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2002

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**Module 5: Physical chemistry and  
transition elements**

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# EXAM PAPERS PRACTICE

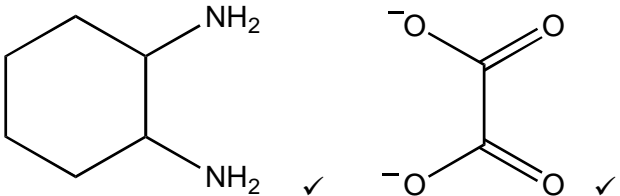
Question		Answer	Marks	Guidance
1	(a)	<p>(A transition element) has (at least) one <b>ion</b> with a partially filled d sub-shell/ d orbital ✓</p> <p>Fe <b>AND</b> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2</math> ✓</p> <p>Fe(II) / <math>Fe^{2+}</math> <b>AND</b> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^6</math> ✓</p> <p>Fe(III) / <math>Fe^{3+}</math> <b>AND</b> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^5</math> ✓</p>	4	<p><b>ALLOW</b> incomplete for partially filled <b>DO NOT ALLOW</b> d shell</p> <p><b>ALLOW</b> 4s before 3d, i.e. <math>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6</math></p> <p><b>IF</b> candidate has used subscripts <b>OR</b> caps <b>OR</b> [Ar], <b>DO NOT ALLOW</b> when first seen but credit subsequently, i.e. <math>1s_2 2s_2 2p_6 3s_2 3p_6 3d_6 4s_2</math> <math>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3D^6</math> [Ar]<math>4s^2 3d^6</math></p> <p>For <math>Fe^{2+}</math> and <math>Fe^{3+}</math>, <b>ALLOW</b> <math>4s^0</math> in electron configuration</p> <p><b>IGNORE</b> electron configurations of elements other than Fe</p>
	(b)	<p><b>EXAMPLES MUST REFER TO <math>Cu^{2+}</math> FOR ALL MARKS</b></p> <hr/> <p><b>PRECIPITATION</b> <b>Reagent</b> NaOH(aq) <b>OR</b> KOH(aq) ✓ States not required</p> <p><b>Transition metal product AND observation</b> <math>Cu(OH)_2</math> <b>AND</b> blue precipitate/solid ✓</p> <p><b>Correct balanced equation</b> <math>Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)</math> ✓ state symbols <b>not</b> required</p> <p><b>IF more than one example shown, mark example giving lower mark</b></p>	3	<p><b>ANNOTATIONS MUST BE USED</b></p> <hr/> <p><b>ALLOW</b> NaOH in equation if 'reagent' not given in description <b>ALLOW</b> a <b>small amount</b> of <math>NH_3</math>/ammonia <b>DO NOT ALLOW</b> concentrated <math>NH_3</math> <b>DO NOT ALLOW</b> just <math>OH^-</math></p> <p><b>ALLOW</b> <math>Cu(OH)_2(H_2O)_4</math> <b>ALLOW</b> any shade of blue <b>ALLOW</b> (s) as state symbol for ppt (may be in equation)</p> <p><b>ALLOW</b> <math>[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2(H_2O)_4 + 2H_2O</math> For <math>NH_3</math>, also <b>ALLOW</b>: <math>[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2(H_2O)_4 + 2NH_4^+</math></p> <p><b>ALLOW</b> full equation, e.g. <math>CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4</math> <math>CuCl_2 + 2NaOH \rightarrow Cu(OH)_2 + 2NaCl</math></p>



