



**General Certificate of Education (A-level)
June 2013**

Chemistry

CHEM5

(Specification 2420)

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

Final

Mark Scheme

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1(d)	$\Delta H_L = \Delta H_a(\text{chlorine}) + \Delta H_a(\text{Ag}) + \text{I.E}(\text{Ag}) + \text{EA}(\text{Cl}) - \Delta H_f^\ominus$ $= 121 + 289 + 732 - 364 + 127$ $= (+) 905 \text{ (kJ mol}^{-1}\text{)}$	1 1 1	Or cycle If AgCl_2 , CE=0/3 Allow 1 for -905 Allow 1 for (+)844.5 (use of 121/2) Ignore units even if incorrect.
1(e)	<p>M1 Greater</p> <p>M2 (Born-Haber cycle method allows for additional) covalent interaction</p> <p>OR</p> <p>M1 Equal</p> <p>M2 AgCl is perfectly ionic / no covalent character</p>	1 1	Do not penalise AgCl_2 Allow AgCl has covalent character. Only score M2 if M1 is correct.

Question	Marking Guidance	Mark	Comments
2(a)	<p>Chloride (ions) are smaller (than bromide ions)</p> <p>So the force of attraction between chloride ions and water is stronger</p> <p>Chloride ions attract the $\delta+$ on H of water / electron deficient H on water</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Must state or imply ions.</p> <p>Allow chloride has greater charge density (than bromide).</p> <p>Penalise chlorine ions once only (max 2/3).</p> <p>This can be implied from M1 and M3 but do not allow intermolecular forces.</p> <p>Allow attraction between ions and polar / dipole water.</p> <p>Penalise H^+ (ions) and mention of hydrogen bonding for M3</p> <p>Ignore any reference to electronegativity.</p> <p>Note: If water not mentioned can score M1 only.</p>
2(b)	<p>$\Delta H_{\text{solution}} = \Delta H_{\text{L}} + \Delta H_{\text{hyd}} K^+ \text{ ions} + \Delta H_{\text{hyd}} Br^- \text{ ions} / = 670 - 322 - 335$</p> <p>$= (+)13 \text{ (kJ mol}^{-1}\text{)}$</p>	<p>1</p> <p>1</p>	<p>Allow $\Delta H_{\text{solution}} = \Delta H_{\text{L}} + \Sigma \Delta H_{\text{hyd}}$</p> <p>Ignore units even if incorrect.</p> <p>+13 scores M1 and M2</p> <p>-13 scores 0</p> <p>-16 scores M2 only (transcription error).</p>

2(c)(i)	<p>The entropy change is positive / entropy increases</p> <p>Because 1 mol (solid) → 2 mol (aqueous ions) / no of particles increases</p> <p>Therefore $T\Delta S > \Delta H$</p>	<p>1</p> <p>1</p> <p>1</p>	<p>ΔS is negative loses M1 and M3</p> <p>Allow the aqueous ions are more disordered (than the solid). Mention of atoms / molecules loses M2</p>
2(c)(ii)	<p>Amount of KCl = $5/M_r = 5/74.6 = \underline{0.067(0)}$ mol</p> <p>Heat absorbed = $17.2 \times 0.0670 = 1.153$ kJ</p> <p>Heat absorbed = mass \times sp ht $\times \Delta T$ (1.153×1000) = $20 \times 4.18 \times \Delta T$</p> <p>$\Delta T = 1.153 \times 1000 / (20 \times 4.18) = 13.8$ K</p> <p>$T = 298 - 13.8 = 284(.2)$ K</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>If moles of KCl not worked out can score M3, M4 only (answer to M4 likely to be 205.7 K)</p> <p>Process mark for M1 \times 17.2</p> <p>If calculation uses 25 g not 20, lose M3 only (M4 = 11.04, M5 = 287)</p> <p>If 1000 not used, can only score M1, M2, M3</p> <p>M4 is for a correct ΔT Note that 311.8 K scores 4 (M1, M2, M3, M4).</p> <p>If final temperature is negative, M5 = 0</p> <p>Allow no units for final temp, penalise wrong units.</p>

