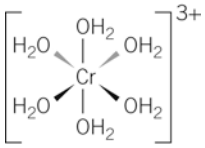
Question number	Answer	Marks	Guidance
1 (a)	Variable oxidation state	1	
	For example, Fe(II) and Fe (III)	1	Any correctly identified pair Allow two formulae showing complexes with different oxidation states even if oxidation state not given
	(Characteristic) colour (of complexes)	1	
	For example, $Cu^{2+}(aq)$ / $[Cu(H_2O)_6]^{2+}$ is blue	1	Any correct ion with colour scores M3 and M4 Must show (aq) or ligands OR identified coloured compound (e.g., $CoCO_3$)
1 (b)	Tetrahedral	1	
	$[CuCl_4]^{2-}$ / $[CoCl_4]^{2-}$	1	Any correct complex (Note charges must be correct)
	Square planar	1	
	$(NH_3)_2PtCl_2$	1	Any correct complex
	Linear	1	Do not allow linear planar
	$[Ag(NH_3)_2]^+$	1	$[AgCl_2]^-$ etc
1 (c) (i)	$[Ca(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [CaEDTA]^{2-} + 6H_2O$	1	If equation does not show increase in number of moles of particles CE = 0/3 for 7(c)(ii) If no equation, mark on
1 (c) (ii)	2 mol of reactants form 7 mol of products	1	Allow more moles/species of products Allow consequential to 7(c)(i)
	Therefore disorder increases	1	
	Entropy increases / +ve entropy change / free-energy change is negative	1	

1 (c) (iii)	Moles EDTA = 6.25 × 0.0532 / 1000 = (3.325×10^{-4})	1	
	Moles of Ca^{2+} in 1 dm^3 = $3.325 \times 10^{-4} \times 1000 / 150$ = (2.217×10^{-3})	1	Mark is for M1 × 1000 / 150 **OR** M1 × 74.1 If ratio of Ca^{2+} : EDTA is wrong or 1000 / 150 is wrong, CE and can score M1 only This applies to the alternative
	Mass of $Ca(OH)_2$ = $2.217 \times 10^{-3} \times 74.1$ = 0.164 g	1	M1 × 74.1 × 1000 / 150 Answer expressed to 3 sig figs or better Must give unit to score mark Allow 0.164 to 0.165
2 (a)	$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$	1	
	$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$	1	
	two negative ions repel / lead to reaction that is slow / lead to reaction that has high E_a	1	
	iron able to act because changes its oxidation state	1	allow iron has variable oxidation state
	With iron ions have alternative route / route with lower activation energy	1	
2 (b) (i)	$[Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_5OH]^{2+} + H^+$	1	can have H_2O on LHS and H_3O^+ on R do not penalise further hydrolysis equations allow high charge density
	Fe^{3+} ion has higher charge (to size ratio) (than Fe^{2+})	1	
	increases polarisation of co-ordinated water / attracts O releasing an H^+ ion / weakens O—H bond		

2 (b) (ii)	$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$	1	OR 6 mol Fe(II) react with 1 mol dichromate If factor of 6 not used max =3 for M2, M4 and M5 e.g., 1:1 gives ans= 8.93 to 8.98% (scores 3)
	moles dichromate = 23.6 × 0.218 / 1000 = 5.14×10^{-4}	1	
	moles iron = $5.14 \times 10^{-4} \times 6 = 0.003\,09$	1	M3 also scores M1
	mass iron = 0.003 09 × 55.8 = 0.172	1	Mark is for moles of iron 55.8 conseq Allow use of 56 for iron
	% by mass of iron = 0.172 × 100 / 0.321 = 53.7%	1	Answer must be to at least 3 sig figures allow 53.6 to 53.9 Mark is for mass of iron × 100 / 0.321 conseq
2 (c)	brown precipitate / solid	1	Allow red-brown / orange solid Not red or yellow solid
	bubbles (of gas) / effervescence/ fizz	1	Allow gas evolved / given off Do not allow just gas or CO_2 or CO_2 gas
	$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(H_2O)_3(OH)_3 + 3CO_2 + 3H_2O$	1	Allow $2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(OH)_3 + 3CO_2 + 9H_2O$ OR Use of Na_2CO_3
3 (a)	A catalyst in the same phase as the reactants	1	
3 (b) (i)	A reaction in which a product acts as a catalyst	1	Do not accept: self-catalysing. You could also have Mn^{3+} as a catalyst, since it is involved in the reaction and is regenerated.
3 (b) (ii)	Mn^{2+}	1	
3 (c) (i)	$2CO + 2NO \rightarrow 2CO_2 + N_2$ The reducing agent is CO.	1 1	Accept: $4CO + 2NO_2 \rightarrow 4CO_2 + N_2$
3 (c) (ii)	Pt, Pd, or Rh Deposited on a ceramic honeycomb or a mesh or sponge which increases the surface area of the catalyst.	1 1 1	

