Solubility Rules!

Rule 1. All compounds of Group IA elements (the alkali metals) are <u>soluble</u>.

For example, $NaNO_3$, KCl, and LiOH are all soluble compounds. This means that an aqueous solution of KCl really contains the predominant species K^+ and Cl^- and, because KCl is soluble, no KCl is present as a solid compound in aqueous solution: $KCl_{(s)} \Rightarrow K^+_{(aq.)} + Cl^-_{(aq.)}$

Rule 2. All ammonium salts (salts of NH_4^+) are <u>soluble</u>.

For example, NH_4OH is a soluble compound. Molecules of NH_4OH completely dissociate to give ions of NH_4^+ and OH^- in aqueous solution.

Rule 3. All nitrate (NO_3^-), chlorate (ClO_3^-), perchlorate (ClO_4^-), and acetate (CH_3COO^- or $C_2H_3O_2^-$) salts are <u>soluble</u>.

For example, KNO_3 would be classified as completely soluble by rules 1 and 3. Thus, KNO_3 could be expected to dissociate completely in aqueous solution into K^+ and NO_3^- ions: $KNO_3 \Rightarrow K^+_{(aq.)} + NO^{3-}_{(aq.)}$

Rule 4. All chloride (Cl^-), bromide (Br^-), and iodide (I^-) salts are <u>soluble</u> except for those of Ag^+, Pb^{2+}, and Hg_2^{2+}.

For example, AgCl is a classic insoluble chloride salt: $AgCl_{(s)} \Leftrightarrow Ag^+_{(aq.)} + Cl^-_{(aq.)}$ ($K_{sp} = 1.8 \times 10^{-10}$).

Rule 5. All sulfate (SO_4^{2-}) compounds are <u>soluble</u> except those of Ba^{2+}, Sr^{2+}, Ca^{2+}, Pb^{2+}, Hg_2^{2+}, and Hg^{2+}, Ca^{2+} and Ag^+ sulfates are only moderately soluble.

For example, $BaSO_4$ is insoluble (only soluble to a very small extent):
$BaSO_{4(s)} \Leftrightarrow Ba^{2+}_{(aq.)} + SO_4^{2-}{}_{(aq.)}$ ($K_{sp} = 1.1 \times 10^{-10}$). Na_2SO_4 is completely soluble: $Na_2SO_{4(s)} \Rightarrow 2\ Na^+_{(aq.)} + SO_4^{2-}{}_{(aq.)}$.

Rule 6. All hydroxide (OH^-) compounds are <u>insoluble</u> except those of Group I-A (alkali metals) and Ba^{2+}, Ca^{2+}, and Sr^{2+}.

For example, $Mg(OH)_2$ is insoluble ($K_{sp} = 7.1 \times 10^{-12}$).
NaOH and $Ba(OH)_2$ are soluble, completely dissociating in aqueous solution:
$NaOH_{(s)} \Rightarrow Na^+_{(aq.)} + OH^-_{(aq.)}$, a strong base
$Ba(OH)_{2(s)} \Rightarrow Ba^{2+}_{(aq.)} + 2OH^-_{(aq.)}$ ($K_{sp} = 3 \times 10^{-4}$)

Rule 7. All sulfide (S^{2-}) compounds are <u>insoluble</u> except those of Groups I-A and II-A (alkali metals and alkali earths).

For example, $Na_2S_{(s)} \Leftrightarrow 2Na^+_{(aq.)} + S^{2-}_{(aq.)}$
MnS is insoluble ($K_{sp} = 3 \times 10^{-11}$).

Rule 8. All sulfites ($SO_3^=$), carbonates ($CO_3^=$), chromates ($CrO_4^=$), and phosphates (PO_4^{3-}) are <u>insoluble</u> except for those of NH_4^+ and Group I-A (alkali metals)(see rules 1 and 2).

For example, calcite, $CaCO_{3(s)} \Leftrightarrow Ca^{2+}_{(aq.)} + CO_3^={}_{(aq.)}$ ($K_{sp} = 4.5 \times 10^{-9}$).

Solubility From EOC Formula Chart

SOLUBILITY OF COMMON IONIC COMPOUNDS IN WATER

Soluble compounds contain	**Common exceptions**
$C_2H_3O_2^-$, CH_3COO^-	None
NH_4^+	None
NO_3^-	None
CN^-	None
ClO^-	None
ClO_2^-	None
ClO_3^-	None
ClO_4^-	None
Br^-	Compounds of Ag^+, Pb^{2+}, and Hg_2^{2+}
Cl^-	Compounds of Ag^+, Pb^{2+}, and Hg_2^{2+}
I^-	Compounds of Ag^+, Pb^{2+}, and Hg_2^{2+}
SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Pb^{2+}, and Hg_2^{2+}

Insoluble compounds contain	**Common exceptions**
CO_3^{2-}	Compounds of NH_4^+ and the alkali metal cations
PO_4^{3-}	Compounds of NH_4^+ and the alkali metal cations
CrO_4^{2-}	Compounds of NH_4^+ and the alkali metal cations
$Cr_2O_7^{2-}$	Compounds of NH_4^+ and the alkali metal cations
OH^-	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}
S^{2-}	Compounds of NH_4^+, the alkali metal cations, Ca^{2+}, Sr^{2+}, and Ba^{2+}