Question Number	Acceptable Answers	Reject	Mark
1(a)(i)	$Cr_2(SO_4)_3(aq) = Cr(H_2O)_6^{3+}$ ALLOW $Cr^{3+}(aq)$ / Cr^{3+} **(1)** A = $Cr(H_2O)_3(OH)_3$ / $Cr(OH)_3$ **(1)** B = $Cr(H_2O)_2(OH)_4^-$ / $Cr(OH)_4^-$ / $Cr(OH)_6^{3-}$ **(1)** C = CrO_4^{2-} **(1)** IGNORE SO_4^{2-} and/or Na+		**4**

Question Number	Acceptable Answers	Reject	Mark
1(a)(ii)	$H_2O_2 + 2e^{(-)} \rightarrow 2OH^-$		**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iii)	Sulfuric acid / H_2SO_4 ALLOW Name or formula of any strong acid (e.g. HCl) IGNORE H^+ and 'an acid' Dilute or concentrated		**1**

Question Number	Acceptable Answers	Reject	Mark
1(a)(iv)	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$ ALLOW Equation showing Na^+ and anion on both sides IGNORE State symbols even if incorrect	Non-ionic equations	**1**

Question Number	Acceptable Answers	Reject	Mark
1(b)	**First mark for both half equations** Mentions / some evidence for the use of BOTH half equations in any way even if reversed or left unbalanced $Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$ ($E^\ominus = -0.41$ V) $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$ $\rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ ($E^\ominus = +1.33$ V) **(1)** **Second mark for** $8Cr^{3+}(aq) + 7H_2O(l) \rightarrow 6Cr^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq)$ **(1)** **Third mark for** $E^\ominus_{cell} = -0.41 - 1.33 = -1.74$ (V) For **second** and **third marks,** ALLOW reverse equation and $E^\ominus_{cell} = +1.74$ (V) (for **reverse** reaction) **(1)** ALLOW 1.74 (V) only if 'positive' stated in words elsewhere **Fourth mark for** EITHER Disproportionation / (proposed) reaction / "it is" **not feasible** (because its $E^\ominus_{cell}$ is negative) OR Reverse of disproportionation **is feasible** (because its $E^\ominus_{cell}$ is positive) **(1)** IGNORE state symbols even if incorrect ALLOW $\rightleftharpoons$ instead of $\rightarrow$ Third and fourth marks can be awarded CQ on incorrect half equation(s) and stated $E^\ominus$ values		**4**

Question Number	Acceptable Answers	Reject	Mark
2 (a)	**A** = copper(II) hydroxide / $Cu(OH)_2$ / $Cu(OH)_2(H_2O)_4$ **(1)** **B** = copper(II) oxide / CuO **(1)** **C** = tetraamminecopper(II) / $Cu(NH_3)_4^{2+}$ / $Cu(NH_3)_4(H_2O)_2^{2+}$ ALLOW $Cu(NH_3)_6^{2+}$ / hexaamminecopper(II) **(1)** **D** = copper / Cu / copper(0) / Cu(0) **(1)** **E** = copper(II) sulfate / $CuSO_4$ / Cu^{2+} / $Cu(H_2O)_6^{2+}$ **(1)** **F** = diamminecopper(I) / $Cu(NH_3)_2^{+}$ **(1)** ALLOW coordination numbers 1-6 in **F** Oxidation number separate from name IGNORE state symbols even if incorrect names without oxidation numbers except for **D**	Formulae with incomplete or unbalanced charges Incorrect oxidation states even with correct formulae	**6**

Question Number	Acceptable Answers	Reject	Mark
2 (b)	(Dilute) sulfuric acid / H_2SO_4 / $H_2SO_4(aq)$ ALLOW concentrated		**1**

Question Number	Acceptable Answers	Reject	Mark
2 (c)(i)	(transition metal / d-block element) complex(es) /complex ion(s) IGNORE ammines	Complex molecules amines, ions, ligands	**1**

