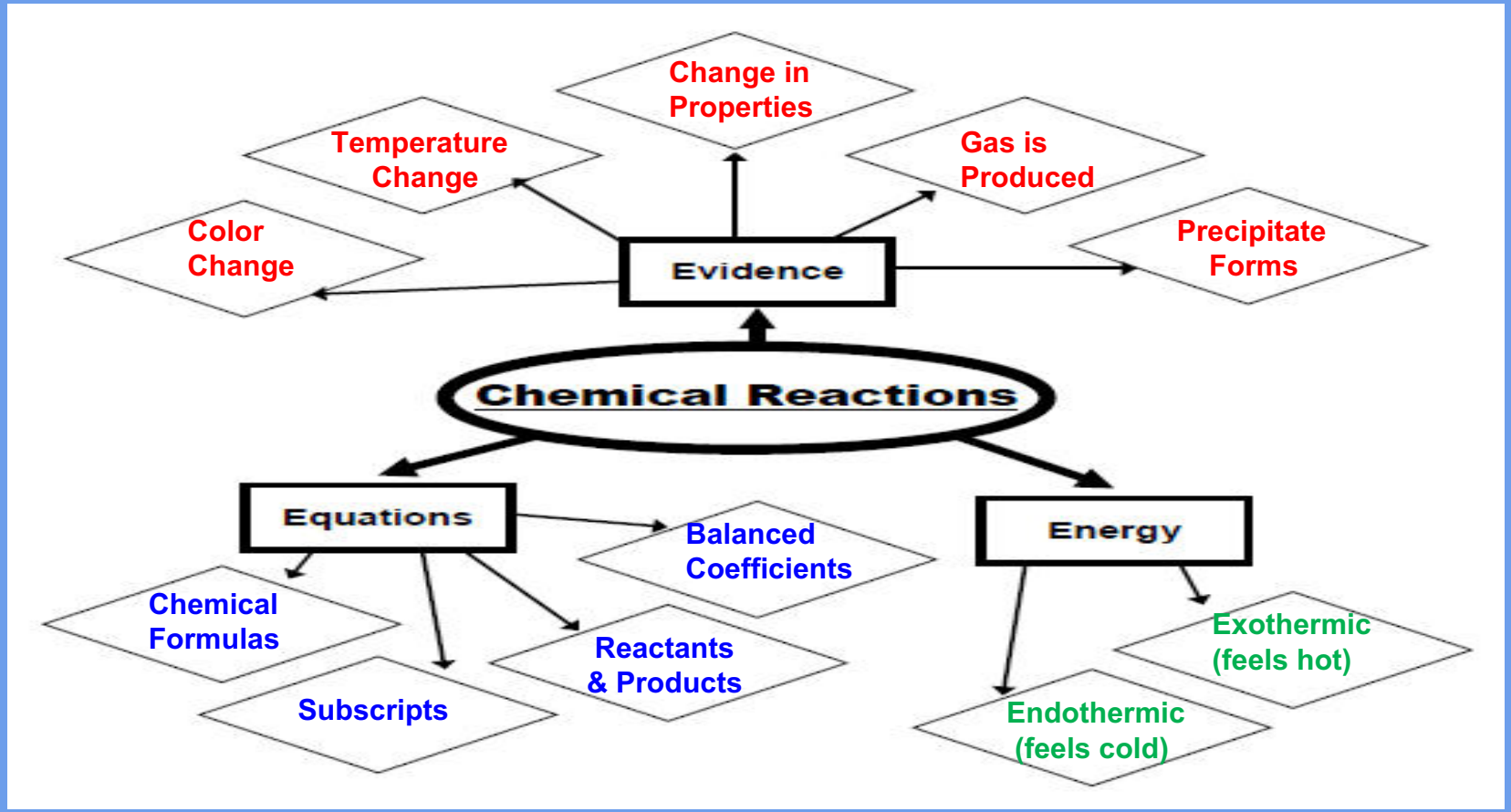

# Unit 7:
# Chemical Reactions


Change in Properties
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# Chemical Reaction

The process by which one or more substances changes to produce one or more different substances is called a **chemical reaction**.

# Evidence for Chemical Reactions

Absorption or release of **heat energy** or **electrical energy**

Absorption or release of **light energy** or **sound energy**

Formation of a **gas** or a **precipitate**

Change in **color** or **odor**

# Chemical or Physical?

To prove a chemical reaction took place one must use **chemical analysis** to investigate if the new substance as a different density, melting/boiling point, and chemical composition among other things.

