Unit 8 - Solubility Equilibrium (Ksp)
Chapter 16

Review the following:

- Polyatomic ions and solubility rules
- Equilibrium constant expressions
- ICE charts
- Reaction quotient, Q
- Le Chatelier's Principle (shifts)
- pH = - log $[H^+]$
- pOH = - log $[OH^-]$
- pH + pOH = 14
- $[H^+] = 10^{-pH}$
- $[OH^-] = 10^{-pOH}$

Things to consider:

- Insoluble salts are actually slightly soluble
- Slightly soluble salts establish a dynamic equilibrium with the hydrated cations and anions in solution
    - When solid is first added to water, no ions are initially present in water
    - As dissolution proceeds, the concentration of ions increases until equilibrium is established **(equilibrium = saturated solution)**
- The presence of a **common ion** in solution **will reduce the molar solubility** of a salt
    - Occurs when a salt is dissolved in a solution that already contains the cations and/or anions of the salt being dissolved
- Q is used to determine whether a precipitate forms
    - Ksp > Q, the system is not at equilibrium (unsaturated), shift forward
    - Ksp = Q, the system is at equilibrium (saturated), no shift
    - Ksp < Q, the system is not at equilibrium (supersaturated), shift reverse

    Precipitate forms when Ksp < Q. Concentrations of dissolved ions (the products) too high, causes reverse shift, thus precipitate (the reactant) forms.

4 Main Types of Ksp Problems:

1. Calculate molar solubility. Molar solubility is "x" from a Ksp ICE chart.
2. Calculate Ksp. Plug-in equilibrium values into Ksp expression and calculate.
3. Will a precipitate form? Calculate Q. Compare Q to Ksp. Determine direction of shift.
4. Which salt precipitates first? Calculate the equilibrium ion concentration needed to start precipitation of each salt. Whichever salt requires the lowest equilibrium ion concentration is the first to precipitate.

Problems:

1. AgCl(s) dissolves in water according to the equation below and has a Ksp value of 1.8×10^{-10}.

$$AgCl(s) \leftrightarrow Ag^+(aq) + Cl^-(aq)$$

    a. Write the Ksp expression for the dissolution of AgCl(s).
    b. What is the molar solubility of AgCl(s) in water?

2. The Ksp of CaF_2 is 4.0×10^{-11}. Calculate the molar solubility of $CaF_2(s)$ in each of the following.
    a. Pure water
    b. 0.025 M NaF(aq)
    c. Calculate the solubility, in grams per liter, of $CaF_2(s)$ in the solution in part (b).

3. The Ksp of $Fe(OH)_2(s)$ is 8.0×10^{-16}. Calculate the molar solubility of $Fe(OH)_2(s)$ in each of the following.
   a. Pure water
   b. 0.010 M $Fe(NO_3)_2(aq)$
   c. 0.020 M NaOH(aq)

4. Copper(I) bromide has a molar solubility of 2.0×10^{-4} M at 25°C. Calculate the Ksp of copper(I) bromide.

5. $Bi_2S_3(s)$ has a molar solubility of 1.0×10^{-15} M at 25°C. Calculate the Ksp of $Bi_2S_3(s)$.

6. A saturated solution of $Mg(OH)_2$ has a pH of 10.36. Calculate the Ksp of $Mg(OH)_2(s)$.

7. A saturated solution of $Cd(OH)_2$ has a pH of 9.333. Calculate the Ksp of $Cd(OH)_2(s)$.

8. 20.0 mL of 0.100 M $Fe(NO_3)_2(aq)$ is mixed with 40.0 mL of 0.0500 M NaOH(aq). Will a precipitate of $Fe(OH)_2$ form? The Ksp of $Fe(OH)_2(s)$ is 8.0×10^{-16}.

9. 0.100 L of 1.5×10^{-3} M $MgCl_2(aq)$ and 0.200 L of 0.025 M NaF(aq) are mixed. Will a precipitate of MgF_2 form? The Ksp of $MgF_2(s)$ is 3.7×10^{-8}.

