Question	Marking Guidance	Mark	Comments
1(a)	To prevent it coming into contact/reacting with oxygen/air	1	Allow because it reacts with air/oxygen And because with air/oxygen it forms an oxide. (Oxide, if identified, must be correct :- P_4O_{10}, P_2O_5, P_4O_6, P_2O_6)
1(b)	One molecule contains 4P and 10O/the molecular formula is P_4O_{10}	1	Allow exists as P_4O_{10} Do not allow reference to combination of two P_2O_5 molecules Ignore any reference to stability
1(c)	P_4O_{10} is a bigger molecule (than SO_3)/greater M_r/more electrons/ greater surface area Van der Waals / vdW forces between molecules are stronger/require more energy to break	1 1	Penalise SO_2 for one mark (max 1) CE = 0 if mention of hydrogen bonding/ionic/ giant molecule/breaking of covalent bonds Do not allow just more vdW forces Ignore any reference to dipole-dipole forces
1(d)	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ pH must be in the range -1 to +2	1 1	Allow correct ionic equations Ignore state symbols Allow -1 to +2 Mark independently

1(e)(i)	$3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$ OR $MgO + 2H_3PO_4 \rightarrow Mg(H_2PO_4)_2 + H_2O$ OR $MgO + H_3PO_4 \rightarrow MgHPO_4 + H_2O$	1	Allow $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$ Allow magnesium phosphates shown as ions and ionic equations Ignore state symbols
1(e)(ii)	MgO is sparingly soluble/insoluble/weakly alkaline	1	Excess/unreacted MgO can be filtered off/separated
1(e)(iii)	An excess of NaOH would make the lake alkaline/toxic/kill wildlife	1	Allow pH increases

Question	Marking Guidance	Mark	Comments
2(a)	$\Delta G = \Delta H - T\Delta S$	1	Ignore ~~o~~
2(b)	0.098 or 98 kJ K^{-1} mol^{-1} J K^{-1} mol^{-1} $-\Delta S/\Delta S$	1 1 1	Allow 0.097 to 0.099/97 to 99 Allow 0.1 only if 0.098 shown in working Allow in any order Unless slope is approx. 100(90-110) accept only kJ K^{-1} mol^{-1}. If no slope value given, allow either units
2(c)	ΔG becomes <u>negative</u> So reaction becomes spontaneous/feasible	1 1	Mark independently unless ΔG +ve then CE = 0 Or reaction can occur below this temperature Or reaction is not feasible above this temperature
2(d)	Ammonia liquefies (so entropy data wrong/different)	1	Allow any mention of <u>change</u> in state or implied change in state even if incorrect eg freezing/boiling

Question	Marking Guidance	Mark	Comments
3(a)	Enthalpy change/heat energy change when one mole of gaseous atoms Form (one mole of) gaseous negative ions (with a single charge)	1 1	Allow explanation with an equation that includes state symbols If ionisation/ionisation energy implied, CE=0 for both marks Ignore conditions
3(b)	Fluorine (atom) is smaller than chlorine/shielding is less/ outer electrons closer to nucleus (Bond pair of) electrons attracted more strongly to the nucleus/protons	1 1	Fluorine molecules/ions/charge density CE=0 for both marks
3(c)	Fluoride (ions) smaller (than chloride) / have larger charge density So (negative charge) attracts (δ+ hydrogen on) water more strongly	1 1	Any reference to electronegativity CE=0 Allow H on water, do not allow O on water Allow F^- hydrogen bonds to water, chloride ion does not Mark independently

3(d)(i)	ΔH(solution) = LE + Σ(hydration enthalpies) / correct cycle *LE* = -20 -(-464 + -506) = (+) 950 kJ mol^{-1}	1 1 1	AgF_2 or other wrong formula CE = 0 Ignore state symbols in cycle Ignore no units, penalise M3 for wrong units -950 scores max 1 mark out of 3 990 loses M3 but M1 and M2 may be correct 808 is transfer error (AE) scores 2 marks 848 max 1 if M1 correct 1456 CE=0 (results from AgF_2)
3(d)(ii)	There is an increase in the number of particles / more disorder / less order	1	Allow incorrect formulae and numbers provided number increases Do not penalise reference to atoms/molecules Ignore incorrect reference to liquid rather than solution
3(d)(iii)	Entropy change is positive/entropy increases and enthalpy change negative/exothermic So ΔG is (always) negative	1 1	

