Dougherty Valley HS • AP Chemistry [Keep for Reference]
Precipitation Reactions
BLUFFER'S GUIDE

1. **Solubility Rules**
   Review/memorize these rules. They can be split into four groups:

ALWAYS SOLUBLE:
alkali metal ions (Na^+, K^+, Li^+, Rb^+, Cs^+), NH_4^+, NO_3^-, $C_2H_3O_2^-$, ClO_3^-, ClO_4^-

USUALLY SOLUBLE:
chlorides, bromides, iodides (Cl-, Br-, I-) except "AP/H" (Ag^+, Pb^{2+}, Hg_2^{2+})

sulfates (SO_4^{2-}) except "CBS/PBS" (Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+})

fluorides (F-) except "CBS/PM" (Ca^{2+}, Ba^{2+}, Sr^{2+}, Pb^{2+}, Mg^{2+})

USUALLY INSOLUBLE:
oxides/hydroxides (O^{2-}, OH^-) except "CBS" ((Ca^{2+}, Ba^{2+}, Sr^{2+})

NEVER SOLUBLE:
CO_3^{2-}, PO_4^{3-}, S^{2-}, SO_3^{2-}, CrO_4^{2-}, $C_2O_4^{2-}$ except alkali metals & NH_4^+

2. **Solubility Product (K_{sp})**
   This type of equilibrium involves solids of low solubility. A saturated solution is a solution at equilibrium. The constant has no denominator.

Example: $Co(OH)_2(s) \rightleftharpoons Co^{2+} + 2OH^-$
$K_{sp} = [Co^{2+}][OH-]^2 = 2.5 \times 10^{-16}$
What is the pH of a saturated solution?

Let x = the amount (moles) of solid that will just saturate 1 L of solution.

$Co(OH)_2(s) \rightleftharpoons Co^{2+} + 2OH^-$

x	0	0
-x	+x	+2x
0	x	2x

$(x)(2x)^2 = 4x^3 = 2.5 \times 10^{-16}$
$x = 3.97 \times 10^{-6}$ $[OH-] = 2x = 7.94 \times 10^{-6}$
pOH = 5.1 pH = 14- pOH = **8.9**

3. **Solubility vs. K_{sp}**
   "Molar solubility" is the concentration of the saturated solution in moles/Liter. (Solubility is sometimes reported in g/100 mL of water.)

   As in the example, for a 1:2 compound, $K_{sp} = 4x^3$ (where x = solubility)

1:1	$K_{sp} = x^2$
1:2	$K_{sp} = 4x^3$
1:3	$K_{sp} = 27x^4$
2:3	$K_{sp} = 108x^5$

4. **Will a Precipitate Form?**
   Ion Product (Q_{sp}) = "reaction quotient".

$Q_{sp} < K_{sp}$ more solid will dissolve
$Q_{sp} = K_{sp}$ solution is saturated
$Q_{sp} > K_{sp}$ ppt will form until $Q_{sp} = K_{sp}$

Note: Be sure to calculate concentration of DILUTED ions.

Example:
50. mL of 2.0×10^{-4} <u>M</u> $Co(NO_3)_2$ is mixed with 200 mL of 1.0×10^{-3} <u>M</u> NaOH. Will a precipitate form?
[Note: K_{sp} given in other example problem.]

$[Co^{2+}] = 2.0 \times 10^{-4}\ \underline{M} \times \frac{50}{250} = 4.0 \times 10^{-5}\ \underline{M}$

$[OH-] = 1.0 \times 10^{-3}\ \underline{M} \times \frac{200}{250} = 8.0 \times 10^{-4}\ \underline{M}$

$Q_{sp} = (4 \times 10^{-5})(8 \times 10^{-4})^2 = 2.56 \times 10^{-11}$
$Q_{sp} > K_{sp}$; a precipitate will form!

5. **Solubility can be influenced by pH.**
   If the anion came from a weak acid, the salt will be more soluble in a solution of strong acid.

   Example: $CaCO_3(s) \rightleftharpoons Ca^{2+} + CO_3^{2-}$

   In a strong acid, H^+ combines with CO_3^{2-} to re-form the weak acid, H_2CO_3 (which may decompose into CO_2 & H_2O). More $CaCO_3(s)$ will dissolve to reach equilibrium.