

The Common Ion Effect and Solubility

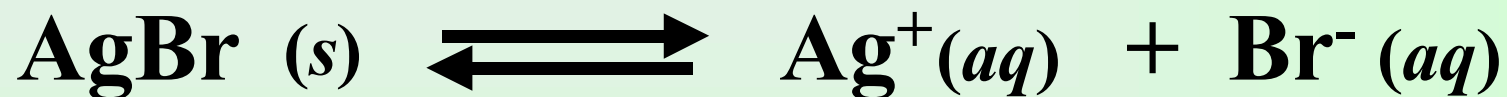
A common ion suppresses the solubility of an ionic substance

Practice Exercise

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

(a) pure water

(b) 0.0010 M NaBr

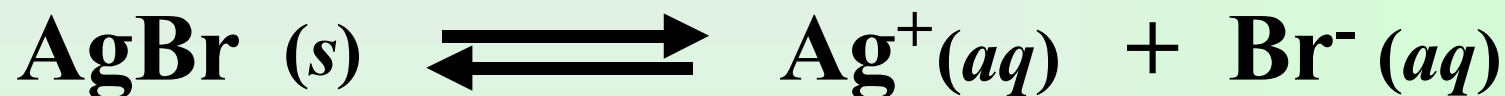


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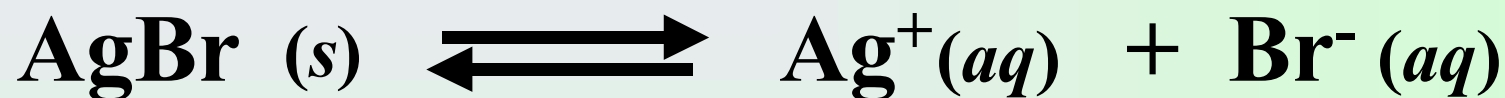


Le Chatelier's principle: the solubility is less in a solution of NaBr than in pure water

Practice Exercise

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

(a) pure water



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

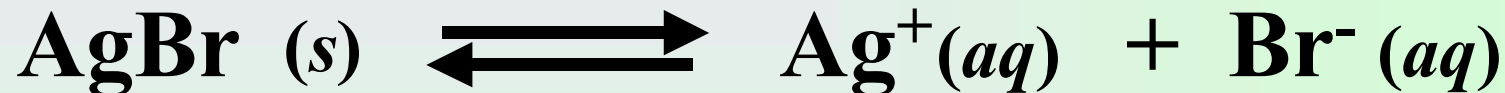
$$x^2 = 7.7 \times 10^{-13}$$

$$x = 8.8 \times 10^{-7} \text{ M} = 1.7 \times 10^{-4} \text{ g/L} \quad \text{solubility of AgBr}$$

Practice Exercise

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

(b) 0.0010 M NaBr



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

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

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

pH and Solubility

pH and Solubility

consider $\text{Mg}(\text{OH})_2$

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



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

Practice Exercise

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

$$\text{pOH} = 4$$



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

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

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

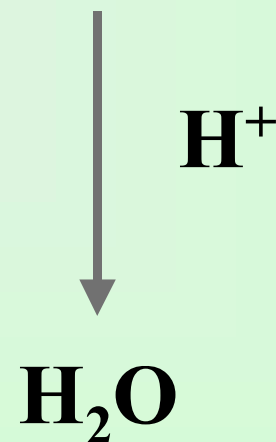
pH and Solubility

consider $\text{Mg}(\text{OH})_2$

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



solubility increases in
acidic solution because
 $[\text{HO}^-]$ is decreased



In General

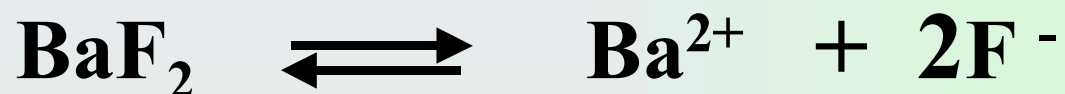
**salts of weak acids will be more soluble
in acid solution than in pure water**

