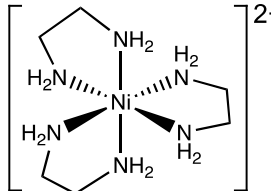
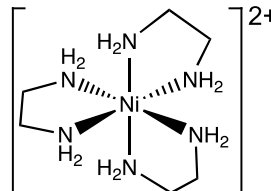


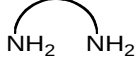
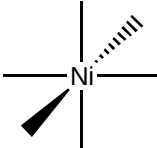
Question	Answer	Marks	Guidance
1	D	1	

Question	Answer	Marks	Guidance
2	A	1	

Question	Answer	Marks	Guidance
3	B	1	
	Total	15	

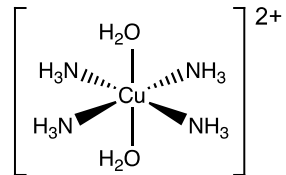
Question			Answer	Marks	Guidance
4	(a)	(i)	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$ ✓ yellow solution $\text{Cu}(\text{OH})_2$ ✓ pale blue precipitate $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ✓ deep blue solution CuI ✓ I_2 ✓ white solid brown solution	5	ALLOW $\text{Cu}(\text{Cl})_4^{2-}$ ALLOW $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$ Brackets required for $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ NOTE: Take great care to check that subscripted numbers and brackets are correct
		(ii)	Reaction 1: ligand substitution ✓ Reaction 2: redox ✓	2	ALLOW ligand exchange ALLOW reduction AND oxidation ALLOW precipitation

Question	Answer	Marks	Guidance
(b)*	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) A comprehensive conclusion using all data to obtain correct formulae for A, B, C and D AND optical isomers shown <i>There is a well-developed line of reasoning which is clear and logically structured with use of 3D structures for both optical isomers of C, use of wedges and bonding to N. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a sound conclusion for the formula of B AND obtains the correct formula of the hydrated complex A OR a 3D diagram of one optical isomer of cation C <i>There is a line of reasoning and supported by some evidence. Calculations are clear and can be followed to obtain correct conclusions. 3D diagram, if present, should use wedges mostly correctly. Formula of A to show water separately or formula of C to show ligands separately, as appropriate.</i> Level 1 (1–2 marks) Reaches a simple conclusion to obtain the correct formula of anhydrous complex B OR shows that A contains 2H₂O <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. Attempts more than one part of the problem.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: 1. Formula of anhydrous complex B NiC₆N₆H₂₄Cl₂ <i>Example of working</i> $\begin{array}{cccccc} \text{Ni} & : & \text{C} & : & \text{N} & : & \text{H} & : & \text{Cl} \\ = & \frac{18.95}{58.7} & : & \frac{23.25}{12.0} & : & \frac{27.12}{14.0} & : & \frac{7.75}{1.00} & : & \frac{22.93}{35.5} \end{array}$ There may be other methods 2. Formula of hydrated complex A NiC₆N₆H₂₄Cl₂•2H₂O OR NiC₆N₆H₂₄Cl₂(H₂O)₂ <i>Example of working</i> $n(\text{anhydrous salt}) = \frac{7.433}{309.7} = 0.02400 \text{ (mol)}$ $n(\text{H}_2\text{O}) = \frac{0.864}{18.0} = 0.04800 \text{ (mol)} \checkmark$ There may be other methods 3. Formula of cation C [NiC₆N₆H₂₄]²⁺ OR [Ni(H₂NCH₂CH₂NH₂)₃]²⁺ (could be in structures 2+ charge can be shown on cation OR optical isomers (i.e. seen somewhere) Bidentate ligand D H₂NCH₂CH₂NH₂ or displayed so that structure is clearly unambiguous. Optical isomers   <i>Accuracy of structures</i>

Question			Answer	Marks	Guidance
					Bonding shown from Ni to N of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ ALLOW $\text{CH}_3\text{CH}(\text{NH}_2)_2$ for ligand For $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ in optical isomers, ALLOW C–C without Hs and  Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge':  Bond into paper can be shown as:

Question	Answer	Marks	AO element	Guidance
5	D	1	AO1.1	
	Total	15		

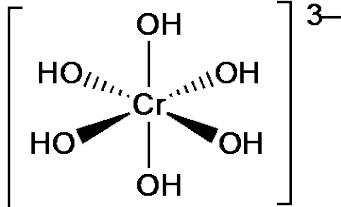
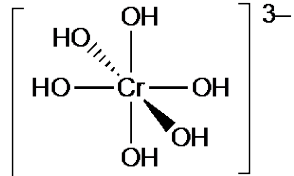
Question			Answer	Marks	Guidance
6	(a)		Ni: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓ Ni^{2+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ✓	2	ALLOW 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ ALLOW $1s^2$ written after answer prompt (ie $1s^2$ twice) ALLOW upper case D, etc and subscripts, e.g. 4S ₂ 3D ₈ ALLOW for Ni^{2+} 4s ⁰ DO NOT ALLOW [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$ Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake

