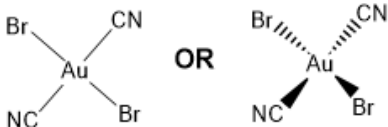
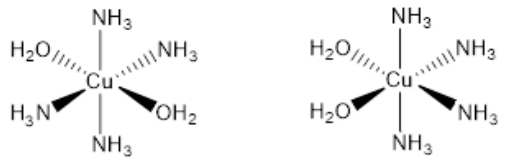


5(a)	<table><tr><th rowspan="2">species</th><th colspan="2">number of unpaired electrons</th></tr><tr><th>3d</th><th>4s</th></tr><tr><td>Cu</td><td>0</td><td>1</td></tr><tr><td>Cu²⁺</td><td>1</td><td>0</td></tr></table>	species	number of unpaired electrons		3d	4s	Cu	0	1	Cu ²⁺	1	0	
species	number of unpaired electrons												
	3d	4s											
Cu	0	1											
Cu ²⁺	1	0											
5(b)	• five 3d orbitals (lines, boxes) in the isolated Cu²⁺ ion of the same energy • splitting: three higher and two lower d orbitals • energy of all five d orbitals in complex higher than all d orbitals in isolated ion any two [1], all three [2]												
5(c)	M1: more than one (stable) oxidation state / exist in variable oxidation states M2: vacant / empty (d) orbitals are energetically accessible OR vacant / empty (d) orbitals can form dative bonds with ligands												
5(d)	<table><tr><th>metal ion</th><th>coordination number</th><th>formula of complex ion</th><th>charge of complex ion</th></tr><tr><td>Ag⁺</td><td>2</td><td><u>Ag(CN)₂</u></td><td>1-</td></tr><tr><td>Fe²⁺</td><td>6</td><td><u>Fe(CN)₆</u></td><td>4-</td></tr></table> each row [1]	metal ion	coordination number	formula of complex ion	charge of complex ion	Ag ⁺	2	<u>Ag(CN)₂</u>	1-	Fe ²⁺	6	<u>Fe(CN)₆</u>	4-
metal ion	coordination number	formula of complex ion	charge of complex ion										
Ag ⁺	2	<u>Ag(CN)₂</u>	1-										
Fe ²⁺	6	<u>Fe(CN)₆</u>	4-										
5(e)	M1:  M2: (shape) square planar AND (bond angle) 180°												
5(f)(i)	M1: moles MnO₄⁻ = 0.075 × 0.0225 = 1.6875 × 10⁻³ M2: moles V²⁺ = 5 / 3 × 1.6875 × 10⁻³ = 2.8125 × 10⁻³ M3: mass V = 50.9 × 2.8125 × 10⁻³ = 0.143 g % of V = 0.143 / 0.250 × 100 = 57.3 min 2sf												
5(f)(ii)	2VO₃⁻ + 3Zn + 12H⁺ → 2V²⁺ + 3Zn²⁺ + 6H₂O M1: 2 : 3 ratio on both sides M2: rest of the equation correct												

5(a)(i)	Co ²⁺ = [Ar] 3d ⁷ AND Co ³⁺ = [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)	[Co(H ₂ O) ₆] ²⁺ + 4HCl → [CoCl ₄] ²⁻ + 6H ₂ O + 4H ⁺ OR [Co(H ₂ O) ₆] ²⁺ + 4Cl ⁻ → [CoCl ₄] ²⁻ + 6H ₂ 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: Nemst 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 = $0.00929 \times 96500 \times 2 = 1792$ M3: time required = $1792 / 0.50 = 3584.8 \text{ s} = 59.7 \text{ minutes } 3\text{sf}$

1(a)	forms (one or more) stable ions / compounds / oxidation states with incomplete / partially filled (3)d orbital(s) / d shell / d sub-shell
1(b)(i)	(orbitals) are at the same energy
1(b)(ii)	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^9$
1(c)(i)	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$ deep / dark / royal blue AND $[\text{CuCl}_4]^{2-}(\text{aq})$ yellow
1(c)(ii)	M1: d orbital(s) of different energy / d-d splitting occurs / d sub-shell splits M2: electron(s) promoted / excited M3: light / wavelength / frequency / photon absorbed AND complementary colour seen
1(d)(i)	M1: ligand exchange / replacement / substitution / displacement M2: $[\text{CuCl}_4]^{2-} + 4\text{NH}_3 + 2\text{H}_2\text{O} \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{Cl}^-$
1(d)(ii)	M1: one correct 3D structure of $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ M2: correct 3D stereoisomer structure of isomer 1 
1(d)(iii)	cis isomer AND dipoles do not cancel
1(e)(i)	(two) oxygen and (one) nitrogen (can donate) three lone pair(s) of electrons (to the metal ion)

1(e)(ii)	$[\text{Co}(\text{C}_4\text{H}_5\text{NO}_4)_2]^-$
1(f)(i)	equilibrium constant for the formation of the complex (ion) in a solvent / water / solution OR from its constituent ions or molecules
1(f)(ii)	$[\text{Ag}(\text{CN})_2]^-$ (aq) AND largest (value of) K_{stab}
1(g)	M1 M2: any two [1], all four [2] • moles $\text{MnO}_4^- = 0.015 \times 18.70 / 1000 = 2.805 \times 10^{-4}$ • moles $\text{SO}_3^{2-} = 2.805 \times 10^{-4} \times 5/2 = 7.0125 \times 10^{-4}$ (in 10 cm³) • moles $\text{SO}_3^{2-} = 1.753 \times 10^{-2}$ (in 250 cm³) • mass $\text{Na}_2\text{SO}_3 = 1.753 \times 10^{-2} \times 126.1 = 2.21$ g M3: % purity = $100 \times 2.21 / 3.75 = \mathbf{58.9 - 59.0 \%}$ min 2sf