The Common Ion Effect and Solubility

A common ion suppresses the solubility of an ionic substance

Practice Exercise

Calculate its solubility of AgBr in g/L (K_{sp} = 7.7 x 10^{-13}) in:

(a) pure water

(b) 0.0010 M NaBr

$$AgBr\ (s) \rightleftharpoons Ag^{+}(aq) + Br^{-}(aq)$$

Practice Exercise

Calculate its solubility of AgBr in g/L (K_{sp} = 7.7×10^{-13}) in:

(a) pure water

(b) 0.0010 M NaBr

$$AgBr\ (s) \rightleftharpoons Ag^{+}(aq) + Br^{-}(aq)$$

Le Chatelier's principle: the solubility is less in a solution of NaBr than in pure water

Practice Exercise

Calculate its solubility of AgBr in g/L (K_{sp} = 7.7 x 10^{-13}) in:

(a) pure water

$$AgBr\ (s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$

$$K_{sp} = [Ag^+][Br^-] = 7.7 \times 10^{-13}$$

$$x^2 = 7.7 \times 10^{-13}$$

$$x = 8.8 \times 10^{-7}\ M = 1.7 \times 10^{-4}\ g/L$$

solubility of AgBr

Practice Exercise

Calculate its solubility of AgBr in g/L (K_{sp} = 7.7×10^{-13}) in:

(b) 0.0010 *M* NaBr

$$AgBr\ (s) \rightleftharpoons Ag^{+}(aq) + Br^{-}(aq)$$

$$K_{sp} = [Ag^{+}][Br^{-}] = 7.7 \times 10^{-13}$$

$$[Ag^{+}]\ (0.0010) = 7.7 \times 10^{-13}$$

$$[Ag^{+}] = 7.7 \times 10^{-10}\ M = 1.4 \times 10^{-7}\ g/L$$

solubility of AgBr

pH and Solubility

pH and Solubility

consider $Mg(OH)_2$

$$K_{sp} = 1.2 \times 10^{-11} = [Mg^{2+}]\,[HO^-]^2$$

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2HO^-$$

solubility decreases in basic solution because increase in $[HO^-]$ requires decrease in $[Mg^{2+}]$

Practice Exercise

Calculate its molar solubility of $Cr(OH)_3$ (K_{sp} = 3.0×10^{-29}) in a pH 10 buffer.