Question	Answer	Marks	Guidance																					
6	(b)* Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) All three reactions are covered in detail with C, D, E and F identified with clear explanations. <i>There is a well-developed line of reasoning which is clear and logically structured with clear chemical communication and few omissions. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) All three reactions are covered but explanations may be incomplete OR Two reactions are explained in detail. <i>There is an attempt at a logical structure with a line of reasoning. The information is relevant e.g. formulae may contain missing brackets or numbers and supported by some evidence.</i> Level 1 (1–2 marks) Make two simple explanations from any one reaction. OR Makes one simple explanation from each of two reactions <i>There is an attempt at a logical structure with a line of reasoning The information is in the most part relevant.</i> 0 marks No response worthy of credit.	6	Indicative scientific points may include: REACTION 1 (CuSO₄/NH₃) Product C : [Cu(NH₃)₄(H₂O)₂]²⁺ Equation [Cu(H₂O)₆]²⁺ + 4NH₃ → [Cu(NH₃)₄(H₂O)₂]²⁺ + 4H₂O Structure of trans stereoisomer  Correct connectivity REACTION 2 (Cu₂O/H₂SO₄) Products D : CuSO₄ OR [Cu(H₂O)₆]²⁺ E: Cu Equation Cu₂O + H₂SO₄ → CuSO₄ + Cu + H₂O Oxidation numbers Cu(+1) → Cu(+2) + Cu(0) REACTION 3 (CuO/HNO₃) Equation CuO + 2HNO₃ → Cu(NO₃)₂ + H₂O Molar ratios <table><tr><td>Cu</td><td>:</td><td>H</td><td>:</td><td>N</td><td>:</td><td>O</td></tr><tr><td>26.29</td><td>:</td><td>2.49</td><td>:</td><td>11.59</td><td>:</td><td>59.63</td></tr><tr><td>63.5</td><td>:</td><td>1.0</td><td>:</td><td>14.0</td><td>:</td><td>16.0</td></tr></table> Formula of F CuH₆N₂O₉ F: Cu(NO₃)₂•3H₂O (OR Cu(NO₃)₂(H₂O)₃)	Cu	:	H	:	N	:	O	26.29	:	2.49	:	11.59	:	59.63	63.5	:	1.0	:	14.0	:	16.0
Cu	:	H	:	N	:	O																		
26.29	:	2.49	:	11.59	:	59.63																		
63.5	:	1.0	:	14.0	:	16.0																		

Question	Answer	Marks	AO	Guidance
7	B	1	AO2.1	

Question	Answer	Marks	AO	Guidance
8	C	1	AO1.1	

9	(a)	<i>Coordinate bond mark</i> O_2 (coordinately or datively) bonds with $Fe^{2+}/Fe(II)/Fe/$Iron ✓ Ligand substitution mark (When required) O_2 is replaced by H_2O OR CO_2 OR O_2 is replaced by CO OR H_2O OR CO_2 is replaced by O_2 ✓ <i>Ligand strength mark</i> CO forms strong(er) bonds (than O_2) ✓	3	1.1 × 2 2.1 × 1	ALLOW names or symbols of ligands ALLOW $H_2O/CO/CO_2$ (coordinately or datively) bonds with $Fe^{2+}/Fe(II)/Fe/$Iron ALLOW oxygen donates electron pair to OR binds with $Fe^{2+}/Fe(II)/Fe/$Iron DO NOT ALLOW Fe^{3+} ALLOW other words for replaced ALLOW K_{stab} for CO (much) higher (than for O_2) ALLOW CO bonds irreversibly OR CO is a strong(er) ligand IGNORE affinity
		Total	9		

Question			Answer	Marks	AO element	Guidance
10	(a)	(i)	$[\text{Cr}(\text{NH}_3)_6]^{3+}(\text{aq})$ ✓	1	1.1	IGNORE state symbols
		(ii)	$\text{CrCl}_3(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{NaCl}(\text{aq})$ or $\text{Cr}^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ ✓ state symbols required	1	2.8	IGNORE square brackets around precipitate formulae ALLOW $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3(\text{s}) + 3\text{H}_2\text{O}(\text{l})$ ALLOW 'hybrid' equations, Eg $\text{Cr}^{3+}(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 3\text{Na}^{+}(\text{aq})$ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}(\text{aq}) + 3\text{OH}^{-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + 6\text{H}_2\text{O}(\text{l})$ $[\text{Cr}(\text{H}_2\text{O})]_6^{3+}(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow$ $\text{Cr}(\text{OH})_3(\text{s}) + 6\text{H}_2\text{O}(\text{l}) + 3\text{Na}^{+}(\text{aq})$
		(iii)	 3-D diagram with all bonds through O in OH ✓ 3- charge ✓	2	1.1 2.3	Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge':  ALLOW dotted line OR unfilled wedge as alternatives for dotted wedge IGNORE charges inside brackets
		(iv)	CrO_4^{2-} ✓	1	3.1	IGNORE compounds e.g. Na_2CrO_4
		(v)	orange ✓	1	1.1	
	(b)	(i)	$(1s^2)2s^22p^63s^23p^63d^2$ ✓	1	1.1	ALLOW upper case D, etc. and subscripts, e.g. $3D_2$ If included, ALLOW $4s^0$
18	b	(ii)	Explanation of colours VO^{2+} goes to V^{3+} (green) AND then V^{3+} goes to V^{2+}	3	3.1 x2	