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

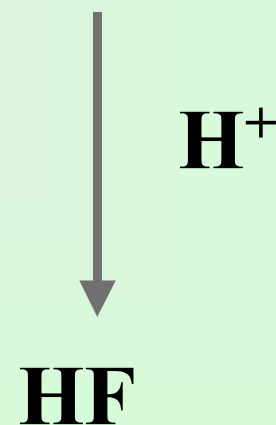
pH and Solubility

BaF₂ is a salt of a weak acid; its anion (F⁻) is basic

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

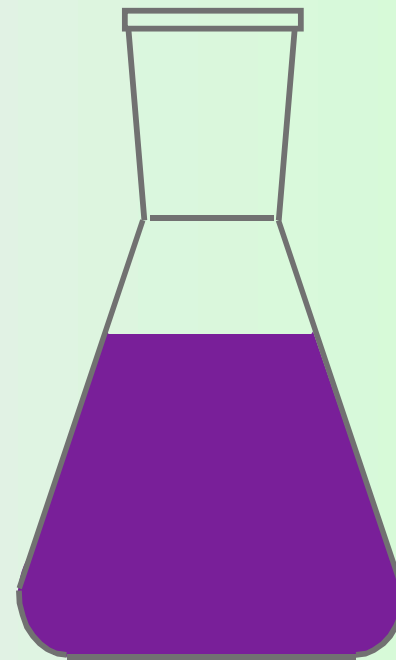
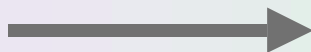
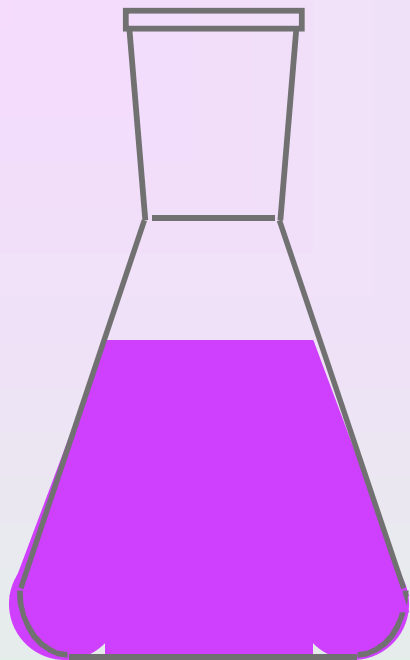


