Answers to examination-style questions

Answers	Marks	Examiner's tips
1 a) N in $Cu(NO_3)_2$ oxidation state: +5 N in NO_2 oxidation state: +4 Oxidation product: oxygen	**3**	You know Cu is +2 here since the formula of copper(II) nitrate is given to start. Since oxygen is normally –2 and in O_2 the oxygen is zero, then oxygen must have been oxidised.
b) $[Cu(H_2O)_6]^{2+}$ octahedral	**2**	When a transition metal compound is added to water, a hexaaqua complex ion is formed.
c) $Cu(H_2O)_4(OH)_2$ or $Cu(OH)_2$ $[Cu(H_2O)_6]^{2+} + 2NH_3$ $\rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	**2**	Accept: copper(II) hydroxide since the identity is asked for. Using two equations, this would be: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow$ $Cu(H_2O)_4(OH)_2 + 2H_2O$
d) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ deep blue $Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow$ $[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$	**3**	This is an example of partial ligand substitution.
e) $[CuCl_4]^{2-}$ yellow-green tetrahedral	**3**	Learn the colours of these transition metal complexes.
f) i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ **ii)** a reducing agent	**2**	Remember the 4s electron is lost first.
2 a) $[Ar]_3d^7$	**1**	
b) $[Co(H_2O)_6]^{2+}$ pink	**2**	When a transition metal compound is added to water, a hexaaqua complex ion is formed. You must learn the colours.
c) i) $[Co(NH_3)_6]^{2+}$	**3**	Remember at this stage there is no

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yellow or pale brown 'straw' coloured		oxidation. That comes in the next part of the question.
ii) $[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$		
d) $[Co(NH_3)_6]^{3+}$ an oxidising agent	**2**	
3 These are examples of answers. There are other equations possible from the species given in the question.	**8**	
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.
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.
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.
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 $EDTA^{4-}$.
b) i) $[Fe(H_2O)_6]^{2+}$	**4**	
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.
iii) Fe^{2+} is oxidised to Fe^{3+}.		Accept: oxidised to or $Fe(OH)_3$ by oxygen in the air.
4 a) $[Co(H_2O)_6]^{2+}$	**2**	When a transition metal compound is added to water, a hexaaqua complex ion is formed.
$Co(H_2O)_4(OH)_2$ or $Co(OH)_2$		Accept: simple hydroxide formula but it is actually the octahedral complex which is made.

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b) $[Co(NH_3)_6]^{2+}$	**1**	This pale brown colour is often referred to as yellow or pale brown 'straw' coloured.
c) Co^{2+} is oxidised to Co^{3+}. oxygen	**2**	
d) iodine Iodide is oxidised to iodine by the Co^{3+} ion.	**2**	
5 a) Forms blue or pink precipitate. $Co(H_2O)_4(OH)_2$ Precipitate dissolves in excess ammonia. Forms yellow or pale brown 'straw' coloured solution. $[Co(NH_3)_6]^{2+}$ Darkens on standing in air. $[Co(NH_3)_6]^{3+}$ formed. Due to oxidation by O_2 in air.	**8**	This sometimes looks lilac. Accept: $Co(OH)_2$. Accept turns brown.
b) Fe^{3+} has a larger charge and smaller size than Fe^{2+}.	**9**	Fe^{3+} has a higher charge/size ratio scores two marks, or Fe^{3+} has a higher charge density scores two marks. However, if you refer to either atoms or molecules and not ions you lose both marks.
The Fe^{3+} polarises a ligand water molecule to a greater extent.		Accept: more hydrolysis occurs, or Fe^{3+} weakens the OH bond more.
The solution of Fe^{3+} contains more H^+ ions.		If you give the hydrolysis equation, then you can get a mark for the equation and then a mark for stating that in Fe^{3+} the equilibrium lies further to the right.
green precipitate with Fe^{2+} $FeCO_3$ brown or red/brown precipitate with Fe^{3+} $[Fe(H_2O)_3(OH)_3]$		Fe^{3+} is more acidic in aqueous solution so it can react with carbonates and give off carbon dioxide (acid + carbonate → salt + water + carbon dioxide). The Fe^{2+} is not acidic enough to react in this way.
Effervescence as carbon dioxide is evolved from the Fe^{3+} reaction.		