Question Number	Acceptable Answers	Reject	Mark
2 (c)(ii)	Copper ion in **C** has partially filled **d** orbital(s) / subshell / $3d^9$ ALLOW unpaired d electron d shell **(1)** Copper ion in **F** has (completely) filled **d** orbitals / subshell / $3d^{10}$ **(1)** Reference to complete / incomplete d orbitals **max 1** EITHER Electronic **transitions** between partially filled (d) orbitals (of different energy) are possible OR Electronic **transitions** between (completely) filled (d) rbitals (of different energy) are not possible **(1)** ALLOW Equivalent words for transition e.g. promotion / jump / movement Penalise use of just 'shell' once IGNORE references to electrons returning to lower energy levels and emission of light	d orbitals empty no unpaired electrons (in F) orbital (singular) Splitting impossible because d orbitals full	**3**

Question Number	Acceptable Answers	Reject	Mark
2 (c)(iii)	Copper(I) is **oxidized** (to copper(II)) ALLOW **F** / it is **oxidized** **(1)** By oxygen / air **(1)** Second mark depends on first IGNORE 'shaking'		**2**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(i)	(simultaneous) oxidation and reduction **(1)** OR Simultaneous increase or decrease in oxidation number of an element **(1)** ALLOW 'Species' 'atoms of the same type' for 'element' Explanation in terms of copper(I) IGNORE Atom / ion / compound / substance / reactant	molecule	**2**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(ii)	$2Cu^{+} \rightarrow Cu + Cu^{2+}$ OR $2CuI + 2H^{+} \rightarrow Cu + Cu^{2+} + 2HI$ OR $2CuI \rightarrow Cu + Cu^{2+} + 2I^{-}$ IGNORE state symbols even if incorrect	Non-ionic equations	**1**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(iii)	ALLOW The use of cell notation (as in the Data Booklet SEP table) in place of equations e.g. $Cu^{+}(aq) \mid Cu(s)$ $E^{\ominus} = +0.52$ (V) (from the data book the equations are) $Cu^{+}(aq) + e^{-} \rightarrow Cu(s)$ $E^{\ominus} = +0.52$ (V) $Cu^{2+}(aq) + e^{-} \rightarrow Cu^{+}(aq)$ $E^{\ominus} = +0.15$ (V) **(1)** So $E^{\ominus}_{cell} = 0.52 - 0.15 = +0.37$ (V) **(1)** Correct answer including sign with no working scores full marks TE for second mark for use of $Cu^{2+}ICu$ +0.34 (V) which gives +0.19(V)/+0.18(V) No TE on incorrect equation in (d)(ii)	**Answer** without + sign	**2**

Question Number	Acceptable Answers	Reject	Mark
2 (d)(iv)	ALLOW In both schemes the use of cell notation (as in the Data Booklet SEP table) in place of equations e.g. $Cu^{2+}(aq) \mid Cu(s)$ $E^{\ominus} = +0.34$ (V) Penalise omission of electrons from equations and vertical lines from cell diagrams and reversal of equation without reversing sign. once only IGNORE omission of + sign for all $E^{\ominus}$ values **Scheme 1 (oxidation of copper)** Copper (formed (by disproportionation)) is oxidized (by nitric acid) must be stated in words stand alone mark **(1)** Relevant half equations are $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E^{\ominus} = +0.34$ (V) **(1)** $2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$ $E^{\ominus} = +0.80$ (V) OR $NO_3^-(aq) + 3H^+(aq) + 2e^- \rightarrow HNO_2(aq) + H_2O(l)$ $E^{\ominus} = +0.94$ (V) **(1)** Correct overall equation scores both marks: $Cu + 2\ NO_3^- + 4H^+ \rightarrow Cu^{2+} + N_2O_4 + 2H_2O$ OR $Cu + NO_3^- + 3H^+ \rightarrow Cu^{2+} + HNO_2 + H_2O$ So $E^{\ominus}_{cell}$ is +0.46 (V) (or +0.60 (V) or just 'positive') **(1)** **Scheme 2 (oxidation of copper(I)** Copper(I) iodide / Cu^+ is oxidized (by nitric acid) must be stated in words **(1)** stand alone mark $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$ $E^{\ominus} = +0.15$ (V) **(1)** $2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$ $E^{\ominus} = +0.80$ (V) OR $NO_3^-(aq) + 3H^+(aq) + 2e^- \rightarrow HNO_2(aq) + H_2O(l)$ $E^{\ominus} = +0.94$ (V) **(1)** Correct overall equation scores both marks:		**4**