pOH = 4

$$Cr(OH)_3(s) \rightleftharpoons Cr^{3+}(aq) + 3OH^-(aq)$$

$$K_{sp} = 3.0 \times 10^{-29} = [Cr^{3+}][OH^-]^3$$

$$3.0 \times 10^{-29} = [Cr^{3+}][10^{-4}]^3$$

$$[Cr^{3+}] = 3 \times 10^{-17} \text{ mol/L}$$

pH and Solubility

consider $Mg(OH)_2$

$$K_{sp} = 1.2 \times 10^{-11} = [Mg^{2+}]\,[HO^-]^2$$

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2\,HO^-$$

$$HO^- \xrightarrow{H^+} H_2O$$

solubility increases in acidic solution because $[HO^-]$ is decreased

In General

salts of weak acids will be more soluble in acid solution than in pure water

because the anion of a weak acid (conjugate base) is basic

pH and Solubility

BaF_2 is a salt of a weak acid; its anion (F-) is basic

$$K_{sp} = 1.7 \times 10^{-6} = [Ba^{2+}]\,[F^-]^2$$

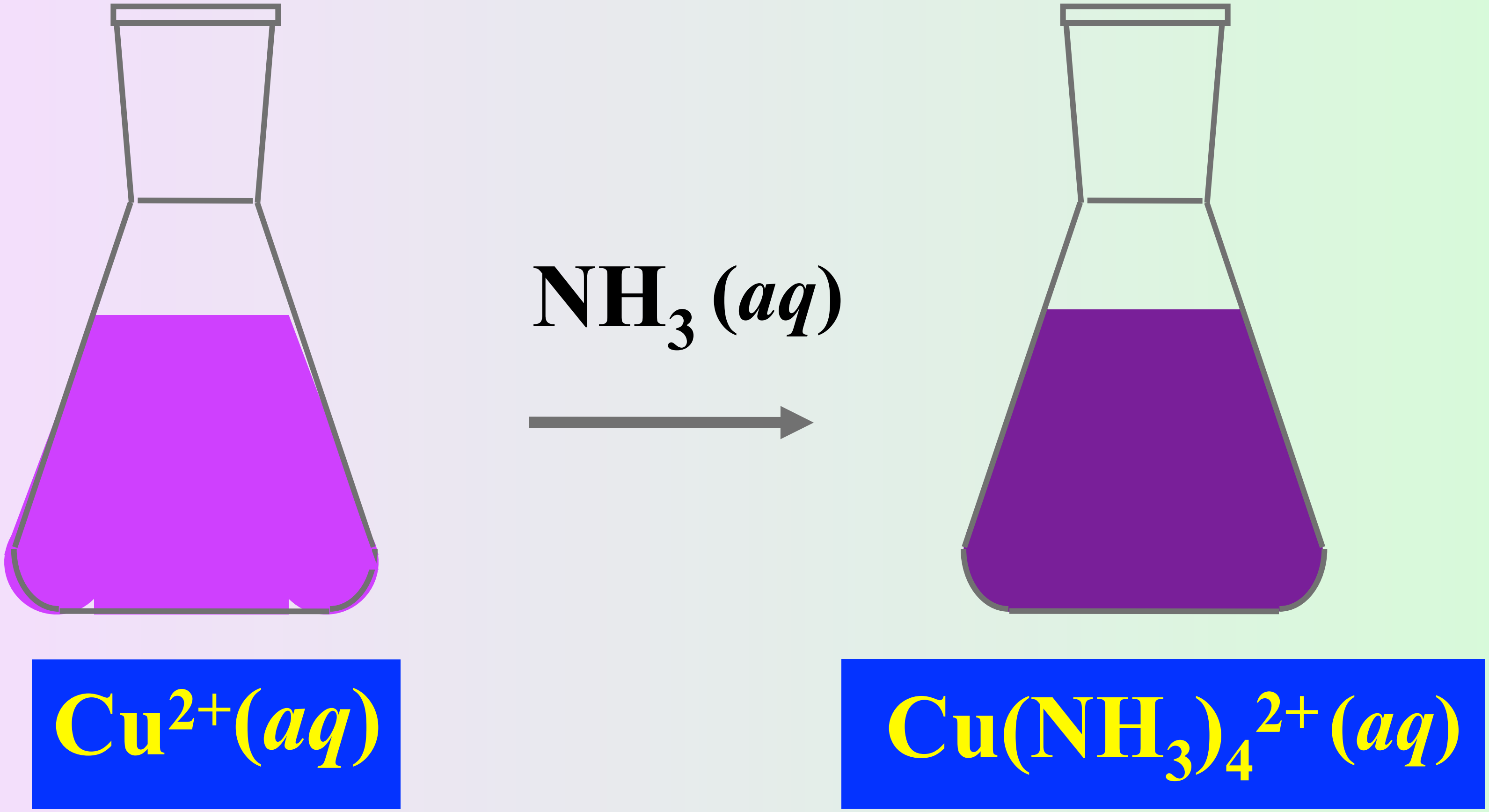
$$BaF_2 \rightleftharpoons Ba^{2+} + 2F^-$$

