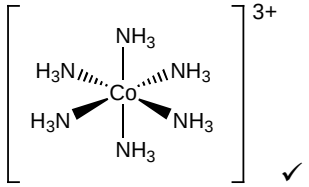
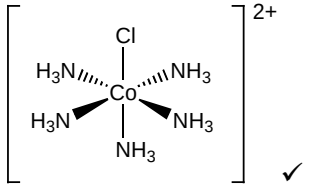
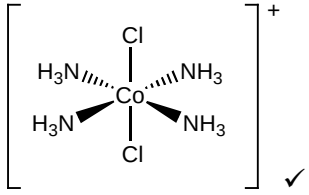
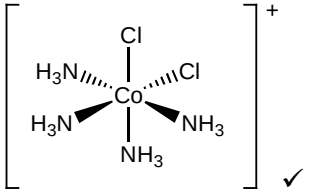
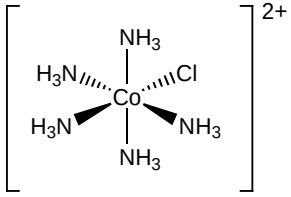
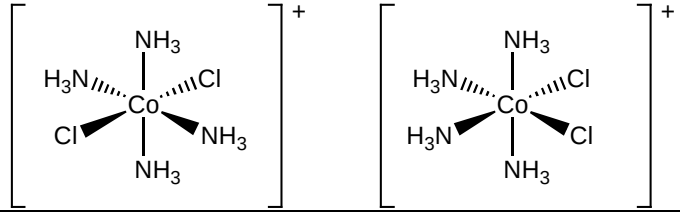
Question			Expected answers	Marks	Additional guidance
1	a		Co: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^7 4s^2$ ✓ Co^{3+}: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^6$ ✓	2	**ALLOW** $(1s^2 2s^2 2p^6)3s^2 3p^6 4s^2 3d^7$ (i.e. 4s before 3d) **ALLOW** upper case D, etc. and subscripts, e.g. $[Ar]4S_2 3D_7$ If included, **ALLOW** $4s^0$
	b		catalyst **OR** coloured ✓	1	**IGNORE** forms different oxidation states
	c		Donates an electron/lone pair to a metal ion **OR** forms a coordinate bond to a metal ion ✓	1	**ALLOW** donates an electron pair/lone pair to a metal/transition element **ALLOW** dative (covalent) bond for coordinate bond
	d	i	$Co(OH)_2$ ✓ precipitation ✓	2	Mark independently **ALLOW** $Co(OH)_2(H_2O)_4$ **ALLOW** precipitate (reaction)
		ii	$CoCl_4^{2-}$ ✓ ligand substitution ✓	2	Mark independently **ALLOW** ligand exchange **DO NOT ALLOW** just substitution

Question	Expected answers	Marks	Additional guidance
e	 ✓  ✓  ✓  ✓	4	***ANNOTATIONS MUST BE USED*** **CARE**: Cl can be on any position, e.g. for **B**  complex ions in **C** and **D** can be other way around In one complex ion, the 2 Cls must be opposite one another In the other complex ion, the 2 Cls must be next to one another **CARE**: Cl atoms can be on any position, e.g. for **C** and **D** 

Marking sequence **See also Appendix 2 for examples**

1. Mark any correct complex ions first
Do **not** look at these complex ions again

2. Mark with crosses a y complex ions with incorrect ligands. This could include Cl in complex **A**, and NH_3Cl and $NH_3^+Cl^-$, but **NOT** NH_3------ connectivity on the **LEFT** only and **NOT** Cl^- and **NOT** just NH_3^+
Do **not** look at these complex ions again

3. In the r maining complex ions, identify errors in ligands (See Appendix 2): e.g.

- NH_3 ligands bonded to an H on the **LEFT** only: NH_3----- *(connectivity error)*
- Cl^-
- NH_3^+

