5(a)

species	number of **unpaired** electrons	
	3d	4s
Cu	0	1
Cu^{2+}	1	0

5(b)

- five 3d orbitals (lines, boxes) in the isolated Cu^{2+} 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

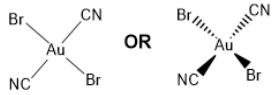
5(d)

metal ion	coordination number	formula of complex ion	charge of complex ion
Ag^+	2	$Ag(CN)_2$	1–
Fe^{2+}	6	$Fe(CN)_6$	4–

each row [1]

5(e)

M1:



M2: (shape) square planar **AND** (bond angle) 180°

5(f)(i)

M1: moles MnO_4^- = 0.075 × 0.0225 = 1.6875 × 10^{-3}

M2: moles V^{2+} = 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)

$2VO_3^- + 3Zn + 12H^+ \rightarrow 2V^{2+} + 3Zn^{2+} + 6H_2O$

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)

$[Co(H_2O)_6]^{2+} + 4HCl \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H^+$ **OR** $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$

5(a)(v)

ligand exchange

5(a)(vi)

$[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2(H_2O)_4 + 2H_2O$ **OR**
$[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(OH)_2 + 6H_2O$

5(b)(i)

M1: Nernst equation $E = E^{\ominus} + (0.059 / z) \times \log(\frac{[\text{oxidised}]}{[\text{reduced}]})$

M2: E = –0.28 + (0.059 / 2) × log(0.02)

5(b)(ii)

1.66 V

5(b)(iii)

$3Co + Cr_2O_7^{2-} + 14H^+ \rightarrow 3Co^{2+} + 2Cr^{3+} + 7H_2O$

5(b)(iv)

Co^{2+} / Co, Co^{2+} / Co, $Cr_2O_7^{2-}$ / Cr^{3+}

5(c)

M1: moles of cobalt = 0.547 / 58.9 = 0.00929

M2: coulombs required = 0.00929 × 96500 × 2 = 1792

M3: time required = 1792 / 0.50 = 3584.8 s = 59.7 minutes 3sf

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)

$[Cu(NH_3)_4(H_2O)_2]^{2+}$(aq) deep / dark / royal blue

AND

$[CuCl_4]^{2-}$(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)

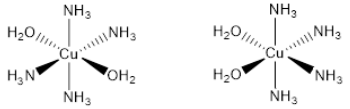
M1: ligand exchange / replacement / substitution / displacement

M2: $[CuCl_4]^{2-} + 4NH_3 + 2H_2O \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4Cl^-$

1(d)(ii)

M1: one correct 3D structure of $[Cu(H_2O)_2(NH_3)_4]^{2+}$

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)	$[Co(C_4H_5NO_4)_2]^-$
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)	$[Ag(CN)_2]^-$(aq) **AND** largest (value of) K_{stab}
1(g)	**M1 M2:** any two [1], all four [2] • moles MnO_4^- = 0.015 ×18.70/1000 = 2.805×10^{-4} • moles SO_3^{2-} = 2.805×10^{-4} × 5/2 = 7.0125×10^{-4} (in 10 cm^3) • moles SO_3^{2-} = 1.753×10^{-2} (in 250 cm^3) • mass Na_2SO_3 = 1.753×10^{-2} × 126.1 = 2.21 g **M3:** % purity = 100 × 2.21 / 3.75 = **58.9 – 59.0 %** min 2sf