Question	Marking Guidance	Mark	Comments
3(a)(i)	(At 0 K) particles are stationary / not moving / not vibrating	1	Allow have zero energy.
	No disorder / perfect order / maximum order	1	Ignore atoms / ions. Mark independently.
3(a)(ii)	As T increases, particles start to move / vibrate	1	Ignore atoms / ions. Allow have more energy.
	<u>Disorder / randomness</u> increases / order decreases	1	If change in state, CE = 0
3(a)(iii)	Mark <u>on temperature axis</u> vertically below second 'step'	1	Must be marked as a line, an 'x', T_b or 'boiling point' <u>on the temperature axis</u> .
3(a)(iv)	L ₂ corresponds to boiling / evaporating / condensing / l → g / g → l And L ₁ corresponds to melting / freezing / s → l / l → s	1	There must be a clear link between L ₁ , L ₂ and the change in state.
	Bigger change in <u>disorder</u> for L ₂ / boiling compared with L ₁ / melting	1	M2 answer must be in terms of changes in state and not absolute states eg must refer to change from liquid to gas not just gas. Ignore reference to atoms even if incorrect.

3(b)(i)	$\Delta G = \Delta H - T\Delta S$ $\Delta H = c$ and $(-)\Delta S = m$ / ΔH and ΔS are constants (approx)	1 1	Allow ΔH is the intercept, and $(-)\Delta S$ is the slope / gradient. Can only score M2 if M1 is correct.
3(b)(ii)	Because the entropy change / ΔS is positive / $T\Delta S$ gets bigger	1	Allow $-T\Delta S$ gets more negative.
3(b)(iii)	<u>Not</u> feasible / <u>un</u> feasible / <u>not</u> spontaneous	1	
3(c)(i)	+ 44.5 J K ⁻¹ mol ⁻¹	1	Allow answer without units but if units given they must be correct (including mol ⁻¹)
3(c)(ii)	At 5440 $\Delta H = T\Delta S$ $= 5440 \times 44.5 = 242\ 080$ (OR using given value = $5440 \times 98 = 533\ 120$) $\Delta H = 242\ \text{kJ mol}^{-1}$ (OR using given value $\Delta H = 533\ \text{kJ mol}^{-1}$)	1 1 1	Mark is for answer to (c)(i) $\times 5440$ Mark is for correct answer to M2 with correct units (J mol ⁻¹ or kJ mol ⁻¹) linked to answer. If answer consequentially correct based on (c)(i) except for incorrect sign (eg -242), max 1/3 provided units are correct.

Question	Marking Guidance	Mark	Comments
4(a)	MgO is ionic Melt it (Molten oxide) conducts electricity	1 1 1	If not ionic, CE = 0 If solution mentioned, cannot score M2 or M3 Allow acts as an electrolyte. Cannot score M3 unless M2 is correct.
4(b)	Macromolecular Covalent bonding Water cannot (supply enough energy to) break the covalent bonds / lattice	1 1 1	CE = 0 if ionic, metallic or molecular. Allow giant molecule. Giant covalent scores M1 and M2 Hydration enthalpy < bond enthalpy.
4(c)	(Phosphorus pentoxide's melting point is) lower <u>Molecular</u> with <u>covalent</u> bonding Weak / easily broken / not much energy to break intermolecular forces OR weak vdW / dipole-dipole forces of attraction <u>between molecules</u>	1 1 1	If M1 is incorrect, can only score M2 M2 can be awarded if molecular mentioned in M3 Intermolecular / IMF means same as between molecules.

4(d)	Reagent (water or acid) Equation eg $\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$	1 1	Can be awarded in the equation. $\text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2$ Equations can be ionic but must show all of the reagent eg $\text{H}^+ + \text{Cl}^-$ Simplified ionic equation without full reagent can score M2 only. Allow $6\text{MgO} + \text{P}_4\text{O}_{10} \rightarrow 2\text{Mg}_3(\text{PO}_4)_2$
4(e)	$\text{P}_4\text{O}_{10} + 12\text{NaOH} \rightarrow 4\text{Na}_3\text{PO}_4 + 6\text{H}_2\text{O}$	1	Allow P_2O_5 and acid salts. Must be NaOH not just hydroxide ions.

