Mr. Bracken
AP Chemistry

Name ___________________________
Period _____

Solubility Equilibrium & Ksp Notes

Solubility Refresher:

- Solute: substance that is dissolved into something else. The minor component of a solution.
- Solvent: substance that makes of the major component of a solution. (water generally)
- Saturated Solution: solution that has the maximum amount of solute dissolved in it.

Solubility:

- Refers to the quantity that will dissolve to form a saturated solution.
- Typical units: grams of solute per Liter of solution
- **Molar solubility** is the maximum molarity of a solute.

Molar solubility = MAXIMUM MOLARITY

Factors Affecting Solubility:

1. **"Common Ion Effect"** (LeChatelier's Principle)

$$NaCl\ (s) \leftrightarrows Na^{1+}\ (aq) + Cl^{1-}\ (aq)$$

Addition of either Na^{1+} (aq) or Cl^{1-} (aq) shifts equilibrium to the left, reducing solubility.
This can be done with aqueous HCl because it dissociates to form H^{1+} and Cl^{1-} ions.
Can also be done with aqueous Na_2SO_4 since it exists as separate Na^{1+} and SO_4^{2-} ions.

BIG IDEA: Adding a "common ion" decreases the solubility of a salt.

In which aqueous system is PbI_2 least soluble?
(a) 0.5 M HI
(b) H_2O
(c) 0.2 M HI
(d) 1.0 M HNO_3
(e) 0.8 M KI

2. **Solubility and pH**

$$Mg(OH)_2\ (s) \leftrightarrows Mg^{2+}\ (aq) + 2\ OH^{1-}\ (aq)$$

Addition of H^{1+} to this will shift this equilibrium to the right.
The H^{1+} will react with the OH^{1-} to produce to water.
Thus, the equilibrium will shift to the right to produce more OH^{1-}, increasing the solubility.
$Mg(OH)_2$ is essentially insoluble in cold water ………… 0.0009 grams per 100 mL

Consider the following process:

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

K =

$CaF_2 (s) \leftrightarrows Ca^{2+} (aq) + \mathbf{2}\, F^{1-} (aq)$

K =

<u>Solubility Product</u>: (Ksp)
Equals the product of the concentration of the ions involved in the equilibrium raised to the power of their coefficients in the equilibrium expression.

Ksp is the equilibrium constant for the equilibrium that exists between a solid ionic solute and its ions in a **saturated** aqueous solution.

The smaller the Ksp value, the lower the solubility.

Precipitation of Ions:

$BaSO_4 (s) \leftrightarrows Ba^{2+} (aq) + SO_4^{2-} (aq)$ $\quad$ $\mathbf{Ksp = [Ba^{2+} (aq)] [SO_4^{2-}(aq)]}$

Q = initial reaction conditions

$$\mathbf{Q = [Ba^{2+} (aq)] [SO_4^{2-}(aq)]}$$

If Q > Ksp "solvent cannot dissolve that many ions" so precipitate forms until Q = Ksp

If Q = Ksp "equilibrium achieved"….we have a perfectly saturated solution

If Q < Ksp "still able to dissolve more ions" so solid dissolves until Q = Ksp

Types of Ksp Problems

I. Dissolving the solid ionic compound into pure water. Solving for a missing variable in a mathematical expression.

The Ksp for CaF_2 is 3.9 x 10^{-11}. What is the molar solubility (max molarity) of a CaF_2 solution?

$Ksp = [Ca^{2+}][F^{1-}]^2$

A saturated solution of sodium chloride has a molarity of 5.65 M. What is the Ksp for NaCl?

II. Dissolving the solid ionic compound into a "Common-Ion" Solution

Picture this as trying to dissolve a compound into a pre-existing solution containing one of the ions.

What will be the molar solubility of AgCl solution that already contains 0.75 M NaCl? Ksp = 1.8 x 10^{-10}.

What is the molar solubility of CaF_2 in a 0.50 M KF solution? The Ksp of CaF_2 is 3.9 x 10^{-11}.

III. Will a precipitate form when two substances are mixed? Compare Q to Ksp.

Throw all of the ions into a beaker of pure water. Are the concentrations of the ions high enough to “find each other” to make a precipitate? Must calculate the molarities of each ion and then plug the ion molarities into the Ksp math expression.

A person mixes 100.0 mL of 0.0016 M $CaCl_2$ and 50.0 mL of 0.0081 M K_2SO_4.

If the Ksp for $CaSO_4$ is 2.4 x 10^{-5}, will a $CaSO_4$ precipitate be observed?

Compare this value (Q) to the Ksp textbook value. If Q>Ksp, a ppt will form. If Q < Ksp then no precipitate forms. If Q = Ksp, the solution is fully saturated. “On the brink of a precipitate!”

IV. Selective Precipitation: Which sparingly soluble solid will form a precipitate first?

A beaker contains 250 mL of a mixture that is labeled as 0.10 M $Sr(NO_3)_2$ and 0.00050 M $Pb(NO_3)_2$. A person slowly adds solid Na_2CO_3 to the beaker until a precipitate starts to form.

Substance	**Ksp Value**
$SrCO_3$	9.3 x 10^{-10}
$PbCO_3$	7.4 x 10^{-14}

Given these conditions, what substance ($SrCO_3$ or $PbCO_3$) starts to precipitate first? What is the concentration of the $[CO_3^{2-}]$ when the first precipitate starts to form?