = 2.28 \text{ mol dm}^{-3}$ (allow 2.25-2.30)</p>	1 1 1 1 1	if no equation and uses given ratio can score M2, M3, M4 & M5 Note value must be quoted to at least 3 sig. figs. M2 is for 4.55×10^{-4} M3 is for $\times 5/2$ (or $7/3$) Mark consequential on molar ratio from candidate's equation M4 is for $\times 10$ M5 is for consequentially correct answer from (answer to mark 4) $\times (1000/5)$ Note an answer of between 2.25 and 2.30 is worth 4 marks) If candidate uses given ratio $3/7$ max 4 marks: M1: Moles of $\text{MnO}_4^- = \underline{4.55 \times 10^{-4}}$ M2: Moles $\text{H}_2\text{O}_2 = (4.55 \times 10^{-4}) \times \underline{7/3} = 1.0617 \times 10^{-3}$ M3: Moles H_2O_2 in 5 cm^3 original $= (1.0617 \times 10^{-3}) \times 10 = 0.01062$ M4: Original $[\text{H}_2\text{O}_2] = 0.01062 \times (1000/5) = 2.12 \text{ mol dm}^{-3}$ (allow 2.10 to 2.15)
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