# Conservation of Energy

All chemical reactions involve a change in energy. If the energy is **absorbed** it is considered a part of the **reactants**; however, if it is **released** it is considered part of the **products**.

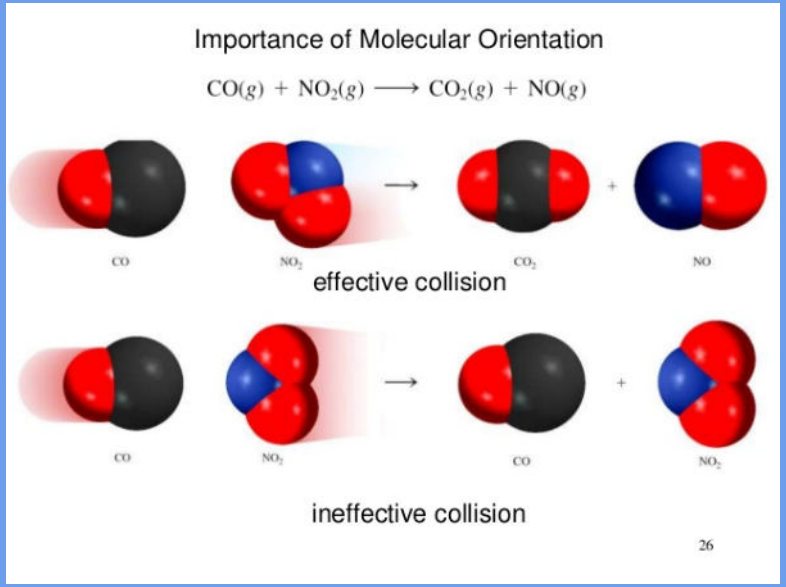
**Energy is absorbed:** $N_2O_4 + \text{energy} \rightarrow 2\,NO_2$

**Energy is released:** $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O + \text{energy}$

# Conservation of Mass

Mass is neither **created** nor destroyed in a chemical reaction. Atoms are just **rearranged** to form new bonds.

Atoms must collide with **significant force** **at the** **proper angle** in order to break and form new bonds.



# Chemical Equations

A **chemical equation** uses chemical formulas and symbols to represent the reaction between the reactants and products.

**Example:** Calcium Phosphate reacts with Ammonium Hydroxide to produce Calcium Hydroxide and Ammonium Phosphate.

$$Ca_3(PO_4)_2 + 6\ NH_4OH \longrightarrow 3\ Ca(OH)_2 + 2\ (NH_4)_3PO_4$$

# Reaction Symbols

Chemists use symbols to show a substance's **state of matter** and what **conditions** are required for the reaction to occur.

| Symbol | Meaning |
|---|---|
| $(s), (l), (g)$ | substance in the solid, liquid, or gaseous state |
| $(aq)$ | substance in aqueous solution (dissolved in water) |
| $\longrightarrow$ | "produces" or "yields," indicating result of reaction |
| $\rightleftarrows$ | reversible reaction in which products can reform into reactants; final result is a mixture of products and reactants |
| $\xrightarrow{\Delta}$ or $\xrightarrow{heat}$ | reactants are heated; temperature is not specified |
| $\xrightarrow{Pd}$ | name or chemical formula of a catalyst, added to speed a reaction |

# Common Symbols

- **Water** is always a **liquid (l)** at room temperature.
- **Water** is always a **gas (g)**, when it is the product of a combustion reaction.
- **Diatomic molecules** are always **gases (g)**. **($H_2$, $N_2$, $F_2$, $O_2$, $I_2$, $Cl_2$, $Br_2$)**
- **Precipitates** are always **solids (s)**.
- **Pure metals** are always **solid (s)**, except for mercury **- Hg (l).**
- **Ionic compounds** are usually **aqueous (aq)** because they dissolve in water.
- **Covalent molecules** are usually **gases (g)**.

# The Laws of Nomenclature

**Chemical Formulas** are set by the laws of nomenclature. Ionic compounds follow the rules for ionic nomenclature, and covalent molecules follow the rules for covalent nomenclature

**Examples:** **Calcium Phosphate = $Ca_3(PO_4)_2$**

- because $Ca^{+2}$ and $PO_4^{-3}$

**Carbon Dioxide = $CO_2$**

- because “di” means two oxygen atoms


**NEVER CHANGE SUBSCRIPTS TO BALANCE A CHEMICAL EQUATION!!!**

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# Coefficients

A **coefficient** is a small whole number that appears as a factor in front of a formula in a chemical reaction; because the chemical formulas cannot change, one must add coefficients in order to balance chemical equations; these coefficients represent the number of molecules or compounds required to complete the reaction.

