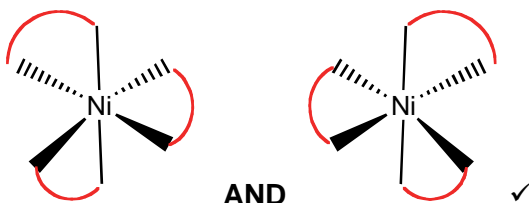


Question			Answer	Marks	Guidance
1	(a)		(+)5 ✓	1	ALLOW 5+ OR V OR Cr⁵⁺
1	(b)		For equations, IGNORE any state symbols; ALLOW multiples ----- Any correct equation for a reaction catalysed by a transition element, compound or ion AND transition element, compound or ion (by formula or name) ✓	1	EXAMPLES N ₂ + 3H ₂ ⇌ 2NH ₃ (allow →) AND Fe/iron oxide 2SO ₂ + O ₂ ⇌ 2SO ₃ (allow →) AND V ₂ O ₅ /Pt 2CO + 2NO → 2CO ₂ + N ₂ AND Pt/Pd/Rh/Au Equation for any alkene + H ₂ → alkane AND Ni/Pt/Pd C ₆ H ₆ + Cl ₂ → C ₆ H ₅ Cl + HCl AND Fe/FeCl ₃ /Fe ³⁺ C ₆ H ₆ + Br ₂ → C ₆ H ₅ Br + HBr AND Fe/FeBr ₃ /Fe ³⁺ 2H ₂ O ₂ → 2H ₂ O + O ₂ AND MnO ₂ For other examples, CHECK with TL
1	(c)	(i)	Donates two electron pairs (to a metal ion) AND forms two coordinate bonds (to a metal ion) ✓ <i>NOTE: Metal ion not required as Ni³⁺ is in the question</i>	1	ALLOW lone pairs for electron pairs ALLOW dative (covalent) bonds for coordinate bonds TWO is only needed once, e.g. Donates two electron pairs to form coordinate bonds Donates electron pairs to form two coordinate bonds
1	(c)	(ii)	C ₃ H ₁₀ N ₂ ✓	1	ALLOW in any order IGNORE structure
1	(c)	(iii)	MARK INDEPENDENTLY ----- H ₂ NCH ₂ CH ₂ CH ₂ NH ₂ ✓ Each N OR each NH ₂ OR amine group has a lone pair/electron pair OR lone pairs shown on N atoms in structure ✓	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW H ₂ NCH ₂ CH(CH ₃)NH ₂ OR H ₂ NCH(CH ₂ CH ₃)NH ₂ ALLOW secondary or tertiary diamines or mixture IGNORE complex ion For other examples, CHECK with TL

Question			Answer	Marks	Guidance
1	(c)	(iv)	6 ✓	1	
1	(c)	(v)	3-D diagrams of BOTH optical isomers required for the mark 	1	In this part, Charge AND Square brackets NOT required IGNORE N or attempts to draw structure of bidentate ligand Other orientations possible but all follow same principle with 2nd structure being a mirror image of the first

