



**General Certificate of Education (A-level)**  
**January 2012**

**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> when <u>1 mol</u> of an (ionic) compound/lattice (under standard conditions)</p> <p>Is dissociated/broken/separated into its (component) ions</p> <p>The ions being in the <u>gaseous</u> state (at infinite separation)</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Allow heat energy change</p> <p>Mark independently. Ignore any conditions.</p>
1(b)	There is an <u>attractive</u> force between the <u>nucleus</u> of an O atom and an external <u>electron</u> .	1	Allow any statement that implies attraction between the nucleus and an electron
1(c)	<p><math>\text{Mg}^{2+}(\text{g}) + \text{O}(\text{g}) + 2\text{e}^-</math></p> <p><math>\text{Mg}^{2+}(\text{g}) + \text{O}^-(\text{g}) + \text{e}^-</math></p> <p><math>\text{Mg}^{2+}(\text{g}) + \text{O}^{2-}(\text{g})</math></p> <p>First new level for <math>\text{Mg}^{2+}</math> and O above last on L</p> <p>Next level for <math>\text{Mg}^{2+}</math> and <math>\text{O}^-</math> below that</p> <p>Next level for <math>\text{Mg}^{2+}</math> and <math>\text{O}^{2-}</math> above that and also above that for <math>\text{Mg}^{2+}</math> and O</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>Ignore lack of state symbols</p> <p>Penalise incorrect state symbols</p> <p>If levels are not correct allow if steps are in correct order with arrows in the correct direction and correct <math>\Delta H</math> values</p> <p>Allow +124</p> <p>Allow M4 with incorrect number of electrons</p>
1(d)	<p>LE <math>\text{MgO} = 602 + 150 + 736 + 1450 + 248 - 142 + 844</math></p> <p><math>= +3888 \text{ kJ mol}^{-1}</math></p>	<p>1</p> <p>1</p>	<p>Note use of 124 instead of 248 CE=0</p> <p>Allow 1 for -3888</p> <p>Allow no units</p> <p>Penalise wrong units</p>

1(e)	Forms a protective layer/barrier of MgO / MgO prevents oxygen attacking Mg	1	Allow activation energy is (very) high Allow reaction (very) slow
1(f)	$\Delta G = \Delta H - T\Delta S$  $\Delta S = (-602 - (-570)) \times 1000 / 298$ $= -107 \text{ J K}^{-1} \text{ mol}^{-1} / -0.107 \text{ kJ K}^{-1} \text{ mol}^{-1}$	1  1  1	$\Delta S = \frac{(\Delta H - \Delta G)}{T}$  If units not correct or missing, lose mark Allow -107 to -108 +107 with correct units scores max 1/3
1(g)	1 mol of solid and 0.5 mol of gas reactants form 1 mol solid products  System becomes more ordered	1  1	Decrease in number of moles (of gas/species) Allow gas converted into solid Numbers of moles/species, if given, must be correct Allow consequential provided $\Delta S$ is -ve in 1(f) If $\Delta S$ is +ve in 1(f) can only score M1

Question	Marking Guidance	Mark	Comments
2(a)	Standard pressure (100 kPa) (and a stated temperature)	1	Allow standard conditions. Do not allow standard states Allow any temperature Allow 1 bar but not 1atm Apply list principle if extra wrong conditions given Penalise reference to concentrations
2(b)	<u>Hydrogen bonds</u> between water molecules <u>Energy</u> must be supplied in order <u>to break</u> (or loosen) them	1 1	Allow M2 if intermolecular forces mentioned Otherwise cannot score M2 CE = 0/2 if covalent or ionic bonds broken
2(c)	$T = \Delta H / \Delta S$ $= (6.03 \times 1000) / 22.1$ $= 273 \text{ K}$	1 1 1	Allow 272 to 273; units K must be given Allow 0°C if units given 0.273 (with or without units) scores 1/3 only Must score M2 in order to score M3 Negative temperature can score M1 only
2(d)	The heat given out escapes	1	

2(e)	(Red end of white) <u>light</u> (in visible spectrum) <u>absorbed</u> by ice Blue light / observed light is reflected / transmitted / left	1 1	Allow complementary colour to blue absorbed Penalise emission of blue light
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Question	Marking Guidance	Mark	Comments
3(a)(i)	Ionic lattice / solid / giant ionic Strong (electrostatic) forces/attraction between ions	1 1	CE = 0/2 if molecules / IMFs / atoms / metallic Allow strong ionic bonds for M2 only Allow lot of energy to break ionic bonds
3(a)(ii)	Molecular/molecules Weak dipole-dipole and/or van der Waals forces <u>between molecules</u>	1 1	QoL Type of force must be mentioned
3(b)	P <sub>4</sub> O <sub>10</sub> bigger molecule/has larger surface area than SO <sub>2</sub> van der Waals forces <u>between molecules</u> stronger	1 1	Allow M <sub>r</sub> of P <sub>4</sub> O <sub>10</sub> greater than for SO <sub>2</sub> If P <sub>4</sub> O <sub>10</sub> macromolecule/ionic, CE = 0/2 Allow stronger IMF
3(c)	Na <sub>2</sub> O + H <sub>2</sub> O → 2Na <sup>+</sup> + 2OH <sup>-</sup> 14 P <sub>4</sub> O <sub>10</sub> + 6H <sub>2</sub> O → 4H <sub>3</sub> PO <sub>4</sub> 0	1 1 1 1	Allow 2NaOH Allow 12-14 Allow ions Allow -1 to +2
3(d)	6Na <sub>2</sub> O + P <sub>4</sub> O <sub>10</sub> → 4Na <sub>3</sub> PO <sub>4</sub>	1	Allow ionic Allow correct formula of product with atoms in any order