**Example:** $2\ H_2\ (g) + 1\ O_2\ (g) \rightarrow 2\ H_2O\ (l)$

# Types of Chemical Reactions

**Synthesis** - joins reactants to make new product(s)

**Decomposition** - breaks a reactant down into smaller components

**Single Replacement** - an element replaces one of the ions in an ionic compound

**Double Replacement** - two ionic reactants swap anions

**Neutralization** - an acid reacts with a base to form an ionic salt and water

**Combustion** - a hydrocarbon burns in the presence of oxygen to form carbon dioxide and water

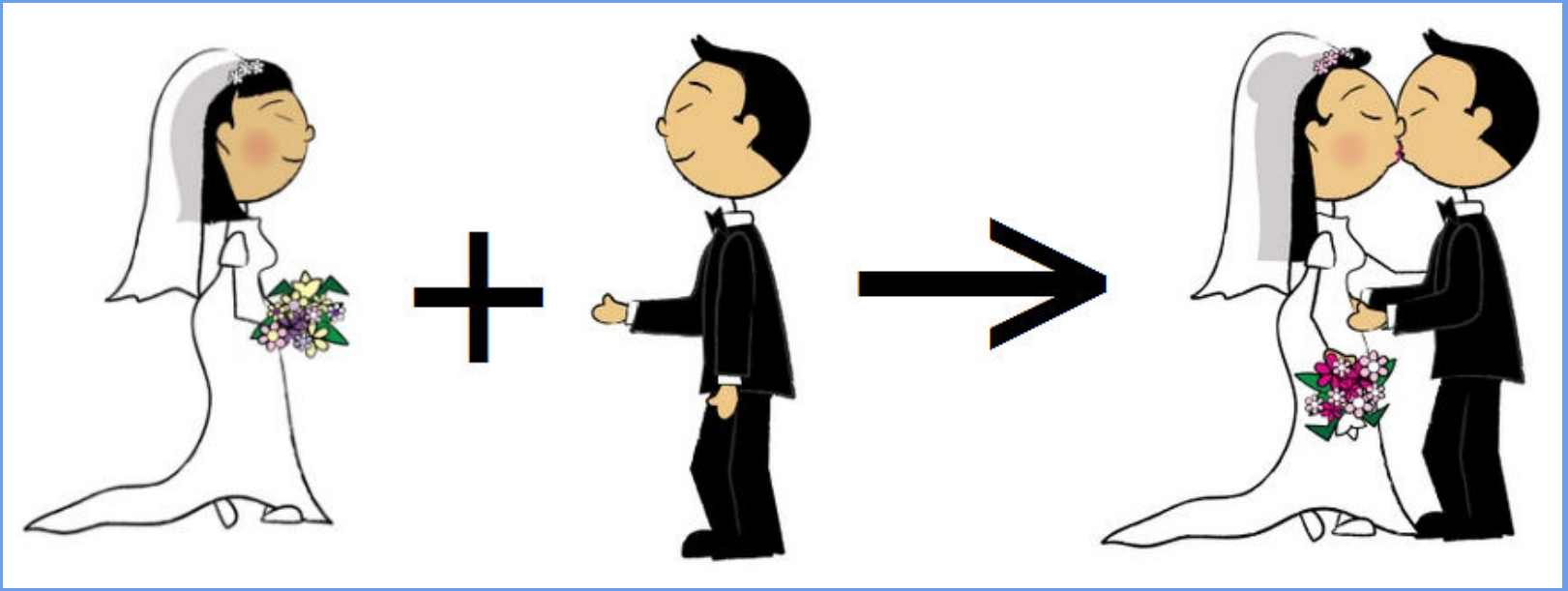
# Synthesis

A **Synthesis Reaction** is a reaction in which two or more substances combine to form one new compound.