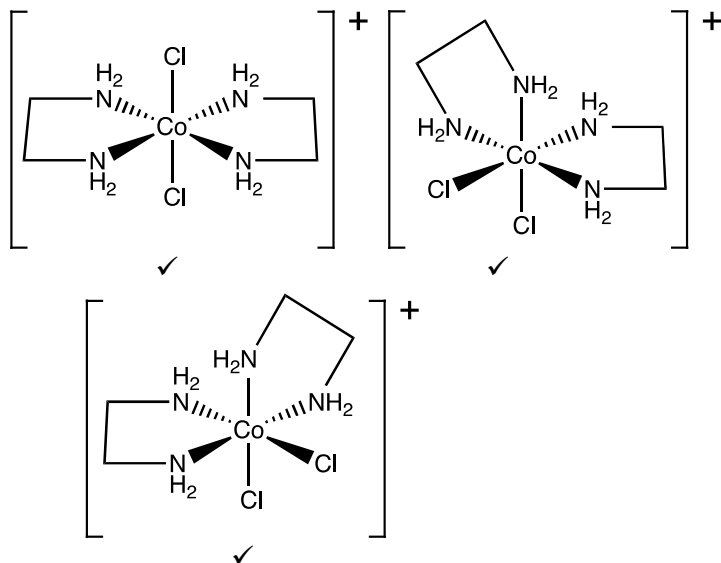
Question		Answer	Marks	Guidance
1	(d)	<p><i>Quality of written communication</i> Observation must be linked to the correct reaction</p> <p>REACTIONS OF AQUEOUS Cu²⁺</p> <p>-----</p> <p>REACTION OF Cu²⁺ with NaOH(aq)</p> <p>-----</p> <p>Correct balanced equation Cu²⁺(aq) + 2OH⁻(aq) → Cu(OH)₂(s) ✓ state symbols not required</p> <p>Observation blue precipitate/solid ✓</p>	2	<p>FULL ANNOTATIONS MUST BE USED THROUGHOUT ALLOW some reactions for Cu²⁺ and some for Co²⁺ ALLOW equilibrium signs in all equations IGNORE any incorrect initial colours IGNORE state symbols IGNORE an incorrect formula for an observation</p> <p>-----</p> <p>ALLOW [Cu(H₂O)₆]²⁺ + 2OH⁻ → Cu(OH)₂(H₂O)₄ + 2H₂O</p> <p>ALLOW full or 'hybrid' equations, e.g. Cu²⁺ + 2NaOH → Cu(OH)₂ + 2Na⁺ [Cu(H₂O)₆]²⁺ + 2OH⁻ → Cu(OH)₂ + 6H₂O</p> <p style="text-align: center;">+ 2NaOH → Cu(OH)₂ + Na₂SO₄</p> <p>ALLOW any shade of blue IGNORE initial precipitation of Cu(OH)₂</p>
1	(d)	<p>REACTION OF Cu²⁺ WITH excess NH₃(aq)</p> <p>Correct balanced equation [Cu(H₂O)₆]²⁺ + 4NH₃ → [Cu(NH₃)₄(H₂O)₂]²⁺ + 4H₂O ✓</p> <p>Observation deep/dark blue (solution) ✓</p>	2	<p>IGNORE [Cu(NH₃)₄]²⁺</p> <p>ALLOW royal blue, ultramarine blue or any blue colour that is clearly darker than for [Cu(H₂O)₆]²⁺</p> <p>DO NOT ALLOW deep blue precipitate for observation</p>
1	(d)	<p>REACTION OF Cu²⁺ WITH HCl(aq)</p> <p>Correct balanced equation [Cu(H₂O)₆]²⁺ + 4Cl⁻ → [CuCl₄]²⁻ + 6H₂O ✓</p> <p>Observation yellow (solution) ✓</p>	2	<p>IGNORE mention of different concentrations of HCl</p> <p>ALLOW CuCl₄²⁻ i.e. no brackets OR Cu(Cl)₄²⁻</p> <p>ALLOW [Cu(H₂O)₆]²⁺ + 4HCl → [CuCl₄]²⁻ + 6H₂O + 4H⁺</p> <p>IGNORE Cu²⁺ + 4Cl⁻ → CuCl₄²⁻</p> <p>ALLOW green–yellow OR yellow–green</p> <p>DO NOT ALLOW yellow precipitate for observation</p>