4 (a)	These are examples of answers. There are other equations possible from the species given in the question.	8	
4 (a) (i)	$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$		Accept: the reverse equation. There is one mark for the two complex ions and one for the balancing.
4 (a) (ii)	$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6H_2O$		One mark for the two complex ions and one for the balanced equation.
4 (a) (iii)	$[Co(H_2O)_6]^{2+} + 3C_2O_4^{2-} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$		One mark for the two complex ions and one for the balanced equation. All substitutions are allowed except NH_3 by H_2O.
4 (a) (iv)	$[Co(H_2O_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$		One mark for the two complex ions and one for the balanced equation. You could also have H_2O or NH_3 substituted by $C_2O_4^{2-}$. Accept NH_3 or Cl^- substituted by $EDTA^{4-}$.
4 (b) (i)	$[Fe(H_2O)_6]^{2+}$	4	
4 (b) (ii)	$Fe(OH)_2$ or $Fe(OH)_2(H_2O)_4$		Accept: the simple hydroxide formula but it is actually the octahedral complex which is made.
4 (b) (iii)	Fe^{2+} is oxidised to Fe^{3+}.		Accept: oxidised to or $Fe(OH)_3$ by oxygen in the air.
5 (a)	$NaOH(s) + (aq) \rightarrow Na^+(aq) + OH^-(aq)$	2	1 mark for correct products, 1 mark for correct reactants
5 (b)	Sodium hydroxide is a strong base because it is fully dissociated into ions in aqueous solution.	1	
5 (c)	No. All solid sodium hydroxide is the same and cannot be more than fully dissociated, nor can solid sodium hydroxide be made more concentrated.	1 1	
5 (d)	ΔH is negative. The reaction is exothermic.	1 1	
5 (e)	If a little water is added to all the sodium hydroxide, the water will get very hot and could be dangerous. If the solid is added to the whole litre of water the heat will be spread out over all the water which will therefore become less hot.	1 1	
5 (f)	2.5 mol dm^{-3}	1	
5 (g)	890	1	
5 (h) (i)	742 g	2	

5 (h) (ii)	The reaction may not go to completion some of the solution could leak away before the reaction is complete.	1 1	
5 (j)	It is ionically rather than covalently bonded.	1	
6 (a)	An electron pair on the ligand Is donated from the ligand to the central metal ion	1 1	
6 (b)	Blue precipitate Dissolves to give a dark blue solution $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$ $Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$	1 1 1 1	
6 (c)	$[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2NCH_2CH_2NH_2 \rightarrow [Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+} + 4NH_3$	1	
6 (d)	Cu—N bonds formed have similar enthalpy / energy to Cu—N bonds broken And the same number of bonds broken and made	1 1	
6 (e)	3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive Therefore, the free-energy change is negative	1 1	 M2 can only be awarded if M1 is correct
7 (a)	**Q** is calcium or magnesium Bromide **R** is aluminium Chloride **S** is iron(III) Sulfate	1 1 1 1 1 1	Mark this question independently
7 (b)	$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ $[Fe(H_2O)_6]^{3+} + 3OH^- \rightarrow Fe(H_2O)_3(OH)_3 + 3H_2O$ $2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(H_2O)_3(OH)_3 + 3H_2O + 3CO_2$ $[Fe(H_2O)_6]^{3+} + 4Cl^- \rightarrow [FeCl_4]^- + 6H_2O$	1 1 1 1	

8 (a)	A transition metal is an element that forms at least one ion with a partially full d-shell of electrons.	1	
8 (b)	Scandium is a d-block element because its highest energy electron is in a d-shell. However it is not a transition metal as scandium only forms Sc^{3+} ions in which the d-shell is empty	1 1	
9 (a)	A complex ion is a metal ion surrounded by ligands. A ligand is an ion or molecule with a lone pair of electrons that it can donate to form a co-ordinate bond	1 1	
9 (b) (i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$	1	
9 (b) (ii)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$	1	
9 (c) (i)		1	
9 (c) (ii)	Octahedral	1	