**solubility increases in acid
because F⁻ concentration
is decreased**

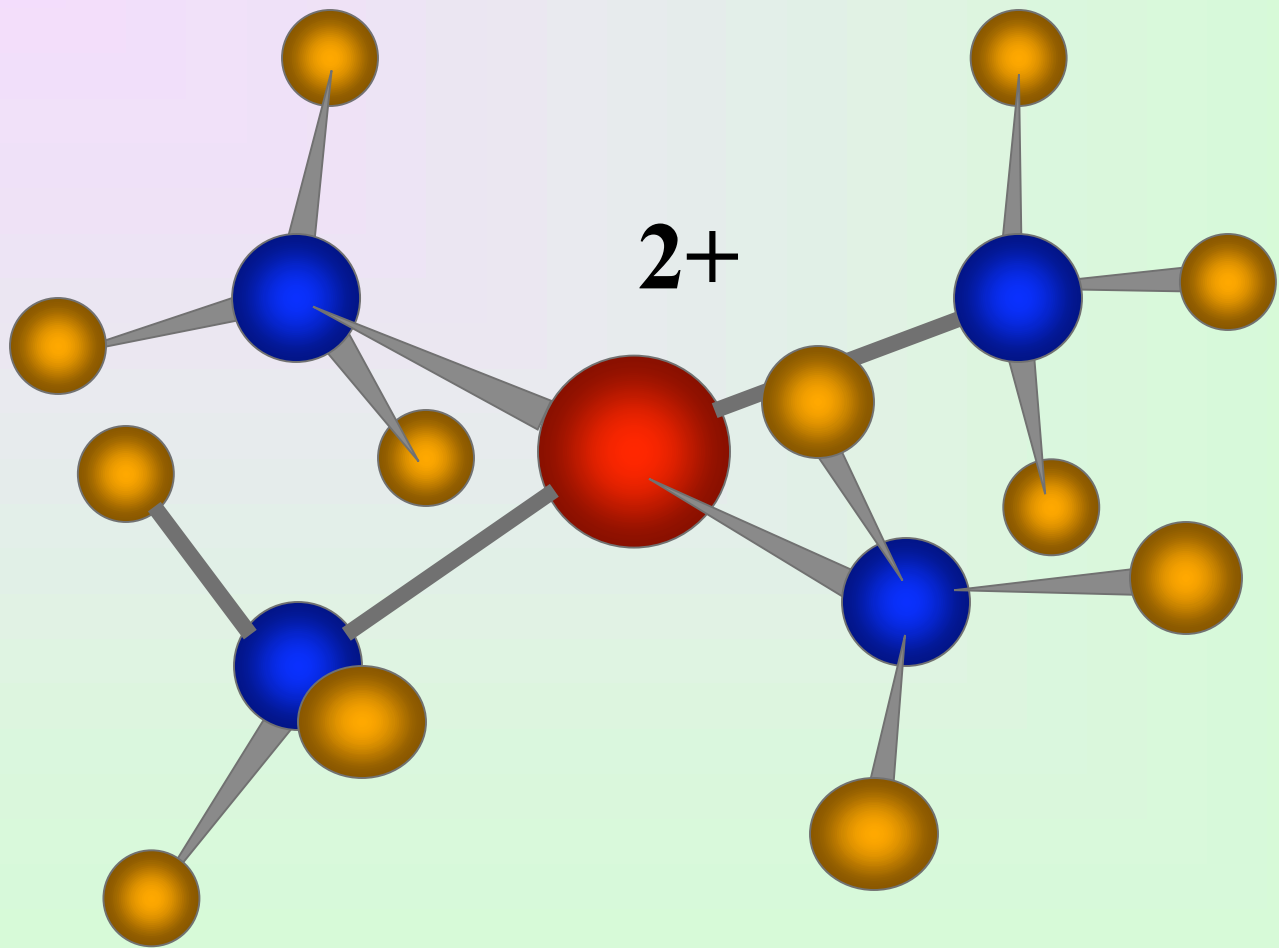


Complex Ion Equilibria and Solubility

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



$$K_f = \frac{[\text{Cu}(\text{NH}_3)_4^{2+}]}{[\text{Cu}^{2+}] [\text{NH}_3]^4} = 5.0 \times 10^{13}$$



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

metal ion is the Lewis acid

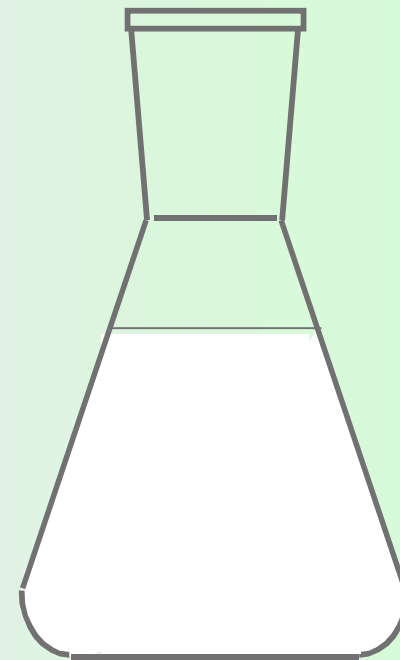
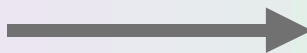
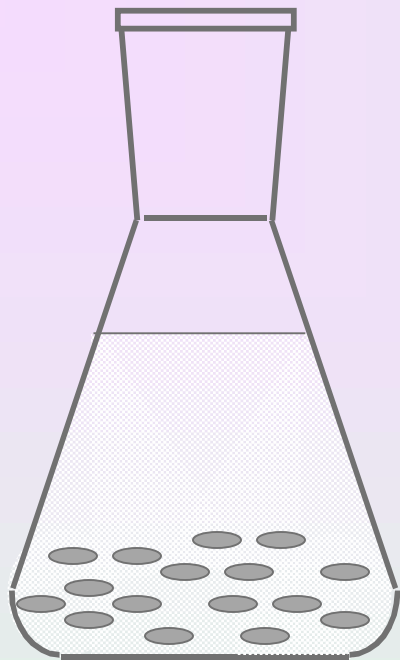
the neutral molecule or ion that acts as the Lewis base is called a **Ligand**