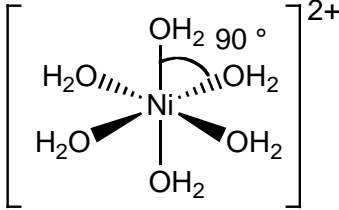
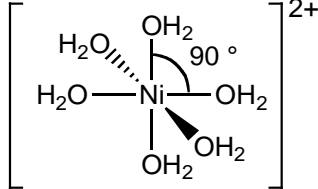
Question	Answer	Marks	Guidance
(b)	<p><b>LIGAND SUBSTITUTION – 2 likely</b></p> <p><b>Reagent</b>  <math>\text{NH}_3(\text{aq})</math>/ammonia ✓            State not required</p> <p><b>Transition metal product AND observation</b>  <math>[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}</math> AND deeper/darker blue (solution) ✓</p> <p><b>Correct balanced equation</b>  <math>[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \longrightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}</math> ✓</p> <p><b>OR</b> -----</p> <p><b>Reagent</b>            Concentrated HCl OR (dilute) HCl(aq) OR NaCl(aq) ✓            State not required</p> <p><b>Transition metal product AND observation</b>  <math>[\text{CuCl}_4]^{2-}</math> AND yellow (solution) ✓</p> <p><b>Correct balanced equation</b>  <math>[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \longrightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}</math> ✓</p>	3	<p><b>IF more than one example shown, mark example giving lower mark</b></p> <p><b>ALLOW</b> <math>\text{NH}_3</math> in equation if 'reagent' not given in description</p> <p><b>DO NOT ALLOW</b> precipitate  <b>ALLOW</b> royal blue, ultramarine blue or any blue colour that is clearly darker than for <math>[\text{Cu}(\text{H}_2\text{O})_6]^{2+}</math> ✓</p> <p>-----</p> <p><b>ALLOW</b> <math>\text{CuCl}_4^{2-}</math> i.e. no brackets  <b>ALLOW</b> any shades of yellow, e.g. yellow–green  <b>DO NOT ALLOW</b> precipitate</p> <p><b>ALLOW other correct ligand substitutions using same principles for marking as in two examples given</b></p>
(c) (i)	<p>Pt oxidised from 0 to +4 ✓            N reduced from +5 to +4 ✓</p>	2	<p><b>ALLOW</b> 1 mark for            Pt from 0 to +4 AND N from +5 to +4            i.e. oxidation and reduction not identified or wrong way round</p> <p><b>DO NOT ALLOW</b> Pt is oxidised and N reduced with no evidence</p> <p><b>DO NOT ALLOW</b> responses using other incorrect oxidation numbers (CON)</p>

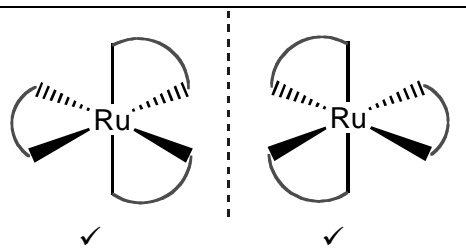


Question		Answer	Marks	Guidance
(c)	(ii)	$\text{Pt} + 6\text{HCl} + 4\text{HNO}_3 \longrightarrow \text{H}_2\text{PtCl}_6 + 4\text{NO}_2 + 4\text{H}_2\text{O} \checkmark\checkmark$	2	<p><b>1st mark for ALL species correct and no extras:</b> i.e:  <math>\text{Pt} + \text{HCl} + \text{HNO}_3 \longrightarrow \text{H}_2\text{PtCl}_6 + \text{NO}_2 + \text{H}_2\text{O}</math>  <b>DO NOT ALLOW</b> charge on Pt, e.g. <math>\text{Pt}^{2+}</math></p> <p><b>2nd mark</b> for correct balancing  <b>ALLOW</b> correct multiples</p>
(d)		<div style="display: flex; align-items: center; justify-content: center;"> <div style="text-align: center;"> <math>\left[ \begin{array}{c} \text{Cl} \\   \\ \text{Cl} \diagdown \text{Pt} \diagup \text{Cl} \\   \\ \text{Cl} \end{array} \right]^{2-}</math> </div> <div style="margin: 0 10px;">OR</div> <div style="text-align: center;"> <math>\left[ \begin{array}{c} \text{Cl} \\   \\ \text{Cl} \diagup \text{Pt} \diagdown \text{Cl} \\   \\ \text{Cl} \end{array} \right]^{2-}</math> </div> </div> <p><b>3-D Shape 1 mark</b>  Correct 3-D diagram of Pt surrounded by 6Cl  <b>ONLY</b> ✓</p> <p><b>Bond angle 1 mark</b>  bond angle of <math>90^\circ</math> on diagram or stated ✓</p> <p><b>Charge 1 mark</b>  <math>2-</math> charge shown outside of brackets ✓</p>	3	<p>Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper <b>OR</b> 4 lines, 1 'out wedge' and 1 'in wedge'</p> <p>For bond into paper, <b>ALLOW</b>:</p> <div style="text-align: center;"> </div> <p><b>IGNORE</b> charges on Pt and Cl for this mark</p> <p>The 2 marks for charge <b>AND</b> bond angle are <b>ONLY</b> available from a diagram showing Pt bonded to 6 Cl <b>ONLY</b></p> <p><b>ALLOW ONLY</b> if diagram has Pt surrounded by 6Cl <b>ONLY</b>  <b>BUT</b> 3-D shape may not be correct</p> <p><b>DO NOT ALLOW</b> if <b>ANY</b> charges shown on Pt or Cl within brackets</p>