Question			Answer	Marks	AO element	Guidance
			(violet) ✓ <i>Explanation using E° values</i> (E° of) system 4 ($\text{VO}^{2+}/\text{V}^{3+}$) is more positive / less negative than system 2 (Fe^{2+}/Fe) OR (E° of) system 3 ($\text{V}^{3+}/\text{V}^{2+}$) is more positive / less negative than system 2 (Fe^{2+}/Fe) ✓ <i>Equilibrium shift related to E° values</i> More positive/less negative system 4 ($\text{VO}^{2+}/\text{V}^{3+}$) shifts right AND More positive/less negative system 3 ($\text{V}^{3+}/\text{V}^{2+}$) shifts right		3.2 x1	IGNORE 'lower/higher' ALLOW reverse argument System 2 more negative than system 4 etc $E = (+)0.78 \text{ V}$ for system 4 + system 2 reaction OR $E = (+)0.18 \text{ V}$ for system 3 + system 2 reaction For shifts right' ALLOW (VO^{2+}) is reduced OR gains electrons (maybe seen as an equation) AND 'For shifts right' ALLOW (V^{3+}) is reduced OR gains electrons (maybe seen as an equation) IGNORE Fe oxidised
		(iii)	$\text{Fe} + 4\text{H}^+ + 2\text{VO}^{2+} \rightarrow \text{Fe}^{2+} + 2\text{H}_2\text{O} + 2\text{V}^{3+}$	1	2.8	IGNORE state symbols ALLOW multiples

Question	Answer	Marks	AO	Guidance
11	C	1	1.1	

Question			Answer	Marks	AO element	Guidance
12	(a)*	(i)	<i>Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.</i> Level 3 (5–6 marks) All three tests are covered in detail, with at least six of B to H identified correctly and equations mostly correct. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) All three tests are covered with at least four of B to H identified correctly. Some attempt at writing equations, but with several omissions or incorrect formulae. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Only two tests covered with at least two of B to H identified correctly, and little attempt at writing equations. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	6	3.3×3 3.4×3	Indicative scientific points may include: Identification of unknowns Can be identified within labelled equation. B is FeSO_4 OR Iron(II) sulfate - Test 1: Fe^{2+} present - Test 2: SO_4^{2-} present D is $\text{Fe}(\text{OH})_2$ OR $[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]$ OR iron(II) hydroxide G is BaSO_4 OR barium sulfate C is CrCl_3 OR chromium(III) chloride - Test 1: Cr^{3+} present - Test 3: Cl^- present E is $\text{Cr}(\text{OH})_3$ OR $[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]$ OR chromium(III) hydroxide F is $[\text{Cr}(\text{NH}_3)_6]^{3+}$ H is silver chloride OR AgCl Equations D: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$ OR $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{H}_2\text{O}$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Fe}(\text{OH})_2 + 4\text{H}_2\text{O} + 2\text{NH}_4^+$ E: $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Cr}(\text{OH})_3 + 6\text{H}_2\text{O}$ OR $\text{Cr}^{3+} + 3\text{OH}^- \rightarrow \text{Cr}(\text{OH})_3$ OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow [\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{H}_2\text{O}$ OR $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow [\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 3\text{NH}_4^+$ OR

Question			Answer	Marks	AO element	Guidance
						$[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 3\text{NH}_3 \rightarrow \text{Cr}(\text{OH})_3 + 3\text{H}_2\text{O} + 3\text{NH}_4^+$ F: $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 6\text{H}_2\text{O}$ OR $\text{Cr}(\text{OH})_3 + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 3\text{OH}^-$ OR $[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3] + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 3\text{H}_2\text{O} + 3\text{OH}^-$ G: $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$ H: $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$

Question			Answer	Marks	AO element	Guidance
	(b)	(i)	$\text{Ni} : \text{S} : \text{N} = \frac{16.26}{58.7} : \frac{35.36}{32.1} : \frac{31.0}{14}$ OR 0.277 : 1.10 : 2.21 OR 1 : 4 : 8 ✓ $x = 4$ ✓ $2 + x + y = 8$ $y = 2$ ✓	3	3.1×1 3.2×2	ALLOW any correct method ALLOW NiS ₄ N ₈ for ratio ALLOW ECF for y from incorrect x
		(ii)	+2 ✓	1	2.1	+ required ALLOW 2+

