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CHEMISTRY

Mark Scheme

OCR
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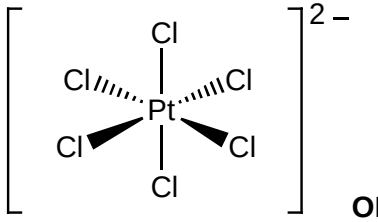
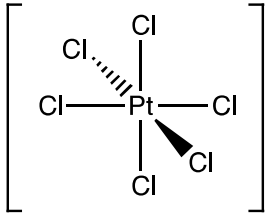
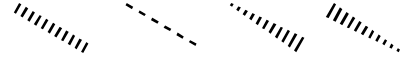
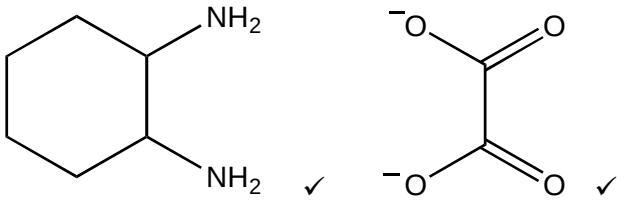
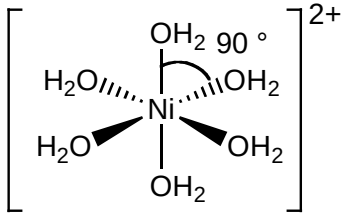
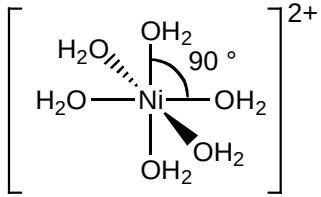
Module 5: Physical chemistry and transiton elements

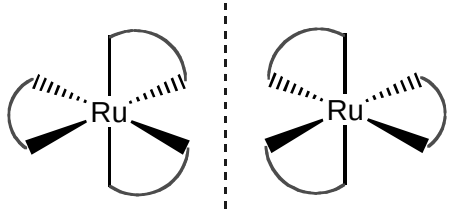
Question			Answer	Marks	Guidance
1	(a)		(A transition element) has (at least) one **ion** with a partially filled d sub-shell/ d orbital ✓ Fe **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ ✓ Fe(II) / Fe^{2+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓ Fe(III) / Fe^{3+} **AND** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$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

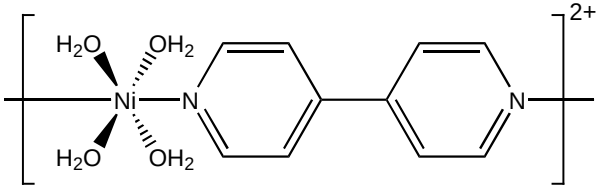
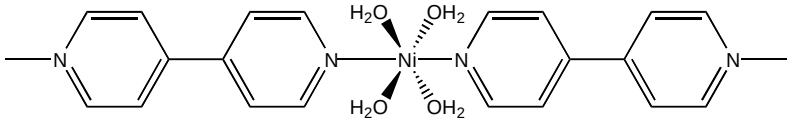
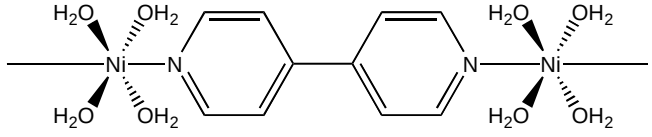
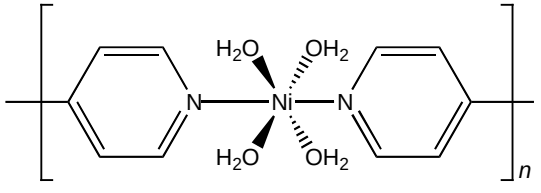
Question			Answer	Marks	Guidance
	(b)		**LIGAND SUBSTITUTION – 2 likely** **Reagent** NH_3(aq)/ammonia ✓ State not required **Transition metal product AND observation** $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **AND** deeper/darker blue (solution) ✓ **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$ ✓ **OR** ---------- **Reagent** Concentrated HCl **OR** (dilute) HCl(aq) **OR** NaCl(aq) ✓ State not required **Transition metal product AND observation** $[CuCl_4]^{2-}$ **AND** yellow (solution) ✓ **Correct balanced equation** $[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$ ✓	3	**IF more than one example shown, mark example giving lower mark** **ALLOW** NH_3 in equation if 'reagent' not given in description **DO NOT ALLOW** precipitate **ALLOW** royal blue, ultramarine blue or any blue colour that is clearly darker than for $[Cu(H_2O)_6]^{2+}$ ✓ ---------- **ALLOW** $CuCl_4^{2-}$ i.e. no brackets **ALLOW** any shades of yellow, e.g. yellow–green **DO NOT ALLOW** precipitate **ALLOW other correct ligand substitutions using same principles for marking as in two examples given**
	(c)	(i)	Pt oxidised from 0 +4 ✓ N reduced from +5 to +4 ✓	2	**ALLOW** 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 **DO NOT ALLOW** Pt is oxidised and N reduced with no evidence **DO NOT ALLOW** responses using other incorrect oxidation numbers **(CON)**

