

19 • 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^- , $\text{C}_2\text{H}_3\text{O}_2^-$, 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-} , $\text{C}_2\text{O}_4^{2-}$ 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: $\text{Co}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Co}^{2+} + 2\text{OH}^-$

$$K_{sp} = [\text{Co}^{2+}][\text{OH}^-]^2 = 2.5 \times 10^{-16}$$

What is the pH of a saturated solution?

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

$\text{Co}(\text{OH})_2(\text{s}) \rightleftharpoons \text{Co}^{2+} + 2\text{OH}^-$		
x	0	0
$-x$	$+x$	$+2x$
0	x	$2x$

$$(x)(2x)^2 = 4x^3 = 2.5 \times 10^{-16}$$

$$x = 3.97 \times 10^{-6} \quad [\text{OH}^-] = 2x = 7.94 \times 10^{-6}$$

$$\text{pOH} = 5.1 \quad \text{pH} = 14 - \text{pOH} = \mathbf{8.9}$$

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,

$$K_{sp} = 4x^3 \quad (\text{where } x = \text{solubility})$$

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 $2.0 \times 10^{-4} \text{ M}$ $\text{Co}(\text{NO}_3)_2$ is mixed with 200 mL of $1.0 \times 10^{-3} \text{ M}$ NaOH. Will a precipitate form?

[*Note: K_{sp} given in other example problem.*]

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

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

$$Q_{sp} = (4 \times 10^{-5})(8 \times 10^{-4})^2 = 2.56 \times 10^{-11}$$

$Q_{sp} > K_{sp}$; 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: $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{Ca}^{2+} + \text{CO}_3^{2-}$

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 $\text{CaCO}_3(\text{s})$ will dissolve to reach equilibrium.