Solubility

"How FAR Does A Reaction Go"? – Chapter 17

Solubility product: K_{sp}

K_{sp} is the equilibrium constant for a specific reaction: the <u>dissociation of a salt</u> into aqueous solution.

e.g. $AgCl\ (s) \rightleftharpoons Ag^{+}\ (aq) + C\ell^{-}\ (aq)$

K_{sp} expression for $Ca(OH)_2$:

✓ *Generate* expressions for K_{sp} and Q_{sp}, and use them to describe the saturation of a salt solution.

Compounds with a larger K_{sp} are more **soluble** than other compounds.

We can measure the **molar solubility** of a compound as the maximum mol/L that can be dissolved (also used is **mass solubility**: g/L)

What is the molar solubility of $KC\ell O_4$ in pure water? $K_{sp} = 1.05 \times 10^{-2}$ for $KC\ell O_4$

Set up the calculation for determining the solubility of $Ca(OH)_2$:

K_{sp} for $Ca(OH)_2$ is 5.5×10^{-6}, and its solubility is 0.82 g/L (molar solubility 0.011 mol/L).

✓ C*alculate* solubility from K_{sp}, and vice versa.

What about mixing solutions containing different concentrations of ions?

Relationship	Shift to Equilibrium?	Type of Solution?
$Q_{sp}>K_{sp}$		
$Q_{sp}=K_{sp}$		
$Q_{sp}<K_{sp}$		

✓ *Generate* expressions for K_{sp} and Q_{sp}, and use them to describe the saturation of a salt solution.

Solubility Demo

We will mix: 100 mL of 0.20 M Ag^+ with 100 mL of either: {0.10 M Cl^- , 0.10 M I^- , or 0.025 M CrO_4^{2-}}
(Total volume: 200 mL)

Ion	[ion] after mixing
Ag^+	(present in all 3 mixtures)
CrO_4^{2-}	
Cl^-	
I^-	

Salt(*s*)	K_{sp}	Q_{sp}
$Ag_2CrO_4(s)$	9.0×10^{-12}	
	Will there be precipitate?	
$AgCl(s)$	1.6×10^{-10}	
	Will there be precipitate?	
$AgI(s)$	1.5×10^{-16}	
	Will there be precipitate?	

✓ *Generate* expressions for K_{sp} and Q_{sp}, and use them to describe the saturation of a salt solution.

Salt(*s*)	Cation	Anion	pH of solution	Effect of adding NH_3?	Effect of add HNO_3?
$Ag_2CrO_4(s)$					
AgCl(*s*)					
AgI(*s*)					

**Information: Ag^+ reacts with water *very* weakly to form an oxide (not a hydroxide). The K_a of Ag^+ is negligible.

Factors that affect solubility:

-Temperature

Note: many K_{sp} reactions are endothermic

-Common-ion effect

-Side Reactions

✓ *Describe* how solubility is affected by a common ion, a change in pH, or formation of a complex.

The molar solubility of $KC\ell O_4$ in pure water was found to be 0.102 M. What is the molar solubility of $KC\ell O_4$ in a 0.0500 M solution of perchloric acid ($HC\ell O_4$)? K_{sp} of $KC\ell O_4 = 1.05 \times 10^{-2}$

Answer: 0.0805 mol/L

✓ *Describe* how solubility is affected by a common ion, a change in pH, or formation of a complex.

Sulfide (S^{2-}) is a weak base ($K_b = 1.6x10^{-7}$), and can react with water.

Lead(II) is a transition metal ion with limited solubility in aqueous solutions.

The solubility of lead sulfide (PbS) in water will be:

a. Less than that predicted by the K_{sp}

b. Greater than that predicted by the K_{sp}

c. Basically as predicted by the K_{sp}

d. Cannot tell

✓ *Describe* how solubility is affected by a common ion, a change in pH, or formation of a complex.

The K_{sp} for lead sulfide is 3×10^{-28}. What will the overall solubility of lead sulfide be in aqueous solution, taking into account the reaction of sulfide with water? (S^{2-} $K_b = 1.6 \times 10^{-7}$)

The solubility is 3.6 10^{-12} M. (without accounting for the basicity of S^{2-}, you would predict only 1.7 10^{-14} M)

Complex Formation

Some metal ions can form *complex ions* that affect their solubility.

e.g.

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_{sp} = 1.8 \times 10^{-10}$$

$$Ag^+(aq) + 2\ NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) \qquad K_f = 1.1 \times 10^7$$

What is the molar solubility of AgCl in a 0.50 M NH_3 solution?

Answer: 0.022 M

✓ *Describe* how solubility is affected by a common ion, a change in pH, or formation of a complex.

Revisiting the demo:

Salt(*s*)	Effect of adding NH_3?	Effect of add HNO_3?	Reason for the effect?
$Ag_2CrO_4(s)$			
AgCl(*s*)			
AgI(*s*)			