

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

**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>(Enthalpy change to) break the bond in 1 mol of chlorine (molecules)</p> <p>To form (2 mol of) gaseous chlorine atoms / free radicals</p>	<p>1</p> <p>1</p>	<p>Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms Do not allow energy or heat instead of enthalpy, allow heat energy</p> <p>Can score 2 marks for 'Enthalpy change for the reaction': <math>\text{Cl}_2(\text{g}) \rightarrow 2\text{Cl}(\text{g})</math></p> <p>Equation alone gains M2 only</p> <p>Can only score M2 if 1 mol of chlorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy)</p> <p>Any mention of ions, CE = 0</p>
1(b)	(For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing $\frac{1}{2}$ mol Chlorine giving 1 mol of atoms	1	<p>Allow breaking of one bond gives two atoms</p> <p>Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol</p> <p>Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation</p> <p>Any mention of ions, CE = 0</p>
1(c)(i)	$\frac{1}{2}\text{F}_2(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{ClF}(\text{g})$	1	



Question	Marking Guidance	Mark	Comments
2(a)	$\text{MgCl}_2(\text{s}) \rightarrow \text{Mg}^{2+}(\text{g}) + 2\text{Cl}^{-}(\text{g})$	1	
2(b)	The magnesium <u>ion</u> is smaller / has a smaller radius / greater charge density (than the calcium ion)  Attraction between ions / to the chloride ion stronger	1  1	If not ionic or if molecules / IMF / metallic / covalent / bond pair / electronegativity mentioned, CE = 0  Allow ionic bonds stronger  Do not allow any reference to polarisation or covalent character  Mark independently
2(c)	The oxide ion has a greater charge / charge density than the chloride ion  So it attracts the magnesium ion more strongly	1  1	If not ionic or if molecules / IMF / metallic / covalent / bond pair mentioned, CE = 0  Allow oxide ion smaller than chloride ion  Allow ionic bonds stronger  Mark independently
2(d)	$\Delta H_{\text{solution}} = \Delta H_{\text{L}} + \Sigma \Delta H_{\text{hyd}} \text{Mg}^{2+} \text{ ions} + \Sigma \Delta H_{\text{hyd}} \text{Cl}^{-} \text{ ions}$  $-155 = 2493 + \Delta H_{\text{hyd}} \text{Mg}^{2+} \text{ ions} - 2 \times 364$  $\Delta H_{\text{hyd}} \text{Mg}^{2+} \text{ ions} = -155 - 2493 + 728$  $= -1920 (\text{kJ mol}^{-1})$	1  1  1	Allow correct cycle    Ignore units  Allow max 1 for +1920  Answer of + or -1610, CE = 0  Answer of -2284, CE = 0

2(e)	Water is polar / O on water has a delta negative charge  Mg <sup>2+</sup> ion / +ve ion / + charge attracts (negative) O on a water molecule	1  1	Allow <u>O</u> (not water) has lone pairs (can score on diagram)  Allow Mg <sup>2+</sup> attracts lone pair(s) M2 must be stated in words (QoL) Ignore mention of co-ordinate bonds CE = 0 if O <sup>2-</sup> or water ionic or H bonding
2(f)	Magnesium oxide reacts with water / forms Mg(OH) <sub>2</sub>	1	Allow MgO does not dissolve in water / sparingly soluble / insoluble

