

2.6. Reactions of Inorganic Compounds in Aqueous Solution

Lewis acids and bases

Definitions: **Lewis acid**: electron pair acceptor
Lewis base: electron pair donor

In the formation of complex ions the ligand is the Lewis base because it is donating a pair of electrons in the dative covalent bond and the metal ion is the Lewis acid.

Metal-aqua ions

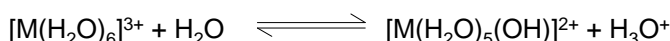
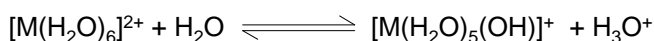
Metal aqua ions are formed in aqueous solution.

$[M(H_2O)_6]^{2+}$, limited to M = Fe (green) and Cu (blue);
 $[M(H_2O)_6]^{3+}$, limited to M = Al (colourless), and Fe (violet)

In solution Fe(III) appears yellow/brown due to hydrolysis reactions. The violet colour is only really seen in solid hydrated salts that contain these complexes.

Acidity or hydrolysis reactions

The following equilibria happen in aqueous solutions of metal ions.



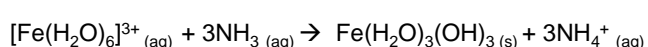
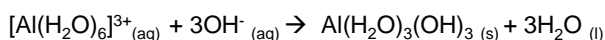
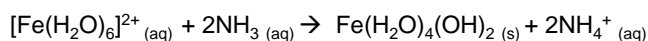
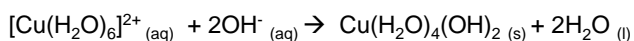
The equilibria lead to generation of acidic solutions with M^{3+} ions, and very weakly acidic solutions with M^{2+} ions. The 3^+ ions are noticeably more acidic.

The acidity of $[M(H_2O)_6]^{3+}$ is greater than that of $[M(H_2O)_6]^{2+}$ because the $3+$ metal ions have **higher charge density** (charge/size ratio) and have greater polarising power. The greater the polarising power, the more strongly it attracts the water molecule. This **weakens the O-H bond** so it breaks more easily **releasing H^+ ions**.

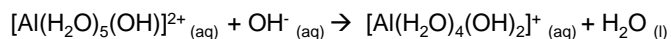
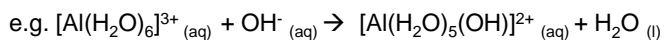
Reaction with limited OH^- and limited NH_3

The bases OH^- and ammonia when in limited amounts form the same hydroxide precipitates. They form in **deprotonation acid base reactions**.

$M(OH)_2(H_2O)_4 (s)$: Cu blue ppt, Fe (II) green ppt
 $M(OH)_3(H_2O)_3 (s)$: Fe(III) brown ppt, Al white ppt



This process can happen step wise removing one proton at a time. Be able to write equations for this too.

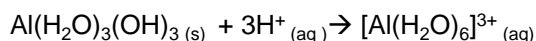
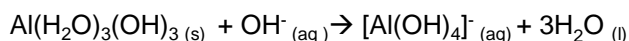


Here the NH_3 and OH^- ions are acting as **Bronsted-Lowry bases** accepting a proton

Reaction with excess OH^-

With excess NaOH the aluminium hydroxide dissolves. Al becomes $[Al(OH)_4]^- (aq)$ colourless solution.

This hydroxide is classed as **amphoteric** because it reacts and dissolves in both acids and bases.

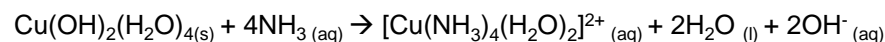


Reaction with excess NH_3

With **excess NH_3** a **ligand substitution** reaction occurs with Cu and its precipitate dissolves to form a deep blue solution.

This substitution is incomplete with Cu.

Cu becomes $[Cu(NH_3)_4(H_2O)_2]^{2+}$ deep blue solution

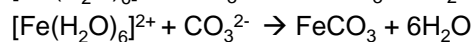
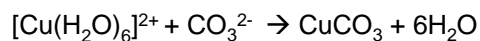
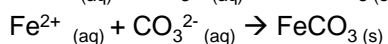
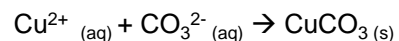


In this reactions NH_3 is acting as a **Lewis base** donating an electron pair.

