



**General Certificate of Education  
June 2010**

**Chemistry                      CHEM5**

**Energetics, Redox and Inorganic Chemistry**

<b><i>Mark Scheme</i></b>
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)		$\text{CaF}_2(\text{s}) \rightarrow \text{Ca}^{2+}(\text{g}) + 2\text{F}^{-}(\text{g})$	1	
1	(b)	(i)	Enthalpy change for formation of 1 mol of substance	1	Allow <u>heat energy change</u> , NOT energy
			From its elements	1	
			Reactants and products/all substances in their standard states	1	Or normal states at 298 K, 1 bar (100 kPa)
1	(b)	(ii)	$\text{Ca}(\text{s}) + \text{F}_2(\text{g}) \rightarrow \text{CaF}_2(\text{s})$	1	
1	(b)	(iii)	$\Delta H_f(\text{CaF}_2) = \Delta H_a(\text{Ca}) + 1\text{st IE}(\text{Ca}) + 2^{\text{nd}} \text{IE}(\text{Ca}) + \text{BE}(\text{F}_2) + 2\text{xEA}(\text{F}) - \Delta H_L(\text{CaF}_2)$  $= 193 + 590 + 1150 + 158 + (2 \times -348) - 2602$  $= -1207 \text{ kJ mol}^{-1}$	1 1 1	Or labelled diagram  Correct answer scores 3 -842 scores 2 (transfer error) -859 scores 1 only (using one E.A.) Units not required, wrong units lose 1 mark
1	(c)		Electrostatic attraction stronger/ionic bonding stronger/attraction between ions stronger/more energy to separate ions	1	Molecular attraction /atoms/intermolecular forces CE=0
			Because fluoride (ion) smaller than chloride	1	Do not allow F or fluorine
1	(d)	(i)	$\Delta H = \Delta H_L + \Sigma \Delta H_{\text{hyd}} = 2237 - 1650 + (2 \times -364)$  $= -141 \text{ kJ mol}^{-1}$	1 1	Can be on cycle/diagram  Correct answer scores 2 Units not required, wrong units lose 1 mark

1	(d)	(ii)	Decreases  Reaction exothermic/ $\Delta H$ -ve  (Equilibrium )shifts to left/backwards (as temperature rises)/ equilibrium opposes the change	1  1  1	If ans to (d)(i) positive allow increases  If (d)(i) +ve allow endothermic/ $\Delta H$ +ve  If (d) (i) +ve allow shifts to right/forwards / equilibrium opposes the change  If no answer to (d) (i) assume –ve $\Delta H$ used If effect deduced incorrectly from any $\Delta H$ CE=0 for these 3 marks
1	(e)		u.v. absorbed: electrons/they move to higher energy (levels)/ electrons excited  visible light given out: electrons/they fall back down/move to lower energy (levels)	1  1	Must refer to absorbing u.v. NOT visible light or this must be implied.

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	(a)		<p><u>Macromolecular</u></p> <p>Covalent bonding (between atoms)</p> <p>Many/strong bonds to be broken (or lots of energy required)</p>	<p>1</p> <p>1</p> <p>1</p>	<p>Or <u>giant</u> molecule Or <u>giant</u> covalent (also gains M2) Do not allow giant atomic</p> <p>Ionic/metallic CE=0 for all 3 marks</p> <p>Do NOT allow if between molecules</p> <p>Lose both bonding marks if contradiction e.g. mention of intermolecular forces Note: 'covalent bonds between molecules' loses M2 but <b>not</b> M3</p>
2	(b)		Al <sub>2</sub> O <sub>3</sub> <u>ionic</u>	1	Allow <u>ionic</u> + covalent/ <u>ionic</u> with covalent character
2	(c)		2Al + 3/2O <sub>2</sub> → Al <sub>2</sub> O <sub>3</sub>	1	<p>Allow multiples</p> <p>Ignore state symbols</p>
2	(d)		Insoluble/impermeable/non-porous	1	<p>Or does not react/inert</p> <p>Do not allow thick layer</p> <p>Must imply property of Al<sub>2</sub>O<sub>3</sub> not Al</p>
2	(e)		Na <sub>2</sub> O + H <sub>2</sub> O → 2NaOH	1	Or Na <sub>2</sub> O + H <sub>2</sub> O → 2Na <sup>+</sup> + 2OH <sup>-</sup>
2	(f)	(i)	Al <sub>2</sub> O <sub>3</sub> + 6HCl → 2AlCl <sub>3</sub> + 3H <sub>2</sub> O	1	<p>Ionic equations with Al<sub>2</sub>O<sub>3</sub> possible e.g. Al<sub>2</sub>O<sub>3</sub> + 6H<sup>+</sup> → 2Al<sup>3+</sup> + 3H<sub>2</sub>O Do not allow formation of Al<sub>2</sub>Cl<sub>6</sub></p>

