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General Certificate of Education
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Chemistry CHEM5

Energetics, Redox and Inorganic Chemistry

Mark Scheme

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)		$CaF_2(s) \rightarrow Ca^{2+}(g) + 2F^-(g)$	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)	$Ca(s) + F_2(g) \rightarrow CaF_2(s)$	1	
1	(b)	(iii)	$\Delta H_f(CaF_2) = \Delta H_a(Ca) + 1st\ IE(Ca) + 2^{nd}\ IE(Ca) + BE(F_2) + 2xEA(F) - \Delta H_L(CaF_2)$	1	Or labelled diagram
			$= 193 + 590 + 1150 + 158 + (2 \times -348) - 2602$	1	
			$= -1207\ kJ\ mol^{-1}$	1	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)	$\Delta H = \Delta H_L + \Sigma\Delta H_{hyd} = 2237 - 1650 + (2 \times -364)$	1	Can be on cycle/diagram
			$= -141\ kJ\ mol^{-1}$	1	Correct answer scores 2 Units not required, wrong units lose 1 mark

1	(d)	(ii)	Decreases
			
			Reaction exothermic/ΔH -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/ΔH +ve
					
					If (d) (i) +ve allow shifts to right/forwards / equilibrium opposes the change
					
					If no answer to (d) (i) assume –ve ΔH used
					If effect deduced incorrectly from any ΔH 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)		Macromolecular	1	Or giant molecule Or giant covalent (also gains M2) Do not allow giant atomic Ionic/metallic CE=0 for all 3 marks
			Covalent bonding (between atoms)	1	Do NOT allow if between molecules
			Many/strong bonds to be broken (or lots of energy required)	1	Lose both bonding marks if contradiction e.g. mention of intermolecular forces Note: 'covalent bonds between molecules' loses M2 but **not** M3
2	(b)		Al_2O_3 ionic	1	Allow ionic + covalent/ ionic with covalent character
2	(c)		$2Al + 3/2O_2 \rightarrow Al_2O_3$	1	Allow multiples Ignore state symbols
2	(d)		Insoluble/impermeable/non-porous	1	Or does not react/inert Do not allow thick layer Must imply property of Al_2O_3 not Al
2	(e)		$Na_2O + H_2O \rightarrow 2NaOH$	1	Or $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$
2	(f)	(i)	$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$	1	Ionic equations with Al_2O_3 possible e.g. $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ Do not allow formation of Al_2Cl_6

2	(f)	(ii)	$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$	1	Other equations with Al_2O_3 are possible e.g. $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ $Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(H_2O)_2(OH)_4]^-$
2	(g)		SiO_2 acidic/Lewis acid/electron pair acceptor $SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$	1 1	Allow SiO_2 **not** amphoteric Do NOT allow BL acid Other equations with SiO_2 are possible e.g. $SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$ $SiO_2 + 2OH^- + 2H_2O \rightarrow Si(OH)_6^{2-}$

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)		$2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-}$	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)		$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Positive and negative (ions)/oppositely charged (ions)	1 1 1	 Equations can be in any order Mark independently
3	(f)		Equations 1 and 2 can occur in any order	1	Allow idea of Fe^{3+} converted to Fe^{2+} then Fe^{2+} converted back to 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 **not** allow d block Do **not** allow half-filled d orbitals
4	(b)		Has ligand(s) linked by co-ordinate bonds	1 1	Allow molecules/ions with lone pairs Allow dative/donation of lone pair
4	(c)		(Blue) light is absorbed (from incident white light) Due to electrons moving to higher levels / electrons excited Red light (that) remains (is transmitted) / light that remains (transmitted light) is the colour observed	1 1 1	 Allow d $\rightarrow$ d transitions Allow red light reflected
4	(d)	(i)	Circle round any O^- Circle round either N	1 1	List principle
4	(d)	(ii)	$EDTA^{4-} + [Co(H_2O)_6]^{2+} \rightarrow [CoEDTA]^{2-} + 6H_2O$	1	Allow missing square brackets Ignore state symbols
4	(d)	(iii)	Increase in entropy/ΔS positive Because 2 mol (of particles/molecules/species/entities) form 7 mol	1 1	Or increase in disorder 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 Covalent bond	1 1	Allow pair of electrons donated by nitrogen/ligand Do not allow pair of electrons donated from Iron/Fe Shared electron pair
4	(e)	(ii)	Transport of oxygen/O_2	1	Allow any statement that implies oxygen carried (around the body) Do not allow transport of carbon dioxide (CO_2). This also contradicts the mark (list principle)
4	(e)	(iii)	Because it bonds to the iron/haemoglobin Displaces <u>oxygen</u>	1 1	Allow blocks site /CO has greater affinity for haemoglobin /carboxyhaemoglobin more stable than oxyhaemoglobin Or prevents transport of <u>oxygen</u> QoL