$$F^- \xrightarrow{H^+} HF$$

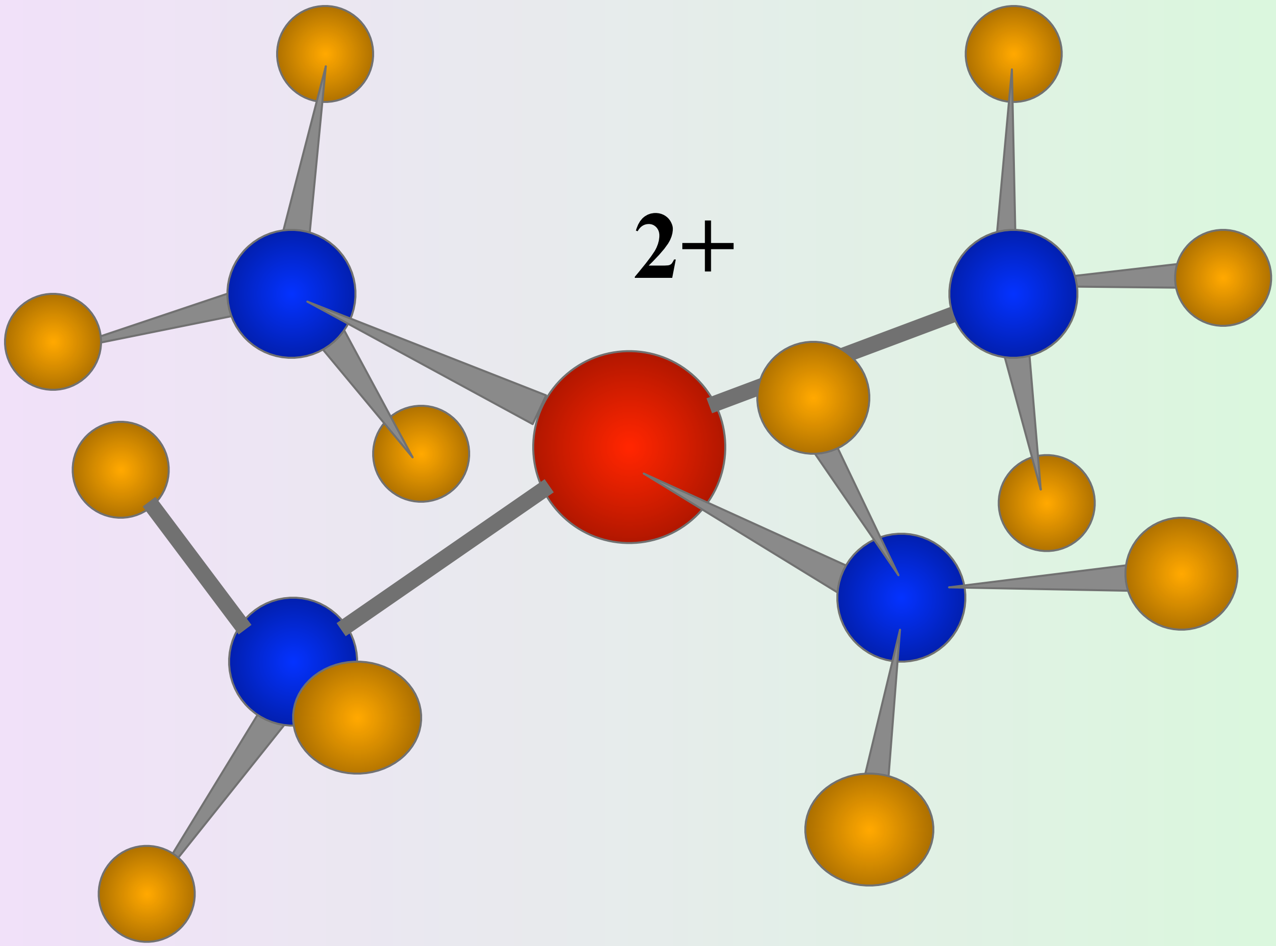
solubility increases in acid because F^- concentration is decreased

Complex Ion Equilibria and Solubility

"A complex ion is an ion containing a central metal cation bonded to one or more molecules or ions."



$$K_f = \frac{[Cu(NH_3)_4^{2+}]}{[Cu^{2+}]\,[NH_3]^4} = 5.0 \times 10^{13}$$


2+

• a complex ion is formed by Lewis acid-Lewis base reaction;

metal ion is the Lewis acid

the neutral molecule or ion that acts as the Lewis base is called a Ligand

• the number of ligands attached to the metal ion is called the coordination number

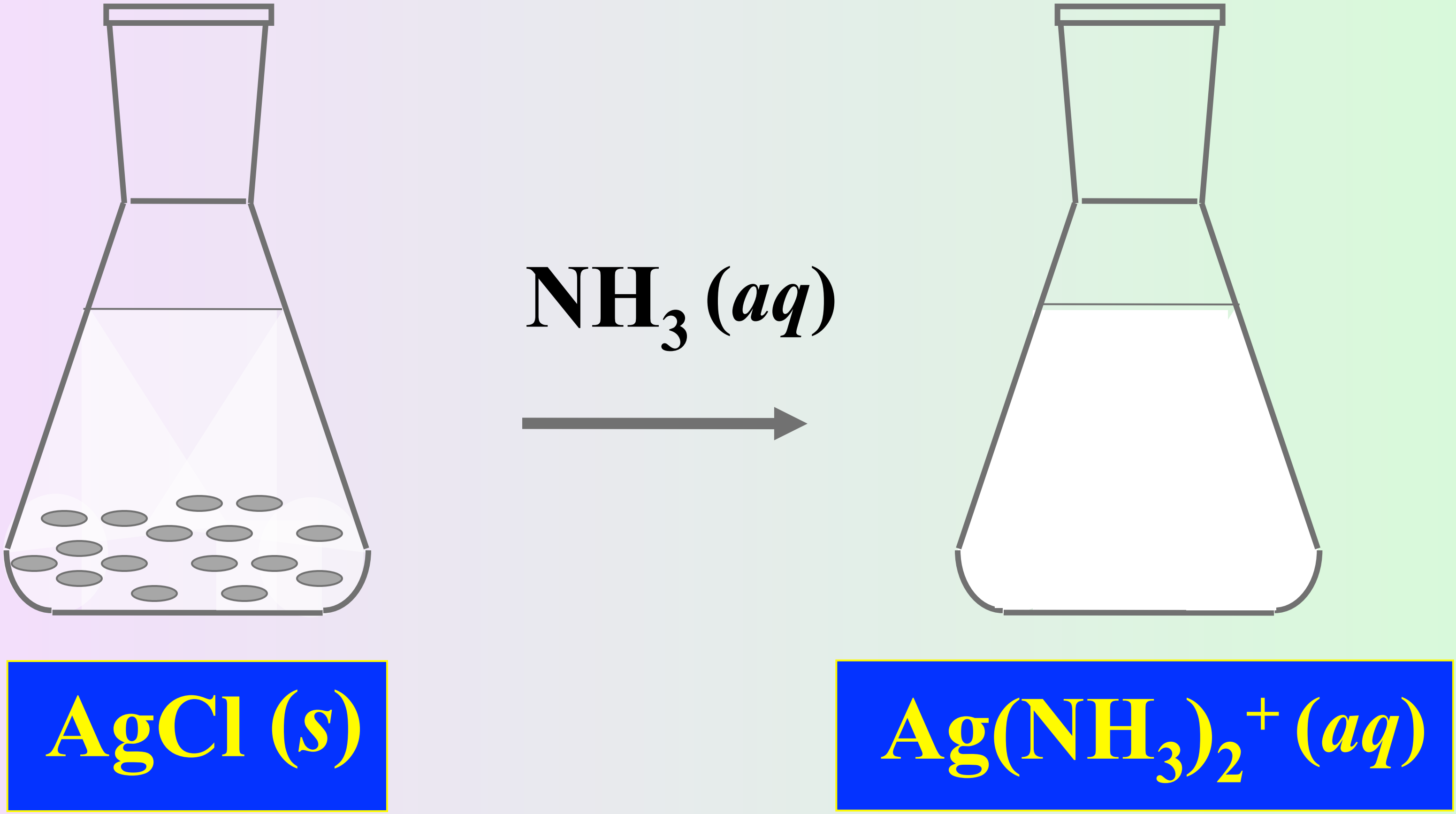
• the bond between the Lewis acid and Lewis base is covalent

• a complex ion is characterized by the formation constant (K_f)

Some typical complex ions

	complex ion	K_f
$Ag^{+} + 2NH_3 \rightleftharpoons$	$Ag(NH_3)_2^{+}$	1.5×10^{7}
$Cu^{2+} + 4CN^{-} \rightleftharpoons$	$Cu(CN)_4^{2-}$	1.0×10^{25}
$Co^{3+} + 6NH_3 \rightleftharpoons$	$Co(NH_3)_6^{3+}$	5.0×10^{31}

The effect of complex ion formation generally is to increase the solubility of a substance.



$$K_f = \frac{[Ag(NH_3)_2^+]}{[Ag^+]\,[NH_3]^2} = 1.5 \times 10^7$$

Practice exercise

What is the molar solubility of AgBr in a 1.0 M solution of NH_3?

$$AgBr\,(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$$

$$K_{sp} = 7.7 \times 10^{-13}$$

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+\,(aq)$$

$$K_f = 1.5 \times 10^{7}$$

$$AgBr\,(s) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+\,(aq) + Br^-(aq)$$

$$K_f K_{sp} = K$$

Practice exercise

What is the molar solubility of AgBr in a 1.0 M solution of NH_3?

$$AgBr\,(s) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+\,(aq) + Br^-\,(aq)$$

the solubility of AgBr in pure water is 9×10^{-7} M

$$K_f K_{sp} = K = 12.3 \times 10^{-6}$$

$$12.3 \times 10^{-6} = \frac{x^2}{1.0}$$

$$x = 0.0035\ M$$

Some typical coordination numbers

	Coordination numbers		Coordination numbers		Coordination numbers
Ag^{+}	*2*	Mn^{2+}	*4,6*	Co^{3+}	*6*
Cu^{+}	*2,4*	Fe^{2+}	*6*	Cr^{3+}	*6*
Au^{+}	*2,4*	Co^{2+}	*4,6*	Au^{3+}	*4*
		Ni^{2+}	*4,6*	Sc^{3+}	*6*
		Cu^{2+}	*4,6*		
		Zn^{2+}	*4,6*		

Some common ligands

H_2O

CO

NO

NH_3

CH_3NH_2

SCN^-

CN^-

I^-

F^-

Cl^-

Br^-