Question	Marking Guidance	Mark	Comments
4(a)	HCl 1.0 mol dm <sup>-3</sup>  (Hydrogen at) 100kPa / 1 bar 298 K	1	Allow H <sub>2</sub> SO <sub>4</sub> 0.5 mol dm <sup>-3</sup> Allow HNO <sub>3</sub> 1.0 mol dm <sup>-3</sup> Allow name or formula Concentration can be given after “conditions”
		1	
		1	
4(b)	Pt / Platinum  Inert / unreactive / does not create a potential difference Conducts electricity / allows electron flow / conducts / conductor	1	Mark on if no answer for M1 If wrong answer for M1, only mark on if electrode is Au, Ag, Pb or Ti
		1	
		1	
4(c)	KCl Does not react with either electrode / solution in electrode Ions can move	1	Allow NaCl, KNO <sub>3</sub> , Na <sub>2</sub> SO <sub>4</sub> etc NOT NH <sub>4</sub> Cl
		1	Allow unreactive / inert
		1	Allow conducts electricity / electrical connection / carries charge Do not allow just connects / completes the circuit Do not allow conducts / carries electrons Mark these independently



4(d)	$\text{Pt} \text{H}_2 \text{H}^+  \text{Fe}^{3+},\text{Fe}^{2+} \text{Pt}$	1	Ignore state symbols Order must be correct   must be correct but allow   instead of , separating $\text{Fe}^{3+}$ from $\text{Fe}^{2+}$ Allow , instead of   separating $\text{H}_2$ and $\text{H}^+$
4(e)(i)	$2\text{Fe}^{3+} + \text{H}_2 \rightarrow 2\text{Fe}^{2+} + 2\text{H}^+$	1	Allow multiples
4(e)(ii)	The $\text{Fe}^{3+}$ ions would be used up / reaction completed	1	Answer must relate to reactants in 4(e)(i) equation if given Allow reactant / reactants used up Do not allow concentration of $\text{Fe}^{3+}$ decreases Allow concentration of $\text{Fe}^{3+}$ falls to zero

Question	Marking Guidance	Mark	Comments
5(a)	$\text{H}_2\text{O}_2$	1	Ignore state symbols
5(b)	$E^\ominus \text{Cl}_2/\text{Cl}^- > E^\ominus \text{O}_2/\text{H}_2\text{O}$  $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow 2\text{Cl}^- + 1/2\text{O}_2 + 2\text{H}^+$	1	Allow potential for chlorine/ $\text{Cl}_2$ greater than for oxygen/ $\text{O}_2$ Allow $1.36 > 1.23$ / E cell = 0.13
		1	Allow multiples Allow + HCl
5(c)	Activation energy is high / light/UV provides the activation energy / light breaks chlorine molecule / Cl–Cl bond	1	If light used to break Cl–Cl bond award 1 mark and ignore product e.g. $\text{Cl}^-$
5(d)	<u>O (-1)</u> (in $\text{H}_2\text{O}_2$ ) Changes to <u>O(-2)</u> (in water)	1	Must give oxidation state of O in $\text{H}_2\text{O}_2$ = -1
		1	Must give oxidation state of O in water = -2 CE = 0/2 if refers to oxidation state of H changing
5(e)	$E^\ominus \text{H}_2\text{O}_2/\text{H}_2\text{O} > E^\ominus \text{O}_2/\text{H}_2\text{O}_2$  $2\text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2\text{H}_2\text{O}$	1	Allow stated in words Allow $1.77 > 0.68$ / E cell = 1.09
		1	Allow multiples $\text{H}^+$ and $\text{e}^-$ must be cancelled

Question	Marking Guidance	Mark	Comments
6(a)	$2\text{MnO}_4^- + 16\text{H}^+ + 5\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$	1 1	For all species correct / moles and species correct but charge incorrect For balanced equation including all charges (also scores first mark)
6(b)	<u>Manganate(VII) ions</u> are <u>coloured</u> (purple) All other reactants and products are <b>not</b> coloured (or too faintly coloured to detect)	1 1	Allow (all) other species are colourless Allow $\text{Mn}^{2+}$ are colourless / becomes colourless / pale pink
6(c)	The catalyst for the reaction is a reaction product Reaction starts off slowly / gradient shallow Then gets faster/rate increases / gradient increases	1 1 1	Allow concentration of $\text{MnO}_4^-$ decreases faster / falls rapidly
6(d)	$\text{Mn}^{2+}$ ions	1	Allow $\text{Mn}^{3+}$ ions
6(e)	$\text{MnO}_4^- + 8\text{H}^+ + 4\text{Mn}^{2+} \rightarrow 5\text{Mn}^{3+} + 4\text{H}_2\text{O}$ $2\text{Mn}^{3+} + \text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Mn}^{2+} + 2\text{CO}_2$	1 1	Allow multiples