Question	Marking Guidance	Mark	Comments
4(a)	$\Delta H = \Sigma(\Delta H_f$ products) - $\Sigma(\Delta H_f$ reactants) /= +34 - +90 = -56 kJ mol^{-1}	1 1	Allow correct cycle Ignore no units, penalise incorrect units
4(b)	$\Delta S = \Sigma(S$ products) - $\Sigma(S$ reactants) /= 240 - (205 +211/2) = -70.5 J K^{-1} mol^{-1} / -0.0705 kJ K^{-1} mol^{-1}	1 1	 Ignore no units, penalise incorrect units Allow -70 to -71/-.070 to -.071
4(c)	$T = \Delta H/\Delta S$ / T = (Ans to part(a) $\times$1000)/ans to part(b) /= -56/(-70.5 $\div$ 1000) = 794 K (789 to 800 K)	1 1	Mark consequentially on answers to parts (a) and (b) Must have correct units Ignore signs; allow + or – and –ve temps
4(d)	Temperatures exceed this value	1	
4(e)	$N_2 + O_2 \rightarrow 2NO$	1	Allow multiples
4(f)	there is no change in the number of moles (of gases) So entropy/disorder stays (approximately) constant / entropy/disorder change is very small / ΔS=0 / $T\Delta S$=0	1 1	Can only score these marks if the equation in (e) has equal number of moles on each side Numbers, if stated must match equation

Question	Marking Guidance	Mark	Comments
5(a)	Electron acceptor / gains electrons / takes electrons away	1	Do not allow electron pair acceptor / gain of electrons / definition of redox (QWC)
5(b)	$Cd(OH)_2$	1	Do not allow '$Cd(OH)_2/Cd$'
	Species (on LHS) with the least positive/most negative electrode potential / lowest *E* / smallest *E*	1	Only allow this mark if M1 answer given correctly or blank Do not allow negative emf
5(c)(i)	1.5 (V) / 1.50	1	
5(c)(ii)	$2MnO_2 + 2H_2O + Zn \rightarrow 2MnO(OH) + 2OH^- + Zn^{2+}$	1	Ignore state symbols e^- must be cancelled (take care that Zn^{2+} is on RHS)
5(c)(iii)	Allows ions to pass (through it) or words to that effect	1	Penalise passage of electrons Allow mention of particular ions
5(c)(iv)	Allows electrons to flow / makes electrical contact / conductor	1	Allow acts as an (inert) electrode / anode / cathode
5(c)(v)	Zn is 'used up' / has reacted / oxidised	1	Allow idea that zinc reacts Do not allow just zinc corrodes

5(d)(i)	3 / +3 / III $2Ni(OH)_2 + Cd(OH)_2 \rightarrow 2NiO(OH) + Cd + 2H_2O$	1 1 1	For correct nickel and cadmium species in correct order (allow H_2O missing and OH^- not cancelled) For balanced equation (also scores M2) Allow max 1 for M2 and M3 if correct balanced equation but reversed. Ignore state symbols
5(d)(ii)	Metal / metal compounds are re-used / supplies are not depleted / It (the cell) can be re-used	1	Allow does not leak / no landfill problems / less mining / less energy to extract metals / less waste Do not allow less CO_2 unless explained
5(e)(i)	$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$	1	Allow C_2H_6O
5(e)(ii)	$C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$	1	Allow C_2H_6O
5(e)(iii)	(+)0.23 (V)	1	
5(e)(iv)	<u>CO_2</u> released by combustion / fermentation / fuel cell / reaction with water (atmospheric) <u>CO_2</u> taken up in <u>photosynthesis</u>	1 1	Can be answered with the aid of equations