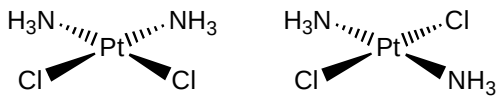
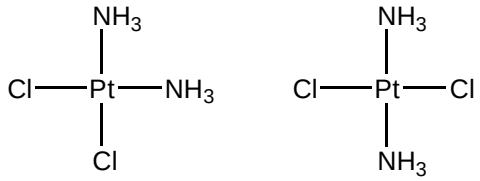
Mark these complex ions to maximise errors but treat any incorrectly bonded NH_3, Cl^- and NH_3 as **ECF**

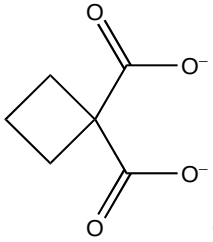
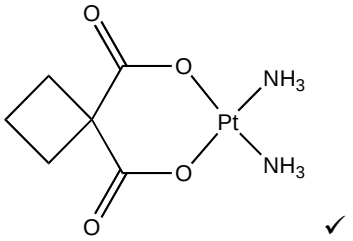
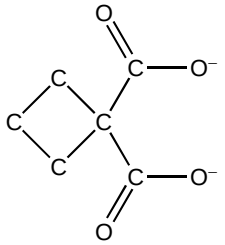
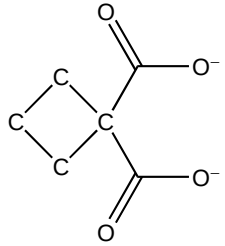
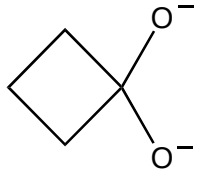
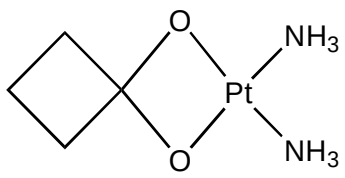
Question			Expected answers	Marks	Additional guidance
			SEE APPENDIX 2 FOR EXAMPLES		
	e	**ii**	143.4 **OR** 107.9 + 35.5 (g mol^{-1}) used *i.e. molar mass AgCl* **OR** amount of AgCl = 0.02(000) mol ✓ **Ratio** ratio complex : **Cl^-** = 1 : 2 **OR** 0.01 : 0.02 ✓ **Identification – available from 1 : 2 ratio OR 2Cl^-** Therefore the complex is **B** ✓	**3**	**DO NOT ALLOW** $AgCl_2$ **DO NOT ALLOW** $\frac{2.868}{0.01}$ *0.01 linked to AgCl, not complex* **ALLOW** this mark **ONLY** for evidence of Cl^- ***Quality of Written Communication*** Identification as **B** is dependent on correct 1 : 2 ratio **OR 2**Cl^- for this mark
			Total	**15**	

Question			Answer	Mark	Guidance
2	(a)		Fe: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^6 4s^2$ ✓ Fe^{2+}: $(1s^2 2s^2 2p^6)3s^2 3p^6 3d^6$ ✓	2	**ALLOW** 4s before 3d, i.e. $(1s^2 2s^2 2p^6)3s^2 3p^6 4s^2 3d^6$ **ALLOW** $4s^0$ **ALLOW** subscripts **IGNORE** $1s^2 2s^2 2p^6$ is written out a second time
	(b)		coloured (compound/complex/precipitate/ions) **OR** catalyst ✓	1	**IGNORE** 'variable oxidation states' **….** but **ALLOW** the idea that Fe^{2+} can react to form an **ion** with a different charge/oxidation state. '**ion**' is essential: 'atom' or 'metal' is **not** sufficient **IGNORE** partially filled d sub-shell/d orbital (question refers to property of Fe^{2+})
	(c)		Fe oxidised from +2 to +3 ✓ Cr reduced from +6 to +3 ✓	2	**CHECK** and credit oxidation numbers on equation **ALLOW** Fe^{2+} oxidised to Fe^{3+} **ALLOW** Cr^{6+} reduced to Cr^{3+} **ALLOW** + sign after number in oxidation number, *ie* 2+, etc **ALLOW** 1 mark only if oxidation numbers given with no identification of which species has been oxidised or reduced, *ie* Fe goes from +2 to +3 **AND** Cr goes from +6 to +3 Fe reduced from +2 to +3 **AND** Cr oxidised from +6 to +3 (*oxidation and reduction the wrong way around*) **DO NOT ALLOW** just 'Fe is oxidised **and** Cr reduced' **IGNORE** other oxidations numbers (even if wrong) **IGNORE** any references to electrons