2	(f)	(ii)	$\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$	1	Other equations with $\text{Al}_2\text{O}_3$ are possible e.g. $\text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{OH})_4]^-$  $\text{Al}_2\text{O}_3 + 2\text{OH}^- + 7\text{H}_2\text{O} \rightarrow 2[\text{Al}(\text{H}_2\text{O})_2(\text{OH})_4]^-$
2	(g)		$\text{SiO}_2$ acidic/Lewis acid/electron pair acceptor  $\text{SiO}_2 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$	1  1	Allow $\text{SiO}_2$ <b>not</b> amphoteric Do NOT allow BL acid  Other equations with $\text{SiO}_2$ are possible e.g. $\text{SiO}_2 + 2\text{OH}^- \rightarrow \text{SiO}_3^{2-} + \text{H}_2\text{O}$ $\text{SiO}_2 + 2\text{OH}^- + 2\text{H}_2\text{O} \rightarrow \text{Si}(\text{OH})_6^{2-}$

Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	(a)		Same phase/state	1	
3	(b)		Because only exist in one oxidation state	1	Allow do not have variable oxidation states
3	(c)		$2\text{I}^- + \text{S}_2\text{O}_8^{2-} \rightarrow \text{I}_2 + 2\text{SO}_4^{2-}$	1	Ignore state symbols Allow multiples
3	(d)		Both (ions) have a negative charge	1	Or both have the same charge Or (ions) repel each other Do not allow both molecules have the same charge (contradiction)
3	(e)		$2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$	1	Equations can be in any order  Mark independently
			$2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	1	
			Positive and negative (ions)/oppositely charged (ions)	1	
3	(f)		Equations 1 and 2 can occur in any order	1	Allow idea of $\text{Fe}^{3+}$ converted to $\text{Fe}^{2+}$ then $\text{Fe}^{2+}$ converted back to $\text{Fe}^{3+}$

Q	Part	Sub Part	Marking Guidance	Mark	Comments
4	(a)		Partially filled/incomplete d sub-shell/orbital/shell	1	Ignore reference to f orbitals  Do <b>not</b> allow d block  Do <b>not</b> allow half-filled d orbitals
4	(b)		Has ligand(s)	1	Allow molecules/ions with lone pairs
			linked by co-ordinate bonds	1	Allow dative/donation of lone pair
4	(c)		(Blue) light is absorbed (from incident white light)	1	
			Due to electrons moving to higher levels / electrons excited	1	Allow d → d transitions
			Red light (that) remains (is transmitted) / light that remains (transmitted light) is the colour observed	1	Allow red light reflected
4	(d)	(i)	Circle round any O <sup>-</sup>	1	List principle
			Circle round either N	1	
4	(d)	(ii)	$\text{EDTA}^{4-} + [\text{Co}(\text{H}_2\text{O})_6]^{2+} \rightarrow [\text{CoEDTA}]^{2-} + 6\text{H}_2\text{O}$	1	Allow missing square brackets Ignore state symbols
4	(d)	(iii)	Increase in entropy/ $\Delta S$ positive	1	Or increase in disorder
			Because 2 mol (of particles/molecules/species/entities) form 7 mol	1	Allow 'increase in number' as stated in words or as shown by any numbers deduced correctly from an incorrect equation  Do not allow increase in ions/atoms