Question	Answer	Marks	AO element	Guidance
13	C	1	AO2.3	
	Total	15		

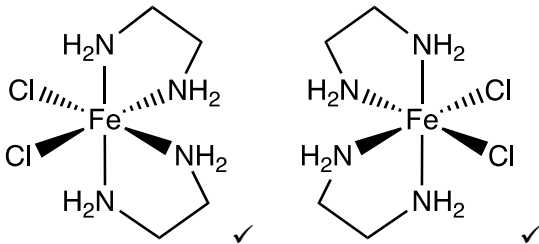
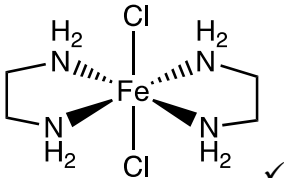
Question			Answer	Marks	AO element	Guidance
14	(a)		Transition element: Has an ion with an incomplete/partially-filled d sub-shell/d-orbital ✓ d-block d sub-shell/d-orbital is being filled/has highest energy OR Electron configurations shown for Sc: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$ AND Zn: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ ✓ <i>Electron configurations of ions</i> Sc³⁺: $1s^2 2s^2 2p^6 3s^2 3p^6$ AND d sub-shell empty / d orbital(s) empty ✓ Zn²⁺: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ AND d sub-shell full / d-orbitals full ✓	4	AO1.1 ×4	FULL ANNOTATIONS MUST BE USED ----- DO NOT ALLOW d shell IGNORE d block IGNORE outer electron electron configurations ALLOW $4s^0$ ALLOW $4s^2$ before 3d, i.e.$4s^2 3d^1$; $4s^2 3d^{10}$ IGNORE other Sc and Zn ions ALLOW ECF for short hand notation. For Sc³⁺, ALLOW Sc⁺³ OR Sc forms a 3+ ion; For Zn²⁺, ALLOW Zn⁺² OR Zn forms a 2+ ion;
	(b)	(i)	Donates two electron pairs (to a metal ion) AND forms two coordinate bonds (to a metal ion) ✓	1	AO1.1 x1	ALLOW lone pairs for electron pairs ALLOW dative (covalent) bonds for coordinate bonds TWO is only needed once if bonds are plural, e.g. Donates 2 electron pairs to form coordinate bonds Donates electron pairs to form 2 coordinate bonds

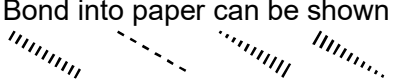
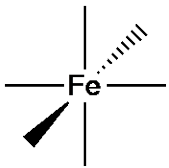
Question			Answer	Marks	AO element	Guidance
		(ii)*	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Reaches a comprehensive conclusion with most detail and few errors to obtain: the formulae of A and B AND ionic equation for ligand substitution AND the 3D structures of B stereoisomers <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a sound conclusion with some detail and some errors for the formula of A OR B AND ionic equation for ligand substitution OR the 3D structures of B stereoisomers <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Obtains the correct formula of A OR B OR 3D structures of B stereoisomers which are mostly correct. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	AO2.2 ×2 AO2.6 ×2 AO3.1 ×2	Indicative scientific points: <u>1. Formula of the hydrated salt A</u> Formula of A: $\text{Cr}_2\text{H}_{24}\text{O}_{24}\text{S}_3$ <i>Example of working</i> $\begin{array}{cccc} \text{Cr} & : & \text{H} & : & \text{O} & : & \text{S} \\ \hline 17.10 & : & 3.94 & : & 63.13 & : & 15.83 \\ 52.0 & : & 1.0 & : & 16.0 & : & 32.1 \end{array}$ There may be other methods Detail <i>Hydrated salt = $\text{Cr}_2(\text{SO}_4)_3 \cdot 12\text{H}_2\text{O}$</i> <u>2. Formula of B and ionic equation</u> Formula of B: $[\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]^-$ Ionic equation $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 2\text{C}_2\text{O}_4^{2-} \rightarrow [\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]^- + 4\text{H}_2\text{O}$ ALLOW ligands in any order, e.g. $[\text{Cr}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$ Detail <i>Use of charges and brackets</i> <u>3. 3D structures of B stereoisomers</u>

Question	Answer	Marks	AO	Guidance
15	B	1	1.2	

Question	Answer	Marks	AO	Guidance
16	B	1	1.2	

Question			Answer	Marks	AO element	Guidance
17	(a)	(i)	(N) donates two electron pairs (to a metal ion/metal/ Fe^{3+}) AND forms two coordinate / dative (covalent) bonds ✓	1	AO1.2	ALLOW lone pairs for electron pairs TWO is only needed once if bonds are plural e.g. donates 2 electron pairs to form co- ordinate bonds OR donates electron pairs to form 2 coordinate bonds .

