Two great mnemonics!

1. OIL RIG: **O**xidation **I**s **L**oss (OIL) and **R**eduction **I**s **G**ain (RIG)
2. LEO **goes** GER: A species **loses electrons** when **oxidized**, and **gains electrons** when **reduced.**

Almost all reaction types (except double replacement) are redox. We will learn sooooooooo much more about oxidation-reduction reactions next unit!

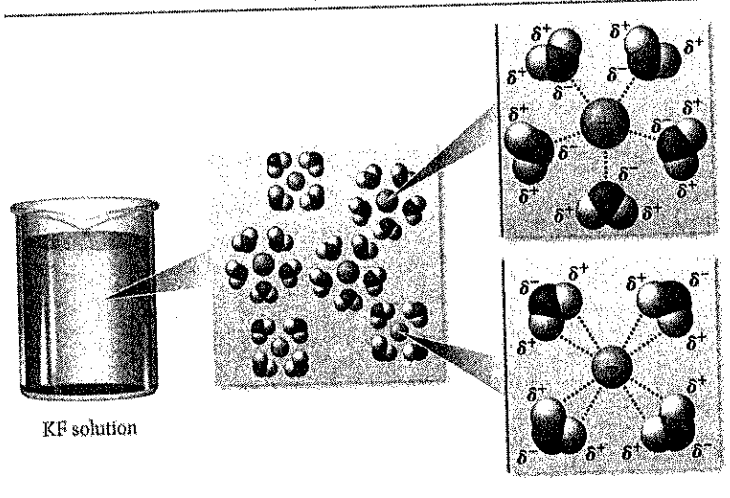
Precipitation Reactions

Precipitation Reactions: a double replacement reaction between aqueous solutions of ionic compounds which produces an ionic compound that is insoluble in water: this insoluble product is called a precipitate.

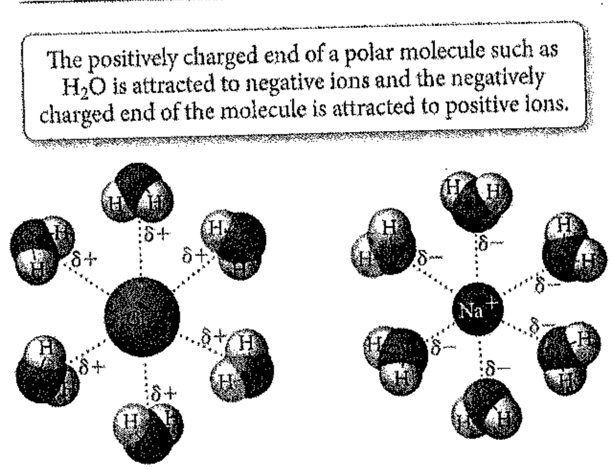
Quick review: **Ionic Compound Solubility**

- When we mix a solute with a solvent, there are attractive forces (ion-dipole IMFs) between the solute and solvent particles – if the attraction is strong enough, this is what allows the solute to dissolve!
- Ions separate (ionize) from one another when dissolved in water (called dissociation)
- The number of ions produced in solution depends on the ratio in the original formula.
  - Ex: $Pb(NO_3)_2$ dissociates to form → $1\ Pb^{2+}_{(aq)} + 2\ NO_3^-{}_{(aq)}$
    - Thus, **1 formula unit** of $Pb(NO_3)_2$ dissociates to form 3 total ions.

Ion–Dipole Interactions

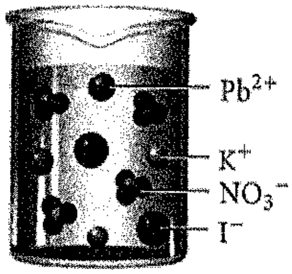


Ion–Dipole Forces



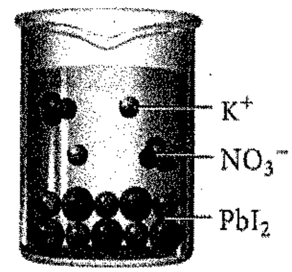
Back to precipitation reactions!