Question			Answer	Mark	Guidance
2	(d)		(K_{stab} =) $\dfrac{\left[[Fe(NH_3)_6]^{2+}\right]}{\left[[Fe(H_2O)_6]^{2+}\right]\left[NH_3\right]^6}$ On **top**, **ONLY** $[Fe(NH_3)_6]^{2+}$ shown **AND** on bottom, $[Fe(H_2O)_6]^{2+}$ **AND** $[NH_3]^6$ shown ✓ correct use of square brackets and double square brackets in expression ✓	2	**IGNORE** state symbols **ALLOW** 1 mark if complete expression with correct use of double brackets is shown but upside down **DO NOT ALLOW** round brackets for concentrations and complex ions **ALLOW for 1 mark** (K_{stab} =) $\dfrac{\left[[Fe(NH_3)_6]^{2+}\right]\left[H_2O\right]^6}{\left[[Fe(H_2O)_6]^{2+}\right]\left[NH_3\right]^6}$
	(e)	(i)	O_2/oxygen bonds to Fe^{2+}/Fe(II)/Fe ✓ When required, O_2 substituted **OR** O_2 released ✓	2	**ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** O_2 binds to Fe^{2+} **OR** O_2 donates electron pair to Fe^{2+} **ALLOW** O_2 bonds to metal ion/metal **DO NOT ALLOW** just O_2 bonds to haemoglobin **OR** O_2 bonds to complex **ALLOW** bond breaks between O_2 and Fe^{2+} when O_2 required **OR** O_2 replaces H_2O **OR** vice versa **ALLOW** O_2 replaces CO_2 **OR** vice versa **ALLOW** O_2 replaces a ligand **OR** vice versa **IGNORE** just 'by ligand substitution' (in the question)

Question			Answer	Mark	Guidance
2	(e)	(ii)	(For complex) with CO, stability constant is greater (than with complex in O_2) **OR** with CO, stability constant is high ✓ (Coordinate) bond with CO is stronger (than O_2) **OR** bond with CO is strong ✓	2	**ANNOTATE WITH TICKS AND CROSSES, etc** **Comparison** of CO and O_2 is **NOT** required **ALLOW** stability constant with/of CO is greater **IGNORE** (complex with) CO is more stable **ALLOW** bond with CO is less likely to break **OR** bond with CO more likely to form **OR** 'CO cannot be removed' **OR** idea that attachment of CO is irreversible **OR** CO is a stronger ligand (than O_2) **OR** CO has greater affinity for ion/metal/haemoglobin (than O_2) **IGNORE** CO bonds more easily
	(f)	(i)	Pt^{2+}/Pt is +2/2+, 2 x Cl^- –2 ✓	1	**DO NOT ALLOW** response in terms of Cl_2 rather than Cl^- **DO NOT ALLOW** 'charges cancel' without the charges involved being stated

Question			Answer	Mark	Guidance
2	(f)	(ii)	 **OR**  ✓✓ For each structure Ligand donates an electron pair to metal (ion)/Pt^{2+}/Pt **OR** forms a coordinate bond to the metal (ion)/Pt^{2+}/Pt ✓	3	**IGNORE** any charge, ie Pt^{2+} **OR** Cl^-, even if wrong **IGNORE** any angle, even if wrong **ACCEPT** bonds to H_3N (does not need to go to 'N') Assume that a solid line is in plane of paper Each structure **must** contain 2 'out wedges' **AND** 2 'in wedges' or **dotted** lines **OR** 4 **solid** lines at right angles (all in plane of paper) **DO NOT ALLOW any** structure that cannot be in one plane **DO NOT ALLOW any** structure with Cl_2 as a ligand **DO NOT** apply **ECF** from one structure to the other **ALLOW** coordinate bonds shown on diagrams provide that they start from a lone pair **ALLOW** 'dative covalent bond' or 'dative bond' as alternative for 'coordinate bond **IGNORE** *cis* and *trans* labels (even if incorrect) **IGNORE** incorrect connectivity to NH_3, ie **ALLOW** NH_3—
		(iii)	platin binds to DNA (of cancer cells) **OR** platin stops (cancer) cells dividing/replicating ✓	1	