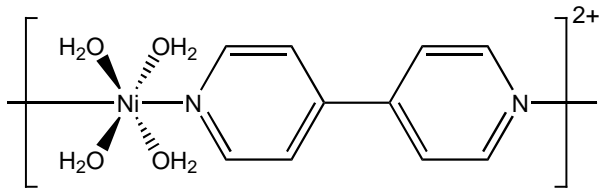
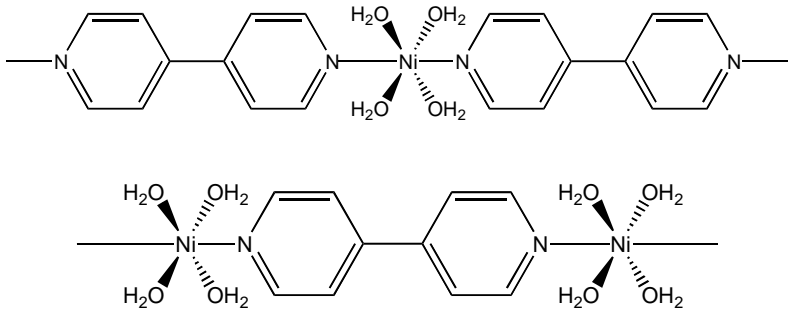
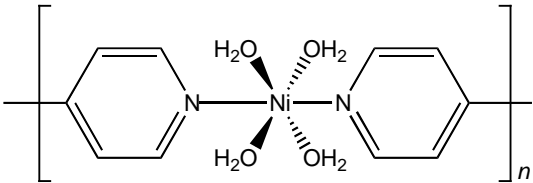
Question			Answer	Marks	Guidance
	(e)	(i)	Donates <b>two</b> electron pairs to a <b>metal</b> (ion) ✓  forms <b>two</b> coordinate bonds ✓	2	<b>ALLOW</b> lone pairs for electron pairs  <b>ALLOW</b> dative (covalent) bond for coordinate bond  <b>ALLOW</b> 1 mark for a full definition of a ligand (without reference to 2: <b>i.e.</b> Donates <b>an</b> electron pair to a metal (ion) forming <b>a</b> coordinate bond ✓
		(ii)		2	<b>ALLOW</b> displayed formulae  '– charges' essential in (COO <sup>–</sup> ) <sub>2</sub> structure  <b>DO NOT ALLOW</b> –H <sub>2</sub> N
			<b>Total</b>	<b>21</b>	



Question			er	Mark	Guidance
2	(a)		<p>Ni <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2</math> ✓</p> <p>d block: (Ni:) 'd' is <b>highest energy</b> sub-shell/orbital ✓</p> <p>Ni<sup>2+</sup>: <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^8</math> ✓</p> <p>Transition element: has <b>an ion</b> with an incomplete/partially-filled d <b>sub-shell/orbital</b> ✓</p> <p>-----</p> <p>A ligand donates an electron pair to Ni<sup>2+</sup> <b>OR</b> metal ion <b>OR</b> metal ✓</p> <p>A complex ion is an ion bonded to ligand(s)/surrounded by ligands ✓</p> <p>Coordinate bond/dative covalent mentioned at least once in the right context ✓</p>	<p>4</p> <p>3</p>	<p><b>ANNOTATE WITH TICKS AND CROSSES, etc</b></p> <p><b>Note:</b> Examples must be for Ni, not other d block elements</p> <p><b>ALLOW</b> 4s before 3d, ie <math>1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8</math></p> <p><b>ALLOW</b> [Ar]4s<sup>2</sup>3d<sup>8</sup> <b>OR</b> [Ar]3d<sup>8</sup>4s<sup>2</sup></p> <p><b>ALLOW</b> upper case D, etc and subscripts, e.g. [Ar]4S<sub>2</sub>3D<sub>8</sub></p> <p><b>DO NOT ALLOW</b> highest energy shell is 'd' <b>OR</b> 'd is the outer sub-shell' (4s as well)</p> <p><b>ALLOW</b> [Ar]3d<sup>8</sup></p> <p><b>ALLOW</b> electron configurations with 4s<sup>0</sup></p> <p><b>ALLOW</b> for example Ni<sup>3+</sup> <math>1s^2 2s^2 2p^6 3s^2 3p^6 3d^7</math> <b>OR</b> [Ar]3d<sup>7</sup></p> <p><b>No other Ni ions are acceptable</b></p> <p><b>ALLOW</b> lone pair forms a coordinate bond to Ni<sup>2+</sup> (which will also collect the coordinate bond mark)</p> <p><b>ALLOW</b> diagram of [Ni(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup> complex ion for 2nd marking point</p>
(b)	(i)		 <p>3D diagram ✓</p> <p>90° bond angle ✓</p>	2	<p>Must contain 2 'out wedges', 2 'in wedges' and 2 lines in plane of paper <b>OR</b> 4 lines, 1 'out wedge' and 1 'in wedge':</p>  <p><b>ALLOW</b> dotted line <b>OR</b> unfilled wedge as alternatives for dotted wedge</p> <p>Accept bonds to H<sub>2</sub>O (does not need to go to 'O')</p> <p>Accept 90 ° written by diagram.</p> <p>Charge <b>NOT</b> needed.</p> <p>Square brackets <b>NOT</b> needed</p>