For example, consider what happens if you mix two solutions, KI(aq) and $Pb(NO_3)_2$(aq). Before mixing, both compounds are Soluble in water: they have **dissociated into ions** in their respective solutions. When the two solutions are mixed together:



KI(*aq*) and $Pb(NO_3)_2$(*aq*)

In the *instant* that the solutions come into contact, all four ions are present:



PbI_2(*s*) and KNO_3(*aq*)

In this reaction, KNO_3 is soluble, but PbI_2 is insoluble. Thus, PbI_2 precipitates.

Solubility Rules

There are many rules to determine which ions are soluble in water. Although you no longer need to know the very large list of solubility rules from the AP test of yore, there are some basic solubility rules you MUST know!

1. **Always soluble:** Alkali **metal cations, NH_4^+, NO_3^-** (also ClO_3^-, ClO_4^-, $C_2H_3O_2^-$, HCO_3^-)
2. Generally soluble:
   a. Bromide, chloride, and iodide anions are soluble except when combined with Ag^+, Pb^{2+}, and Hg_2^{2+}.
   b. SO_4^{2-} is soluble except when combined with Sr^{2+}, Ba^{2+}, Pb^{2+}, and Hg_2^{2+}.
3. Generally insoluble:
   a. OH^- and S^{2-} are insoluble except when combined with Ca^{2+}, Sr^{2+}, Ba^{2+}, (and things from rule 1).
   b. CO_3^{2-}, PO_4^{3-}, SO_3^{2-}, and CrO_4^{2-} are insoluble except when combined with things from rule 1.

Note: Precipitation reactions do not always occur when two aqueous solutions are mixed!

	Precipitation Rxn?	Why?
RbCl(*aq*) + NaBr(*aq*) → RbBr(aq) + NaCl(aq)	Nope.	No insoluble substance produced.
HCl(*aq*) + $AgNO_3$(*aq*) → AgCl(*s*) + HNO_3(*aq*)	Yes!	Solid produced from aqueous reactants.
3 MnO_2(aq) + 4 Al(s) → 3 Mn(s) + 2 Al_2O_3(aq)	Nope.	Not starting from only aqueous reactants.

Ways to Represent a Precipitation Reaction

Complete ionic equation: Starting from the full equation, split any aqueous substances into their ions, but leave non-aqueous substances intact.

Net ionic equation: Starting from the complete ionic equation, remove all ions that found in exactly the same form on both sides of the equation (called spectator ions, since they do not participate in reaction).

Example

Molecular (Full) Equation: $2AgNO_3(aq) + CaCl_2(aq) \rightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$

Complete Ionic Equation: $2Ag^+(aq) + 2NO_3^-(aq) + Ca^{2+}(aq) + 2Cl^-(aq) \rightarrow 2AgCl(s) + Ca^{2+}(aq) + 2NO_3^-(aq)$

Net ionic equation: $2Ag^+(aq) + 2Cl^-(aq) \rightarrow 2AgCl(s)$ simplifies to: $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

Let's Try!

1. Why is a precipitation reaction best represented by a net ionic equation, rather than the complete or molecular equation? A net ionic eq'n shows the formation of the precipitate, while omitting spectator ions which don't participate in the chemical rxn.

2. Complete and balance the following reaction, then write the complete AND net ionic equations.

$\underline{1}\ H_2SO_4(aq) + \underline{2}\ NaOH(aq) \rightarrow \underline{2}\ H_2O_{(l)} + \underline{1}\ Na_2SO_{4(aq)}$

Complete: $2H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Na^+_{(aq)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + 2Na^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

net: $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

3. Write the net ionic equation for the following reactions.

   a. $(NH_4)_2SO_4(aq) + 2\ AgNO_3(aq) \rightarrow 2\ NH_4NO_3(aq) + Ag_2SO_4(s)$

   $2\ Ag^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow Ag_2SO_{4(s)}$

   b. $H_2SO_4(aq) + 2\ LiOH(aq) \rightarrow 2\ H_2O(l) + Li_2SO_4(aq)$

   $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$