Question		Answer	Marks	Guidance
1	(d)	<p><i>Quality of written communication</i> Observation must be linked to the correct reaction</p> <p>REACTIONS OF AQUEOUS Co²⁺</p> <p>-----</p> <p>REACTION OF Co²⁺ with NaOH(aq)</p> <p>Correct balanced equation Co²⁺(aq) + 2OH⁻(aq) → Co(OH)₂(s) ✓ state symbols not required</p> <p>Observation blue precipitate/solid ✓</p>	2	<p>FULL ANNOTATIONS MUST BE USED THROUGHOUT ALLOW some reactions for Cu²⁺ and some for Co²⁺ ALLOW equilibrium signs in all equations IGNORE any incorrect initial colours IGNORE state symbols IGNORE an incorrect formula for an observation</p> <p>-----</p> <p>ALLOW [Co(H₂O)₆]²⁺ + 2OH⁻ → Co(OH)₂(H₂O)₄ + 2H₂O</p> <p>ALLOW full or 'hybrid' equations, e.g. Co²⁺ + 2NaOH → Co(OH)₂ + 2Na⁺ [Co(H₂O)₆]²⁺ + 2OH⁻ → Co(OH)₂ + 6H₂O + 2NaOH → Co(OH)₂ + Na₂SO₄</p> <p>ALLOW any shade of blue IGNORE changes in colour over time IGNORE initial precipitation of Co(OH)₂</p>
1	(d)	<p>REACTION OF Co²⁺ WITH excess NH₃(aq)</p> <p>Correct balanced equation [Co(H₂O)₆]²⁺ + 6NH₃ → [Co(NH₃)₆]²⁺ + 6H₂O ✓</p> <p>Observation brown/yellow (solution) ✓</p>	2	<p>ALLOW any shade of brown or yellow</p> <p>DO NOT ALLOW brown/yellow precipitate for observation</p>
1	(d)	<p>REACTION OF Co²⁺ WITH HCl(aq)</p> <p>Correct balanced equation [Co(H₂O)₆]²⁺ + 4Cl⁻ → [CoCl₄]²⁻ + 6H₂O ✓</p> <p>Observation blue (solution) ✓</p>	2	<p>IGNORE mention of different concentrations of HCl</p> <p>ALLOW CoCl₄²⁻ i.e. no brackets OR Co(Cl)₄²⁻ ALLOW [Co(H₂O)₆]²⁺ + 4HCl → [CoCl₄]²⁻ + 6H₂O + 4H⁺ IGNORE Co²⁺ + 4Cl⁻ → CoCl₄²⁻</p> <p>ALLOW any shades of blue DO NOT ALLOW blue precipitate for observation</p>
		Total	14	

Question	Answer	Marks	Guidance
2 (a)	<p>(Transition element) has an ion with an incomplete/partially-filled d sub-shell/d-orbital ✓</p> <p>Scandium/Sc and zinc/Zn are not transition elements ✓</p> <p><i>Electron configurations of ions</i> Sc³⁺ AND 1s²2s²2p⁶3s²3p⁶ ✓</p> <p>Zn²⁺ AND 1s²2s²2p⁶3s²3p⁶3d¹⁰ ✓</p> <p>Sc³⁺ AND d sub-shell empty / d orbital(s) empty ✓ Note: Sc³⁺ must be the ONLY scandium ion shown for this mark</p> <p>Zn²⁺ AND d sub-shell full / ALL d-orbitals full ✓ Note: Zn²⁺ must be the ONLY zinc ion shown for this mark</p>	6	<p>FULL ANNOTATIONS MUST BE USED</p> <p>-----</p> <p>ALLOW capital 'D' within definition DO NOT ALLOW d shell</p> <p>ALLOW if ONLY Sc and Zn are used to illustrate d block elements that are NOT transition elements This can be from anywhere in the overall response in terms of Sc, Sc³⁺, Zn, Zn²⁺ OR incorrect charges, i.e. only Sc⁺, Sc²⁺, Zn⁺</p> <p>In electron configurations, IF subscripts OR caps used, DO NOT ALLOW when first seen but credit subsequently</p> <p>ALLOW 4s⁰ in electron configurations IGNORE [Ar] IGNORE electron configurations for other Sc and Zn ions</p> <p>ALLOW for Sc³⁺: Sc forms a 3+ ion; ALLOW Sc⁺³ ALLOW for Zn²⁺: Zn forms a 2+ ion; ALLOW Zn⁺²</p> <p>ALLOW Sc³⁺ has no d sub-shell DO NOT ALLOW 'd sub-shell is incomplete' (in definition)</p> <p>DO NOT ALLOW 'd sub-shell is incomplete' (in definition)</p>

	(b)	(i)	<p>Donates two electron/lone pairs to a metal ion OR Co^{3+} ✓ DO NOT ALLOW metal (complex contains Co^{3+})</p> <p>Electron/lone pair on N OR NH_2 (groups) ✓</p>		<p>ALLOW 'forms two coordinate bonds/dative covalent/dative bonds' as an alternative for 'donates two electron/lone pairs' <i>Two is required for 1st marking point</i> <i>Two can be implied using words such as 'both' or 'each'</i></p> <p>For metal ion, ALLOW transition (metal) ion</p> <p>2 Second mark is for the atom that donates the electron/lone pairs</p> <p>ALLOW both marks for a response that communicates the same using N as the focus: e.g. The two N atoms each donate an electron pair to metal ion</p>
	(b)	(ii)	$[\text{Co}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_2\text{Cl}_2]^+$ ✓	1	<p>Square brackets AND + charge required DO NOT ALLOW any charges included within square brackets</p> <p>ALLOW $[\text{Co}(\text{C}_2\text{H}_8\text{N}_2)_2\text{Cl}_2]^+$ OR $[\text{CoC}_4\text{H}_{16}\text{N}_4\text{Cl}_2]^+$</p> <p>ALLOW structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>IGNORE $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ <i>simplifies question</i></p> <p>Within formula, ALLOW $\dots(\text{Cl})_2$, (Cl_2)</p> <p>ALLOW CO Within the context of the question, CO is Co</p>
	(b)	(iii)	6 ✓	1	

