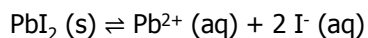


## Solubility Equilibrium

AP Chemistry 30 – Ms. Hayduk

### Ion Product Constant



$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{I}^{-}]^2$$

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

### 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

## 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)
- $K_{\text{sp}}$  – ion product constant

### Example

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



### Calculate $K_{\text{sp}}$

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

### Example 1: $K_{sp}$

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

### Example 2: $K_{sp}$

Calculate the  $K_{sp}$  value for bismuth sulfide ( $\text{Bi}_2\text{S}_3$ ) which has a solubility of  $1.0 \times 10^{-15}$  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  $\text{CaCO}_3$  at 25°C,  $K_{sp}$  is  $3.8 \times 10^{-9}$ . Determine its solubility in pure water in:

a. Moles per litre (standard unit)

b. Grams per litre

### Example 2: Solubility

For  $\text{Cu}(\text{IO}_3)_2$  at 25°C,  $K_{sp}$  is  $1.4 \times 10^{-7}$ . 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  $\text{CaF}_2$  ( $K_{\text{sp}} = 4.0 \times 10^{-11}$ ) 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  $K_{\text{sp}}$  expression
2. Determine ion concentrations after dilution
3. Substitute ion concentrations and solve for  $Q$  – compare to  $K_{\text{sp}}$

## Example: Reaction Quotient

A solution is prepared by adding 750.0 mL of  $4.00 \times 10^{-3}$  M  $\text{Ce}(\text{NO}_3)_3$  to 300.0 mL of  $2.00 \times 10^{-2}$  M  $\text{KIO}_3$ . Will  $\text{Ce}(\text{IO}_3)_3$  ( $K_{\text{sp}} = 1.9 \times 10^{-10}$ ) 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  $1.0 \times 10^{-4}$  M  $\text{Cu}^+$  and  $2.0 \times 10^{-3}$  M  $\text{Pb}^{2+}$ .

- a. If a source of  $\text{I}^-$  is added gradually to this solution, will  $\text{PbI}_2$  ( $K_{\text{sp}} = 1.4 \times 10^{-8}$ ) or  $\text{CuI}$  ( $K_{\text{sp}} = 5.3 \times 10^{-12}$ ) precipitate first?
- b. Specify the concentration of  $\text{I}^-$  needed to begin precipitation of each salt.