

Topic 14 – Metal Ions in Solution

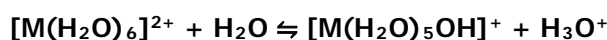
Revision Notes

1) Metal-aqua ions

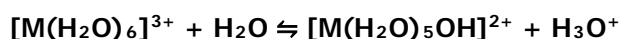
- When metal compounds dissolve in water, metal-aqua ions are formed
- 2+ metal-aqua ions include: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$
- 3+ metal-aqua ions include: $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$, $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
- The metal ions are behaving as Lewis acids because they are electron pair acceptors
- The water molecules are behaving as Lewis bases because they are electron pair donors

2) Acidity of metal-aqua ions

- M^{2+} solutions are very weakly acidic (pH about 6) due to the following equilibrium:



- M^{3+} solutions are acidic (pH about 3) due to the following equilibrium:

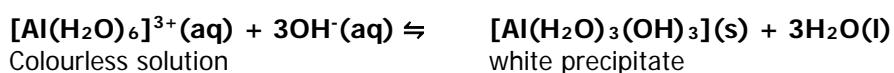
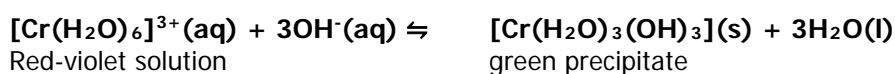
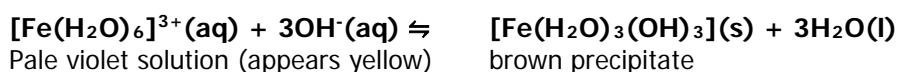
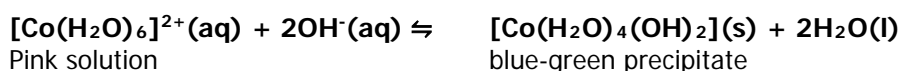
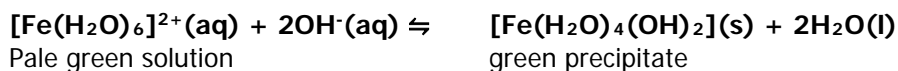
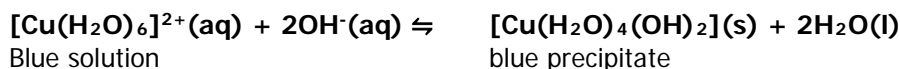


- The acidity is caused by an O-H bond breaking in one of the ligands. This is an example of hydrolysis.
- M^{3+} solutions are more acidic than M^{2+} solutions because, in M^{3+} , the metal ion has a greater charge/size ratio which means it has more ability to weaken bonds in the water molecules

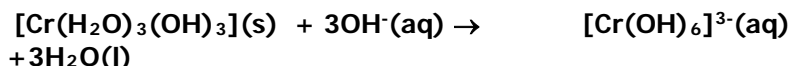
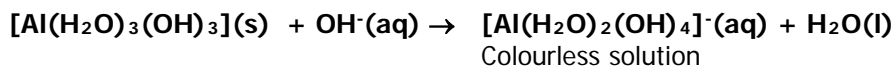
3) Reactions with bases

a) NaOH

- With OH^- ions, a precipitation reaction occurs. The OH^- acts as a Bronsted-Lowry base



- $[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2](\text{s})$ is a green precipitate that turns to a brown solid on standing as it is oxidised by air to $[\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3](\text{s})$
- The precipitation reactions are reversible. If acid is added to $[\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2](\text{s})$, for example, the precipitate will dissolve to give a blue solution containing $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$
- The precipitates of aluminium hydroxide and chromium hydroxide dissolve in excess NaOH

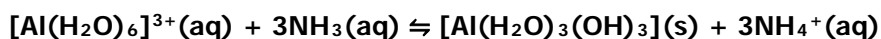
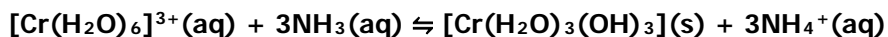
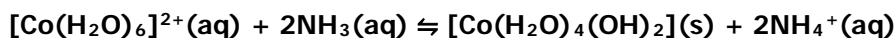
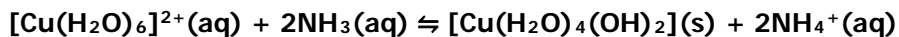


Green solution

- Because the precipitates of aluminium hydroxide and chromium hydroxide dissolve in both acids and bases they are described as amphoteric

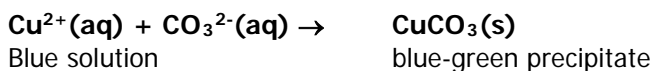
b) $\text{NH}_3(\text{aq})$

- The same precipitates are obtained with ammonia solution, $\text{NH}_3(\text{aq})$. The ammonia acts as a Bronsted-Lowry base

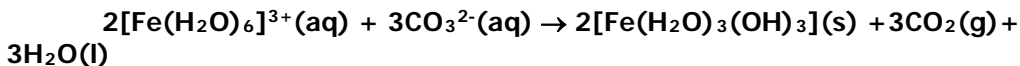


c) Carbonates

- With M^{2+} , the metal carbonate is precipitated e.g.



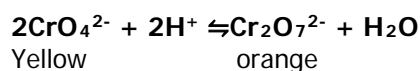
- CoCO_3 is a mauve precipitate and FeCO_3 is a green precipitate
- With the more acidic M^{3+} , effervescence and a coloured precipitate are seen e.g.



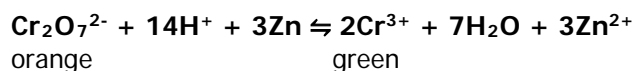
4) Variable oxidation state

a) Chromium

- The main oxidation states of chromium are +6, +3 and +2
- The +6 state occurs in chromate(VI), CrO_4^{2-} , and dichromate(VI), $\text{Cr}_2\text{O}_7^{2-}$
- Chromium(VI) species can be interconverted using H^+ and OH^- (applying Le Chatelier's principle). Note that there is no change of oxidation state in this reaction



- Chromium can be reduced from its +6 oxidation state to the +3 state using zinc in acid solution:

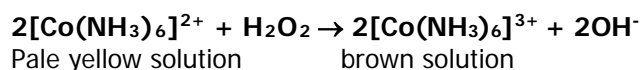


- In the absence of air, the reduction with zinc can continue to give blue $\text{Cr}^{2+}(\text{aq})$
- Chromium(III) can be oxidised to chromium(VI) using hydrogen peroxide in alkaline solution ($\text{H}_2\text{O}_2/\text{NaOH}$):



b) Cobalt

- Cobalt(II) can be oxidised to cobalt(III) using hydrogen peroxide in alkaline solution ($\text{H}_2\text{O}_2/\text{NaOH}$):



- Cobalt(II) can be oxidised to cobalt(III) by air in ammoniacal solution:

