

REACTIONS in AQUEOUS SOLUTIONS

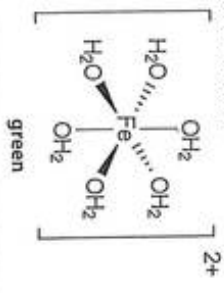


COMPOUNDS

When transition metal compounds dissolve in water they form complex ions in solution. These solutions are often brightly coloured. These compounds are called **hexaqua compounds** because there are six H_2O ligands around the central metal ion. If the metal in the complex has an oxidation state of +2, the general formula for the complex is $[M(H_2O)_6]^{2+}$ where M is the metal.

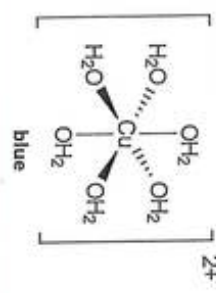
Fe(II)

Fe(II) compounds dissolve to form $[Fe(H_2O)_6]^{2+}$, which is a green-coloured solution.



Cu(II)

Cu(II) compounds dissolve to form $[Cu(H_2O)_6]^{2+}$, which is a blue-coloured solution.

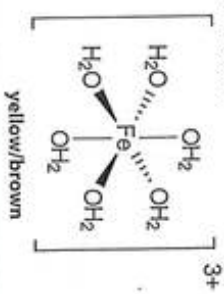


COMPOUNDS

Some non-transition metals can also form hexaqua compounds, including aluminium, which forms a 3+ ion. Solutions of Al(III) complexes are not coloured because Al is not a transition metal. If the metal in the complex has an oxidation state of +3, the general formula for the complex is $[M(H_2O)_6]^{3+}$ where M is the metal.

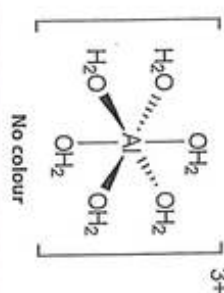
Fe(III)

Fe(III) compounds dissolve to form $[Fe(H_2O)_6]^{3+}$, which is a yellow-brown solution.



Al(III)

Al(III) compounds dissolve to form $[Al(H_2O)_6]^{3+}$, which is a colourless solution.



REACTIONS

All of these reactions produce precipitates (abbreviated to ppt).

WITH NaOH

Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$Fe(OH)_2 \cdot H_2O$	Iron(II) hydroxide	Green
Cu(II)	$Cu(OH)_2 \cdot H_2O$	Copper(II) hydroxide	Blue

Neither of these precipitates redissolves if an excess of $NaOH(aq)$ is added.

WITH NH_3

In water, ammonia reacts to form ammonium and hydroxide ions:

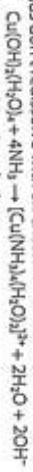


So ammonium solutions form the same precipitates as sodium hydroxide solution.



Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$Fe(OH)_2 \cdot H_2O$	Iron(II) hydroxide	Green
Cu(II)	$Cu(OH)_2 \cdot H_2O$	Copper(II) hydroxide	Blue

Fe(II) compounds don't redissolve with an excess of ammonia, but Cu(II) compounds do:



This Cu(II) complex is deep blue in solution.

WITH Na_2CO_3

Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$FeCO_3$	Iron(II) carbonate	Grey-green
Cu(II)	$CuCO_3$	Copper(II) carbonate	Green

RELATIVE ACIDITY

Solutions of $[M(H_2O)_6]^{3+}$ complexes are (in general) more acidic than $[M(H_2O)_6]^{2+}$ complexes. This is because the charge-size ratio (or charge density) of a 3+ ion is greater than that of a 2+ ion, and 3+ ions are able to polarise the H_2O ligands bound to them to the point that H^+ is released.



As a result M^{3+} and M^{2+} compounds react differently with carbonates. M^{3+} compounds form carbonates, whereas M^{2+} compounds form acidic solutions which then react to form hydroxides and carbon dioxide gas.

AMPHOTERIC BEHAVIOUR

Some metal complexes display amphoteric behaviour – they can dissolve in acidic and basic solutions.

EXAMPLE: Aluminium(III) hydroxide, $[Al(H_2O)_5(OH)]$

Acting as an acid: $[Al(H_2O)_5(OH)] + OH^- \rightleftharpoons [Al(H_2O)_4(OH)_2]^- + H_2O$

Acts as a proton donor

Acting as a base: $[Al(H_2O)_5(OH)] + 3H^+ \rightleftharpoons [Al(H_2O)_6]^{3+}$

Acts as a proton acceptor

REACTIONS

All of these reactions produce precipitates (abbreviated to ppt).

WITH NaOH

Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$Fe(OH)_2 \cdot H_2O$	Iron(II) hydroxide	Brown
Al(III)	$Al(OH)_3 \cdot H_2O$	Aluminium(III) hydroxide	White

Fe(II) hydroxide does not redissolve in an excess of $NaOH(aq)$, but Al(III) hydroxide does – between four and six of the H_2O ligands can be replaced:



This solution is always colourless.

WITH NH_3

Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$Fe(OH)_2 \cdot H_2O$	Iron(II) hydroxide	Brown
Al(III)	$Al(OH)_3 \cdot H_2O$	Aluminium(III) hydroxide	White

Neither of these precipitates redissolves in an excess of ammonia.

WITH Na_2CO_3

Ion	Compound formed	Compound name	Precipitate colour
Fe(II)	$Fe(OH)_2 \cdot H_2O$	Iron(II) hydroxide	Brown
Al(III)	$Al(OH)_3 \cdot H_2O$	Aluminium(III) hydroxide	White

M^{3+} compounds do not typically form carbonates as M^{3+} compounds do.