Question	Marking Guidance	Mark	Comments
5(a)	It has mobile ions / ions can move through it / free ions	1	Do not allow movement of electrons. Allow specific ions provided they are moving but do not react.
5(b)	<u>Chloride</u> ions react with <u>copper ions</u> / <u>Cu²⁺</u> OR [CuCl ₄] ²⁻ formed	1	If incorrect chemistry, mark = 0
5(c)	The Cu ²⁺ ions / CuSO ₄ in the <u>left-hand</u> electrode more concentrated So the reaction of Cu ²⁺ with 2e ⁻ will occur (in preference at) <u>left-hand</u> electrode / Cu → Cu ²⁺ + electrons at <u>right-hand</u> electrode	1 1	Allow converse. Allow <u>left-hand</u> electrode positive / <u>right-hand</u> electrode negative. Also reduction at <u>left-hand</u> electrode / oxidation at <u>right-hand</u> electrode. Also <u>left-hand</u> electrode has oxidising agent / <u>right-hand</u> electrode has reducing agent. Allow <i>E</i> left-hand side > <i>E</i> right-hand side
5(d)	(Eventually) the copper ions / CuSO ₄ in each electrode will be at the same concentration	1	
5(e)(i)	-3.05 (V)	1	Must have minus sign. -3.05 only.

5(e)(ii)	<p>$\text{LiMnO}_2 \rightarrow \text{Li} + \text{MnO}_2$ correct equation</p> <p>Correct direction</p>	<p>1</p> <p>1</p>	<p>Allow 1 for reverse equation. Allow multiples.</p> <p>If Li^+ not cancelled but otherwise correct, max = 1</p> <p>If electrons not cancelled, CE = 0</p> <p>$\text{LiMnO}_2 \rightarrow \text{Li} + \text{MnO}_2$ scores 2</p> <p>$\text{Li}^+ + \text{LiMnO}_2 \rightarrow \text{Li}^+ + \text{Li} + \text{MnO}_2$ scores 1</p> <p>$\text{Li} + \text{MnO}_2 \rightarrow \text{LiMnO}_2$ scores 1</p>
5(e)(iii)	<p>Electricity for recharging the cell may come from power stations <u>burning</u> (fossil) fuel</p>	1	<p>Allow any reference to <u>burning</u> (of carbon-containing) fuels.</p> <p>Note combustion = burning.</p>

Question	Marking Guidance	Mark	Comments
6(a)	$\Delta E = h\nu$ $\nu = \Delta E / h = 2.84 \times 10^{-19} / 6.63 \times 10^{-34} = 4.28 \times 10^{14} \text{ s}^{-1} / \text{Hz}$	1 1	Allow = hf Allow $4.3 \times 10^{14} \text{ s}^{-1} / \text{Hz}$ Answer must be in the range: $4.28 - 4.30 \times 10^{14}$
6(b)	(One colour of) light is absorbed (to excite the electron) The remaining colour / frequency / wavelength / energy is transmitted (through the solution)	1 1	If light emitted, CE = 0 Allow light reflected is the colour that we see.
6(c)	Bigger Blue light would be absorbed OR light that has greater energy than red light would be absorbed OR higher frequency (of light absorbed / blue light) leads to higher ΔE	1 1	Can only score M2 if M1 is correct.

6(d)	Any three from: <ul style="list-style-type: none"> • (Identity of the) metal • Charge (on the metal) / oxidation state / charge on complex • (Identity of the) ligands • Co-ordination number / number of ligands • Shape 	3 max	
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Question	Marking Guidance	Mark	Comments
7(a)	<p>Iron(II): green (solution) gives a green precipitate</p> $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{CO}_3^{2-} \rightarrow \text{FeCO}_3 + 6\text{H}_2\text{O}$ <p>Iron(III):: yellow / purple / brown / lilac / violet (solution) gives a brown / rusty precipitate</p> <p>Effervescence / gas / bubbles</p> $2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{CO}_2 + 3\text{H}_2\text{O}$	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>Apply list principle throughout if extra colours and/or extra observations given. Ignore state symbols in equations.</p> <p>Not blue-green ppt.</p> <p>Must start from $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$</p> <p>Allow equations with Na_2CO_3</p> <p>Allow CO_2 evolved but not just CO_2</p>
7(b)	<p>Copper(II): blue (solution) gives a green / yellow solution OR blue solution (turns) to green / yellow / olive green</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>Cobalt(II): pink (solution) gives a blue solution OR pink solution turns blue</p> $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>Apply list principle throughout if extra colours and/or extra observations given. Ignore state symbols in equations.</p> <p>Allow equations with HCl</p>

