

7.2: Relationship Between Solubility and K_{sp}

Learning Objectives

- Quantitatively related K_{sp} to solubility

Considering the relation between solubility and K_{sp} is important when describing the solubility of slightly ionic compounds. However, this article discusses ionic compounds that are difficult to dissolve; they are considered "slightly soluble" or "almost insoluble." Solubility product constants (K_{sp}) are given to those solutes, and these constants can be used to find the molar solubility of the compounds that make the solute. This relationship also facilitates finding the K_{sp} of a slightly soluble solute from its solubility.

Introduction

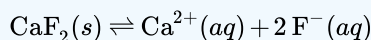
Recall that the definition of *solubility* is the maximum possible concentration of a solute in a solution at a given temperature and pressure. We can determine the solubility product of a slightly soluble solid from that measure of its solubility at a given temperature and pressure, provided that the only significant reaction that occurs when the solid dissolves is its dissociation into solvated ions, that is, the only equilibrium involved is:



In this case, we calculate the solubility product by taking the solid's solubility expressed in units of moles per liter (mol/L), known as its **molar solubility**.

✓ Calculation of K_{sp} from Equilibrium Concentrations

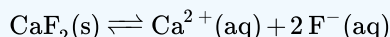
We began the chapter with an informal discussion of how the mineral fluorite is formed. Fluorite, CaF_2 , is a slightly soluble solid that dissolves according to the equation:



The concentration of Ca^{2+} in a saturated solution of CaF_2 is $2.1 \times 10^{-4} M$; therefore, that of F^{-} is $4.2 \times 10^{-4} M$, that is, twice the concentration of Ca^{2+} . What is the solubility product of fluorite?

Solution

First, write out the K_{sp} expression, then substitute in concentrations and solve for K_{sp} :



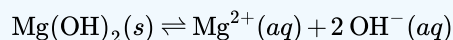
A saturated solution is a solution at equilibrium with the solid. Thus:

$$\begin{aligned} K_{sp} &= [\text{Ca}^{2+}][\text{F}^{-}]^2 \\ &= (2.1 \times 10^{-4})(4.2 \times 10^{-4})^2 \\ &= 3.7 \times 10^{-11} \end{aligned}$$

As with other equilibrium constants, we do not include units with K_{sp} .

? Exercise 7.2.1

In a saturated solution that is in contact with solid $\text{Mg}(\text{OH})_2$, the concentration of Mg^{2+} is $3.7 \times 10^{-5} M$. What is the solubility product for $\text{Mg}(\text{OH})_2$?



Answer

$$2.0 \times 10^{-13}$$

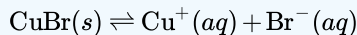
✓ Determination of Molar Solubility from K_{sp}

The K_{sp} of copper(I) bromide, CuBr , is 6.3×10^{-9} . Calculate the molar solubility of copper bromide.

Solution

The solubility product constant of copper(I) bromide is 6.3×10^{-9} .

The reaction is:



First, write out the solubility product equilibrium constant expression:

$$K_{sp} = [\text{Cu}^+][\text{Br}^-]$$

Create an ICE table (as introduced in the chapter on fundamental equilibrium concepts), leaving the CuBr column empty as it is a solid and does not contribute to the K_{sp} :

	$\text{CuBr} \rightleftharpoons \text{Cu}^+ + \text{Br}^-$	
Initial concentration (M)	0	0
Change (M)	x	x
Equilibrium concentration (M)	$0 + x = x$	$0 + x = x$

At equilibrium:

$$\begin{aligned}
 K_{sp} &= [\text{Cu}^+][\text{Br}^-] \\
 6.3 \times 10^{-9} &= (x)(x) = x^2 \\
 x &= \sqrt{(6.3 \times 10^{-9})} = 7.9 \times 10^{-5}
 \end{aligned}$$

Therefore, the molar solubility of CuBr is $7.9 \times 10^{-5} M$.



Finding the Solubility of a Salt: <https://youtu.be/98BuldrICXM>

Summary

Solubility is defined as the maximum amount of solute that can be dissolved in a solvent at equilibrium. Equilibrium is the state at which the concentrations of products and reactant are constant after the reaction has taken place. The solubility product constant (K_{sp}) describes the equilibrium between a solid and its constituent ions in a solution. The value of the constant identifies the degree to which the compound can dissociate in water. The higher the K_{sp} , the more soluble the compound is. K_{sp} is defined in terms of activity rather than concentration because it is a measure of a concentration that depends on certain conditions such as temperature, pressure, and composition. It is influenced by surroundings. K_{sp} is used to describe the saturated solution of ionic compounds. (A saturated solution is in a state of equilibrium between the dissolved, dissociated, undissolved solid, and the ionic compound.)

Contributors and Attributions

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