(b) (iv)



Note: For each structure, **ALL** NH₂ groups must be shown **AND** bonding between Co **AND** N of NH₂.

For H₂NCH₂CH₂NH₂, **ALLOW** C–C without Hs and

IF NH₂ shown without Hs, e.g. , penalise first time **ONLY**

IF ALL 3 isomers are 'correct', but 2 x Cl **AND** no Ns, e.g.

AWARD 1 mark

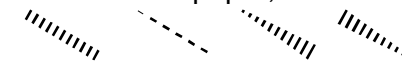
FULL ANNOTATIONS MUST BE USED

IGNORE charges (**anywhere**) and labels (even if wrong)

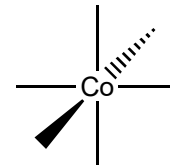
Square brackets **NOT** required

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':

For bond into paper, **ALLOW**:



ALLOW following geometry throughout:



3

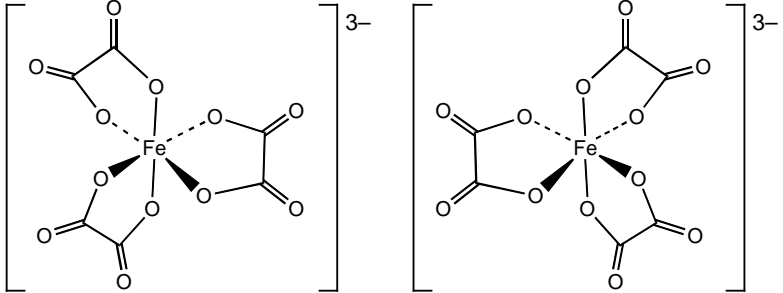
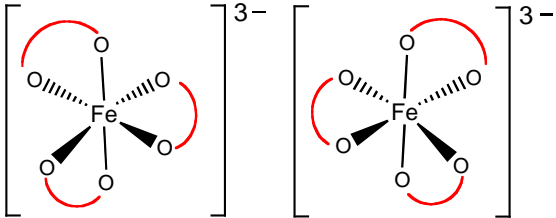
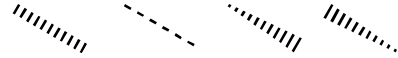
TAKE CARE: structures may be in different orientations.

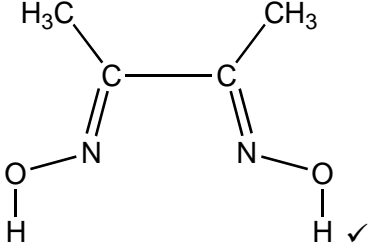
For H₂NCH₂CH₂NH₂, **ALLOW** (connectivity within 'loop' only)