Question	Marking Guidance	Mark	Comments
6(a)	Co-ordinate / dative / dative covalent / dative co-ordinate	1	Do not allow covalent alone
6(b)	(lone) pair of electrons on <u>oxygen/O</u> forms co-ordinate bond with <u>Fe</u> / donates electron pair to <u>Fe</u>	1 1	If co-ordination to O^{2-}, CE=0 'Pair of electrons on O donated to Fe' scores M1 and M2
6(c)	180° / 180 / 90	1	Allow any angle between 85 and 95 Do not allow 120 or any other incorrect angle Ignore units eg ^{o}C
6(d)(i)	3 : 5 / 5 FeC_2O_4 reacts with 3 MnO_4^-	1	Can be equation showing correct ratio

6(d)(ii)	**M1** Moles of MnO_4^- per titration = 22.35 × 0.0193/1000 = $\underline{4.31 \times 10^{-4}}$ Method marks for each of the next steps (no arithmetic error allowed for M2): **M2** moles of FeC_2O_4= ratio from (d)(i) used correctly × 4.31 × 10^{-4} **M3** moles of FeC_2O_4 in 250 cm^3 = M2 ans × 10 **M4** Mass of $FeC_2O_4.2H_2O$ = M3 ans × 179.8 **M5** % of $FeC_2O_4.2H_2O$ = (M4 ans/1.381) × 100 (OR for M4 max moles of $FeC_2O_4.2H_2O$ = 1.381/179.8 (= 7.68× 10^{-3}) for M5 % of $FeC_2O_4.2H_2O$ = (M3 ans/above M4ans) × 100) eg using correct ratio 5/3: Moles of FeC_2O_4 = 5/3 × 4.31 × 10^{-4} = 7.19 × 10^{-4} Moles of FeC_2O_4 in 250 cm^3 = 7.19 × 10^{-4} × 10 = 7.19 × 10^{-3} Mass of $FeC_2O_4.2H_2O$ = 7.19 × 10^{-3} × 179.8 = 1.29 g % of $FeC_2O_4.2H_2O$ = 1.29 × 100/1.381 = 93.4 (allow 92.4 to 94.4) Note correct answer (92.4 to 94.4) scores 5 marks	1 1 1 1 1	Allow $\underline{4.3 \times 10^{-4}}$ (2 sig figs) Allow other ratios as follows: eg from given ratio of 7/3 **M2** = 7/3 × 4.31 × 10^{-4} = 1.006 × 10^{-3} **M3** = 1.006 × 10^{-3} × 10 = 1.006 × 10^{-2} **M4** = 1.006 × 10^{-2} × 179.8 = 1.81 g **M5** = 1.81 × 100/1.381 = 131 % (130 to 132) Allow consequentially on candidates ratio eg **M2** = 5/2 × 4.31 × 10^{-4} = 1.078 × 10^{-3} **M3** = 1.0078 × 10^{-3} × 10 = 1.078 × 10^{-2} **M4** = 1.078 × 10^{-2} × 179.8 = 1.94 g **M5** = 1.94 × 100/1.381 = 140 % (139 to 141) Other ratios give the following final % values 1:1 gives 56.1% (55.6 to 56.6) 5:1 gives 281% (278 to 284) 5:4 gives 70.2% (69.2 to 71.2)

Question	Marking Guidance	Mark	Comments
7(a)	Orange dichromate Changes to purple / green / ruby / red-violet / violet Chromium(III) (Note green complex can be $[Cr(H_2O)_5Cl]^{2+}$ etc) That changes further to blue Chromium(II) $[Cr_2O_7]^{2-} + 14H^+ + 3Zn \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$ $2Cr^{3+} + Zn \rightarrow 2Cr^{2+} + Zn^{2+}$ / $[Cr_2O_7]^{2-} + 14H^+ + 4Zn \rightarrow 2Cr^{2+} + 4Zn^{2+} + 7H_2O$	1 1 1 1 1	Allow max 2 for three correct colours not identified to species but in correct order Do not allow green with another colour Allow max 1 for two correct colours not identified but in correct order Ignore any further reduction of Cr^{2+} Ignore additional steps e.g. formation of CrO_4^{2-}
7(b)	Green precipitate (Dissolves to form a) green solution $[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(H_2O)_3(OH)_3 + 3H_2O$ $Cr(H_2O)_3(OH)_3 + 3OH^- \rightarrow [Cr(OH)_6]^{3-} + 3H_2O$	1 1 1 1	Solution can be implied if ‘dissolves’ stated Penalise $Cr(OH)_3$ once only Allow $[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$ Allow formation of $[Cr(H_2O)_2(OH)_4]^-$ and $[Cr(H_2O)(OH)_5]^{2-}$ in balanced equations Ignore state symbols, mark independently

