Solubility Equilibria

Solubility Product Constant (K_{sp})

- Example $\mathbf{CaF_2(s) \Leftrightarrow Ca^{2+}(aq) + 2F^{-}(aq)}$ $\mathbf{K_{sp} = [Ca^{2+}][F^{-}]^2}$
- 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 - H_2O, NH_3, Cl^-, CN^-, OH^-, SCN^-

Coordination number - the number of ligands attached to a metal ion. The most common coordination numbers are 6, 4, and 2. Example: $Co(OH_2)_6^{2+}$, $Ni(NH_3)_6^{2+}$, $CoCl_4^{2-}$, $Cu(NH_3)_4^{2+}$, $Ag(NH_3)^{2+}$

(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, $\mathbf{K_f}$, associated with each step of the complex ion formation.

Example: The reaction taking place when solutions containing Ag^+ and NH_3 are mixed.

$$\mathbf{Ag^+(aq) + NH_3(aq) \Leftrightarrow Ag(NH_3)^+(aq)} \qquad \mathbf{K_f = 2.1 \times 10^3}$$

$$\mathbf{Ag(NH_3)^+(aq) + NH_3(aq) \Leftrightarrow Ag(NH_3)_2^+(aq)} \qquad \mathbf{K_f = 8.2 \times 10^3}$$

- Note, all the species, NH_3, Ag^+, $Ag(NH_3)^+$, and $Ag(NH_3)_2^+$ exist at equilibrium.

Qualitative Analysis

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