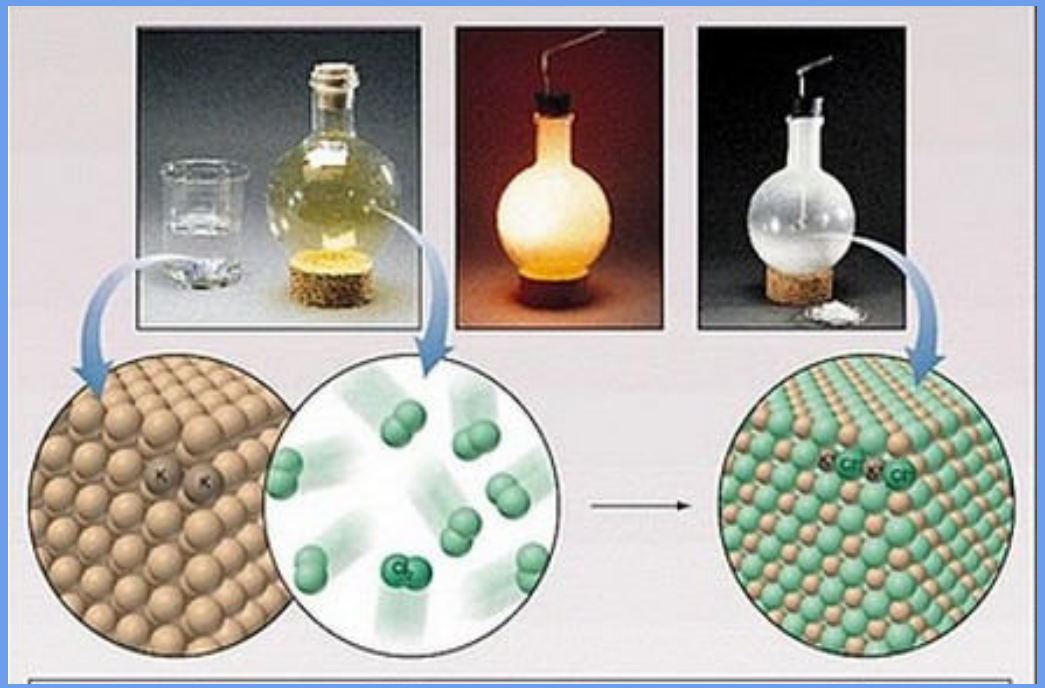
**Example#1:** $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$