Question	Answer	Marks	AO element	Guidance
(ii)	Empirical formula $\text{FeC}_4\text{H}_{16}\text{N}_4\text{Cl}_2$ (any order) AND charge = (1)+ ✓ Structures i.e. Optical isomers (<i>cis</i>)  i.e. <i>trans</i> isomer 	4	AO1.2 x1 AO3.1 x3	DO NOT ALLOW $\text{Fe}(\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2)\text{Cl}_2$ for empirical formula ALLOW any order TAKE CARE: structures may be in different orientations and in different order IGNORE charges (anywhere) IF connectivity between Fe AND N of NH_2 is incorrect then penalise first time ONLY

Question	Answer	Marks	AO element	Guidance
	For $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$, ALLOW skeletal, structural, displayed formula AND C-C without Hs and  IF NH_2 shown with incorrect number of H, eg. N  N, penalise first time ONLY IF ALL 3 isomers are 'correct', but 2 x CI AND no Ns, e.g.  AWARD 1 mark			Each structure to contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper OR 4 lines, 1 'out wedge' and 1 'in wedge': Bond into paper can be shown as:  ALLOW 
(b) (i)	$\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 \checkmark$	1	AO2.6	IGNORE state symbols, even if wrong ALLOW $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4 + 2\text{H}_2\text{O}$ OR $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2 + 6\text{H}_2\text{O}$

Question			Answer	Marks	AO element	Guidance
		(ii)	Explanation of the brown precipitate The brown ppt is $\text{Fe}(\text{OH})_3$ OR $\text{Fe}(\text{OH})_2$ loses electrons/ $\text{Fe}(\text{OH})_2$ oxidised ✓ Comparison of E values (E of) Fe/Redox system 1 is more negative/less positive (than E of O_2/redox system 2) OR (E of) O_2/Redox system 2 is more positive/less negative (than E of Fe/redox system 1) ✓ Equilibrium shift More negative/less positive OR Fe system OR Redox system 1 shifts left OR More Positive/less negative OR O_2 system OR Redox system 2 shifts right ✓ Equation $4\text{Fe}(\text{OH})_2(\text{s}) + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{Fe}(\text{OH})_3(\text{s})$ ✓	4	AO3.1 ×4	ORA ALLOW Fe^{2+} is oxidised to Fe^{3+} ALLOW Fe ALLOW E_{cell} is (+) 0.96V IGNORE 'lower/higher' For equilibrium shift ALLOW E_{cell} is +ve therefore the reaction is feasible. OR Direction of half equation correctly written. ALLOW multiples ALLOW equilibrium IGNORE state symbols, even if wrong DO NOT ALLOW uncanceled species

Question		Answer	Marks	AO element	Guidance														
	(c)	Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G. AND most correct equations and identifies some changes in oxidation number AND Calculation of M_r of the gas <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G. AND EITHER some correct equations OR Any one correct equation and a relevant change in oxidation number OR any one correct equation and a correct calculation of the M_r <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i>	6	AO3.1 ×3 AO3.2 ×3	Indicative scientific points may include <table><tr><th></th><th>Formula</th></tr><tr><td>B</td><td>CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$</td></tr><tr><td>C</td><td>$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4</td></tr><tr><td>D</td><td>SO_2</td></tr><tr><td>E</td><td>$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$</td></tr><tr><td>F</td><td>CuI</td></tr><tr><td>G</td><td>I_2</td></tr></table> Experiment 1 Equation $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O} + 4\text{H}^+$ Experiment 2 Evidence $n(\text{D}) = \frac{45}{24000} = 1.875 \times 10^{-3}$$\text{Molar mass (D)} = \frac{0.12}{1.875 \times 10^{-3}} = 64$ Equation $\text{Cu} + 2\text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{SO}_2 + 2\text{H}_2\text{O}$ Oxidation numbers $\text{Cu } 0 \rightarrow \text{Cu } +2; \quad \text{S } +6 \rightarrow \text{S } +4$		Formula	B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$	C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4	D	SO_2	E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$	F	CuI	G	I_2
	Formula																		
B	CuCl_4^{2-} OR $[\text{CuCl}_4]^{2-}$																		
C	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ OR CuSO_4																		
D	SO_2																		
E	$\text{Cu}(\text{NO}_3)_2$ OR $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$																		
F	CuI																		
G	I_2																		

Question			Answer	Marks	AO element	Guidance
			Level 1 (1–2 marks) Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G OR The correct formulae for 1 of B, C, D, E, F and G with correct equation or calculation. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>			Experiment 3 Equation $\text{CuO} + 2\text{HNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + \text{H}_2\text{O}$ $2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI} + \text{I}_2$ OR $2\text{Cu}(\text{NO}_3)_2 + 4\text{KI} \rightarrow 2\text{CuI} + \text{I}_2 + 4\text{KNO}_3$ Oxidation numbers $\text{Cu} +2 \rightarrow \text{Cu} +1$; $\text{I} -1$ to 0