Question			Answer	Marks	Guidance
	(c)	(ii)	$Pt + 6HCl + 4HNO_3 \longrightarrow H_2PtCl_6 + 4NO_2 + 4H_2O$ ✓✓	2	**1st mark for ALL species correct and no extras:** i.e: $Pt + HCl + HNO_3 \longrightarrow H_2PtCl_6 + NO_2 + H_2O$ **DO NOT ALLOW** charge on Pt, e.g. Pt^{2+} **2nd mark** for correct balancing **ALLOW** correct multiples
	(d)		 **OR**  **3-D Shape 1 mark** Correct 3-D diagram of Pt surrounded by 6Cl **ONLY** ✓ **Bond angle 1 mark** bond angle of 90º on diagram or stated ✓ **Charge 1 mark** 2– charge shown outside of brackets ✓	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' For bond into paper, **ALLOW**:  **IGNORE** charges on Pt and Cl for this mark The 2 marks for charge **AND** bond angle are **ONLY** available from a diagram showing Pt bonded to 6 Cl **ONLY** **ALLOW ONLY** if diagram has Pt surrounded by 6Cl **ONLY BUT** 3-D shape may not be correct **DO NOT ALLOW** if **ANY** charges shown on Pt or Cl within brackets

Question			Answer	Marks	Guidance
	(e)	(i)	Donates **two** electron pairs to a **metal** (ion) ✓ forms **two** coordinate bonds ✓	2	**ALLOW** lone pairs for electron pairs **ALLOW** dative (covalent) bond for coordinate bond **ALLOW** 1 mark for a full definition of a ligand (without reference to 2: **i.e.** Donates **an** electron pair to a metal (ion) forming **a** coordinate bond ✓
		(ii)	 ✓ ✓	2	**ALLOW** displayed formulae '– charges' essential in $(COO^-)_2$ structure **DO NOT ALLOW** $–H_2N$
			Total	**21**	

