Finding and Using Solubility Products

The value of K_{sp} for a substance is calculated from the concentrations of ions at equilibrium. As an example, consider a particular experiment in which $AgCl(s)$ is added to pure water and allowed to come to equilibrium with a solution of its ions at $25°C$.

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

At equilibrium, $\left[Ag^+\right] = 1.3\times10^{-5}\ M$ and $\left[Cl^-\right] = 1.3\times10^{-5}\ M$. Inserting these values into the solubility product expression yields the value for K_{sp}.

$$\begin{aligned} K_{sp} &= \left[Ag^+\right]\left[Cl^-\right] \\ &= \left(1.3\times10^{-5}\right)\left(1.3\times10^{-5}\right) \\ &= 1.7\times10^{-10} \end{aligned}$$

Example 1

At $25°C$, the concentration of Pb^{2+} ions in a saturated solution of PbF_2 is $1.9\times10^{-3}\ M$. What is the value of K_{sp} for PbF_2?

The included chart shows the K_{sp} values for a number of substances at $25°C$. As with other equilibrium situations, the value of the solubility product gives us important information about the reaction. A small value of K_{sp} indicates that a substance is not very soluble in water.

It is important to distinguish between the solubility of a given solid and its solubility product. The solubility is the amount that can dissolve in a given solvent. Solubility is an equilibrium position and has an infinite number of possible values at a given temperature, depending on what other solutes are present. The solubility product, on the other hand, is a constant and has only one value for a given solid at a given temperature.

The **molar solubility** of a solid is the number of moles of that solid that will dissolve per liter of solvent. If you know the K_{sp} value for a solid, it is possible to determine its molar solubility using an ICE table.

Example 2

What is the molar solubility of silver carbonate (Ag_2CO_3), given that it has a $K_{sp} = 6.3 \times 10^{-12}$?

So far we have used the equilibrium concentrations of ions in a saturated solution to calculate the value of the solubility product. We have also used the value of the solubility product to determine the molar solubility of a solid. It is also possible to use the value of the solubility product to predict the equilibrium concentrations of ions in a saturated solution.

Example 3
What will be the equilibrium concentrations of the dissolved ions in a saturated solution of $CaSO_4$ at $25°C$?

Example 4

What will be the equilibrium concentrations of the dissolved ions in a saturated solution of $Mg(OH)_2$ at $25°C$?

Worksheet

1. A sample of $Cd(OH)_2(s)$ is added to pure water and allowed to come to equilibrium at $25°C$. The concentration of Cd^{2+} is $1.7\times10^{-5}\ M$ at equilibrium. What is the value of K_{sp} for $Cd(OH)_2$?

2. A sample of $Ce(OH)_3(s)$ is added to pure water and allowed to come to equilibrium at $25°C$. The concentration of Ce^{3+} is $5.2\times10^{-6}\ M$ at equilibrium. What is the value of K_{sp} for $Ce(OH)_3$?

3. A sample of $SrCO_3(s)$ is added to pure water and allowed to come to equilibrium at $25°C$. The concentration of Sr^{2+} is $4.0\times10^{-5}\ M$ at equilibrium. What is the value of K_{sp} for $SrCO_3$?

4. At $18°C$, the concentration of Pb^{2+} ions in a saturated solution of lead oxalate (PbC_2O_4) is $5.23\times10^{-6}\ M$. What is the value of K_{sp} for PbC_2O_4?

5. What is the molar solubility of silver bromide ($AgBr$) at $25°C$?

6. What is the molar solubility of tin(II) hydroxide ($Sn(OH)_2$) at $25°C$? ($K_{sp} = 1.4\times10^{-28}$)

7. What are the equilibrium concentrations of Ca^{2+} and F^- in a saturated solution of CaF_2? ($K_{sp} = 3.9\times10^{-11}$)

8. Calculate the number of moles of $BaCrO_4$ that must dissolve to produce 1.0 L of a saturated solution at $25°C$.

9. What are the equilibrium concentrations of the dissolved ions in a saturated solution of $Fe(OH)_2$ at $25°C$?

10. What are the equilibrium concentrations of the dissolved ions in a saturated solution of Ag_2SO_4 at $25°C$? ($K_{sp} = 1.2\times10^{-5}$)