7(c)	(ligand) substitution / replacement / exchange The energy levels/gaps of the d electrons are different (for each complex) So a different wavelength/frequency/colour/energy of light is absorbed (when d electrons are excited) OR light is absorbed and a different wavelength/frequency/colour/energy (of light) is transmitted/reflected	1 1 1	Allow nucleophilic substitution Ignore any reference to emission of light
7(d)	*E* O_2 (/ H_2O) > *E* Cr^{3+} (/ Cr^{2+}) / e.m.f = 1.67 V So Cr^{2+} ions are oxidised by oxygen/air With $[Cr(H_2O)_6]^{2+}$ get $CrCO_3$ with $[Cr(H_2O)_6]^{3+}$ get $Cr(H_2O)_3(OH)_3$ / $Cr(OH)_3$ and CO_2 Cr(III) differs from Cr(II) because it is acidic / forms H^+ ions because Cr^{3+} ion polarises water	1 1 1 1 1 1 1	Allow E(cell) = 1.67 Allow any equation of the form: $Cr^{2+} + O_2 \rightarrow Cr^{3+}$ If named must be chromium(II) carbonate Allow 0 to 3 waters in the complex Can score M3, M4, M5 in equations even if unbalanced Ignore charge/size ratio and mass/charge

Question	Marking Guidance	Mark	Comments
8(a)			For reactions 1 to 3 must show complex ions as reactants and products Take care to look for possible identification on flow chart
	Reaction 1		
	ammonia solution	1	
	W is $[Co(NH_3)_6]^{2+}$	1	Correct equation scores all 3 marks
	$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$	1	
	Reaction 2		Allow oxygen, Do not allow air
	H_2O_2	1	
	X is $[Co(NH_3)_6]^{3+}$	1	
	$2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$	1	Allow $2[Co(NH_3)_6]^{2+} + {}^1/_2O_2 + H_2O \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$ Correct equations score all 3 marks
	Reaction 3		
	HCl	1	Do not allow Cl^- but mark on
	Y is $[CoCl_4]^{2-}$	1	
	$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$/	1	Correct equation scores previous mark
	$[Co(H_2O)_6]^{2+} + 4HCl \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H^+$		This equation scores all three marks

	Reaction 4 Na_2CO_3 Or $NaOH/NH_3$ **Z** is $CoCO_3$ $Co(OH)_2/Co(H_2O)_4(OH)_2$ $[Co(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CoCO_3 + 6H_2O$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(H_2O)_4(OH)_2 + 2H_2O$ etc Or $[Co(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CoCO_3 + 6H_2O + 2Na^+$	1 1 1	Do not allow $CaCO_3$ as a reagent but mark on Allow waters to stay co-ordinated to Co. This mark also previous mark Allow $Co^{2+} + CO_3^{2-} \rightarrow CoCO_3$
8(b)	$SO_3^{2-} + {}^1/_2O_2 \rightarrow SO_4^{2-}$ The activation energy is lower (for the catalysed route) ${}^1/_2O_2 + 2Co^{2+} + 2H^+ \rightarrow H_2O + 2Co^{3+}$ $2Co^{3+} + SO_3^{2-} + H_2O \rightarrow 2Co^{2+} + SO_4^{2-} + 2H^+$	1 1 1 1	Allow multiples Or Co^{3+} attracts SO_3^{2-}/Co^{2+} attracts SO_3^{2-} /oppositely charged ions attract Allow these equations in either order