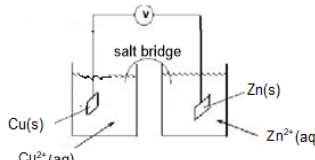


2(a)	the (3)d and (4)s sub-shells / orbitals / electrons are close / similar in energy
2(b)	species or ion formed by a central metal atom/ion AND surrounded by/bonded to (one or more) ligands
2(c)(i)	NaOH / OH ⁻ (aq) AND precipitation / ligand exchange / deprotonation / acid–base
2(c)(ii)	M1: Fe(H₂O)₄(OH)₂ is oxidised (from + 2 to + 3 on standing) M2: $E^\ominus$ of Fe(H₂O)₃(OH)₃ is more negative than $E^\ominus$ of O₂ OR $E^\ominus_{\text{cell}} = 0.40 - (-0.56) = (+)0.96 \text{ V}$ M3: $4\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2 + \text{O}_2 \rightarrow 4\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 2\text{H}_2\text{O}$
2(d)	$\Delta G^\ominus = -2 \times 1.67 \times 96\,500 = -322\,310 \text{ J mol}^{-1}$ M1: $\Delta G^\ominus = -nE^\ominus_{\text{cell}}F$ AND $n = 2$ OR $-2 \times 1.67 \times 96\,500$ M2: $\Delta G^\ominus = -322.3 \text{ kJ mol}^{-1}$

4(a)	M1: potential difference / voltage / EMF AND between two half-cells / two electrodes (in a cell) M2: (at concentration of) 1 mol dm⁻³ AND (pressure of) 1 atm / 101 kPa AND (temperature of) 298 K / 25 °C
4(b)(i)	 M1: salt bridge labelled AND voltmeter / V AND wire to electrode and liquid level shown [complete circuit] M2: Cu(s) AND Cu²⁺(aq) M3: Zn(s) AND Zn²⁺(aq)
4(b)(ii)	ions AND electrons
4(b)(iii)	M1: Nernst equation $E = E^\ominus + (0.059/z) \log(\text{Zn}^{2+}/\text{Zn})$ M2: $E = -0.76 + (0.059/2) \log(0.25) = -0.778 \text{ V}$ OR $E = -0.76 + (8.31 \times 298) / (96\,500 \times 2) \ln(0.25) = -0.778 \text{ V min 2sf}$
4(c)(i)	(from) +4 (to) +3
4(c)(ii)	$\text{Zn} + 2\text{MnO}_2 \rightarrow \text{ZnO} + \text{Mn}_2\text{O}_3$
4(c)(iii)	$E^\ominus(\text{MnO}_2/\text{Mn}_2\text{O}_3) = 1.47 - 1.28 = (+)0.19 \text{ V}$

5(a)(i)	$\text{Co}^{2+} = [\text{Ar}] 3d^7$ AND $\text{Co}^{3+} = [\text{Ar}] 3d^6$
5(a)(ii)	has vacant d orbitals that are energetically accessible
5(a)(iii)	- pink - blue - aqueous Any two [1], all three [2]
5(a)(iv)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^+$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$

5(a)(v)	ligand exchange
5(a)(vi)	$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ OR $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Co}(\text{OH})_2 + 6\text{H}_2\text{O}$
5(b)(i)	M1: Nernst equation $E = E^\ominus + (0.059/z) \times \log\left(\frac{[\text{oxidised}]}{[\text{reduced}]}\right)$ M2: $E = -0.28 + (0.059/2) \times \log(0.02)$
5(b)(ii)	1.66 V
5(b)(iii)	$3\text{Co} + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \rightarrow 3\text{Co}^{2+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$
5(b)(iv)	$\text{Co}^{2+} / \text{Co}, \text{Co}^{2+} / \text{Co}, \text{Cr}_2\text{O}_7^{2-} / \text{Cr}^{3+}$
5(c)	M1: moles of cobalt = $0.547 / 58.9 = 0.00929$ M2: coulombs required = $0.00929 \times 96\,500 \times 2 = 1792$ M3: time required = $1792 / 0.50 = 3584.8 \text{ s} = 59.7 \text{ minutes } 3\text{sf}$