If Cl₂s are shown instead of Cl, penalise 1st time only

	(c)	(i)	<p>O₂/oxygen bonds to Fe²⁺/Fe(II) ✓ Fe²⁺/Fe(II) <i>essential for 1st marking point</i></p> <p>(When required,) O₂ substituted OR O₂ released ✓ Fe²⁺ <i>not required for 2nd marking point (e.g. IGNORE Fe)</i></p>	2	<p>ASSUME that 'it' refers to oxygen ALLOW O₂ binds to Fe²⁺ OR O₂ donates electron pair to Fe²⁺ OR O₂ is a ligand with Fe²⁺</p> <p>IGNORE O₂ reacts with Fe²⁺ OR O₂ is around Fe²⁺</p> <p>ALLOW bond to O₂ breaks when O₂ required OR H₂O replaces O₂ OR vice versa ALLOW CO₂ replaces O₂ OR vice versa ALLOW O₂ bonds/binds reversibly</p>
	(c)	(ii)	<p>(K_{stab} =) $\frac{[\text{HbO}_2(\text{aq})]}{[\text{Hb}(\text{aq})][\text{O}_2(\text{aq})]}$ ✓</p> <p>ALL Square brackets essential</p>	1	<p>ALLOW expression without state symbols <i>(given in question)</i></p>
	(c)	(iii)	<p>Both marks require a comparison</p> <p>Stability constant/K_{stab} value with CO is greater (than with complex in O₂) ✓</p> <p>(Coordinate) bond with CO is stronger (than O₂) OR CO binds more strongly ✓</p>	2	<p>IGNORE (complex with) CO is more stable</p> <p>ALLOW bond with CO is less likely to break (than O₂) OR CO is a stronger ligand (than O₂) OR CO has greater affinity for ion/metal/haemoglobin (than O₂)</p> <p>ALLOW CO bond formation is irreversible OR CO is not able to break away</p> <p>IGNORE CO bonds more easily OR CO complex forms more easily</p>
			Total	18	

Question		er	Marks	Guidance
3	(a)	$2\text{Fe} + 3\text{Cl}_2 \longrightarrow 2\text{FeCl}_3$ ✓	1	ALLOW $2\text{Fe} + 3\text{Cl}_2 \longrightarrow \text{Fe}_2\text{Cl}_6$ ALLOW multiples, e.g. $\text{Fe} + 1\frac{1}{2}\text{Cl}_2 \longrightarrow \text{FeCl}_3$ IGNORE state symbols DO NOT ALLOW $2\text{Fe} + 3\text{Cl}_2 \longrightarrow 2\text{Fe}^{3+} + 6\text{Cl}^-$
	(b)	$\text{Fe}^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_3$ ✓	1	IGNORE state symbols ALLOW $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}$ ALLOW $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \longrightarrow \text{Fe}(\text{OH})_3 + 6\text{H}_2\text{O}$
	(c) (i)	$2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + \text{Zn} \longrightarrow 2[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + \text{Zn}^{2+}$ All chemical species correct (IGNORE e^- for 1st mark) ✓ Balancing with '2' in front of both Fe complex ions ✓	2	IGNORE state symbols For 1 mark, ALLOW balancing if (aq) species have been used instead of complex ions: $2\text{Fe}^{3+} + \text{Zn} \longrightarrow 2\text{Fe}^{2+} + \text{Zn}^{2+}$
	(ii)	redox ✓	1	ALLOW reduction AND oxidation CARE: possible confusion with (d)(ii)
	(d) (i)	Formula of E as $[\text{Fe}(\text{CN})_6]^{3-}$ shown as product in equation ✓ Correct balanced equation: $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{CN}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{H}_2\text{O}$ ✓ Notice different charges on complex ions: LHS 3+, RHS 3- state symbols not required	2	ALLOW equations with KCN, i.e.: $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{KCN} \rightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ $[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 6\text{K}^+ + 6\text{CN}^- \rightarrow [\text{Fe}(\text{CN})_6]^{3-} + 6\text{K}^+ + 6\text{H}_2\text{O}$ ALLOW ECF for an equation showing formation of $[\text{Fe}(\text{CN})_6]^{4-}$ from $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 6\text{CN}^- \longrightarrow [\text{Fe}(\text{CN})_6]^{4-} + 6\text{H}_2\text{O}$ Notice different charges on complex ions: LHS 2+, RHS 4-
	(ii)	ligand substitution ✓	1	ALLOW ligand exchange OR ligand replacement CARE: possible confusion with (c)(ii)

Question	er	Marks	Guidance
(e)	<p>F and G:</p>  <p>1 mark for each isomer ✓✓ Bonds must go to O ligand atoms on EACH structure IGNORE charges on Fe³⁺ and O⁻ at this stage</p> <p>3- charge outside brackets of BOTH isomers AND NO charges shown on Fe or O within brackets Note: This mark is only available from structures with three bidentate ligands bonded to Fe via two Os on each ligand ✓</p>	3	<p>ALLOW any attempt to show bidentate ligand Bottom line is the diagram below.</p>  <p>IGNORE structure between two Os in ligand even if slightly different</p> <p>Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper. For bond into paper, ALLOW:</p> 
(f)	FeO_4^{2-} ✓	1	<p>Formula AND charge needed</p> <p>ALLOW other 2- ions containing: Fe AND O AND Fe has ox no of +6 i.e. ALLOW $\text{Fe}_2\text{O}_7^{2-}$, $\text{Fe}_3\text{O}_{10}^{2-}$, etc.</p>
Total		12	

