

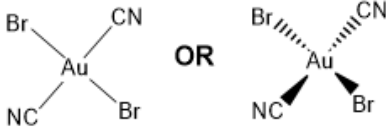
3(a)(i)	M1 Heat (solid FA 5) AND observe condensation, droplets, steam, water vapour M2 Make an aqueous solution of FA 5 / dissolve in water to use for tests M3 (To portion of the solution) add aqueous NH₃ AND white ppt AND insoluble in excess NH₃ M4 (To portion of the solution) add aqueous barium chloride or barium nitrate AND white precipitate M5 to distinguish sulfate / sulfite (white precipitate from M4) insoluble in hydrochloric OR nitric acid OR KMnO₄ is not decolourised / remains purple (added after M4 or directly to FA 5 (aq))																										
3(a)(ii)	<table><tr><td>Zn²⁺</td><td>X</td></tr><tr><td>SO₄²⁻</td><td>✓</td></tr><tr><td>H₂O</td><td>✓</td></tr></table>				Zn ²⁺	X	SO ₄ ²⁻	✓	H ₂ O	✓																	
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3(b)(i)	• (FA 6) starting colour purple • solid jumps / moves around • black residue • test with glowing splint • splint relights / glows more brightly																										
3(b)(ii)	(dark) Green																										
3(c)(i)	'No change' 2 correct = *, 3 correct = ** 2* = 1 mark Max mark = 4 <table><tr><th rowspan="2">test</th><th colspan="3">observations</th></tr><tr><th>FA 7</th><th>FA 8</th><th>FA 9</th></tr><tr><td>Test 1 Add hydrogen peroxide</td><td>Bubbles/ effervescence * Purple / FA 7 (solution) to colourless (solution) * (Gas / oxygen) relights glowing splint *</td><td>No change</td><td>Bubbles / effervescence * (Gas/ oxygen) relights glowing splint *</td></tr><tr><td>Test 2 Add sodium hydroxide, then</td><td></td><td>Off-white ppt*</td><td>No change</td></tr><tr><td>leave to stand</td><td></td><td>brown ppt on standing*</td><td></td></tr><tr><td>Test 3 Add aqueous iron(II) sulfate</td><td>Turns colourless / yellow OR colourless / yellow solution formed*</td><td>No change</td><td></td></tr></table>				test	observations			FA 7	FA 8	FA 9	Test 1 Add hydrogen peroxide	Bubbles/ effervescence * Purple / FA 7 (solution) to colourless (solution) * (Gas / oxygen) relights glowing splint *	No change	Bubbles / effervescence * (Gas/ oxygen) relights glowing splint *	Test 2 Add sodium hydroxide, then		Off-white ppt*	No change	leave to stand		brown ppt on standing*		Test 3 Add aqueous iron(II) sulfate	Turns colourless / yellow OR colourless / yellow solution formed*	No change	
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3(c)(ii)	manganese / Mn																										

3(c)(iii)		FA 6 / FA 7	FA 8
	oxidation state	(+)7	(+)2

3(a)(i)	2 * = 1 mark (round down). Max 5 marks.		
	<i>test</i>	<i>observations</i>	
		FA 4	FA 5
	1 + NaOH(aq)	red-brown / brown ppt AND insoluble in excess *	white ppt * soluble in excess *
	2 + NH ₃ (aq)	red-brown / brown ppt AND insoluble in excess *	white ppt AND insoluble in excess *
	3 + Na ₂ CO ₃ (aq)	fizzing * gas gives white ppt with limewater * red-brown ppt *	white ppt * fizzing * gas gives white ppt with limewater (award if not awarded for FA 4)
	4 + BaCl ₂ (aq) / Ba(NO ₃) ₂ (aq)	white ppt AND	white ppt *
3(a)(ii)	5 + H ⁺ / KMnO ₄ (aq)	stays purple / no change AND	stays purple / no change *
	<i>ions</i>	FA 4	FA 5
	cations	Fe ³⁺ , H ⁺	Al ³⁺
	anions	SO ₄ ²⁻	SO ₄ ²⁻
	5 ions correct = 3 marks 3 or 4 ions correct = 2 marks 2 ions correct = 1 mark		
3(b)(i)	2 * = 1 mark (round down)		
	<i>test</i>	<i>observations</i>	
		FA 6	FA 7
	1 + H ⁺ / KMnO ₄ (aq)	(turns paler pink)	(purple fades slightly)
	and warm	decolourises / turns colourless / turns (pale) yellow *	decolourises / turns colourless / turns (pale) yellow *
	2 + I ₂ (aq) + NaOH (and warm)	no change *	ppt * that is (pale) yellow *
	3 + Na ₂ CO ₃ (aq)	fizzing *	no change *