**Example #2:** $Na_2O\ (aq) + H_2O\ (l) \rightarrow NaOH\ (aq)$

# Synthesis is like a marriage



# Synthesis Reaction



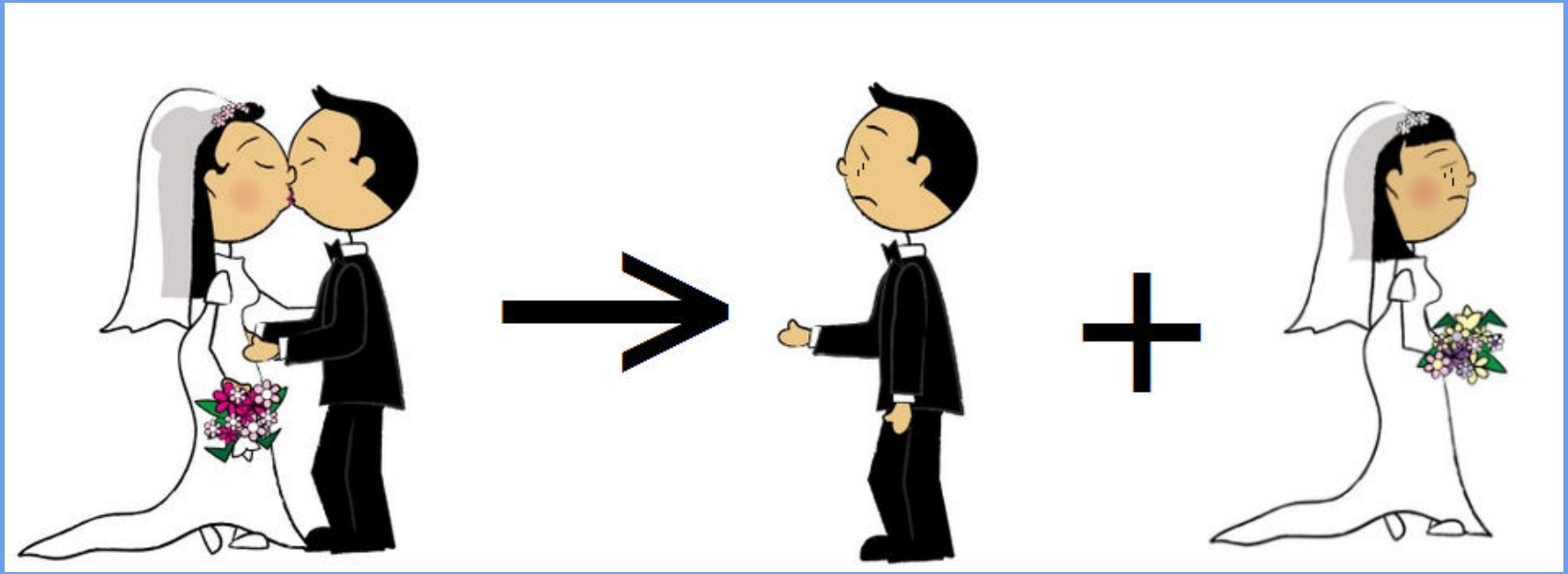
# Decomposition

A **Decomposition Reaction** **is** a reaction in which a single compound breaks down to form two or more simpler substances.

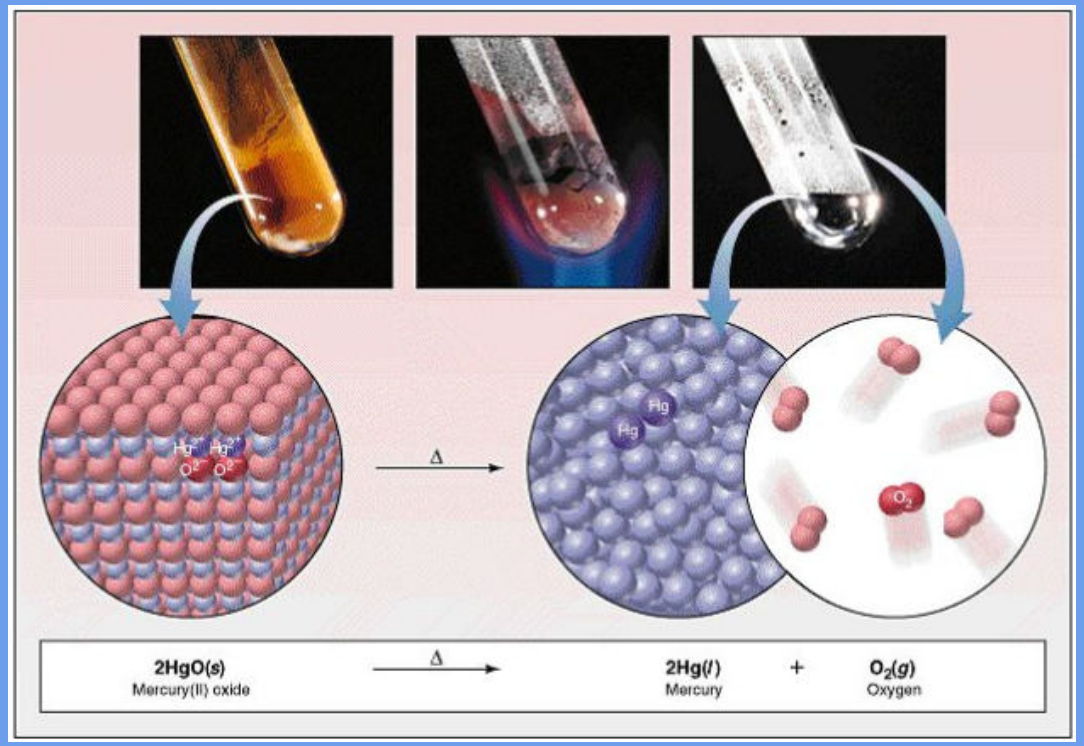
**Example#1:** $MgCl_2\ (aq) \rightarrow Mg\ (s) + Cl_2\ (g)$

**Example #2:** $Na_2CO_3\ (aq) \rightarrow Na_2O\ (aq) + CO_2\ (g)$

# Decomposition is like a divorce



# Decomposition Reaction



# Single Replacement

A **Single Replacement Reaction** **is** a reaction in which an element replaces one of the ions in an ionic compound.

A **metal** will replace a **cation**.