Question			er	Mark	Guidance
2	(a)		Ni $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓ d block: (Ni:) 'd' is **highest energy** sub-shell/orbital ✓ Ni^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ ✓ Transition element: has **an ion** with an incomplete/partially-filled d **sub-shell/orbital** ✓ --- A ligand donates an electron pair to Ni^{2+} **OR** metal ion **OR** metal ✓ A complex ion is an ion bonded to ligand(s)/surrounded by ligands ✓ Coordinate bond/dative covalent mentioned at least once in the right context ✓	**4** **3**	**ANNOTATE WITH TICKS AND CROSSES, etc** **Note:** Examples must be for Ni, not other d block elements **ALLOW** 4s before 3d, ie $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$ **ALLOW** $[Ar]4s^2 3d^8$ **OR** $[Ar]3d^8 4s^2$ **ALLOW** upper case D, etc and subscripts, e.g. $[Ar]4S_2 3D_8$ **DO NOT ALLOW** highest energy shell is 'd' **OR** 'd is the outer sub-shell' (4s as well) **ALLOW** $[Ar]3d^8$ **ALLOW** electron configurations with $4s^0$ **ALLOW** for example Ni^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$ **OR** $[Ar]3d^7$ ***No other Ni ions are acceptable*** **ALLOW** lone pair forms a coordinate bond to Ni^{2+} (which will also collect the coordinate bond mark) **ALLOW** diagram of $[Ni(H_2O)_6]^{2+}$ complex ion for 2nd marking point
	(b)	(i)	 3D diagram ✓ 90º bond angle ✓	**2**	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 Accept bonds to H_2O (does not need to go to 'O') Accept 90 ° written by diagram. Charge **NOT** needed. Square brackets **NOT** needed

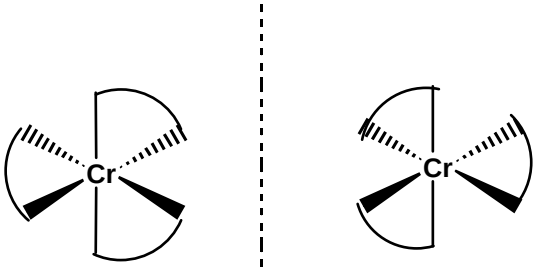
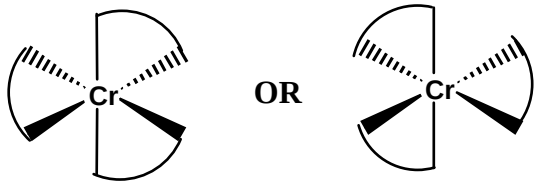
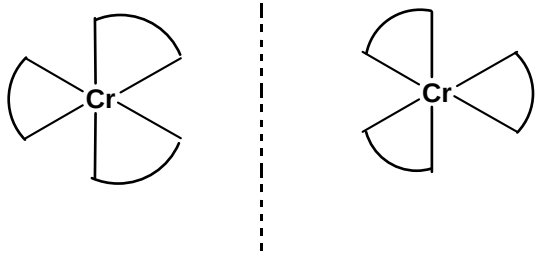
Question			er	Mark	Guidance
	(b)	(ii)	**A:** $NiCl_4^{2-}$ ✓ **B**: $Ni(OH)_2$ ✓	**2**	**ALLOW** $[NiCl_4]^{2-}$ **DO NOT ALLOW** $Ni(Cl^-)_4^{2-}$ **ALLOW** $Ni(OH)_2(H_2O)_4$ **OR** $[Ni(OH)_2(H_2O)_4]$
		(iii)	**C**: $[Ni(NH_3)_6]^{2+}$ ✓	**1**	**Square** brackets essential 2+ charge must be outside square brackets **ALLOW** $[Ni(OH)_6]^{4-}$
		(iv)	$[Ni(H_2O)_6]^{2+} + 6NH_3 \longrightarrow [Ni(NH_3)_6]^{2+} + 6H_2O$ ✓ ✓	**2**	**1 mark for each side of equation** **ALLOW** equilibrium sign **ALLOW ECF** from **(iii)** for the following: $[Ni(NH_3)_4]^{2+}$ (wrong number of NH_3) **Any** 6 coordinate Ni^{2+} complex with NH_3 and H_2O ligands, e.g. $[Ni(NH_3)_4(H_2O)_2]^{2+}$, $[Ni(NH_3)_5(H_2O)]^{2+}$, etc **ALLOW** from $[Ni(OH)_6]^{4-}$, $[Ni(H_2O)_6]^{2+} + 6OH^- \longrightarrow [Ni(OH)_6]^{4-} + 6H_2O$ **OR** $[Ni(H_2O)_6]^{2+} + 6NH_3 \longrightarrow [Ni(OH)_6]^{4-} + 6NH_4^+$
	(c)	(i)	$C_{10}H_8N_2$ ✓	**1**	**ALLOW** atoms in any order
		(ii)	4 ✓	**1**	
		(iii)	 ✓ ✓ One mark for each structure *2nd structure must be correct mirror image of 1st structure*	**2**	Charge and N atom labels **NOT** needed **ALLOW** 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: **ALLOW** structures with Ni in centre