10. Will a precipitate of Ag_2CrO_4 form when 1.00 mg of $Na_2CrO_4(s)$ is added to 225 mL of 1.5×10^{-4} M $AgNO_3(aq)$? The Ksp of $Ag_2CrO_4(s)$ is 1.1×10^{-12}.

11. 20.0mL of a 0.0100M $Mg(NO_3)_2$ is mixed with 10.0mL of a 0.0010M $ZnCl_2$. Sodium hydroxide solution is then slowly added to the mixture. Assume no volume change with the addition of sodium hydroxide.
    a) Which salt, $Mg(OH)_2$ (Ksp = 6.0×10^{-12}) or $Zn(OH)_2$ (Ksp = 4.0×10^{-17}) will precipitate first?
    b) What is the hydroxide concentration when the first precipitate begins to form?

12. A solution is 0.045M in NaCl and 0.045 M in NaBr. Solid lead(II) nitrate is added without changing the volume of the solution.
    a. Which salt, $PbBr_2$ (Ksp=$6.6 * 10^{-6}$) or $PbCl_2$ (Ksp=$1.7 * 10^{-5}$) will precipitate first?
    b. What is the $[Pb^{+2}]$ when the first salt begins to precipitate?

13. A solution is 0.035M in Na_2SO_4 and 0.035 M in Na_2CrO_4. Solid lead(II) nitrate is added without changing the volume of the solution.
    a. Which salt, $PbSO_4$ (Ksp=$1.8 * 10^{-8}$) or $PbCrO_4$ (Ksp=$2.0 * 10^{-14}$) will precipitate first?
    b. What is the $[Pb^{+2}]$ when the salt in "a" first begins to precipitate?

14. A 65mL solution of 0.40M $Al(NO_3)_3$ is mixed with 125 mL of 0.17M iron(II) nitrate. Solid sodium hydroxide is then added without changing the volume.
    a. Which will precipitate first, $Al(OH)_3$ (Ksp=$2 * 10^{-31}$) or $Fe(OH)_2$ (Ksp=$5 * 10^{-17}$)?
    b. What is the $[OH^-]$ when the first compound begins to precipitate?

Ksp Equilibrium HW WS

1. Copper (II) sulfide has a Ksp of $1.0 * 10^{-36}$. What is the molar solubility in moles per liter of copper (II) sulfide in
   a. 0.020M copper (II) sulfate solution?
   b. 0.010 M sodium sulfide solution?

2. $Mg_3(PO_4)_2$ has a Ksp of $1.0 * 10^{-24}$. What is the molar solubility in grams per liter of magnesium phosphate in
   a. 0.010M sodium phosphate solution?
   b. 0.030M magnesium nitrate solution?

3. Calculate the $[OH^-]$ in equilibrium with $1.00 * 10^{-4}$ M Zn^{+2} if the Ksp of $Zn(OH)_2$ is $4.0 * 10^{-17}$?

4. What is the pH of the solution in question #3

5. Silver nitrate is added to a solution of $2.00 * 10^{-2}$ M sodium phosphate. What is the equilibrium concentration of Ag^+? (Ksp of silver phosphate is $1.0 * 10^{-16}$)

6. Lead (II) chromate, $PbCrO_4$, is the yellow paint pigment known as "chrome yellow". A solution is prepared by mixing a solution that is $1.0 * 10^{-4}$ M in lead (II) ion with a solution that is $5.0 * 10^{-3}$ M in chromate ion. Ignoring dilution effects, would a precipitate form? The Ksp of lead (II) chromate is $2.0 * 10^{-14}$?

7. A solution is prepared by mixing 25.0 mL of 0.100 M iron(II) nitrate with 50.0 mL of a sodium hydroxide solution of pH 9.00. Will a precipitate form? The Ksp of iron(II) hydroxide is $5.0 * 10^{-17}$?

Answers: 1a) 5.0×10^{-35} M 1b) 1.0×10^{-34} M 2a) 1.89×10^{-5} g/L 2b) 2.53×10^{-8} g/L 3) 6.32×10^{-7} M
4) 7.801 5) 1.71×10^{-5} M 6) Q=5.0 10^{-7}, thus a ppt will form 7) Q=1.47×10^{-12}, thus a ppt will form