Q	Part	Sub Part	Marking Guidance	Mark	Comments
5	(a)		W is $CuCl_4^{2-}$	1	
			Yellow-green/yellow/green	1	Not necessary to indicate solution Do not allow precipitate/solid
			$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$	1	Allow $+ 4HCl \rightarrow 4H^+$
5	(b)		X is $Cu(H_2O)_4(OH)_2$	1	Allow $Cu(OH)_2$/copper hydroxide
			Blue precipitate/solid	1	Ignore shades
			$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1	Allow any balanced equation/equations leading to this hydroxide or $Cu(OH)_2$ But must use ammonia
5	(c)		Y is $[Cu(NH_3)_4(H_2O)_2]^{2+}$	1	
			Deep/dark/royal <u>blue solution</u>	1	QoL
			$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$	1	Accept equation for formation from $Cu(OH)_2$
5	(d)		Z is $CuCO_3$	1	Allow copper carbonate
			Green solid/precipitate	1	Allow blue-green precipitate
			$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$	1	
5	(e)	(i)	$Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$	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)	Any two correct points about copper extraction from two of these three categories: Any relevant mention of lower energy consumption Any relevant mention of benefits of less mining (of copper ore) Less release of CO_2 (or CO) into the atmosphere	Max 2	 Do not allow reference to electricity alone or to temperature alone. Allow avoids depletion of (copper ore) resources Not just greenhouse gases. Must mention CO_2 or CO

Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	(a)		$\Delta H = \Sigma\Delta H_f$(products) – $\Sigma\Delta H_f$(reactants)	1	
			= –201 – 242 –(–394)	1	
			= –49 kJ mol^{-1}	1	+49 kJ mol^{-1} = 1 mark units not required, wrong units lose 1 mark
6	(b)		$\Delta S = \Sigma S$(products) – ΣS(reactants)	1	
			=238 + 189 –(214 + 3x131)	1	
			= –180 J K^{-1} mol^{-1}	1	+180 = 1 mark units not required, wrong units lose 1 mark
6	(c)		$\Delta G = \Delta H - T\Delta S$	1	If use G not ΔG penalise M1 but not M2 and M3
			(ΔS is negative so) at high temp $-T\Delta S$ (is positive and) greater than ΔH / large	1	Do not award M2 or M3 if positive ΔS value used
			So $\Delta G > 0$	1	Independent mark unless positive ΔS value used
			(Limiting condition $\Delta G = 0$ so) $T = \Delta H/\Delta S$	1	
			= 272 K	1	Allow 297-298 if used given values. Do not award M5 if T –ve or if M4 should give T -ve
			Reaction is too slow at this temperature/to speed up the reaction	1	

6	(d)		$CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$	1	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
			2.5 mol give 3 mol (gases)	1	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
			Therefore ΔS is positive/entropy increases	1	If correct deduction from wrong equation is ΔS =0 or ΔS very small must say ΔH –ve
			(combustion exothermic so ΔH –ve so $\Delta H - T\Delta S$) and hence ΔG always negative (less than zero)	1	Allow G instead of ΔG 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 Note, if equation wrong AND there is an incorrect deduction about the change in number of moles, CE = 0

6	(e)		CO_2 /CO/CH_4 may be produced during H_2 manufacture/building the plant/transport/operating the plant	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	(a)		Hydrogen /H_2 gas/bubbles	1	
			1.0 mol dm^{-3} HCl / H^+	1	
			At 298K and 100kPa	1	Allow 1 bar instead of 100 kPa Do not allow 1 atm
			Pt (electrode)	1	
7	(b)		$Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$	1	Ignore state symbols
			–0.13(V)	1	
7	(c)		Fe^{3+} ions reduced to Fe^{2+}	1	Can score from equation/scheme
			Because $E(Fe^{3+}/Fe^{2+}) > E(H^+/H_2)$ /E(hydrogen)	1	Allow emf/E_{cell} +ve/0.77V Allow Fe^{3+} better oxidising agent than H^+ Allow H_2 better reducing agent than Fe^{2+} Only award this explanation mark if previous mark given

7	(d)		Moles $Cr_2O_7^{2-}$ =23.7 x 0.01/1000 = 2.37 x 10^{-4}	1	
			1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles Fe^{2+} in 25 cm^3 = 6 x 2.37 x 10^{-4} = 1.422 x 10^{-3}	1	M1 x 6
			Moles Fe^{2+} in 250 cm^3 = 1.422 x 10^{-2}	1	M2 x 10 or M4/10
			Original moles Fe^{2+} = 10.00/277.9 = 0.0360	1	Independent mark
			Moles 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)