Question	Answer	Marks	AO element	Guidance
18	D	1	AO1.2	

Question		Answer	Marks	AO element	Guidance
19	(a)	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5–6 marks) Explains the terms ‘d-block element’ AND ‘transition element’ AND Explains why not all d-block are transition elements AND At least THREE correct electron configurations (need to be one electron configuration of d block atom, transition element ion and zinc (or scandium) ion) <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Explains both the terms ‘d-block element’ and ‘transition element’ AND Explains why not all d-block are transition elements OR Explains both the terms ‘d-block element’ and ‘transition element’ AND Links terms to at least TWO correct electron configurations OR Explains the terms ‘d-block element’ OR ‘transition element’ AND Explains why not all d-block are transition elements AND Links terms to at least ONE correct electron configuration	6	AO1.1 ×4 AO1.2 ×2	Indicative scientific points may include: Terms d-block element: element with highest energy/ valence electron in d-orbital/sub-shell OR d subshell is being filled DO NOT ALLOW d block for d-subshells Transition element: element forming one or more ions (allow atom and ion - IUPAC definition) with incomplete/partially filled d-subshell/d-orbitals DO NOT ALLOW d shell d-block element: ALLOW examples with an ion with an incomplete d-subshell, e.g. Fe²⁺ - [Ar]4s⁰3d⁶ ALLOW examples with highest energy electrons in a d-subshell, e.g. Fe - [Ar]4s²3d⁶ Not all d-block are transition elements: Sc and Zn form ions with complete or empty d-shells ORA For Sc³⁺, ALLOW Sc³⁺ OR Sc forms a 3+ ion For Zn²⁺, ALLOW Zn²⁺ OR Zn forms a 2+ ion Sc³⁺ 1s²2s²2p⁶3s²3p⁶ Sc³⁺ AND d subshell empty / d orbital(s) empty Zn²⁺ 1s²2s²2p⁶3s²3p⁶3d¹⁰ Zn²⁺ AND d subshell full / ALL d orbitals full

Question			Answer	Marks	AO element	Guidance
			<i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Explains the term ‘d-block element’ OR ‘transition element’ AND Attempts to link terms with ONE correct electron configuration OR Explains the term ‘d-block element’ AND ‘transition element’ OR Explains the term ‘d-block element’ OR ‘transition element’ AND Explains why not all d-block are transition elements OR Any TWO out of THREE correct electron configurations (one element and one ion that is a transition element and one ion that is not a transition element) <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit			ALLOW minor slips on inner shell electron configurations ----- NOTE: A clear and logically structured response would link definitions to electron configurations to support the explanations. If stated, for the level, there should be clear indication that the d subshell is full/empty or partially full

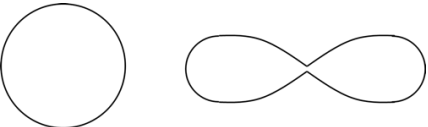
Question			Answer	Marks	AO element	Guidance
	(b)	(i)	Cu Precipitation with OH⁻/NH₃ 2 marks (Pale) Blue (precipitate) AND Cu(OH)₂ (can be seen in the equation)✓ $\text{Cu}^{2+} + 2\text{OH}^- \rightarrow \text{Cu(OH)}_2 \checkmark$ OR Precipitation with I⁻ 2 marks White (precipitate) AND CuI ✓ $2\text{Cu}^{2+} + 4\text{I}^- \rightarrow 2\text{CuI} + \text{I}_2 \checkmark$ Cr Precipitation with OH⁻/NH₃ 2 marks (Dark) Grey-Green (precipitate) AND Cr(OH)₃ ✓ $\text{Cr}^{3+} + 3\text{OH}^- \rightarrow \text{Cr(OH)}_3 \checkmark$	2	AO1.1 AO1.2	ALLOW any one precipitation reaction any one ligand substitution ALLOW other correct equations linked to correct colour change -check with TL IGNORE state symbols DO NOT ALLOW dark/royal blue (complex ion colour) ALLOW Cu(H₂O)₄(OH)₂ ALLOW $[\text{Cu(H}_2\text{O)}_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu(OH)}_2(\text{H}_2\text{O)}_4 + 2\text{H}_2\text{O}$ OR $[\text{Cu(H}_2\text{O)}_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu(OH)}_2 + 6\text{H}_2\text{O}$ OR $[\text{Cu(H}_2\text{O)}_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu(OH)}_2(\text{H}_2\text{O)}_4 + 2\text{NH}_4^+$ ALLOW Green ALLOW Cr(H₂O)₃(OH)₃ ALLOW $[\text{Cr(H}_2\text{O)}_6]^{3+} + 3\text{OH}^- \rightarrow \text{Cr(OH)}_3(\text{H}_2\text{O)}_3 + 3\text{H}_2\text{O}$ OR $[\text{Cr(H}_2\text{O)}_6]^{3+} + 3\text{NH}_3 \rightarrow \text{Cr(OH)}_3(\text{H}_2\text{O)}_3 + 3\text{NH}_4^+$ OR $[\text{Cr(H}_2\text{O)}_6]^{3+} + 3\text{OH}^- \rightarrow \text{Cr(OH)}_3 + 6\text{H}_2\text{O}$