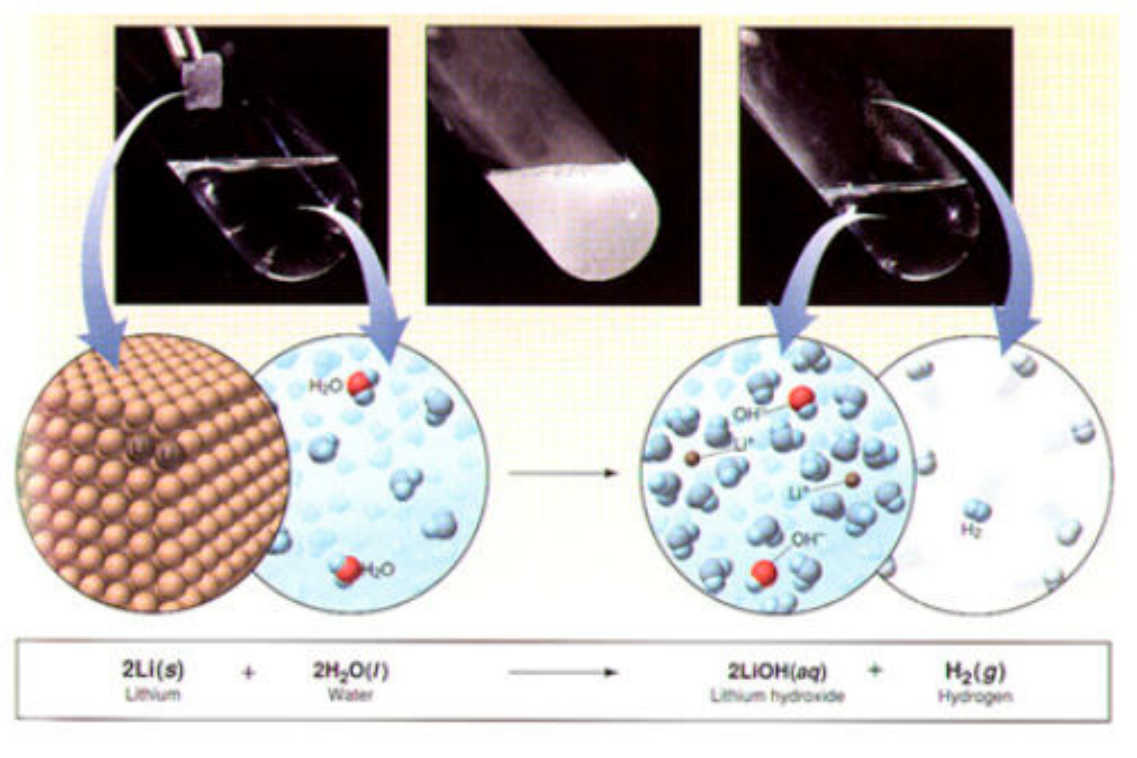
**Example: $Cu\ (s) + AgNO_3\ (aq) \rightarrow Ag\ (s) + Cu(NO_3)_2\ (aq)$**

A **nonmetal** will replace an **anion**.

**Example: $Cl_2\ (g) + NaBr\ (aq) \rightarrow NaCl\ (aq) + Br_2\ (g)$**

# A Single Replacement Reaction is like someone cutting in at a dance.

# Single Replacement Reaction



# Double Replacement

A **Double Replacement Reaction** **is** a reaction in which two ionic compounds exchange anions. If one of the products forms a solid, it's called a **precipitate**.

**Example #1:**

$$Al_2(SO_4)_3\ (aq) + Ca_3(PO_4)_2\ (aq) \rightarrow 2\ AlPO_4\ (aq) + 3\ CaSO_4\ (aq)$$

**Example #2:**

$$AgNO_3\ (aq) + NaCl\ (aq) \rightarrow AgCl\ (s) + NaNO_3\ (aq)$$

# Precipitates

A **precipitate** is an insoluble ionic compound that forms as the result of a double replacement reaction. All precipitates will be followed by the **(s)** symbol to show they are insoluble solids.

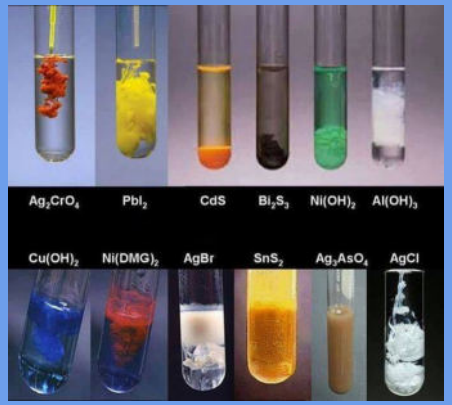
All compounds of Group 1 and $NH_4^+$ are soluble.

