More Stuff about Aqueous Equilibria : CH 17 Part 5

Electrolytes are ionic compounds

- A strong electrolyte dissociates completely into ions when dissolved in water
- A weak electrolyte only dissociates partially when dissolved in water.

Solubility of Ionic compounds

- Not all ionic compounds dissolve significantly in water
- A list of solubility rules is used to decide what combinations of ions will dissolve.

Solubility Equilibria

- Fore "insoluble salts" how much do they dissolve?
  - There is an equilibrium constant called solubility-product constant, Ksp.
  - Assume that MA is an ionic solid dissolving in water.

$$MA(s) + H_2O \rightleftharpoons M^+(aq) + A^-(aq)$$

$$K_{sp} = [M^+][A^-]$$

or

$$A_xB_y(s) + H_2O \rightleftharpoons xA^{+y}(aq) + yB^{-x}(aq)$$

$$K_{sp} = [A^{+y}]^x[B^{-x}]^y$$

Solubility Product Examples

$$BaSO_4(s) + H_2O \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$$

$$K_{sp} = [Ba^{2+}][SO_4^{2-}]$$

$$Ba_3(PO_4)_2(s) \rightleftharpoons 3\,Ba^{2+}(aq) + 2\,PO_4^{3-}(aq)$$

$$K_{sp} = [Ba^{2+}]^3[PO_4^{3-}]^2$$

Solubility vs Solubility Product

- K_{sp} is not the same as solubility, but it can be used to calculate solubility.
- Solubility is the quantity of a substance that dissolves to form a saturated solution.

Calculating Solubility from K_{sp}

~~① write~~ K_{sp} for CaF is 3.9×10^{-11} at 25°C. What is Molar solubility?

① Write rxn: $CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$

② Write K_{sp}: $K_{sp} = [Ca^{2+}][F^-]^2 = 3.9 \times 10^{-11}$

③ Ice table:

	$CaF_2(s)$	$[Ca^{2+}]$ (M)	$[F^-]$(M)
I	—	0	0
C	—	$+x$	$+2x$
E	—	x	$2x$

④ Substitute the equilibrium concentration values from the table into the solubility-product equation:

$$K_{sp} = [Ca^{2+}][F^-]^2 = 3.9 \times 10^{-11}$$
$$= (x)(2x)^2 = 4x^3$$
$$x = 2.1 \times 10^{-4}\ M$$

Solubility of Ag_3PO_4?

$$Ag_3PO_4 \rightarrow 3Ag^+ \quad PO_4^{3-}$$
$$3x \qquad x$$

$$K_{sp} = 1.8 \times 10^{-8} = [Ag^+]^3[PO_4^{3-}]$$
$$(3x)^3 \quad (x)$$
$$1.8 \times 10^{-8} = 27x^4$$

BaF_2 has a solubility of 1.82×10^{-2} M

$$BaF_2(s) \rightleftharpoons Ba^{2+}(aq) + 2F^-(aq)$$

$$K_{sp} = [Ba^{2+}][F^-]^2$$
$$= (1.82 \times 10^{-2})(2 \times 1.82 \times 10^{-2})^2$$
$$= 2.4 \times 10^{-5}$$

Clicker: which is more soluble, AgCl or Ag_2CrO_4?

$$\underset{}{AgCl(s)} \rightleftharpoons \underset{x}{Ag^+(aq)} + \underset{x}{Cl^-(aq)}$$

$K_{sp} = 1.6 \times 10^{-10}$

$x^2 = 1.6 \times 10^{-10}$ $x = 1.3 \times 10^{-5}$

$$Ag_2CrO_4(s) \rightleftharpoons \underset{2x}{2Ag^+(aq)} + \underset{x}{CrO_4^{2-}(aq)}$$

$K_{sp} = 9.0 \times 10^{-10}$

$(2x)^2 x = 4x^3 = 9.0 \times 10^{-10}$

$x = 1.3 \times 10^{-4}$ M

Ag_2CrO_4 because it produces more ions

Assume we have a solution of calcium fluoride happily at equilibrium

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$$

What happens if we add some solid calcium nitrate?

$$Ca(NO_3)_2(s) \rightarrow Ca^{2+}(aq) + 2NO_3^-(aq)$$

<u>Factors Affecting Solubility</u>

- The Common-Ion Effect

  If one of the ions in a sln. equilibrium is added to the sln., the solubility of the salt will decrease

  For example, calcium fluoride is less soluble if either Ca^{2+} ions or F^- are added

What is the molar solubility of CaF_2 in 0.010 M $Ca(NO_3)_2$?

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$$

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

	$CaF_2(s)$	$[Ca^{2+}]$(M)	$[F^-]$(M)
I	—	0.010	0
C	—	+x	+2x
E	—	0.010 +x	2x

$$K_{sp} = [Ca^{2+}][F^-]^2 = 3.9 \times 10^{-11}$$
$$= (0.010 + x)(2x)^2$$

Assume that $x << 0.010$, so that $0.010 + x = 0.010$

$$3.9 \times 10^{-11} = (0.010)(2x)^2$$
$$x = 3.1 \times 10^{-5}\ M$$

Solubility of AgCl in 0.55 M NaCl?

$[Cl^-] = 0.55 M + x \approx 0.55 M$ Cl coming from AgCl

$[Ag^+] = x$

$$K_{sp} = 1.6 \times 10^{-10} = (0.55 + x)x$$

$$x = 2.9 \times 10^{-10}\ M$$