

Answers to examination-style questions

Answers	Marks	Examiner's tips
1 a) N in $\text{Cu}(\text{NO}_3)_2$ 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) $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ octahedral	2	When a transition metal compound is added to water, a hexaaqua complex ion is formed.
c) $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Cu}(\text{OH})_2$ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3$ $\rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$	2	Accept: copper(II) hydroxide since the identity is asked for. Using two equations, this would be: $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$ $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow$ $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{H}_2\text{O}$
d) $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ deep blue $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 4\text{NH}_3 \rightarrow$ $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-$	3	This is an example of partial ligand substitution.
e) $[\text{CuCl}_4]^{2-}$ 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) $[\text{Ar}]_3d^7$	1	
b) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ pink	2	When a transition metal compound is added to water, a hexaaqua complex ion is formed. You must learn the colours.
c) i) $[\text{Co}(\text{NH}_3)_6]^{2+}$	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) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3$ $\rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$		
d) $[\text{Co}(\text{NH}_3)_6]^{3+}$ 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) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3$ $\rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$		Accept: the reverse equation. There is one mark for the two complex ions and one for the balancing.
ii) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^-$ $\rightarrow \text{CoCl}_4^{2-} + 6\text{H}_2\text{O}$		One mark for the two complex ions and one for the balanced equation.
iii) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 3\text{C}_2\text{O}_4^{2-}$ $\rightarrow [\text{Co}(\text{C}_2\text{O}_4)_3]^{4-} + 6\text{H}_2\text{O}$		One mark for the two complex ions and one for the balanced equation. All substitutions are allowed except NH_3 by H_2O .
iv) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + \text{EDTA}^{4-}$ $\rightarrow [\text{Co}(\text{EDTA})]^{2-} + 6\text{H}_2\text{O}$		One mark for the two complex ions and one for the balanced equation. You could also have H_2O or NH_3 substituted by $\text{C}_2\text{O}_4^{2-}$. Accept NH_3 or Cl^- substituted by EDTA^{4-} .
b) i) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$	4	
ii) $\text{Fe}(\text{OH})_2$ or $\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4$		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 $\text{Fe}(\text{OH})_3$ by oxygen in the air.
4 a) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$	2	When a transition metal compound is added to water, a hexaaqua complex ion is formed.
$\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Co}(\text{OH})_2$		Accept: simple hydroxide formula but it is actually the octahedral complex which is made.

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b) $[\text{Co}(\text{NH}_3)_6]^{2+}$	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. $\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2$ Precipitate dissolves in excess ammonia. Forms yellow or pale brown 'straw' coloured solution. $[\text{Co}(\text{NH}_3)_6]^{2+}$ Darkens on standing in air. $[\text{Co}(\text{NH}_3)_6]^{3+}$ formed. Due to oxidation by O_2 in air.	8	This sometimes looks lilac. Accept: $\text{Co}(\text{OH})_2$. Accept turns brown.
b) Fe^{3+} has a larger charge and smaller size than Fe^{2+} . The Fe^{3+} polarises a ligand water molecule to a greater extent. The solution of Fe^{3+} contains more H^+ ions. green precipitate with Fe^{2+} FeCO_3 brown or red/brown precipitate with Fe^{3+} $[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]$ Effervescence as carbon dioxide is evolved from the Fe^{3+} reaction.	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. Accept: more hydrolysis occurs, or Fe^{3+} weakens the OH bond more. 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. Fe^{3+} is more acidic in aqueous solution so it can react with carbonates and give off carbon dioxide (acid + carbonate \rightarrow salt + water + carbon dioxide). The Fe^{2+} is not acidic enough to react in this way.