Question	Marking Guidance	Mark	Comments
3(a)	$\Delta G = \Delta H - T\Delta S$ If $\Delta G$ / expression $\leq 0$ reaction is feasible	1	Or expression $\Delta H - T\Delta S$ must be evaluated
		1	Or any explanation that this expression $\leq 0$ Do not allow just $\Delta G = 0$
3(b)	The molecules become more disordered / random when water changes from a liquid to a gas / evaporates  Therefore the entropy change is positive / Entropy increases  $T\Delta S > \Delta H$  $\Delta G < 0$	1	For M1 must refer to change in state AND increase in disorder
		1	Only score M2 if M1 awarded
		1	Allow M3 for $T$ is large / high (provided M2 is scored)
		1	Mark M3, M4 independently
3(c)(i)	Condition is $T = \Delta H / \Delta S$  $\Delta S = 189 - 205/2 - 131 = -44.5$ ;  $\Delta H = -242$ therefore $T = (-242 \times 1000) / -44.5$  $= 5438 \text{ K}$ (allow 5400 – 5500 K)	1	Units essential (so 5438 alone scores 3 out of 4) 2719K allow score of 2 5.4(K) scores 2 for M1 and M2 only 1646(K) scores 1 for M1 only
		1	
		1	
		1	
3(c)(ii)	It would decompose into <u>hydrogen and oxygen</u> / its elements  Because $\Delta G$ for this reaction would be $\leq 0$	1	Can score this mark if mentioned in M2
		1	Allow the reverse reaction / decomposition is feasible Only score M2 if M1 awarded

3(d)	$\Delta H = T\Delta S$	1	Allow correct substituted values instead of symbols
	$\Delta S = 70-189 = -119\text{JK}^{-1}\text{mol}^{-1}$	1	
	$\Delta H = (-119 \times 373)/1000 = -44.4\text{kJ}(\text{mol}^{-1})$ (allow -44 to -45)	1	Allow -44000 to -45000 J (mol <sup>-1</sup> ) Answer must have correct units of kJ or J



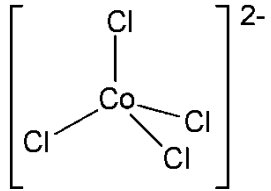
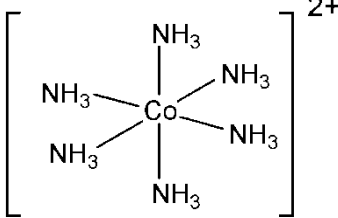
Question	Marking Guidance	Mark	Comments
4(a)	Na <sub>2</sub> O is an ionic <u>lattice</u> / giant ionic / ionic crystal	1	CE= 0 if molecules, atoms, metallic mentioned
	With strong forces of attraction between ions	1	Mention of electronegativity max 1 out of 2 Allow strong ionic bonds/lots of energy to separate ions
4(b)	SO <sub>3</sub> is a larger molecule than SO <sub>2</sub>	1	Allow greater M <sub>r</sub> / surface area
	So <u>van der Waals'</u> forces <u>between molecules</u> are stronger	1	Any mention of ions, CE= 0
4(c)	Ionic	1	Do not allow ionic with covalent character
	Contains <u>O<sup>2-</sup></u> ions / oxide ions	1	Equations of the form O <sup>2-</sup> + H <sup>+</sup> → OH <sup>-</sup> / O <sup>2-</sup> + 2H <sup>+</sup> → H <sub>2</sub> O /
	These / O <sup>2-</sup> ions (accept protons to) form OH <sup>-</sup> / hydroxide / water (must score M2 to gain M3)	1	O <sup>2-</sup> + H <sub>2</sub> O → 2OH <sup>-</sup> score M2 and M3
4(d)(i)	SO <sub>2</sub> + H <sub>2</sub> O → H <sup>+</sup> + HSO <sub>3</sub> <sup>-</sup>	1	Allow 2H <sup>+</sup> + SO <sub>3</sub> <sup>2-</sup> but no ions, no mark Only score (d)(ii) if (d)(i) correct
4(d)(ii)	Reaction is an equilibrium / reversible reaction displaced mainly to the left / partially ionised / dissociated	1	Allow reaction does not go to completion
4(e)	SiO <sub>2</sub> reacts with bases / NaOH / CaO / CaCO <sub>3</sub>	1	Ignore incorrect formulae for silicate