4	(e)	(i)	Co-ordinate/dative/dative covalent bond	1	Allow pair of electrons donated by nitrogen/ligand Do not allow pair of electrons donated from Iron/Fe
			Covalent bond	1	Shared electron pair
4	(e)	(ii)	Transport of oxygen/O <sub>2</sub>	1	Allow any statement that implies oxygen carried (around the body)  Do not allow transport of carbon dioxide (CO <sub>2</sub> ). This also contradicts the mark (list principle)
4	(e)	(iii)	Because it bonds to the iron/haemoglobin	1	Allow blocks site /CO has greater affinity for haemoglobin /carboxyhaemoglobin more stable than oxyhaemoglobin
			Displaces <u>oxygen</u>	1	Or prevents transport of <u>oxygen</u> QoL

Q	Part	Sub Part	Marking Guidance	Mark	Comments
5	(a)		W is $\text{CuCl}_4^{2-}$	1	
			Yellow-green/yellow/green	1	Not necessary to indicate solution Do not allow precipitate/solid
			$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow \text{CuCl}_4^{2-} + 6\text{H}_2\text{O}$	1	Allow $+ 4\text{HCl} \rightarrow 4\text{H}^+$
5	(b)		X is $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$	1	Allow $\text{Cu}(\text{OH})_2$ /copper hydroxide
			Blue precipitate/solid	1	Ignore shades
			$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$	1	Allow any balanced equation/equations leading to this hydroxide or $\text{Cu}(\text{OH})_2$ But must use ammonia
5	(c)		Y is $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$	1	
			Deep/dark/royal <u>blue solution</u>	1	QoL
			$\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-$	1	Accept equation for formation from $\text{Cu}(\text{OH})_2$
5	(d)		Z is $\text{CuCO}_3$	1	Allow copper carbonate
			Green solid/precipitate	1	Allow blue-green precipitate
			$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + \text{CO}_3^{2-} \rightarrow \text{CuCO}_3 + 6\text{H}_2\text{O}$	1	
5	(e)	(i)	$\text{Cu}^{2+}(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Fe}^{2+}(\text{aq})$	1	Allow hydrated ions State symbols not essential but penalise if wrong
			Blue	1	Do not allow description of solids
			Green	1	Allow yellow/(red-)brown/orange

5	(e)	(ii)	<p>Any two correct points about copper extraction from two of these three categories:</p> <p>Any relevant mention of lower energy consumption</p> <p>Any relevant mention of benefits of less mining (of copper ore)</p> <p>Less release of CO<sub>2</sub> (or CO) into the atmosphere</p>	Max 2	<p>Do not allow reference to electricity alone or to temperature alone.</p> <p>Allow avoids depletion of (copper ore) resources</p> <p>Not just greenhouse gases. Must mention CO<sub>2</sub> or CO</p>
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	(a)		$\Delta H = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$ $= -201 - 242 - (-394)$ $= -49 \text{ kJ mol}^{-1}$	1 1 1	+49 kJ mol <sup>-1</sup> = 1 mark units not required, wrong units lose 1 mark
6	(b)		$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$ $= 238 + 189 - (214 + 3 \times 131)$ $= -180 \text{ J K}^{-1} \text{ mol}^{-1}$	1 1 1	+180 = 1 mark units not required, wrong units lose 1 mark
6	(c)		$\Delta G = \Delta H - T\Delta S$  $(\Delta S \text{ is negative so) at high temp } -T\Delta S \text{ (is positive and) greater than } \Delta H / \text{large}$  So $\Delta G > 0$  $(\text{Limiting condition } \Delta G = 0 \text{ so) } T = \Delta H / \Delta S$  $= 272 \text{ K}$  Reaction is too slow at this temperature/to speed up the reaction	1 1 1 1 1 1	If use $G$ not $\Delta G$ penalise M1 but not M2 and M3  Do not award M2 or M3 if positive $\Delta S$ value used  Independent mark unless positive $\Delta S$ value used  Allow 297-298 if used given values. Do not award M5 if $T$ -ve or if M4 should give $T$ -ve