Question			Answer	Marks	AO element	Guidance
	(b)	(ii)	Cu Ligand substitution with NH_3/Cl^- 2 marks NH_3 Deep/dark/royal blue (solution) AND $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ ✓ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓ OR Cl^- yellow (solution) AND $[\text{CuCl}_4]^{2-}$ ✓ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$ ✓ Cr Ligand substitution with NH_3 2 marks NH_3 Purple (solution) AND $[\text{Cr}(\text{NH}_3)_6]^{3+}$ ✓ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{NH}_3 \rightarrow [\text{Cr}(\text{NH}_3)_6]^{3+} + 6\text{H}_2\text{O}$ ✓ OR Dark Green (solution) AND $[\text{Cr}(\text{OH})_6]^{3-}$ ✓ $[\text{Cr}(\text{H}_2\text{O})_6]^{3+} + 6\text{OH}^- \rightarrow [\text{Cr}(\text{OH})_6]^{3-} + 6\text{H}_2\text{O}$ ✓	2	AO1.1 AO1.2	ALLOW other correct equations linked to correct colour change -check with TL ALLOW ECF on any incorrect charges of the complex ions when linked to colour via an equation.
	(c)		Charge: -1 OR $-$ OR $1-$ ✓ Coordination number: 6 ✓	2	AO1.2 ×2	ALLOW $[\text{Co}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^-$ DO NOT ALLOW Co^- IGNORE sign

Question			Answer	Marks	AO element	Guidance
	(d)		$3\text{V}^{3+} + \text{Cr}_2\text{O}_7^{2-} + 2\text{H}^+ \rightarrow 3\text{VO}_2^+ + 2\text{Cr}^{3+} + \text{H}_2\text{O}$ ALL reactant and product species correct ✓ Correct balancing (of correct equation) AND cancelling of species ✓	2	AO2.5 AO2.6	IGNORE Balancing and electrons for first mark DO NOT ALLOW electrons in final answer

Question	Answer	Marks	Guidance
20	D	1	

Question	Answer	Marks	Guidance
21	C	1	

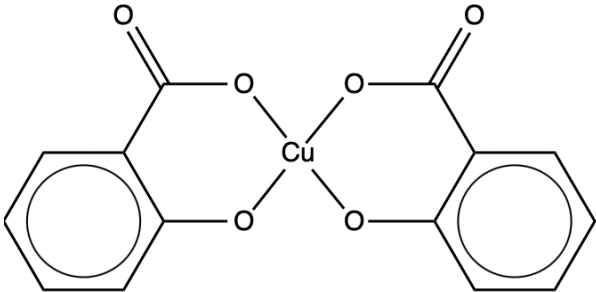
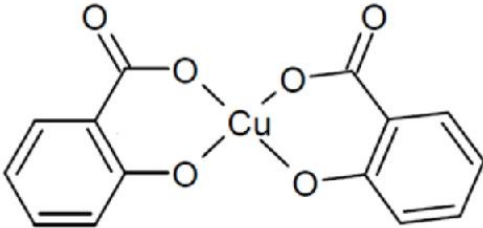
Question			Answer	Marks	Guidance
22	(a)		s orbital p orbital ✓  Fe = $(1s^2)2s^22p^63s^23p^64s^23d^6$ AND Fe²⁺ = $(1s^2)2s^22p^63s^23p^63d^6$ ✓	2	IGNORE shading IGNORE axes directions x, y, z DO NOT ALLOW multiple p orbitals For electron configuration, ALLOW $4s^2$ after $3d^6$ i.e. $1s^22s^22p^63s^23p^63d^64s^2$ ALLOW upper case D, etc and subscripts, e.g.$4S_23D_1$ ALLOW $4s^0$ IGNORE $[Ar]3d^6 4s^2$
	(b)	(i)	(A =) $[Co(H_2O)_6]^{2+}$ ✓ (B =) $Co(OH)_2$ ✓ (C =) $[CoCl_4]^{2-}$ OR $CoCl_4^{2-}$ ✓	3	IGNORE state symbols even if incorrect [] essential ALLOW $[Co(OH)_2(H_2O)_4]$ OR $Co(OH)_2(H_2O)_4$ ALLOW -2 for 2- i.e. $[CoCl_4]^{-2}$

Question			Answer	Marks	Guidance
		(ii)	Complex : $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$ ✓ Charge +1 / + / 1+ ✓	2	IGNORE Any charges for 1 st mark ALLOW $[\text{CoCl}_2(\text{NH}_3)_4]$ ALLOW $[\text{Co}(\text{Cl})_2(\text{NH}_3)_4]$ DO NOT ALLOW $[\text{Co}(\text{Cl}_2)(\text{NH}_3)_4]$ DO NOT ALLOW if charges shown in formula within brackets for 2 nd mark
		(c)	Oxygen (O lone pair) forms a <u>coordinate/dative</u> bond to <u>Fe(II)/Fe/Iron/Fe²⁺</u> ✓ replaced by H ₂ O or CO ₂ OR O ₂ bonds <u>reversibly</u> (with metal ion) ✓ FIRST CHECK ANSWER ON ANSWER LINE If 7.3(0) AND not healthy / below 7.35 award three calculation marks ----- $[\text{H}^+] = K_a \times \frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]}$ OR $\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]} \quad \checkmark$ $[\text{H}^+] = 5.02 \times 10^{-8} \quad \checkmark$	5	ALLOW word equations using → and ⇌ IGNORE number of coordinate bonds ALLOW ORA Check for alternative methods on mark scheme. ALLOW ECF throughout ALLOW [A ⁻] for [HCO ₃ ⁻] AND/OR [HA] for [H ₂ CO ₃] (asked for in 19 a) ii) ALLOW $[\text{H}^+] = K_a \div \frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$ ALLOW $\frac{[\text{H}_2\text{CO}_3]}{[\text{HCO}_3^-]} = \frac{[\text{H}^+]}{K_a}$ [H ⁺] value subsumes MP3 ALLOW $[\text{H}^+] = 5.02 \times 10^{-8}$ up to the calculator value (5.023529412 x 10 ⁻⁸) DO NOT ALLOW a weak acid approach for marking points 3 and 5. i.e. [H ⁺] can be awarded.