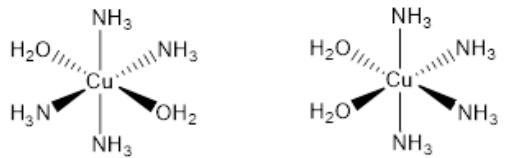
3(b)(ii)	M1 (FA 6) is methanoic acid because it produces CO_2 / reacts with sodium carbonate AND it can be oxidised / it reacts with KMnO_4 M2 (FA 7) is propan-2-ol as it gives a ppt in test 2 OR gives a positive tri-iodomethane/iodoform test OR has the $-\text{CH}(\text{OH})\text{CH}_3$ group
3(c)	Correct equation $\text{CH}_3\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$ OR $\text{C}_2\text{H}_5\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightarrow \text{C}_2\text{H}_5\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$

3(a)(i)	- selects (aqueous) silver nitrate and (aqueous) ammonia * - white ppt * - soluble in (aqueous) ammonia * NaCl * 2 * = 1 mark						
3(a)(ii)	(The acid) removes / reacts with the hydrogencarbonate ions OR silver ions react with hydrogencarbonate ions						
3(b)(i)	- green (at start) * - turns to a black powder / solid * - powder very fluid / moves around the test-tube * - condensation (on walls of test-tube) * 2 * = 1 mark						
3(b)(ii)	- forms green-blue solution * - effervescence * - vigorous reaction * - attempts to test with limewater * - gas / carbon dioxide gives white precipitate / solid with limewater * 2 * = 1 mark						
3(b)(iii)	<table border="1"> <tr> <td>Test 1 Add $\text{NaOH}(\text{aq})$</td><td>(pale) blue precipitate insoluble in excess *</td></tr> <tr> <td>Test 2 Add $\text{NH}_3(\text{aq})$</td><td>(pale) blue precipitate * (precipitate dissolves forming) dark / deep blue solution in excess *</td></tr> <tr> <td>Test 3 Add aluminium foil</td><td>effervescence / fizzing* (gas) pops with a lighted splint * pink-brown solid * turns colourless / pale blue solution formed * gets hotter *</td></tr> </table> Metal ion in FB 7: Cu^{2+} * 2 * = 1 mark	Test 1 Add $\text{NaOH}(\text{aq})$	(pale) blue precipitate insoluble in excess *	Test 2 Add $\text{NH}_3(\text{aq})$	(pale) blue precipitate * (precipitate dissolves forming) dark / deep blue solution in excess *	Test 3 Add aluminium foil	effervescence / fizzing* (gas) pops with a lighted splint * pink-brown solid * turns colourless / pale blue solution formed * gets hotter *
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3(c)(i)	<table border="1"> <tr> <td>Test 1 Add $\text{NaOH}(\text{aq})$</td><td>green precipitate * insoluble in excess * (precipitate) turns brown (on surface) *</td></tr> <tr> <td>Test 2 Add acidified KMnO_4</td><td>purple to colourless / (pale) yellow solution OR KMnO_4 decolourised*</td></tr> </table> 2 * = 1 mark Metal ion in FB 8: Fe^{2+}	Test 1 Add $\text{NaOH}(\text{aq})$	green precipitate * insoluble in excess * (precipitate) turns brown (on surface) *	Test 2 Add acidified KMnO_4	purple to colourless / (pale) yellow solution OR KMnO_4 decolourised*		
Test 1 Add $\text{NaOH}(\text{aq})$	green precipitate * insoluble in excess * (precipitate) turns brown (on surface) *						
Test 2 Add acidified KMnO_4	purple to colourless / (pale) yellow solution OR KMnO_4 decolourised*						
3(c)(ii)	Redox reaction AND change to colourless linked to reduction of manganate(VII) ions OR change to yellow colour linked to oxidation of Fe^{2+} or production of Fe^{3+}.						

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–
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Ag ⁺	2	<u>Ag(CN)₂</u>	1–										
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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 = $1792 / 0.50 = 3584.8 \text{ s} = 59.7 \text{ minutes}$ 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)	$[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}(\text{aq})$ 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