K_{sp} for Copper (II) Tartrate

We have learned about many equilibrium systems during the past four (or more) weeks. The equilibrium constant, the measure of the extent of a reaction, we have discussed include,

K_p, K_c

K_a, K_b, K_w, $K_{neutralization}$

For every equilibrium constant we needed a chemical equation. The chemical equation was always provided for K_c and K_p, but for the acid-base equilibrium systems, an acid-base theory (Arrhenius or Brønsted-Lowry) was used to arrive at the chemical equation.

This new equilibrium system is described by the dissolution of an ionic compound. The equilibrium constant is K_{sp}(solubility product). An example is K_{sp} (AgCl) that has a value of

$$K_{sp} = 1.7 \times 10^{-10}$$

and the chemical equation is

$$AgCl_{(s)} \rightleftharpoons Ag^+_{(aq)} + Cl^-_{(aq)}$$

The equilibrium expression,

$$K_{sp} = [Ag^+]^1[Cl^-]^1$$

Remember the solid is not included in the equilibrium expression since its concentration does not change.

The magnitude of the K_{sp} is very small. Looking at the dissolution chemical equation a small K_{sp} means that AgCl is not very soluble, since the concentrations of the ions is so small.

There are two common types of problems that are solved when discussing equilibrium systems:

1) given initial amounts of reactants & products and an equilibrium amount, calculate K.
2) given the initial amounts of R & P and K, we calc all the equilibrium amounts.

For dissolution chemical equations

type 1 problems: need to be given the molar solubility and calculate K_{sp}

in type 2 problems give K_{sp}, calculate molar solubility of the ionic cmpd.

Example Type 1 problem: Calculate the K_{sp} for AgCl given the solubility of AgCl is 1.863×10^{-4} grams AgCl in 100 mL of water.

$$\frac{1.863 \times 10^{-4}\,g\,AgCl}{100\,mL}\left(\frac{1\,mol}{143\,g}\right)\left(\frac{1000\,mL}{1\,L}\right) = 1.3 \times 10^{-5}\,\frac{mol}{L}$$

molar solubility

$$AgCl_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$$

	$AgCl_{(s)}$	$Ag^{+}_{(aq)}$	$Cl^{-}_{(aq)}$
I	–	0	0
C	–	x	x
E	–	x	x

x = molar solubility AgCl $\frac{mol\ AgCl}{1\,L}$

$K_{sp} = [Ag^{+}][Cl^{-}]$

$K_{sp} = (x)(x) = x^2$

$= (1.3 \times 10^{-5})^2 = 1.7 \times 10^{-10}$

Example Type 2 problem: The K_{sp} for $Mg(OH)_2$ is 8.9×10^{-12} calculate the solubility of $Mg(OH)_2$ in moles per liter.

$$Mg(OH)_{2(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2OH^-_{(aq)}$$

	$Mg(OH)_{2(s)}$	Mg^{2+}	$2OH^-$
I	–	0	0
C	–	x	2x
E	–	x	2x

x = molar solubility $Mg(OH)_2$

$$K_{sp} = [Mg^{2+}][OH^-]^2$$

$$8.9\times10^{-12} = (x)(2x)^2$$

$$8.9\times10^{-12} = 4x^3$$

$$2.25\times10^{-12} = x^3$$

$$1.3\times10^{-4}\,M = x = \text{solubility of } Mg(OH)_2$$