Question			Answer	Mark	Guidance
2	(g)		**1,1-cyclobutanedicarboxylate ion**  ✓ **Correct charge required** **(could also be 2– outside square brackets)** **carboplatin** (*cis* isomer shown below)  ✓	2	Must show cyclobutane ring with both COO^- groups bonded to same carbon **ALLOW** COO^- **OR** CO_2^- for each carboxylate ion **ALLOW** structures showing CH_2 or C atoms provided it is clear that C skeleton is shown, **Note**: H atoms are not required if C atoms shown, *ie*   **DO NOT ALLOW** circle inside cyclobutane ring Two bonds from Pt to O atoms Any bonds from ligand **MUST** come from O **OR** from atom with lone pair **IGNORE** any charge shown **Note**: H atoms are not required if C atoms shown, (see ion in 1st structure) **ALLOW ECF** from 1st structure provided that the attached atoms are capable of forming coordinate bonds (*ie* they contain a lone pair of electrons) ***Example*** if 1st structure is as below, then **ALLOW** 1 mark **ECF**   **X** **ECF ✓**
			Total	**18**	

Question			Answer	Mark	Guidance
3	(a)	(i)	**amount $S_2O_3^{2-}$ used** $= 0.00100 \times \frac{24.6}{1000} = 2.46 \times 10^{-5}$ mol ✓ **amount O_2 in 25 cm^3 sample** $= \frac{2.46 \times 10^{-5}}{4} = 6.15 \times 10^{-6}$ mol ✓ **Concentration of O_2 in sample** $= 6.15 \times 10^{-6} \times \frac{1000}{25} = 2.46 \times 10^{-4}$ (mol dm^{-3}) ✓ **mass concentration of O_2 in mg dm^{-3}** $= 2.46 \times 10^{-4} \times 32$ g $= 7.872 \times 10^{-3}$ (g dm^{-3}) = 7.872 (mg dm^{-3}) ✓	4	**ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** 0.0000246 (mol) **ECF** = $\frac{\text{answer above}}{4}$ **ALLOW** 0.00000615 g **ECF** answer above × $\frac{1000}{25}$ **ALLOW** 0.000246 g **ECF** = answer above × 32 x 1000 **ALLOW** 7.9 **OR** 7.87 **ALLOW** 2 SF up to calculator value **Must be in mg for mark** **Note:** Candidate may work out steps 3 and 4 in the opposite order, *ie* **mass of O_2 in sample** $= 6.15 \times 10^{-6} \times 32 \times 1000 = 1.968 \times 10^{-1}$ mg **mass concentration of O_2 in mg dm^{-3}** $= 1.968 \times 10^{-1} \times \frac{1000}{25} = 7.872$ (mg dm^{-3})
		(ii)	**Comment** 7.872 > 5 so fish can survive ✓	1	**ECF** If final answer > 5 fish **can** survive If final answer < 5 fish **cannot** survive
	(b)	(i)	NO ✓	1	**ALLOW** N_2H_2

Question			er	Mark	Guidance
	(b)	(ii)	$2H_2O + 2^- + 2NO_2^- \longrightarrow 2NO + I_2 + 4OH^-$ **OR** $2H^+ + {}^- + 2NO_2^- \longrightarrow 2NO + I_2 + 2OH^-$ **species** ✓ **balance** ✓	2	**IGNORE** state symbols **ALLOW** multiples **For species ONLY, IGNORE** any extra H_2O or e^- on either side of the equation **ALLOW** on LHS: $2HI + 2NO_2^-$ **OR** $2I^- + 2HNO_2$ **ALLOW** species and equation involving N_2H_2: $6H_2O + 8I^- + 2NO_2^- \longrightarrow N_2H_2 + 4I_2 + 10OH^-$ **OR** $6H^+ + 8I^- + 2NO_2^- \longrightarrow N_2H_2 + 4I_2 + 4OH^-$ **species** ✓ **balance** ✓
			Total	**8**	

