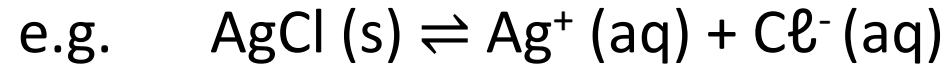


Solubility

“How FAR Does A Reaction Go”? – Chapter 17

Solubility product: K_{sp}

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



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 $KClO_4$ in pure water? $K_{sp} = 1.05 \times 10^{-2}$ for $KClO_4$

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).

✓ Calculate 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: $\{0.10 \text{ M Cl}^- , 0.10 \text{ M I}^- , \text{ or } 0.025 \text{ M CrO}_4^{2-}\}$
(Total volume: 200 mL)

Ion	[ion] after mixing	Salt(s)	K_{sp}	Q_{sp}
Ag^+	(present in all 3 mixtures)	$\text{Ag}_2\text{CrO}_4(s)$	9.0×10^{-12}	
				Will there be precipitate?
CrO_4^{2-}		$\text{AgCl}(s)$	1.6×10^{-10}	
Cl^-				Will there be precipitate?
I^-		$\text{AgI}(s)$	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 ₂ CrO 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 KClO_4 in pure water was found to be 0.102 M. What is the molar solubility of KClO_4 in a 0.0500 M solution of perchloric acid (HClO_4)? K_{sp} of $\text{KClO}_4 = 1.05 \times 10^{-2}$

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 ($K_b = 1.6 \times 10^{-7}$), 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

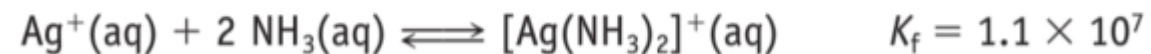
The K_{sp} for lead sulfide is 3×10^{-28} . What will the overall solubility of lead sulfide be in aqueous solution, taking into account the reaction of sulfide with water? (S^{2-} $K_b = 1.6 \times 10^{-7}$)

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.



What is the molar solubility of AgCl in a 0.50 M NH₃ 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?
$\text{Ag}_2\text{CrO}_4(\text{s})$			
$\text{AgCl}(\text{s})$			
$\text{AgI}(\text{s})$			