- 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	$\text{Ag}(\text{NH}_3)_2^+$	1.5×10^7
Cu^{2+}	+ 4CN ⁻	\rightleftharpoons	$\text{Cu}(\text{CN})_4^{2-}$	1.0×10^{25}
Co^{3+}	+ 6NH ₃	\rightleftharpoons	$\text{Co}(\text{NH}_3)_6^{3+}$	5.0×10^{31}

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



$$K_f = \frac{[\text{Ag(NH}_3)_2^+]}{[\text{Ag}^+][\text{NH}_3]^2} = 1.5 \times 10^7$$

Practice exercise

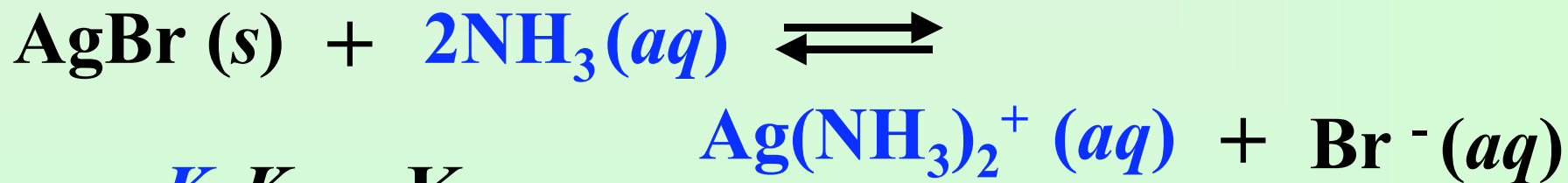
What is the molar solubility of AgBr in a 1.0 M solution of NH₃?



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



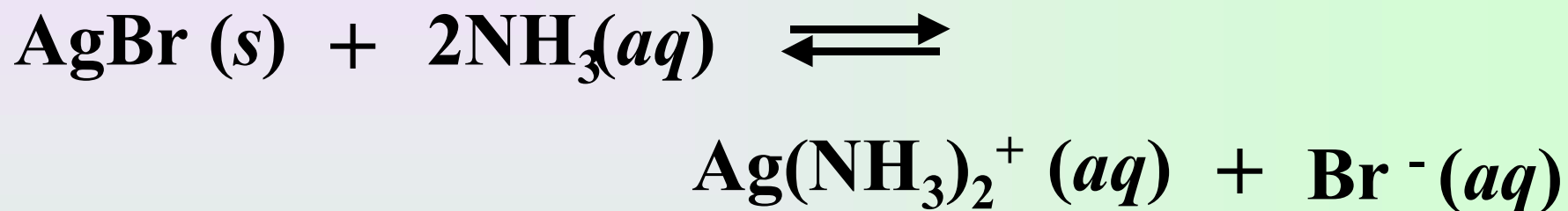
$$K_f = 1.5 \times 10^7$$



$$K_f K_{sp} = K$$

Practice exercise

What is the molar solubility of AgBr in a 1.0 M solution of NH₃?



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

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

the solubility of
AgBr in pure water
is $9 \times 10^{-7} \text{ M}$

$$x = 0.0035 \text{ M}$$

Some typical coordination numbers

<i>Coordination numbers</i>		<i>Coordination numbers</i>		<i>Coordination numbers</i>	
Ag⁺	2	Mn²⁺	4,6	Co³⁺	6
Cu⁺	2,4	Fe²⁺	6	Cr³⁺	6
Au⁺	2,4	Co²⁺	4,6	Au³⁺	4
		Ni²⁺	4,6	Sc³⁺	6
		Cu²⁺	4,6		
		Zn²⁺	4,6		

Some common ligands