Question			Answer	Marks	Guidance																				
			pH = $-\log(5.02 \times 10^{-8}) = 7.3(0)$ AND not healthy / below 7.35 ✓ <u>Alternative method 1:</u> pH of healthy blood is between 7.35 and 7.45 <table><tr><td>pH 7.35</td><td></td><td>pH 7.45</td><td></td></tr><tr><td>$[\text{H}^+] = 4.47 \times 10^{-8}$</td><td>OR</td><td>$[\text{H}^+] = 3.55 \times 10^{-8}$</td><td>✓</td></tr><tr><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$</td><td></td><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$</td><td>✓</td></tr><tr><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$</td><td></td><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$</td><td></td></tr><tr><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 9.55:1$</td><td></td><td>$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 12.03:1$</td><td></td></tr></table> 8.5:1 does not lie in the range of 9.55:1 to 12.03:1 AND unhealthy ✓	pH 7.35		pH 7.45		$[\text{H}^+] = 4.47 \times 10^{-8}$	OR	$[\text{H}^+] = 3.55 \times 10^{-8}$	✓	$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$	✓	$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 9.55:1$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 12.03:1$			ALLOW 7.3 up to calculator value (pH =7.298991951) ALLOW $[\text{H}^+] = 3.98 \times 10^{-8}$ from average pH 7.40 used. 3
pH 7.35		pH 7.45																							
$[\text{H}^+] = 4.47 \times 10^{-8}$	OR	$[\text{H}^+] = 3.55 \times 10^{-8}$	✓																						
$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{K_a}{[\text{H}^+]}$	✓																						
$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{4.47 \times 10^{-8}}$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{4.27 \times 10^{-7}}{3.55 \times 10^{-8}}$																							
$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 9.55:1$		$\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = 12.03:1$																							

Question	Answer	Marks	Guidance
23	B	1	
		15	

Question			Answer	Mark	Guidance
24	(a)	(i)	$\text{Fe } (1s^2) 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ ✓ $\text{Cu}^{2+} (1s^2) 2s^2 2p^6 3s^2 3p^6 3d^9$ ✓	2	ALLOW $(1s^2) 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$ ALLOW upper case letter S and P, and subscripts, e.g. $2S_2 2P_5$ IGNORE $(4s^0)$ IGNORE electron configuration of copper under the line. Treat as working DO NOT ALLOW [Ar] as shorthand for $(1s^2) 2s^2 2p^6 3s^2 3p^6$
		(ii)	Green precipitate (FeSO_4) ✓ (Pale) blue precipitate (CuSO_4) ✓	2	ALLOW 1 mark for both correct colours stated without precipitate mentioned ALLOW ppt / solid DO NOT ALLOW dark blue for CuSO_4
	(b)	(i)	<u>Donates</u> one/an electron pair (to a metal ion) AND forms one/a dative (covalent) / coordinate bond (to a metal ion) ✓	1	ALLOW lone pair for electron pair

Question	Answer	Mark	Guidance
(ii)	$\text{Fe} = \frac{12.6}{55.8} : \text{C} = \frac{54.3}{12} : \text{H} = \frac{4.5}{1} : \text{N} = \frac{12.6}{14} : \text{Cl} = \frac{16.0}{35.5}$ $= 0.226 : 4.525 : 4.5 : 0.900 : 0.451$ $1 : 20 : 20 : 4 : 2 \checkmark$ $\text{FeC}_{20}\text{H}_{20}\text{N}_4\text{Cl}_2 \checkmark$ (pyridine ligands =) Four / 4 $\checkmark$ (coordination number =) Six / 6 $\checkmark$	4	ALLOW other methods ALLOW $\text{FeC}_{20}\text{H}_{20}\text{N}_4\text{Cl}_2$ OR $\text{Fe}(\text{C}_5\text{H}_5\text{N})_4\text{Cl}_2$ for ratio CORRECT empirical formulae subsumes ratio mark DO NOT ALLOW $\text{Fe}(\text{C}_5\text{H}_5\text{N})_4\text{Cl}_2$ for $\text{FeC}_{20}\text{H}_{20}\text{N}_4\text{Cl}_2$ (not the empirical formulae)
(c)	Cis isomer  <i>Cis/trans</i> $\checkmark$	2	IGNORE charge and brackets ALLOW  ALLOW geometric ALLOW E/Z