Question			Answer	Marks	Guidance
4	(a)		$MnO_2 + 4OH^- \longrightarrow MnO_4^{2-} + 2H_2O$ **+ 2e⁻** ✓ $3H_2O + ClO_3^-$ **+ 6e⁻** ✓ $\longrightarrow 6OH^- + Cl^-$	2	**ALLOW** 'e': i.e. – sign not required
	(b)		**Role of CO_2** CO_2 reacts with H_2O forming an acid **OR** carbonic acid/H_2CO_3 forms **OR** CO_2 is acidic ✓ **Equation involving OH^-** $H_2CO_3 + OH^- \longrightarrow H_2O + HCO_3^-$ **OR** $H_2CO_3 + 2OH^- \longrightarrow 2H_2O + CO_3^{2-}$ **OR** $CO_2 + OH^- \longrightarrow CO_3^{2-} + H^+$ **OR** $CO_2 + OH^- \longrightarrow HCO_3^-$ **OR** $CO_2 + 2OH^- \longrightarrow CO_3^{2-} + H_2O$ **OR** $H^+ + OH^- \longrightarrow H_2O$ ✓ **Effect on equilibrium with reason** equilibrium shifts to right **AND** to restore OH^- ✓	3	***ANNOTATIONS MUST BE USED*** --- **ALLOW** equation: $CO_2 + H_2O \longrightarrow H_2CO_3$ **OR** $CO_2 + H_2O \longrightarrow H^+ + HCO_3^-$ **OR** $CO_2 + H_2O \longrightarrow 2H^+ + CO_3^{2-}$ **ALLOW** for 'restores OH^-' the following: 'makes more OH^-', 'OH^- has been used up' **DO NOT ALLOW** just 'equilibrium shifts to right'

Question	Answer	Marks	Guidance
(c)	**FOLLOW through stages to mark** --- **Moles in titration** $n(KMnO_4) = 0.0200 \times \frac{26.2}{1000} = 5.24 \times 10^{-4}$ mol ✓ $n(SO_3^{2-}) = 1.31 \times 10^{-3}$ mol ✓ **Scaling** $n(SO_3^{2-})$ in original 100 cm^3 $= 4 \times 1.31 \times 10^{-3} = 5.24 \times 10^{-3}$ mol ✓ **Mass** Mass of Na_2SO_3 in sample $= 126.1 \times 5.24 \times 10^{-3}$ g = 0.660764 g ✓ **Percentage** % $Na_2SO_3 = \frac{0.660764}{0.720} \times 100 = 91.8\%$ ✓	5	***ANNOTATIONS MUST BE USED*** ***AT LEAST 3 SF for each step*** --- **ECF** 2.5 x answer above **ECF** 4 x answer above **ECF** 126.1 x answer above **ALLOW** 0.661 g up to calculator value **ECF** $\frac{\text{calculated mass above}}{0.720} \times 100$ **ALLOW** 91.8% (1 DP) up to calculator value of 91.77277778 i.e. **DO NOT ALLOW** 92%
	ALLOW alternative approach based on theoretical content of Na_2SO_3 for last 2 marks **Theoretical amount, in moles, of Na_2SO_3 in sample** $n(Na_2SO_3) = \frac{0.720}{126.1} = 5.71 \times 10^{-3}$ mol ✓ **Percentage** % $Na_2SO_3 = \frac{5.24 \times 10^{-3}}{5.71 \times 10^{-3}} \times 100 = 91.8\%$ ✓		**COMMON ERRORS**: 36.8(1)% 4 marks no 2.5 factor 22.9(4)% 4 marks no scaling by 4 9.18% 3 marks no 2.5 and no x 4 Watch for random ECF %s for % from incorrect $M(Na_2SO_3)$, e.g. use of $M(SO_3^{2-})$ = 80.1 giving 58.3%
	Total	**10**	