Question			er	Mark	Guidance
	(c)	(iv)	**3 marks available** **1st mark** Correct 4,4'-bipy structure shown separately or within attempted structure with Ni^{2+} ✓ **2 marks** The remaining 2 marks are available for a section of the polymer with repeat unit identified as follows: **IF** Ni is bonded to 4 H_2Os (bond to O) with a bond to N end **of two** 4,4'-bipy structure **OR** **IF each N of** 4,4'-bipy is bonded to a Ni bonded to 4 H_2Os (bond to O), award 1 mark ✓ **IF** correct repeat unit is shown, award 2 marks ✓✓ 	**3**	**ALLOW** aromatic rings   Charge **NOT** needed. Square brackets **NOT** needed Bonds around Ni do **NOT** need to be shown 3D Accept bonds to H_2O (does **NOT** need to go to 'O') **ALLOW** the following structure for repeat unit for all 2nd and 3rd marks: 
			Total	**21**	

Question			er	Mark	Guidance
3			**step 1** $Cu + 4HNO_3 \longrightarrow Cu^{2+} + 2NO_3^- + 2NO_2 + 2H_2O$ **OR** $Cu + 2H^+ + 2HNO_3 \longrightarrow Cu^{2+} + 2NO_2 + 2H_2O$ **OR** $Cu + 4H^+ + 2NO_3^- \longrightarrow Cu^{2+} + 2NO_2 + 2H_2O$ ✓ **step 2** **2 equations with 1 mark for each** $Cu^{2+} + CO_3^{2-} \longrightarrow CuCO_3$ ✓ $2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$ ✓ **step 4** $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$ ✓	**4**	**ANNOTATE ALL Q8 WITH TICKS AND CROSSES, etc** **ALLOW** multiples throughout **IGNORE** state symbols throughout **ALLOW** $Cu(NO_3)_2$ for $Cu^{2+} + 2NO_3^-$ **AWARD 2 MARKS for a combined equation:** $Cu^{2+} + 2H^+ + 2CO_3^{2-} \longrightarrow CuCO_3 + H_2O + CO_2$ ✓✓ **DO NOT ALLOW** $2H^+ + CO_3^{2-} \longrightarrow H_2CO_3$ **ALLOW** $2Cu^{2+} + 4KI \longrightarrow 2CuI + I_2 + 4K^+$ **ALLOW** $Cu^{2+} + I^- \longrightarrow Cu^+ + \frac{1}{2}I_2$

