Solubility Equilibrium

AP Chemistry 30 – Ms. Hayduk

Solubility

- How much of a solute can dissolve in a specific volume of solution
- When max amount of solid is dissolved, equilibrium is established (saturated solution)
- K_{sp} – ion product constant

Ion Product Constant

$$PbI_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + 2\ I^-\ (aq)$$
$$K_{sp} = [Pb^{2+}][I^-]^2$$

- Tells you max ions that dissolve as low solubility salt is added to water
- Minimum concentration of ions needed for precipitate to form

Example

Write the dissociation equation and K_{sp} expression for each of the following:

CaF_2

CaC_2O_4

Solubility Rules: AP Style

- Compounds with nitrate ion, ammonium ion or group I metal ions are soluble
  - What do these have in common?
- Soluble = more than 3 g dissolves in 100 mL of water
- Everything else is low solubility

Calculate K_{sp}

- Use equilibrium concentrations to determine K_{sp}
- Steps:
  1. Write dissociation equation and K_{sp} expression
  2. Determine ion concentrations from given
  3. Solve

Example 1: K_{sp}

Copper(I) bromide has a measured solubility of 2.0×10^{-4} mol/L at 25°C. Calculate the K_{sp} value.

Example 2: K_{sp}

Calculate the K_{sp} value for bismuth sulfide (Bi_2S_3) which has a solubility of 1.0×10^{-15} mol/L at 25°C.

Calculating Solubility

- Can only compare solubilities if salts have the same ion:ion ratio
- Use K_{sp} and values for x to determine solubility
- Generally, solubility is calculated at 25°C. Solubility can vary up or down based on temperature.

Calculating Solubility

Steps:

1. Write dissociation equation and K_{sp} expression
2. Assign ion concentrations values of x using coefficients
3. Solve for x

Example 1: Solubility

For $CaCO_3$ at 25°C, K_{sp} is 3.8×10^{-9}. Determine its solubility in pure water in:

a. Moles per litre (standard unit)

b. Grams per litre

Example 2: Solubility

For $Cu(IO_3)_2$ at 25°C, K_{sp} is 1.4×10^{-7}. Calculate its solubility at that temperature.

Common Ion Effect

- One of the ions from the salt is present in the solution
- Decreases solubility (Le Chatelier's principle – increased product concentration)
- Use *x* for the other ion and the given concentration for the present ion

Example: Common Ion Effect

Calculate the solubility of solid CaF_2 ($K_{sp} = 4.0 \times 10^{-11}$) in a 0.025 M NaF solution.

Return of Reaction Quotient

- Use reaction quotient (Q) to determine if precipitate will form
  - $Q < K$, no precipitate (unsaturated solution)
  - $Q \geq K$, precipitate forms (saturated or supersaturated solution)

Reaction Quotient

Steps:

1. Write dissociation equation and K_{sp} expression
2. Determine ion concentrations <u>after dilution</u>
3. Substitute ion concentrations and solve for Q – compare to K_{sp}

Example: Reaction Quotient

A solution is prepared by adding 750.0 mL of 4.00×10^{-3} M $Ce(NO_3)_3$ to 300.0 mL of 2.00×10^{-2} M KIO_3. Will $Ce(IO_3)_3$ ($K_{sp} = 1.9 \times 10^{-10}$) precipitate from this solution?

Selective Precipitation

- When multiple ions are in a solution, selective precipitation is used to remove them one at a time
- Can be done with different solutions or by minimizing concentrations
- No steps here – use what you already know

Example: Selective Precipitation

A solution contains 1.0×10^{-4} M Cu^{+} and 2.0×10^{-3} M Pb^{2+}.

a. If a source of I^{-} is added gradually to this solution, will PbI_2 ($K_{sp} = 1.4 \times 10^{-8}$) or CuI ($K_{sp} = 5.3 \times 10^{-12}$) precipitate first?
b. Specify the concentration of I^{-} needed to begin precipitation of each salt.