Reactions with carbonate solution

The 2+ ions react differently to the 3+ ions with carbonate solutions.

The **2+** ions with **carbonate** solution results in **MCO₃ ppt** being formed (Cu blue/green, Fe(II) green)

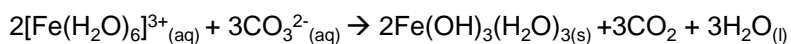


These are
precipitation
reactions

The **3+** ions with **carbonate** solution form a **M(OH)₃ ppt** and **CO₂** gas is evolved.

Al forms white ppt of $\text{Al}(\text{OH})_3(\text{H}_2\text{O})_3 + \text{CO}_2$

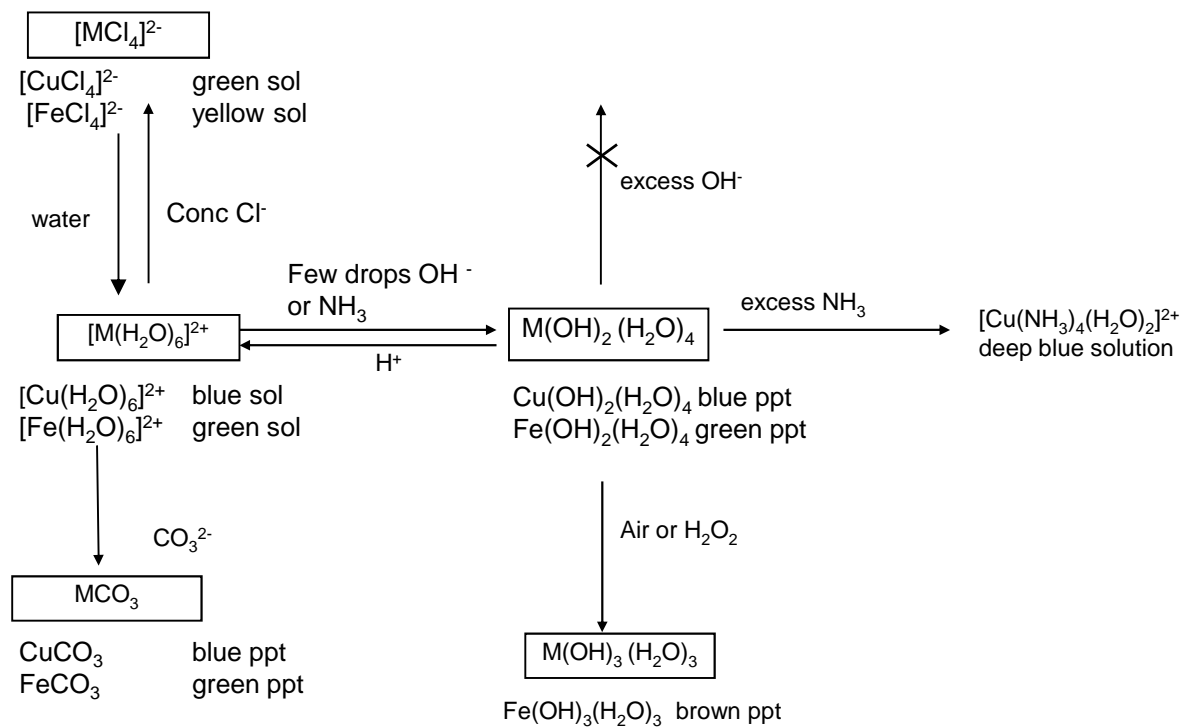
Fe(III) forms brown ppt of $\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3 + \text{CO}_2$



These are classed as **acidity reactions**.

MCO₃ is formed with 2+ ions but M₂(CO₃)₃ is not formed with 3+ ions. The difference is explained by the greater polarising power of the 3+ ion due to its higher charge density.

2+ Ion Summary



3+ Ion Summary