Question	Marking Guidance	Mark	Comments
5(a)	Yellow (solution)	1	Allow equation with H <sub>2</sub> SO <sub>4</sub>
	Orange <u>solution</u>	1	
	$2\text{CrO}_4^{2-} + 2\text{H}^+ \rightarrow \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$	1	
5(b)	Yellow / purple (solution)	1	Allow orange / brown (solution)
	Brown precipitate / solid	1	
	$[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}$	1	
5(c)	Blue (solution)	1	Allow pale blue
	Dark / deep blue <u>solution</u>	1	Ignore any reference to blue ppt
	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$	1	Can be in two equations
5(d)	Colourless (solution)	1	Do not allow grey Do not allow just CO <sub>2</sub>
	White precipitate / solid	1	
	Bubbles / effervescence / gas evolved / given off	1	
	$2[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	1	

Question	Marking Guidance	Mark	Comments
6(a)	Variable / many oxidation states	1	
6(b)	$\text{V}_2\text{O}_5 + \text{SO}_2 \rightarrow \text{V}_2\text{O}_4 + \text{SO}_3$ $\text{V}_2\text{O}_4 + \frac{1}{2}\text{O}_2 \rightarrow \text{V}_2\text{O}_5$	1  1	Equations can be in either order Allow multiples
6(c)(i)	In a different phase / state <u>from reactants</u>	1	
6(c)(ii)	Impurities poison / deactivate the catalyst / block the active sites	1	Allow (adsorbs onto catalyst AND reduces surface area)
6(d)(i)	The catalyst is a reaction product	1	
6(d)(ii)	Mn <sup>2+</sup> / Mn <sup>3+</sup> ion(s)	1	
6(d)(iii)	$4\text{Mn}^{2+} + \text{MnO}_4^- + 8\text{H}^+ \rightarrow 5\text{Mn}^{3+} + 4\text{H}_2\text{O}$ $2\text{Mn}^{3+} + \text{C}_2\text{O}_4^{2-} \rightarrow 2\text{Mn}^{2+} + 2\text{CO}_2$	1  1	Equations can be in either order

Question	Marking Guidance	Mark	Comments
7(a)	Diagram of an $\text{Fe}^{3+}/\text{Fe}^{2+}$ electrode that includes the following parts labelled: Solution containing $\text{Fe}^{2+}$ and $\text{Fe}^{3+}$ ions  Platinum electrode connected to one terminal of a voltmeter  Salt bridge  298 K and 100 kPa / 1 bar  <u>all solutions</u> unit / $1 \text{ mol dm}^{-3}$ concentration	1  1  1  1  1	Must be in the solution of iron ions (one type will suffice)  Do not allow incorrect material for salt bridge and salt bridge must be in the solution (ie it must be shown crossing a meniscus)  Allow zero current / high resistance voltmeter as alternative to M4 or M5  Ignore hydrogen electrode even if incorrect
7(b)	$\text{Cu}^{2+} + \text{Fe} \rightarrow \text{Cu} + \text{Fe}^{2+}$  $\text{Fe} \text{Fe}^{2+}  \text{Cu}^{2+} \text{Cu}$ correct order  Phase boundaries and salt bridge correct, no Pt    Copper electrode	1  1  1    1	Ignore state symbols  Allow $\text{Cu} \text{Cu}^{2+}  \text{Fe}^{2+} \text{Fe}$  Allow single/double dashed line for salt bridge Penalise phase boundary at either electrode end Can only score M3 if M2 correct  Allow any reference to copper

7(c)	$E^\ominus \text{Au}^+/\text{Au} > E^\ominus \text{O}_2/\text{H}_2\text{O}$  So $\text{Au}^+$ ions will oxidise water / water reduces $\text{Au}^+$  $2\text{Au}^+ + \text{H}_2\text{O} \rightarrow 2\text{Au} + 1/2\text{O}_2 + 2\text{H}^+$	1  1  1	Allow $E_{\text{cell/e.m.f.}} = 0.45 \text{ V}$ Allow $1.68 > 1.23$  QoL  Allow multiples
7(d)	$E^\ominus \text{Ag}^+/\text{Ag} > E^\ominus \text{Fe}^{2+}/\text{Fe}$  And $E^\ominus \text{Ag}^+/\text{Ag} > E^\ominus \text{Fe}^{3+}/\text{Fe}^{2+}$  So silver ions will oxidise iron (to iron(II) ions) and then oxidise Fe(II) ions (further to Fe(III) ions producing silver metal)	1  1  1	Allow $E_{\text{cell/e.m.f.}} = 1.24$ Allow $0.80 > -0.44$  Allow $E_{\text{cell/e.m.f.}} = 0.03$ Allow $0.80 > 0.77$  Allow $\text{Ag}^+$ ions will oxidise iron to iron(III)