Question		er	Marks	Guidance
4	(a)	$(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^8 4s^2$ ✓ $(1s^2 2s^2 2p^6) 3s^2 3p^6 3d^8$ ✓	2	ALLOW 4s before 3d, i.e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ IF candidate has used subscripts OR caps, DO NOT ALLOW when first seen but credit subsequently, i.e. $1s_2 2s_2 2p_6 3s_2 3p_6 3d_8 4s_2$ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3D^8$ For Ni^{2+} ALLOW $4s^0$ in electron configuration
	(b)	(i)	1	Acts as a base OR alkali AND removes/accepts a proton (from DMGH) ✓
		(ii)	1	4 ✓
		(iii)	1	(Each) DMG has 1- charge which cancel 2+ charge on Ni^{2+} ✓ ALLOW $2 \times -1 + 2 = 0$ For Ni^{2+} , ALLOW Ni has an oxidation number of (+)2 ALLOW Ni^{2+} cancelled out by 2 DMG^- ALLOW 'balanced' for cancelled
		(iv)	1	 ALLOW OH for O—H ALLOW CH ₃ — DO NOT ALLOW —H—O

Question	er	Marks	Guidance
(c)	<p>Marks are for correctly calculated values</p> <p><i>amount of Ni</i> -----</p> <p>amount Ni(DMG)₂ OR amount hydrated salt OR amount Ni²⁺</p> $= \frac{2.57}{288.7} = \mathbf{8.9(0) \times 10^{-3}} \text{ mol } \checkmark$ <p><i>M values</i> -----</p> $M(\text{hydrated salt}) = \frac{2.50}{8.90 \times 10^{-3}} = \mathbf{280.9} \text{ (g mol}^{-1}\text{)} \checkmark$ $M(\text{anhydrous salt}) = \frac{1.38}{8.90 \times 10^{-3}} = \mathbf{155.0} \text{ (g mol}^{-1}\text{)} \checkmark$ <p><i>H₂O</i> -----</p> <p>mass H₂O = 2.50 – 1.38 = 1.12 g ✓</p> <p><i>n(H₂O) from mass or M values</i></p> $= \frac{1.12}{18.0} = \mathbf{6.2(2) \times 10^{-2}} \text{ OR } 280.9 - 155.0 \sim \mathbf{125.9} \checkmark$ <p><i>waters of crystallisation</i></p> $= \frac{6.22 \times 10^{-2}}{8.90 \times 10^{-3}} = \mathbf{7} \text{ OR } \frac{125.9}{18.0} = \mathbf{7} \checkmark$ <p><i>Anion</i> -----</p> <p>Molar mass of anion = 280.9 – (58.7 + 7 × 18) = 96.1 (g mol⁻¹)</p> <p>OR</p> <p>Molar mass of anion = 155.0 – 58.7 = 96.3 (g mol⁻¹) ✓</p> <p><i>Formula</i> -----</p> <p>Formula of salt is NiSO₄•7H₂O ✓</p>	<p>7 max</p>	<p>ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>Note: The answers incorporate three different approaches to solving this problem.</p> <p>IF candidate attempts calculation via another method, consult your TL</p> <p>ECF answer above</p> <p>ALLOW numerical answers 280.8 – 280.9 (ALLOW 281)</p> <p>IGNORE further figures</p> <p>ALLOW numerical answers 155.0 – 155.1 (ALLOW 155)</p> <p>IGNORE further figures</p> <p>ASSUME that ‘unlabelled 1.12 g’ applies to H₂O unless contradicted</p> <p>ALLOW numerical answers 125.7 – 125.9 (ALLOW 126)</p> <p>ECF answer above</p> <p>7 as whole number is required</p> <p>Note: Mark for 7 can be credited within formula BUT there must be some relevant working to derive ~7, e.g. 6.99</p> <p>ALLOW numerical answers 96.0 – 96.4 (ALLOW 96)</p>
	Total	13	