AQA Chemistry A-level

3.2.6: Reaction of Metal Aqua Ions

Detailed Notes

3.2.6.1 - Ions in aqueous solution

Metal ions become **hydrated** in water with H_2O ligands around the central metal ion. The reaction of four major metal aqua ions have to be known for this A-Level specification; **iron(II), copper(II), iron(III) and aluminium**. They form **coloured precipitates** that can be used to identify the metal ion present.

Acid-base Properties

When these ions are in solution, they are **acidic**. Metal ions that form **2^+ ions**, iron(II) and copper(II), form weaker acidic solutions than those that form **3^+ ions**, Iron(III) and aluminium. Therefore the 3^+ ions dissociate more and have a greater attractive power to OH^-, basic ions, ie. they are stronger acids.

Reactions with NaOH

Solutions of these metal ions **react as acids** with sodium hydroxide in a **neutralisation** reaction to form a salt and water.

Example:

The precipitates formed are coloured, indicated by the colour of the text. Aluminium forms a white precipitate.

$$[Fe(H_2O)_6]^{2+} + 2OH^- \longrightarrow [Fe(H_2O)_4(OH)_2] + 2H_2O$$

$$[Cu(H_2O)_6]^{2+} + 2OH^- \longrightarrow [Cu(H_2O)_4(OH)_2] + 2H_2O$$

$$[Fe(H_2O)_6]^{3+} + 3OH^- \longrightarrow [Fe(H_2O)_3(OH)_3] + 3H_2O$$

$$[Al(H_2O)_6]^{3+} + 3OH^- \longrightarrow [Al(H_2O)_3(OH)_3] + 3H_2O$$

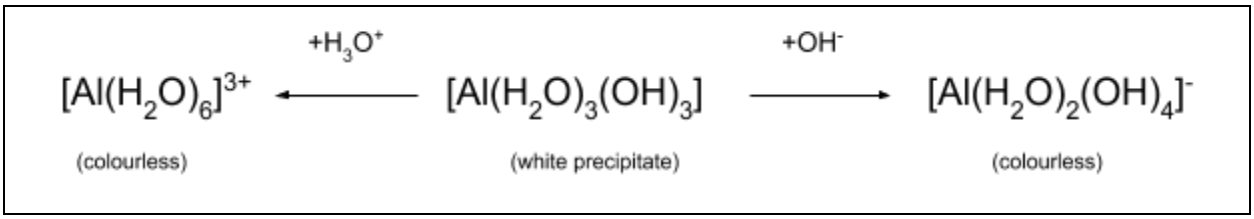
It is easiest to remember the formulas of the precipitates by remembering that the number of OH^- substituted is the same as the value of the charge on the initial ion.

These reactions **hydrolyse** the metal ions to form the coloured precipitates.

Amphoteric Salts

The **aluminium salt** can act as an acid or a base meaning it is **amphoteric**. This means that if sodium hydroxide is added in **excess**, the salt acts as an acid and is hydrolysed further.

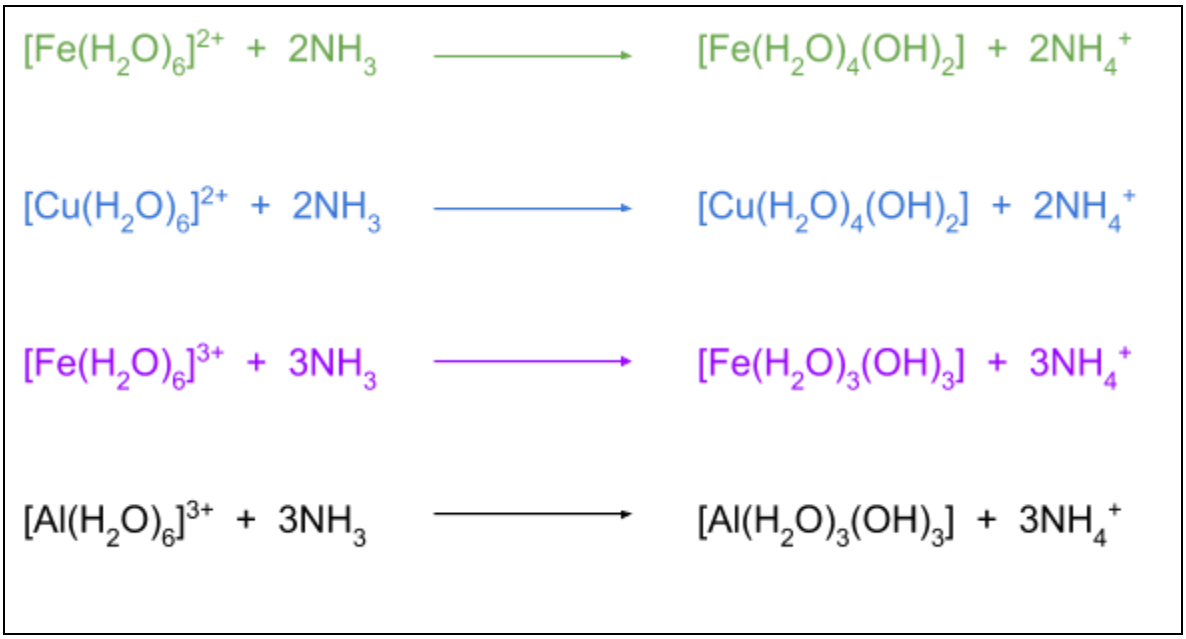
Example:



Reactions with NH_3

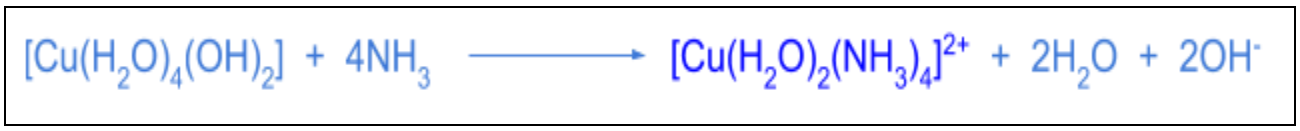
Solutions of these metal ions react in a similar way with **aqueous ammonia** to form a salt and ammonium ions.

Example:



When ammonia is added in **excess** to these precipitates, the **copper(II) salt undergoes ligand substitution** to form a **deep blue** solution.

Example:



Reactions with Na_2CO_3

Solutions of these metal 2^+ ions react with **sodium carbonate as acids**, forming **insoluble carbonates** and water.

Example:

$$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \longrightarrow FeCO_3 + 6H_2O$$

$$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \longrightarrow CuCO_3 + 6H_2O$$

Solutions of the metal 3^+ ions act as **stronger acids** meaning they react with sodium carbonate to form a salt, water and carbon dioxide.

Example:

$$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \longrightarrow 2[Fe(H_2O)_3(OH)_3] + 3H_2O + 3CO_2$$

$$2[Al(H_2O)_6]^{3+} + 3CO_3^{2-} \longrightarrow 2[Al(H_2O)_3(OH)_3] + 3H_2O + 3CO_2$$

Reactions with Cl^- ions

All metal aqua ions undergo **ligand substitution** reactions to form **tetrahedral ions with four Cl^- ligands**. This occurs when they react with concentrated hydrochloric acid.

Example:

$$[Fe(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [FeCl_4]^{2-} + 6H_2O$$

$$[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$$

$$[Fe(H_2O)_6]^{3+} + 4Cl^- \longrightarrow [FeCl_4]^{-} + 6H_2O$$

$$[Al(H_2O)_6]^{3+} + 4Cl^- \longrightarrow [AlCl_4]^{-} + 6H_2O$$