Question			er	Mark	Guidance
	(b)	(ii)	A: $\text{NiCl}_4^{2-}$ ✓  B: $\text{Ni}(\text{OH})_2$ ✓	2	<b>ALLOW</b> $[\text{NiCl}_4]^{2-}$ <b>DO NOT ALLOW</b> $\text{Ni}(\text{Cl})_4^{2-}$ <b>ALLOW</b> $\text{Ni}(\text{OH})_2(\text{H}_2\text{O})_4$ <b>OR</b> $[\text{Ni}(\text{OH})_2(\text{H}_2\text{O})_4]$
		(iii)	C: $[\text{Ni}(\text{NH}_3)_6]^{2+}$ ✓	1	<b>Square</b> brackets essential 2+ charge must be outside square brackets <b>ALLOW</b> $[\text{Ni}(\text{OH})_6]^{4-}$
		(iv)	$[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \longrightarrow [\text{Ni}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ <div style="text-align: center;"> <span style="margin-right: 100px;">✓</span> <span>✓</span> </div>	2	<b>1 mark for each side of equation</b> <b>ALLOW</b> equilibrium sign <b>ALLOW ECF</b> from (iii) for the following: $[\text{Ni}(\text{NH}_3)_4]^{2+}$ (wrong number of $\text{NH}_3$ ) <b>Any</b> 6 coordinate $\text{Ni}^{2+}$ complex with $\text{NH}_3$ and $\text{H}_2\text{O}$ ligands, e.g. $[\text{Ni}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ , $[\text{Ni}(\text{NH}_3)_5(\text{H}_2\text{O})]^{2+}$ , etc <b>ALLOW</b> from $[\text{Ni}(\text{OH})_6]^{4-}$ , $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 6\text{OH}^- \longrightarrow [\text{Ni}(\text{OH})_6]^{4-} + 6\text{H}_2\text{O}$ <b>OR</b> $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \longrightarrow [\text{Ni}(\text{OH})_6]^{4-} + 6\text{NH}_4^+$
	(c)	(i)	$\text{C}_{10}\text{H}_8\text{N}_2$ ✓	1	<b>ALLOW</b> atoms in any order
		(ii)	4 ✓	1	
		(iii)	<div style="text-align: center;">  </div> <p>One mark for each structure            2nd structure must be correct mirror image of 1st structure</p>	2	Charge and N atom labels <b>NOT</b> needed <b>ALLOW</b> any attempt to show bipy. Bottom line is the diagram on the left.  1 mark for 3D diagram with ligands attached for ONE stereoisomer. Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper: <b>ALLOW</b> structures with Ni in centre



Question	er	Mark	Guidance
(c) (iv)	<p><b>3 marks available</b></p> <p><b>1st mark</b> Correct 4,4'-bipy structure shown separately or within attempted structure with <math>\text{Ni}^{2+}</math> ✓</p> <p><b>2 marks</b> The remaining 2 marks are available for a section of the polymer with repeat unit identified as follows:</p> <p><b>IF</b> Ni is bonded to 4 <math>\text{H}_2\text{Os}</math> (bond to O) with a bond to N end <b>of two</b> 4,4'-bipy structure</p> <p><b>OR</b></p> <p><b>IF each N of</b> 4,4'-bipy is bonded to a Ni bonded to 4 <math>\text{H}_2\text{Os}</math> (bond to O), award 1 mark ✓</p> <p><b>IF</b> correct repeat unit is shown, award 2 marks ✓✓</p> 	3	<p><b>ALLOW</b> aromatic rings</p>  <p>Charge <b>NOT</b> needed. Square brackets <b>NOT</b> needed</p> <p>Bonds around Ni do <b>NOT</b> need to be shown 3D Accept bonds to <math>\text{H}_2\text{O}</math> (does <b>NOT</b> need to go to 'O')</p> <p><b>ALLOW</b> the following structure for repeat unit for all 2nd and 3rd marks:</p> 
	Total	21	



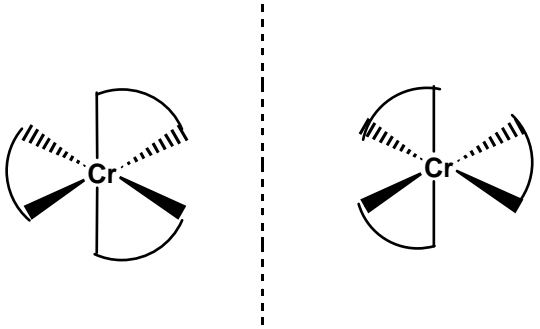
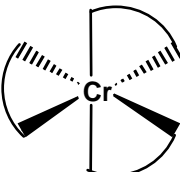
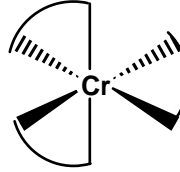
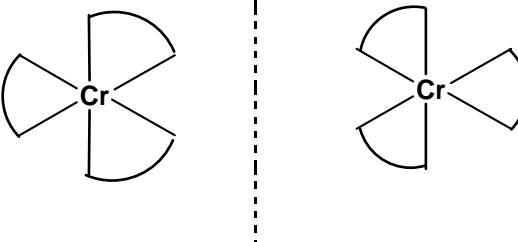
Question	er	Mark	Guidance
3	<p><b>step 1</b>  <math>\text{Cu} + 4\text{HNO}_3 \longrightarrow \text{Cu}^{2+} + 2\text{NO}_3^- + 2\text{NO}_2 + 2\text{H}_2\text{O}</math>  <b>OR</b> <math>\text{Cu} + 2\text{H}^+ + 2\text{HNO}_3 \longrightarrow \text{Cu}^{2+} + 2\text{NO}_2 + 2\text{H}_2\text{O}</math>  <b>OR</b> <math>\text{Cu} + 4\text{H}^+ + 2\text{NO}_3^- \longrightarrow \text{Cu}^{2+} + 2\text{NO}_2 + 2\text{H}_2\text{O} \checkmark</math></p> <p><b>step 2</b>  <b>2 equations with 1 mark for each</b>  <math>\text{Cu}^{2+} + \text{CO}_3^{2-} \longrightarrow \text{CuCO}_3 \checkmark</math>  <math>2\text{H}^+ + \text{CO}_3^{2-} \longrightarrow \text{H}_2\text{O} + \text{CO}_2 \checkmark</math></p> <p><b>step 4</b>  <math>2\text{Cu}^{2+} + 4\text{I}^- \longrightarrow 2\text{CuI} + \text{I}_2 \checkmark</math></p>	4	<p><b>ANNOTATE ALL Q8 WITH TICKS AND CROSSES, etc</b></p> <p><b>ALLOW</b> multiples throughout  <b>IGNORE</b> state symbols throughout</p> <p><b>ALLOW</b> <math>\text{Cu}(\text{NO}_3)_2</math> for <math>\text{Cu}^{2+} + 2\text{NO}_3^-</math></p> <p><b>AWARD 2 MARKS for a combined equation:</b>  <math>\text{Cu}^{2+} + 2\text{H}^+ + 2\text{CO}_3^{2-} \longrightarrow \text{CuCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \checkmark\checkmark</math></p> <p><b>DO NOT ALLOW</b> <math>2\text{H}^+ + \text{CO}_3^{2-} \longrightarrow \text{H}_2\text{CO}_3</math></p> <p><b>ALLOW</b> <math>2\text{Cu}^{2+} + 4\text{KI} \longrightarrow 2\text{CuI} + \text{I}_2 + 4\text{K}^+</math>  <b>ALLOW</b> <math>\text{Cu}^{2+} + \text{I}^- \longrightarrow \text{Cu}^+ + \frac{1}{2}\text{I}_2</math></p>



