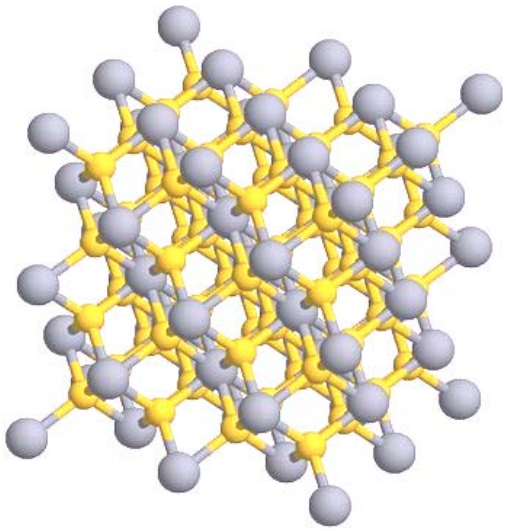
16. Ksp = Equilibrium Constant for Solubility Products

Background Knowledge for Solubility Product constant (Ksp)



1. The ***solubility*** of $CaF_{2(s)}$ is 2.05 x 10^{-4} moles /L at 25 ^{o}C. What does that mean?

The maximum amount of calcium fluoride that could dissolve at 25 ^{o}C is 2.05 x 10^{-4} moles per liter of solution.

2. What actually happens to a crystal of CaF_2 as it dissolves in water? (a)draw an ionic representation and (b) write an equilibrium equation to represent this.

Each calcium ion will be surrounded by water molecules with oxygen facing the positive ion, and each fluoride ion will have hydrogen atoms form water molecules facing them.

$$CaF_{2(S)} \rightleftharpoons Ca^{2+}_{(aq)} + 2\ F^{-}_{(aq)}$$

3. How does the K for this equilibrium relate to a saturated solution?

The K will be proportional to the solubility because:

$$K = [Ca^{2+}][\ F^{-}]^2$$

4. Write equilibrium equations for the following as they dissolve in water:

a) $Al(OH)_{3(s)} \rightleftharpoons Al^{3+}_{(aq)} + 3\ OH^{-}_{(aq)}$

b) $Li_3PO_{4(s)} \rightleftharpoons 3\ Li^{+}_{(aq)} + PO_4^{3-}{}_{(aq)}$

c) $Mg_3(AsO_4)_{2(s)} \rightleftharpoons 3\ Mg^{+2}_{(aq)} + 2\ AsO_4^{3-}{}_{(aq)}$

d) $Hg(SCN)_{2(s)} \rightleftharpoons Hg^{+2}_{(aq)} + 2\ SCN^{-}_{(aq)}$

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

f) $Ag_2C_2O_{4(s)} \rightleftharpoons 2\ Ag^{+}_{(aq)} + C_2O_4^{2-}{}_{(aq)}$

The K_{sp} is specifically used for an equilibrium between an undissolved solid and its ions in solution.

How to interpret K_{sp}

$MX_{(s)} \rightleftharpoons M^{+}_{(aq)} + X^{-}_{(aq)}$

K_{sp} =

Low K_{sp}	Low solubility
High K_{sp}	High solubility

Example 1 Solid silver chromate is added to pure water at 25 ^{o}C. Some of the solid remains undissolved $Ag_2CrO_{4(s)}$ at the bottom of the flask. The mixture is stirred for several days to ensure that equilibrium is achieved between the undissolved and the solution. Analysis of the equilibrated solution shows that its silver ion concentration is 1.3 X10^{-4} moles/L.
Assuming that Ag_2CrO_4 dissociates completely in water and that there are no other important equilibria involving the Ag+ or CrO_4^{-2} ions in the solution, calculate Ksp for this compound.

	$Ag_2C_2O_{4(s)}$	$2\ Ag^{+}_{(aq)}$	$C_2O_4^{2-}{}_{(aq)}$
I	? not needed	0	0
C	Solubility= 6.5 X 10^{-5} moles/L (1:1 ratio between this and $C_2O_4^{2-}{}_{(aq)}$	1.3 X10^{-4} moles/L.	1.3 X10^{-4} moles/L/2 due to ratio = 6.5 X 10^{-5} moles/L
E	not needed	1.3 X10^{-4} moles/L.	6.5 X 10^{-5} moles/L

$Ksp = [Ag^{+}]^2[C_2O_4^{2-}] = [1.3\ X10^{-4}]^2[6.5\ X\ 10^{-5}] = 1.1\ X10^{-12}$

Example 2 The Ksp for CaF_2 is 3.9×10^{-11} at 25 °C. Assuming that CaF_2 dissociates completely upon dissolving and that there are no other important equilibria affecting its solubility, calculate the solubility of CaF_2 in grams per liter.

	$CaF_{2\,(s)}$	$Ca^{+2}_{(aq)}$	$2\ F^{-}_{(aq)}$
I	? not needed	0	0
C	Solubility= x	x (1:1 ratio)	2x (2:1 ratio)
E	not needed	0 + x = x	2x

$$Ksp = [Ca^{+2}][F^{-}]^2 = 3.9 \times 10^{-11}$$

$$x(2x)^2 = 3.9 \times 10^{-11}$$

$$4x^3 = 3.9 \times 10^{-11}$$

$$x = 0.002136329341 \text{ moles } CaF_2 / L$$

$$0.002136329341 \text{ moles } CaF_2 / L * 78 \text{ g/mole} =$$

$$= 1.7 \times 10^{-2} \text{ g } CaF_2/L \text{ soln}$$

Example 3 $LaF_{2(s)} + \text{heat} \rightleftharpoons La^{+2}_{(aq)} + 2\ F^{-}_{(aq)}$

In the above equilibrium, list two ways by which the solubility of LaF_2 could be reduced.

1) reduce heat to shift equilibrium backwards
2) add more $La^{+2}_{(aq)}$ *or* $F^{-}_{(aq)}$ from a different source

Example 4 For which substance would Ksp increase with a lower temperature? Explain your reasoning.

If Ksp increases then we want a higher solubility and this has to happen, for this question, at low temperatures. NH_3 and $Ce_2(SO_4)_3$ meet those criteria.