

## Solubility Equilibria

### Solubility Product Constant ( $K_{sp}$ )

- Example  $\text{CaF}_2(\text{s}) \rightleftharpoons \text{Ca}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$        $K_{sp} = [\text{Ca}^{2+}][\text{F}^{-}]^2$
- Solubility is an equilibrium position; the solubility product and the solubility of a substance are not the same thing.
- The solid is not included in the equilibrium expression - the amount of excess solid in a solution does not affect the position of the equilibrium and thus does not affect the solubility of that solid.
- Molar solubility can be obtained from  $K_{sp}$  and vice versa.

Examples will be worked in class.

### Common Ion Effect

- The solubility of a slightly soluble ionic compound is lowered when a common ion is present.
- This is commonly used in analytical chemistry.

### Precipitation

**Ion product ( $Q_{ip}$ )** - (reaction quotient) uses the initial concentrations.

To determine if a reaction will occur:

1. Determine initial concentrations of ions.
2. Calculate  $Q_{ip}$ .
3. Compare  $Q_{ip}$  and  $K_{sp}$  to determine if a reaction will occur.

$Q_{ip} > K_{sp}$     Precipitation should occur and continue until the concentrations satisfy  $K_{sp}$ .

$Q_{ip} < K_{sp}$     No precipitation occurs

**Complete precipitation** is favored when

1.  $K_{sp}$  is very small
2. The target ion has a high initial concentration.
3. There is a common ion whose concentration greatly exceeds that of the target ion.

### Selective Precipitation

- Separation of ions by precipitation.

## Effects of pH

- The solubility of an ionic solute can be greatly affected by changes in pH.
- Changes in pH can also be used to selectively precipitate out ions.

## Complex Ions

**Complex ion** - a charged species consisting of a metal ion surrounded by ligands.

**Ligand** - a Lewis base; a molecule or ion having a lone electron pair that can be donated to an empty orbital on the metal ion to form a covalent bond.

**Common ligands** -  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{Cl}^-$ ,  $\text{CN}^-$ ,  $\text{OH}^-$ ,  $\text{SCN}^-$

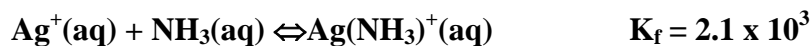
**Coordination number** - the number of ligands attached to a metal ion. The most common coordination numbers are 6, 4, and 2. Example:  $\text{Co}(\text{OH}_2)_6^{2+}$ ,  $\text{Ni}(\text{NH}_3)_6^{2+}$ ,  $\text{CoCl}_4^{2-}$ ,  $\text{Cu}(\text{NH}_3)_4^{2+}$ ,  $\text{Ag}(\text{NH}_3)_2^+$

(Note: a handout will be given in class to show naming and reactions for complex ions)

Metal ions add ligands one at a time.

**Formation constants (stability constants)** - the equilibrium constant,  $K_f$ , associated with each step of the complex ion formation.

Example: The reaction taking place when solutions containing  $\text{Ag}^+$  and  $\text{NH}_3$  are mixed.



- Note, all the species,  $\text{NH}_3$ ,  $\text{Ag}^+$ ,  $\text{Ag}(\text{NH}_3)^+$ , and  $\text{Ag}(\text{NH}_3)_2^+$  exist at equilibrium.

## Qualitative Analysis

- identifies the components of unknown materials.
- can be done by selective precipitation.