Question	er	Mark	Guidance
	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF</b> answer = 67.6%, award <b>5</b> marks.  <b>Ignore any attempted equation in step 4</b></p> <p><b>IF</b> answer = <b>33.8% AND IF</b> <math>\text{Cu}^{2+}/\text{I}_2</math> in <b>step 4</b> equation shown with 1:1 molar ratio, award 5 marks for <b>ECF</b></p> <p>-----</p> <p>amount <math>\text{S}_2\text{O}_3^{2-}</math> used = <math>0.100 \times \frac{29.8}{1000} = 2.98 \times 10^{-3} \text{ mol } \checkmark</math></p> <p>amount <math>\text{I}_2 = 1.49 \times 10^{-3} \text{ mol}</math>  <b>OR</b> amount <math>\text{Cu}^{2+} = 2.98 \times 10^{-3} \text{ mol } \checkmark</math></p> <p>amount <math>\text{Cu}^{2+}</math> in original <math>250 \text{ cm}^3 = 10 \times 2.98 \times 10^{-3}</math>  <math>= 2.98 \times 10^{-2} \text{ mol } \checkmark</math></p> <p>Mass of <math>\text{Cu}/\text{Cu}^{2+}</math> in brass = <math>63.5 \times 2.98 \times 10^{-2} \text{ g}</math>  <math>= 1.8923 \text{ g } \checkmark</math></p> <p>percentage Cu in brass = <math>\frac{1.8923}{2.80} \times 100</math>  <math>= 67.6\% \checkmark</math>  <b>MUST</b> be to <b>one</b> decimal place (in the question)</p>	<p><b>5</b></p>	<p><b>IF</b> there is an alternative answer, check to see if there is any <b>ECF</b> credit possible using working below</p> <p>-----</p> <p><b>Working must be to 3 SF throughout until final % mark</b>  <b>BUT</b> ignore trailing zeroes, ie for 0.490 allow 0.49</p> <p><b>ECF</b> answer above</p> <p><b>ECF</b> 10 x answer above</p> <p><b>ECF</b> 63.5 x answer above  <b>ALLOW</b> 1.88 g</p> <p><b>ECF</b> <math>\frac{\text{answer above}}{2.80} \times 100</math>          Answer <b>must</b> be to one decimal place</p> <p><b>ALLOW</b> % Cu = 67.5 % <b>IF</b> mass of Cu has been rounded to 1.89 g in previous step</p> <p><b>Common ECFs:</b>  <b>6.76%</b>          x10 missing      3/5 marks for calculation          2 d.p.              MS states 1 d.p.</p> <p><b>33.8%</b>  <b>IF</b> <math>\text{Cu}^{2+}/\text{I}_2</math> in <b>step 4</b> equation with 2:1 ratio <b>OR</b> not attempted, response, 4/5 marks for calculation (moles <math>\text{Cu}^{2+}</math> incorrect)</p>
	Total	9	