	$2Cu^+ + 2NO_3^- + 4H^+ \rightarrow 2Cu^{2+} + N_2O_4 + 2H_2O$ $2Cu^+ + NO_3^- + 3H^+ \rightarrow 2Cu^{2+} + HNO_2 + H_2O$ So $E^{\ominus}_{cell}$ is +0.65 (V) (or +0.79 (V) or just 'positive') **(1)** IGNORE (omission of) state symbols even if incorrect		

Question Number	Acceptable Answers	Reject	Mark
3 (a) (i)	(Ligands cause) d orbitals / sub-shell / sub level to split **(1)** **Some** frequencies of light (energy) are absorbed **(1)** To promote electrons (within d level / d → d transitions) **(1)** ALLOW as alternative for second mark Remaining light is transmitted / reflected (resulting in the colour seen) **Mark independently**	Description of flame test	**3**

Question Number	Acceptable Answers	Reject	Mark
3 (a) (ii)	Concentrated HCl / HCl / HCl (aq) **(1)** **Ligand** exchange / replacement / substitution **(1)** **Mark independently**	Dilute HCl	**2**

Question Number	Acceptable Answers	Reject	Mark
3 (b) (i)	$[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$ **(1) (1)** ALLOW $[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5(OH)]^{2+} + H_2O + H^+$ **(1) (1)** ALLOW second mark for number of H_3O^+ ions related to incorrect complex e.g. $[Cr(H_2O)_4(OH)_2]^{2+} + 2H_3O^+$ scores second mark Ignore state symbols even if wrong		**2**

Question Number	Acceptable Answers	Reject	Mark
3 (b) (ii)	The concentration of oxonium / hydrogen ions is less in the $[Cu(H_2O)_6]^{2+}$ / fewer hydrogen ions produced or reverse argument based on Cr ion **(1)** ALLOW $[Cr(H_2O)_6]^{3+}$ / chromium ion deprotonates more easily if H_3O^+ shown in equation in (b) (i) Because copper ion is 2+ whilst the chromium ion is 3+ / charge on copper ion is less than charge on Cr ion / less charge density on 2+ ions / Cr (3+) draws more electron density from the O-H bond **(1)**	Just chromium complex more acidic The concentration of oxonium / hydrogen ions is greater in the $[Cu(H_2O)_6]^{2+}$ / more hydrogen ions produced Ligand exchange	**2**

Question Number	Acceptable Answers	Reject	Mark
3 (c)	$Cr(OH)_3$ / $Cr(H_2O)_3(OH)_3$		**1**

Question Number	Acceptable Answers	Reject	Mark
3 (d)	NaOH is a (strong) base / alkali **(1)** $Cr(H_2O)_3(OH)_3$ loses (three) protons / undergoes further deprotonation **OR** $Cr(OH)_3$ is amphoteric (so reacts with strong bases) **(1)** To reverse reaction 4 add (sulfuric) acid / H^+ / HCl **(1)**	Chromium is amphoteric	**3**

Question Number	Acceptable Answers	Reject	Mark
3 (e)	$[Cr(NH_3)_6]^{3+} + (edta)^{4-} \rightarrow [Cr(edta)]^- + 6NH_3$ **(1)** Ignore missing brackets Ignore state symbols even if wrong During the reaction number of particles increases (2 to 7) / more moles of product than reactants AND entropy (of system) increases **(1)**	Entropy increases because a gas is produced only Just more products than reactants	**2**