Question	Marking Guidance	Mark	Comments
8(a)	<p>A ligand is an electron pair / lone pair donor</p> <p>A bidentate ligand donates two electron pairs (to a transition metal ion) from different atoms / two atoms (on the same molecule / ion)</p>	<p>1</p> <p>1</p>	<p>Allow uses lone / electron pair to form a co-ordinate bond</p> <p>QoL</p>
8(b)	<p>CoCl<sub>4</sub><sup>2-</sup> diagram</p> <p>Tetrahedral shape</p> <p>109° 28'</p> <p>[Co(NH<sub>3</sub>)<sub>6</sub>]<sup>2+</sup> diagram</p> <p>Octahedral shape</p> <p>90°</p> <div style="text-align: center;">     </div>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>Four chlorines attached to Co with net 2- charge correct</p> <p>Charge can be placed anywhere, eg on separate formula</p> <p>Penalise excess charges</p> <p>Allow 109° to 109.5°</p> <p>Six ammonia / NH<sub>3</sub> molecules attached to Co with 2+ charge correct</p> <p>Allow 180° if shown clearly on diagram</p> <p>CE= 0 if wrong complex but mark on if only charge is incorrect</p>
8(c)	<p>In different complexes the <u>d</u> orbitals / <u>d</u> electrons (of the cobalt) will have different energies / <u>d</u> orbital splitting will be different</p> <p>Light / energy is absorbed causing an electron to be excited</p> <p>Different frequency / wavelength / colour of light will be absorbed / transmitted / reflected</p>	<p>1</p> <p>1</p> <p>1</p>	

8(d)	<p>1 mol of H<sub>2</sub>O<sub>2</sub> oxidises 2 mol of Co<sup>2+</sup></p> <p><math>M_r \text{ CoSO}_4 \cdot 7\text{H}_2\text{O} = 281</math></p> <p>Moles Co<sup>2+</sup> = <math>9.87/281 = 0.03512</math></p> <p>Moles H<sub>2</sub>O<sub>2</sub> = <math>0.03512/2 = 0.01756</math></p> <p>Volume H<sub>2</sub>O<sub>2</sub> = <math>(\text{moles} \times 1000)/\text{concentration}</math>  <math>= 0.01756 \times 1000/5.00</math>  <math>= 3.51 \text{ cm}^3 / (3.51 \times 10^{-3} \text{ dm}^3)</math></p>	1 1 1 1    1	<p>Or <math>\text{H}_2\text{O}_2 + 2\text{Co}^{2+} \rightarrow 2\text{OH}^- + 2\text{Co}^{3+}</math></p> <p>If <math>M_r</math> wrong, max 3 for M1, M4, M5</p> <p>M4 is method mark for (M3)/2 (also scores M1)</p> <p>Units essential for answer</p> <p>M5 is method mark for (M4) x 1000/5 Allow 3.4 to 3.6 cm<sup>3</sup></p> <p>If no 2:1 ratio or ratio incorrect Max 3 for M2, M3 &amp; M5</p> <p>Note : Answer of 7 cm<sup>3</sup> scores 3 for M2, M3, M5 (and any other wrong ratio max 3)</p> <p>Answer of 16.8 cm<sup>3</sup> scores 3 for M1, M4, M5 (and any other wrong <math>M_r</math> max 3)</p> <p>Answer of 33.5 cm<sup>3</sup> scores 1 for M5 only (so wrong <math>M_r</math> AND wrong ratio max 1)</p>
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