Question			Expected Answers	Marks	Additional Guidance
4	a		$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ ✓	1	<b>ALLOW</b> $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ (i.e. 4s before 3d) <b>ALLOW</b> $[Ar] 4s^1 3d^5$ <b>OR</b> $[Ar] 3d^5 4s^1$
		ii	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ ✓	1	<b>ALLOW</b> $[Ar] 3d^3$ <b>ALLOW</b> $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^0$ <b>OR</b> $[Ar] 3d^3 4s^0$
	b		$Zn \longrightarrow Zn^{2+} + 2e^-$ ✓ $Cr_2O_7^{2-} + 14H^+ + 8e^- \longrightarrow 2Cr^{2+} + 7H_2O$ ✓  $4Zn + Cr_2O_7^{2-} + 14H^+ \longrightarrow 4Zn^{2+} + 2Cr^{2+} + 7H_2O$ ✓	3	<b>ALLOW</b> multiples  <b>WATCH</b> for balancing of the equations printed on paper <b>IF</b> printed equations and answer lines have different balancing numbers <b>OR</b> electrons, <b>IGNORE</b> numbers on printed equations (i.e. treat these as working) and mark responses on answer lines <b>only</b>  <b>NO ECF</b> for overall equation i.e. the expected answer is the <b>ONLY</b> acceptable answer
	c	i	Ligand substitution ✓	1	<b>ALLOW</b> ligand exchange
		ii	$[Cr(H_2O)_6]^{3+} + 6NH_3 \longrightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ ✓ ✓	2	1 mark is awarded for each side of equation <b>ALLOW</b> equilibrium sign <b>ALLOW</b> 1 mark for 2+ shown instead of 3+ on both sides of equation <b>ALLOW</b> 1 mark for substitution of 4 $NH_3$ : $[Cr(H_2O)_6]^{3+} + 4NH_3 \longrightarrow [Cr(NH_3)_4(H_2O)_2]^{3+} + 4H_2O$
	d	i	Donates an electron pair to a metal ion <b>OR</b> forms a coordinate bond to a metal ion ✓	1	<b>ALLOW</b> donates an electron pair to a metal <b>ALLOW</b> dative (covalent) bond for coordinate bond
		ii	Donates <b>two</b> electron pairs <b>OR</b> forms <b>two</b> coordinate bonds ✓  Lone pairs on two O atoms ✓	2	First mark is for the idea of two coordinate bonds  <b>ALLOW</b> lone pair on O and N <b>DO NOT ALLOW</b> lone pairs on $COO^-$ (could involve C)  Second mark is for the atoms that donate the electron pairs Look for the atoms with lone pairs also on response to <b>(d)(iii)</b> and credit here if not described in <b>(d)(ii)</b>

Question	Expected Answers	Marks	Additional Guidance
iii	<p>Forms two optical isomers <b>OR</b> two enantiomers  <b>OR</b> two non-superimposable mirror images ✓</p> <div style="text-align: center;">  </div> <p>✓✓ For each structure</p>	3	<p><b>IGNORE</b> any charges shown</p> <p><b>ALLOW</b> any attempt to show bidentate ligand.          Bottom line is the diagram on the left.</p> <p>1 mark for 3D diagram with ligands attached for ONE stereoisomer.          Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper:</p> <div style="text-align: center;">  <span style="margin: 0 20px;">OR</span>  </div> <p>2nd mark for reflected diagram of <b>SECOND</b> stereoisomer.          The diagram below would score the 2nd mark but not the first</p> <div style="text-align: center;">  </div>

Question	Expected Answers	Marks	Additional Guidance
e	<p>N : H : Cr : O 11.1/14 : 3.17/1 : 41.27/52 : 44.45/16 <b>OR</b> 0.793 : 3.17 : 0.794 : 2.78 ✓</p> <p><b>A:</b> <math>\text{N}_2\text{H}_8\text{Cr}_2\text{O}_7</math> ✓</p> <p>Ions: <math>\text{NH}_4^+</math> ✓ <math>\text{Cr}_2\text{O}_7^{2-}</math> ✓</p> <p><b>B:</b> <math>\text{Cr}_2\text{O}_3</math> ✓</p> <p>Correctly calculates molar mass of <b>C</b> <math>= 1.17 \times 24.0 = 28.08 \text{ (g mol}^{-1}\text{)}</math> ✓</p> <p><b>C:</b> <math>\text{N}_2</math> ✓</p> <p>Equation: <math>(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \longrightarrow \text{Cr}_2\text{O}_3 + 4\text{H}_2\text{O} + \text{N}_2</math> ✓</p>	8	<p><b>ANNOTATIONS MUST BE USED</b></p> <p><b>ALLOW A:</b> <math>(\text{NH}_4)_2\text{Cr}_2\text{O}_7</math></p> <p><b>IF</b> candidate has obtained <math>\text{NH}_4\text{CrO}_4</math> for A, <b>ALLOW</b> <math>\text{NH}_4^+</math> <b>DO NOT ALLOW</b> <math>\text{CrO}_4^-</math></p> <p><b>ALLOW:</b> (relative) molecular mass <b>ALLOW:</b> 28 <b>ALLOW:</b> 'C is 28'</p> <p><b>ALLOW</b> <math>\text{N}_2\text{H}_8\text{Cr}_2\text{O}_7</math> in equation.</p>
	Total	22	