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General Certificate of Education (A-level)
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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)	Enthalpy change for the formation of 1 mol of gaseous atoms	1	allow heat energy change for enthalpy change
	From the element (in its standard state)	1	ignore reference to conditions
	Enthalpy change to separate 1 mol of an ionic lattice/solid/compound	1	enthalpy change not required but penalise energy
	Into (its component) gaseous ions	1	mark all points independently
1(b)	$\Delta H_L = {}^{-}\Delta H_f + \Delta H_a$ + I.E. + 1/2E(Cl-Cl) + EA	1	Or correct Born-Haber cycle drawn out
	= +411 + 109 + 494 + 121 – 364	1	
	= +771 (kJ mol $^{-1}$)	1	–771 scores 2/3 +892 scores 1/3 –51 scores 1/3 –892 scores zero +51 scores zero ignore units
1(c)(i)	Ions are perfect spheres (or point charges)	1	mention of molecules/intermolecular forces/covalent bonds CE = 0
	Only electrostatic attraction/no covalent interaction	1	allow ionic bonding only If mention of atoms CE = 0 for M2
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

Question	Marking Guidance	Mark	Comments
2(a)	Because it is a gas compared with solid 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 θ in ΔG^{θ}
2(d)	ΔG is less than or equal to zero ($\Delta G \leq 0$)	1	Allow ΔG is less than zero ($\Delta G < 0$) Allow ΔG is equal to zero ($\Delta G = 0$) Allow ΔG is negative
2(e)	When $\Delta G = 0$ $T = \underline{\Delta H / \Delta S}$ $\Delta H = +90.4$ $\Delta S = \sum S(\text{products}) - \sum S(\text{reactants})$ $\Delta S = 211.1 - 205.3/2 - 192.2/2 = \underline{12.35}$ $T = (90.4 \times 1000)/12.35 = 7320$ K /7319.8 K	1 1 1 1 1	 Allow $\Delta H = +90$ Allow 7230 to 7350 K (Note 7.32 K scores 4 marks) Units of temperature essential to score the mark

2(g)	$\Delta H = 1.9$ (kJ mol^{-1}) $\Delta S = 2.4 - 5.7 = -3.3$ (J K^{-1} mol^{-1}) ΔG is always positive	1 1 1	 for M1 and M2 allow no units, penalise wrong units This mark can only be scored if ΔH is +ve and ΔS 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_2O 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_2 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^+ (or Li ion) smaller than Na^+	1	Must imply Li^+ ion Allow Li^+ has higher charge/size ratio **not** charge/mass
	Attracts O^{2-} ion more strongly	1	Allow stronger ionic bonding Allow additional attraction due to polarisation in Li_2O 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 ***OR*** low energy needed to break van der Waals' forces

3(d)	Allow –1 to +2	1	
	$P_4O_{10} + 6H_2O \rightarrow 12H^+ + 4PO_4^{3-}$ (or $4H_3PO_4$)	1	Allow balanced equations to form HPO_4^{2-} or $H_2PO_4^-$ ignore state symbols
	Allow 12 to 14	1	
	$Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$	1	Allow $2Na^+ + O^{2-}$ on LHS, 2NaOH on RHS, ignore s.s. Mark independently

3(e)	$6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$	1	
	Acid-base	1	Allow neutralisation, mark independently of M1 Do not allow Acid + Base → 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)	$[H_3N–Ag–NH_3]^+$	1	Allow $[Cl–Ag–Cl]^–$ 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 $NiX_4^{2–}$ etc
4(c)(iii)	$[CuCl_4]^{2–}$ drawn out as tetrahedral ion	1	Or $[CoCl_4]^{2–}$ drawn out
4(d)(i)	$SO_2 + 1/2O_2 \rightarrow SO_3$	1	Allow multiples Allow $SO_2 + 1/2O_2 + H_2O \rightarrow H_2SO_4$ ignore state symbols
4(d)(ii)	In a different phase/state (from the reactants)	1	
4(d)(iii)	$V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ $V_2O_4 + 1/2O_2 \rightarrow V_2O_5$	1 1	can be in either order allow multiples
4(d)(iv)	Surface area is increased By use of powder or granules or finely divided	1 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 donates 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	1	Allow molecules/entities instead of particles Penalise incorrect numbers (should be 2→5)
	Disorder increases or entropy increases (or entropy change is positive)	1	Allow ΔG must be negative because ΔH = 0 and ΔS is +ve
4(e)(iii)	6	1	
	Cyanide strongly bound to Co (by co-ordinate/covalent bond)	1	

Question	Marking Guidance	Mark	Comments
5(a)(i)	Co/Cobalt	1	If Co or Cobalt not given CE = 0 ignore case in symbol for Co
	(+) 4	1	
	(+) 3	1	Allow 4 and 3 in either order
5(a)(ii)	$Li \rightarrow Li^+ + e^-$	1	Ignore state symbols Allow e without -ve sign Do not allow equilibrium sign
5(a)(iii)	Platinum is a conductor	1	Ignore mention of surface area or catalyst
	(Platinum is) unreactive/inert	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)	Li reacts with water/forms lithium hydroxide	1	Allow water breaks down (or is electrolysed) on re-charge