Question			er	Mark	Guidance
			FIRST, CHECK THE ANSWER ON ANSWER LINE **IF** answer = 67.6%, award **5 marks.** **Ignore any attempted equation in step 4** **IF** answer = **33.8% AND IF** Cu^{2+}/I_2 in **step 4** equation shown with 1:1 molar ratio, award 5 marks for **ECF** --- amount $S_2O_3^{2-}$ used = 0.100 x $\frac{29.8}{1000}$ = 2.98 x 10^{-3} mol ✓ amount I_2 = 1.49 x 10^{-3} mol **OR** amount Cu^{2+} = 2.98 x 10^{-3} mol ✓ amount Cu^{2+} in original 250 cm^3 = **10 x** 2.98 x 10^{-3} = 2.98 x 10^{-2} mol ✓ Mass of Cu/Cu^{2+} in brass = 63.5 x 2.98 x 10^{-2} g = 1.8923 g ✓ percentage Cu in brass = $\frac{1.8923}{2.80} \times 100$ = 67.6% ✓ **MUST** be to **one** decimal place (in the question)	**5**	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below --- **Working must be to 3 SF throughout until final % mark** BUT ignore trailing zeroes, ie for 0.490 allow 0.49 **ECF** answer above **ECF** 10 x answer above **ECF** 63.5 x answer above **ALLOW** 1.88 g **ECF** $\frac{\text{answer above}}{2.80} \times 100$ Answer **must** be to one decimal place **ALLOW** % Cu = 67.5 % **IF** mass of Cu has been rounded to 1.89 g in previous step **Common ECFs:** **6.76%** x10 missing 3/5 marks for calculation 2 d.p. MS states 1 d.p. **33.8%** **IF** Cu^{2+}/I_2 in **step 4** equation with 2:1 ratio **OR** not attempted, response, 4/5 marks for calculation (moles Cu^{2+} incorrect)
			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	**ALLOW** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ (i.e. 4s before 3d) **ALLOW** $[Ar]4s^1 3d^5$ **OR** $[Ar]3d^5 4s^1$
		ii	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ ✓	1	**ALLOW** $[Ar]3d^3$ **ALLOW** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^0$ **OR** $[Ar]3d^3 4s^0$
	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	**ALLOW** multiples **WATCH** for balancing of the equations printed on paper **IF** printed equations and answer lines have different balancing numbers **OR** electrons, **IGNORE** numbers on printed equations (i.e. treat these as working) and mark responses on answer lines **only** **NO ECF** for overall equation i.e. the expected answer is the **ONLY** acceptable answer
	c	i	Ligand substitution ✓	1	**ALLOW** 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 **ALLOW** equilibrium sign **ALLOW** 1 mark for 2+ shown instead of 3+ on both sides of equation **ALLOW** 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 **OR** forms a coordinate bond to a metal ion ✓	1	**ALLOW** donates an electron pair to a metal **ALLOW** dative (covalent) bond for coordinate bond
		ii	Donates **two** electron pairs **OR** forms **two** coordinate bonds ✓ Lone pairs on two O atoms ✓	2	First mark is for the idea of two coordinate bonds **ALLOW** lone pair on O and N **DO NOT ALLOW** 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 **(d)(iii)** and credit here if not described in **(d)(ii)**

Question			Expected Answers	Marks	Additional Guidance
		iii	Forms two optical isomers **OR** two enantiomers **OR** two non-superimposable mirror images ✓  ✓✓ For each structure	3	**IGNORE** any charges shown **ALLOW** any attempt to show bidentate ligand. 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:  2nd mark for reflected diagram of SECOND stereoisomer. The diagram below would score the 2nd mark but not the first 

Question			Expected Answers	Marks	Additional Guidance
	e				***ANNOTATIONS MUST BE USED***
			N : H : Cr : O 11.1/14 : 3.17/1 : 41.27/52 : 44.45/16 **OR** 0.793 : 3.17 : 0.794 : 2.78 ✓	8	
			A: $N_2H_8Cr_2O_7$ ✓		**ALLOW A**: $(NH_4)_2Cr_2O_7$
			Ions: NH_4^+ ✓ $Cr_2O_7^{2-}$ ✓		**IF** candidate has obtained NH_4CrO_4 for A, **ALLOW** NH_4^+ **DO NOT ALLOW** CrO_4^-
			B: Cr_2O_3 ✓		
			Correctly calculates molar mass of **C** = 1.17 × 24.0 = 28.08 (g mol^{-1}) ✓		**ALLOW**: (relative) molecular mass **ALLOW**: 28 **ALLOW**: '**C** is 28'
			C: N_2 ✓		
			Equation: $(NH_4)_2Cr_2O_7 \longrightarrow Cr_2O_3 + 4H_2O + N_2$ ✓		**ALLOW** $N_2H_8Cr_2O_7$ in equation.
			Total	**22**	