6	(d)	<p><math>\text{CH}_3\text{OH} + 3/2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}</math></p> <p>2.5 mol give 3 mol (gases)</p> <p>Therefore <math>\Delta S</math> is positive/entropy increases</p> <p>( combustion exothermic so <math>\Delta H</math> -ve so <math>\Delta H - T\Delta S</math>) and hence <math>\Delta G</math> always negative (less than zero)</p>	1	<p>Allow multiples. Ignore state symbols. Do not allow equation for wrong compound but mark on provided number of moles increases or stays the same. If no equation or equation that gives a decrease in the number of moles, CE = 0</p>
			1	<p>Allow statement 'increase in number of moles/molecules' If numerical values given, they must match the equation in M1 Ignore the effect of incorrect state symbols on the number of moles of particles unless used correctly</p>
			1	<p>If correct deduction from wrong equation is <math>\Delta S = 0</math> or <math>\Delta S</math> very small must say <math>\Delta H</math> -ve</p>
			1	<p>Allow <math>G</math> instead of <math>\Delta G</math> Can score 3 out of 4 marks if equation wrong but leads to increase or no change in number of moles M4 dependent on M3</p> <p>Note, if equation wrong AND there is an incorrect deduction about the change in number of moles, CE = 0</p>
6	(e)	<p><math>\text{CO}_2/\text{CO}/\text{CH}_4</math> may be produced during <math>\text{H}_2</math> manufacture/building the plant/transport/operating the plant</p>	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	(a)		Hydrogen /H <sub>2</sub> <u>gas/bubbles</u>	1	Allow 1 bar instead of 100 kPa Do not allow 1 atm
			1.0 mol dm <sup>-3</sup> HCl / H <sup>+</sup>	1	
			At 298K and 100kPa	1	
			Pt (electrode)	1	
7	(b)		Li <sup>+</sup> + MnO <sub>2</sub> + e <sup>-</sup> → LiMnO <sub>2</sub>	1	Ignore state symbols
			-0.13(V)	1	
7	(c)		Fe <sup>3+</sup> ions reduced to Fe <sup>2+</sup>	1	Can score from equation/scheme
			Because $E(\text{Fe}^{3+}/\text{Fe}^{2+}) > E(\text{H}^+/\text{H}_2) / E(\text{hydrogen})$	1	

Allow emf/ $E_{\text{cell}}$  +ve/0.77V  
 Allow Fe<sup>3+</sup> better oxidising agent than H<sup>+</sup>  
 Allow H<sub>2</sub> better reducing agent than Fe<sup>2+</sup>  
 Only award this explanation mark if previous mark given

7	(d)	Moles $\text{Cr}_2\text{O}_7^{2-} = \underline{23.7 \times 0.01/1000} = 2.37 \times 10^{-4}$	1	
		1 mol $\text{Cr}_2\text{O}_7^{2-}$ reacts with 6 mol $\text{Fe}^{2+}$ so moles $\text{Fe}^{2+}$ in $25 \text{ cm}^3 = 6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$	1	M1 x 6
		Moles $\text{Fe}^{2+}$ in $250 \text{ cm}^3 = 1.422 \times 10^{-2}$	1	M2 x 10 or M4/10
		Original moles $\text{Fe}^{2+} = \underline{10.00/277.9} = 0.0360$	1	Independent mark
		Moles $\text{Fe}^{2+}$ oxidised = $0.0360 - 0.0142 = 0.0218$	1	M4 – M3
		% oxidised = $(0.0218 \times 100)/0.0360 = 60.5\%$	1	(M5 x 100)/M4 Allow 60 to 61 Note Max 3 if mol ratio for M2 wrong eg 1:5 gives 67.1% 1:1 gives 93.4%  Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)