



**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>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<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)	$\Delta H_L = \Delta H_f + \Delta H_a + \text{I.E.} + 1/2E(\text{Cl-Cl}) + \text{EA}$ $= +411 + 109 + 494 + 121 - 364$ $= +771 \text{ (kJ mol}^{-1}\text{)}$	<p>1</p> <p>1</p> <p>1</p>	<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>	<p>1</p> <p>1</p>	<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 $\theta$ in $\Delta G^\theta$
2(d)	$\Delta G$ is less than or equal to zero ( $\Delta G \leq 0$ )	1	Allow $\Delta G$ is less than zero ( $\Delta G < 0$ ) Allow $\Delta G$ is equal to zero ( $\Delta G = 0$ ) Allow $\Delta G$ is negative
2(e)	When $\Delta G = 0$ $T = \underline{\Delta H / \Delta S}$ $\Delta H = +90.4$ $\Delta S = \sum S(\text{products}) - \sum S(\text{reactants})$ $\Delta S = 211.1 - 205.3/2 - 192.2/2 = \underline{12.35}$ $T = (90.4 \times 1000)/12.35 = 7320 \text{ K} / 7319.8 \text{ K}$	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)	$\Delta H = 1.9 \text{ (kJ mol}^{-1}\text{)}$ $\Delta S = 2.4 - 5.7 = -3.3 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ $\Delta G$ is always positive	1 1 1	for M1 and M2 allow no units, penalise wrong units This mark can only be scored if $\Delta H$ is +ve and $\Delta S$ 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)	Na <sub>2</sub> O ionic	1	mention of molecules/intermolecular forces/delocalised electrons, CE = 0
	Strong forces between ions/strong ionic bonding	1	Allow lots of energy to break bonds provided M1 scored
	SiO <sub>2</sub> macromolecular	1	Allow giant molecular/giant covalent. If ions mentioned, CE = 0
	Strong <u>covalent bonds</u> (between atoms)	1	Allow lots of energy to break <u>covalent</u> bonds If breaking intermolecular forces are mentioned, CE = 0 for M4
3(b)	Higher	1	
	Li <sup>+</sup> (or Li ion) smaller than Na <sup>+</sup>	1	Must imply Li <sup>+</sup> ion Allow Li <sup>+</sup> has higher charge/size ratio <b>not</b> charge/mass
	Attracts O <sup>2-</sup> ion more strongly	1	Allow stronger ionic bonding Allow additional attraction due to polarisation in Li <sub>2</sub> O M3 can only be scored if M2 gained
3(c)(i)	Molecular	1	Do not allow simple covalent BUT simple covalent molecule scores M1 and M2
	Covalent bonds (between P and O)	1	Ignore reference to van der Waals' or dipole-dipole

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 <b>OR</b> low energy needed to break van der Waals' forces
3(d)	Allow –1 to +2 $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 12\text{H}^+ + 4\text{PO}_4^{3-}$ (or $4\text{H}_3\text{PO}_4$ )  Allow 12 to 14 $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Na}^+ + 2\text{OH}^-$	1 1  1 1	Allow balanced equations to form $\text{HPO}_4^{2-}$ or $\text{H}_2\text{PO}_4^-$ ignore state symbols  Allow $2\text{Na}^+ + \text{O}^{2-}$ on LHS, $2\text{NaOH}$ on RHS, ignore s.s. Mark independently
3(e)	$6\text{Na}_2\text{O} + \text{P}_4\text{O}_{10} \rightarrow 4\text{Na}_3\text{PO}_4$ 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 $\text{NiX}_4^{2-}$ 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)	$\text{V}_2\text{O}_5 + \text{SO}_2 \rightarrow \text{V}_2\text{O}_4 + \text{SO}_3$	1	can be in either order
	$\text{V}_2\text{O}_4 + 1/2\text{O}_2 \rightarrow \text{V}_2\text{O}_5$	1	allow multiples
4(d)(iv)	Surface area is increased	1	
	By use of powder or granules or finely divided	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 $\Delta G$ must be negative because $\Delta H = 0$ and $\Delta S$ 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	<p>State symbols and ‘,’ not necessary</p> <p>Allow   in place of ‘,’ NOT ‘,’ in place of  </p> <p>Ignore <math>\text{H}^{+}</math> and <math>\text{H}_2\text{O}</math></p> <p>Deduct one mark for each mistake (e.g. Pt missed twice counts as two mistakes)</p> <p>Allow reverse order for whole cell</p> <p><math>\text{Pt} \mid \text{Cl}^{-}, \text{ClO}_3^{-} \parallel \text{SO}_4^{2-}, \text{SO}_3^{2-} \mid \text{Pt}</math></p>
5(b)(ii)	$\text{ClO}_3^{-} + 3\text{SO}_3^{2-} \rightarrow \text{Cl}^{-} + 3\text{SO}_4^{2-}$ Oxidising agent $\text{ClO}_3^{-}$ Reducing agent $\text{SO}_3^{2-}$	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 $\text{CO}_2$ evolved. Do not allow $\text{CO}_2$ 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

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