5(b)(i)	Pt | SO_3^{2-} (aq), SO_4^{2-} (aq) || ClO_3^- (aq), Cl^-(aq) | Pt	2	State symbols and ',' not necessary Allow | in place of ',' NOT ',' in place of | Ignore H^+ and H_2O Deduct one mark for each mistake (e.g. Pt missed twice counts as two mistakes) Allow reverse order for whole cell Pt | Cl^-, ClO_3^- || SO_4^{2-}, SO_3^{2-} | Pt

5(b)(ii)	$ClO_3^- + 3SO_3^{2-} \rightarrow Cl^- + 3SO_4^{2-}$ Oxidising agent ClO_3^- Reducing agent SO_3^{2-}	1 1 1	

Question	Marking Guidance	Mark	Comments
6(a)	Brown ppt/solid	1	
	Gas evolved/effervescence	1	Must be stated, Allow CO_2 evolved. Do not allow CO_2 alone
	$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(H_2O)_3(OH)_3 + 3CO_2 + 3H_2O$	2	Correct iron product (1) allow $Fe(OH)_3$ and in equation Balanced equation (1)
6(b)	White ppt/solid	1	
	Colourless Solution	1	Only award M2 if M1 given or initial ppt mentioned
	$[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(H_2O)_3(OH)_3 + 3H_2O$	1	Allow $[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(OH)_3 + 6H_2O$
	$Al(H_2O)_3(OH)_3 + 3OH^- \rightarrow [Al(OH)_6]^{3-} + 3H_2O$	1	Allow formation of $[Al(H_2O)_{6-x}(OH)_x]^{(x-3)-}$ where x=4,5,6 Allow product without water ligands Allow formation of correct product from $[Al(H_2O)_6]^{3+}$
6(c)	Blue ppt/solid	1	
	(Dissolves to give a) deep blue solution	1	Only award M2 if M1 given or initial ppt mentioned
	$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1	Allow $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2 + 2NH_4^+ + 4H_2O$ Allow two equations: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ then $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 4H_2O$ etc
	$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2OH^- + 2H_2O$	1	Allow $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$
6(d)	Green/yellow solution	1	
	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$	1	

Question	Marking Guidance	Mark	Comments
7(a)(i)	Ammonia	1	If reagent is missing or incorrect cannot score M3
	Starts as a pink (solution)	1	
	Changes to a yellow/straw (solution)	1	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	1	Do not allow red or blue If ppt mentioned contradiction/CE =0
	Green	1	If ppt mentioned contradiction/CE =0
	$[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$	1	
	Formula of product	1	Can score this mark in (b) (ii)
7(b)(ii)	$H_2O_2 + 2e^- \rightarrow 2OH^-$	1	
	$2[Cr(OH)_6]^{3-} + 3H_2O_2 \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$	2	Allow 1 mark out of 2 for a balanced half-equation such as $Cr(III) \rightarrow Cr(VI) + 3e^-$ or $Cr^{3+} + 4H_2O \rightarrow CrO_4^{2-} + 8H^+ + 3e^-$ etc also for $2Cr(III) + 3H_2O_2 \rightarrow 2CrO_4^{2-}$ (unbalanced)
	Yellow	1	Do not allow orange

7(c)	$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$	1	if no equation and uses given ratio can score M2, M3, M4 & M5
	Moles MnO_4^- = (24.35/1000) x 0.0187 = $\underline{4.55 \times 10^{-4}}$	1	Note value must be quoted to at least 3 sig. figs. M2 is for 4.55×10^{-4}
	Moles H_2O_2 = (4.55×10^{-4}) $\underline{\times 5/2}$ = 1.138×10^{-3}	1	M3 is for x 5/2 (or7/3) Mark consequential on molar ratio from candidate's equation
	Moles H_2O_2 in 5 cm^3 original = (1.138×10^{-3}) $\underline{\times 10}$ = 0.01138	1	M4 is for x 10
	Original $[H_2O_2]$ = 0.01138 $\underline{\times (1000/5)}$ = 2.28 mol dm^{-3} (allow 2.25-2.30)	1	M5 is for consequentially correct answer from (answer to mark 4) x (1000/5) Note an answer of between 2.25 and 2.30 is worth 4 marks) If candidate uses given ratio 3/7 max 4 marks: **M1**: Moles of MnO_4^- = $\underline{4.55 \times 10^{-4}}$ **M2**: Moles H_2O_2 = (4.55×10^{-4}) $\underline{\times 7/3}$ = 1.0617×10^{-3} **M3**: Moles H_2O_2 in 5 cm^3 original = (1.0617×10^{-3}) x 10 = 0.01062 **M4**: Original $[H_2O_2]$ = 0.01062 x (1000/5) = 2.12 mol dm^{-3} (allow 2.10 to 2.15)