Question			Expected answers	Marks	Additional guidance
5	a		$Fe_2O_3 + 6H^+ \longrightarrow 2Fe^{3+} + 3H_2O$ ✓	1	**ALLOW** $Fe_2O_3 + 6HCl \longrightarrow 2FeCl_3 + 3H_2O$ **OR** $Fe_2O_3 + 6HCl \longrightarrow 2Fe^{3+} + 6Cl^- + 3H_2O$ **ALLOW** correct multiples **IGNORE** state symbols **DO NOT ALLOW** Fe_2Cl_6 as a product
	b		$Sn^{2+} + 2Fe^{3+} \longrightarrow Sn^{4+} + 2Fe^{2+}$ ✓ $6Fe^{2+} + Cr_2O_7^{2-} + 14H^+ \longrightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$ ✓	2	**IGNORE** state symbols **ALLOW** overall equations: $SnCl_2 + 2FeCl_3 \longrightarrow SnCl_4 + 2FeCl_2$ $6FeCl_2 + K_2Cr_2O_7 + 14HCl \rightarrow 6FeCl_3 + 2CrCl_3 + 2KCl + 7H_2O$ **ALLOW** correct multiples

Question			Expected answers	Marks	Additional guidance
	c		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 54.6%, award **5 marks** --- **Amount Fe^{2+} in 250 cm^3 solution – 3 marks** amount $Cr_2O_7^{2-}$ used = $0.0200 \times \frac{26.5}{1000}$ $= 5.30 \times 10^{-4}$ (mol) ✓ amount Fe^{2+} = **6** × 5.30 x 10^{-4} $= 3.18 \times 10^{-3}$ mol ✓ amount Fe^{2+} in original 250 cm^3 = **10** × 3.18 x 10^{-3} $= 3.18 \times 10^{-2}$ (mol) ✓		***ANNOTATIONS MUST BE USED*** **IF** there is an alternative answer, 1st check common errors below. Then see if there is any **ECF** credit possible using working below --- **Working must be to at least 3 SF throughout** **BUT** ignore trailing zeroes, *i.e.* for 0.490 allow 0.49 **ALLOW ECF** from different Fe^{2+} ratio in equation from **8(b)** **BUT** still **ALLOW** 6 : 1 even from different ratio in equation If no equation use actual 6 : 1 ratio **DO NOT AWARD** 'ratio mark' at all for use of 1 : 1 ratio *– makes problem easier* **ECF** 10 × answer above
			% Fe in ore – 2 marks mass of Fe in ore = $55.8 \times 3.18 \times 10^{-2}$ g = 1.77444 g ✓		**ECF** 55.8 × answer above **IF** answer above has **not** been used **AND** × 55.8, **DO NOT ALLOW** this mark but do **ALLOW** final % **IF** answer above **AND** 55.8 are **BOTH not** used, then **DO NOT ALLOW ANY** further marks
			percentage Fe in ore = $\frac{1.77444}{3.25} \times 100$ = 54.6% ✓	**5**	**ECF** $\frac{\text{answer above}}{3.25} \times 100$ **ALLOW** 54.5% (from 1.77 g) **AND** any answer with > 1 decimal place that rounds back to 54.5 **OR** 54.6
					COMMON ERRORS 5.46 ✓✓✓✓ × *10 omitted* 51.5 ✓✓✓✓ *titre taken as 25.0* 156.2 ✓✓✓✓ × *159.6 instead of 55.8* 15.62 ✓✓✓ × *159.6 and* × *10 omitted* 45.5 ✓✓✓✓ *5 : 1 ratio* 1.52 ✓✓✓✓ ÷ 6 instead of × 6

Question			Expected answers	Marks	Additional guidance
	d		$E^{\ominus}$ for MnO_4^- is more positive/greater than Cl_2 **OR** $E^{\ominus}$ for $Cr_2O_7^{2-}$ is less positive/smaller than Cl_2 ✓ MnO_4^- reacts with Cl^- **OR** HCl (forming Cl_2 gas) **OR** $Cr_2O_7^{2-}$ does **not** react with Cl^- ions ✓	**2**	**ORA:** $E^{\ominus}$ for Cl_2 is less positive/smaller than MnO_4^- **OR** $E^{\ominus}$ for Cl_2 is more positive/greater than $Cr_2O_7^{2-}$
			Total	**10**	