Question	Marking Guidance	Mark	Comments
7(a)	Variable oxidation state eg Fe(II) and Fe (III)  (Characteristic) colour (of complexes) eg $\text{Cu}^{2+}(\text{aq})$ / $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ is blue	1 1  1 1	Any correctly identified pair  Allow two formulae showing complexes with different oxidation states even if oxidation state not given  Any correct ion with colour scores M3 and M4 Must show (aq) or ligands OR identified coloured compound (e.g. $\text{CoCO}_3$ )
7(b)	Tetrahedral $[\text{CuCl}_4]^{2-}$ / $[\text{CoCl}_4]^{2-}$  Square planar $(\text{NH}_3)_2\text{PtCl}_2$ Linear $[\text{Ag}(\text{NH}_3)_2]^+$	1 1  1 1 1 1	Any correct complex (Note charges must be correct)  Any correct complex Do not allow linear planar $[\text{AgCl}_2]^-$ etc
7(c)(i)	$[\text{Ca}(\text{H}_2\text{O})_6]^{2+} + \text{EDTA}^{4-} \rightarrow [\text{CaEDTA}]^{2-} + 6\text{H}_2\text{O}$	1	If equation does not show increase in number of moles of particles CE = 0/3 for 7(c)(ii)  If no equation, mark on

7(c)(ii)	2 mol of reactants form 7 mol of products  Therefore disorder increases  Entropy increases / +ve entropy change / free-energy change is negative	1  1  1	Allow more moles/species of products  Allow consequential to 7(c)(i)
7(c)(iii)	$\text{Moles EDTA} = 6.25 \times 0.0532 / 1000 = (3.325 \times 10^{-4})$ $\text{Moles of Ca}^{2+} \text{ in } 1 \text{ dm}^3 = 3.325 \times 10^{-4} \times 1000 / 150 = (2.217 \times 10^{-3})$  $\text{Mass of Ca(OH)}_2 = 2.217 \times 10^{-3} \times 74.1 = 0.164 \text{ g}$	1  1  1	Mark is for $\text{M1} \times 1000 / 150$ <b>OR</b> $\text{M1} \times 74.1$ If ratio of $\text{Ca}^{2+} : \text{EDTA}$ is wrong or $1000 / 150$ is wrong, CE and can score M1 only This applies to the alternative $\text{M1} \times 74.1 \times 1000 / 150$ Answer expressed to 3 sig figs or better Must give unit to score mark Allow 0.164 to 0.165

Question	Marking Guidance	Mark	Comments
8(a)	Electron <u>pair</u> donor	1	Allow lone <u>pair</u> donor
8(b)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$ (Blue solution) gives a (pale) <u>blue precipitate/solid</u>	1 1	M2 only awarded if M1 shows Bronsted-Lowry reaction
8(c)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$ (Blue solution) gives a <u>dark/deep blue solution</u>	1 1	Allow formation in two equations via hydroxide If 8(b) and 8(c) are the wrong way around allow one mark only for each correct equation with a correct observation (max 2/4) M2 only awarded if M1 shows Lewis base reaction
8(d)	(Start with) green (solution) <u>Green precipitate</u> of $\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2$ / $\text{Fe}(\text{OH})_2$ / iron(II) hydroxide  Slowly changes to <u>brown solid</u>  (Iron(II) hydroxide) oxidised by air (to iron(III) hydroxide)	1 1 1 1	Do not allow observation if compound incorrect or not given  Allow red-brown ppt Allow turns brown or if precipitate implied Can only score M3 if M2 scored Allow $\text{Fe}(\text{OH})_2$ oxidised to $\text{Fe}(\text{OH})_3$ by air / $\text{O}_2$ Ignore equations even if incorrect

8(e)(i)	$2[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \rightarrow 2\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3 + 3[\text{H}_3\text{NCH}_2\text{CH}_2\text{NH}_3]^{2+}$ <p>White precipitate</p>	1 1  1	For correct Al species For correct balanced equation Allow equation with formation of $3[\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_3]^+$ from 1 mol $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$
8(e)(ii)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 3\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \rightarrow [\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+} + 6\text{H}_2\text{O}$ <p>Complex with 3 en showing 6 correct bonds from N to Co</p> <p>Co-ordinate bonds (arrows) shown from N to Co</p> $4[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{2+} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_3]^{3+} + 4\text{OH}^-$	1  1   1 1 1	Ignore charge Accept N – N for ligand Ignore incorrect H If C shown, must be 2 per ligand Can only score M3 if M2 correct For Co(III) species For balanced equation (others are possible) Allow $+ \text{O}_2 + 4\text{H}^+ \rightarrow 2\text{H}_2\text{O}$ If en used can score M4 and M5 only If Cu not Co, can only score M2 and M3 Allow $\text{N}_2\text{C}_2\text{H}_8$ in equations