All nitrates are soluble.

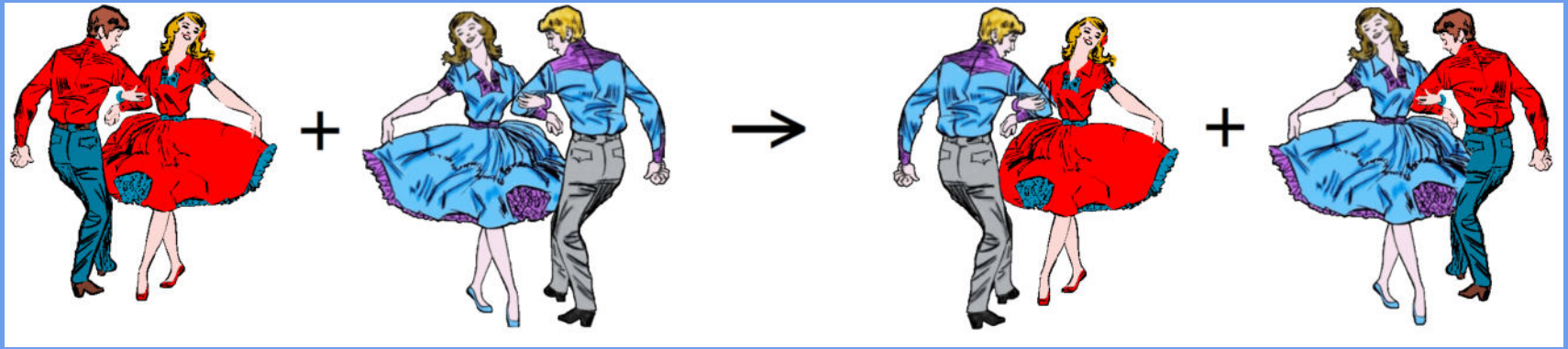
All halides, except those of $Ag^+$ and $Pb^{2+}$, are soluble.

All sulfates, except $Ca^+$, $Sr^+$, $Ba^{2+}$, $Hg_2^{2+}$ and $Pb^{2+}$, are soluble.

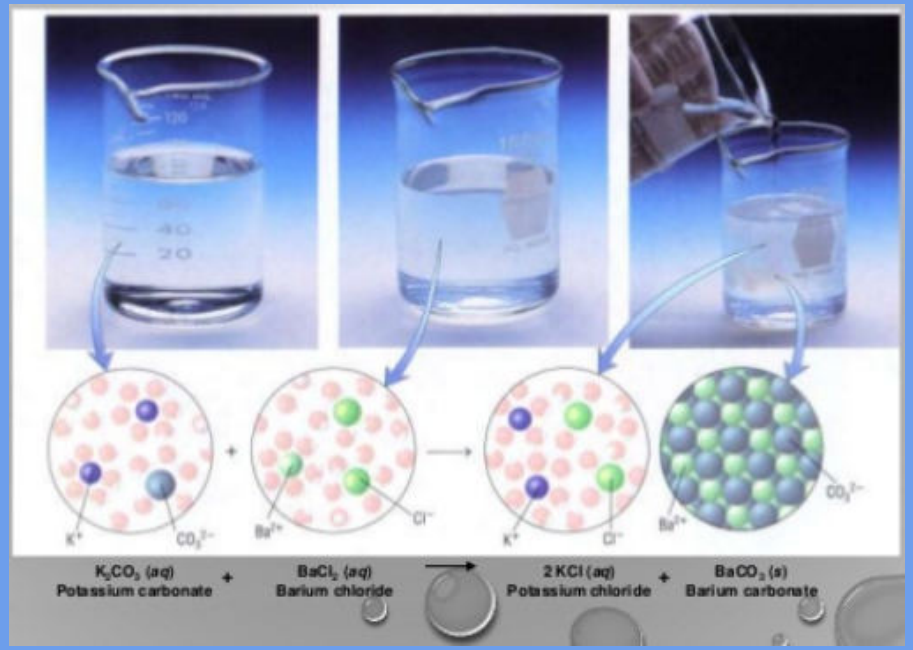
All carbonates, except those of Group 1 and $NH_4^+$, are insoluble.

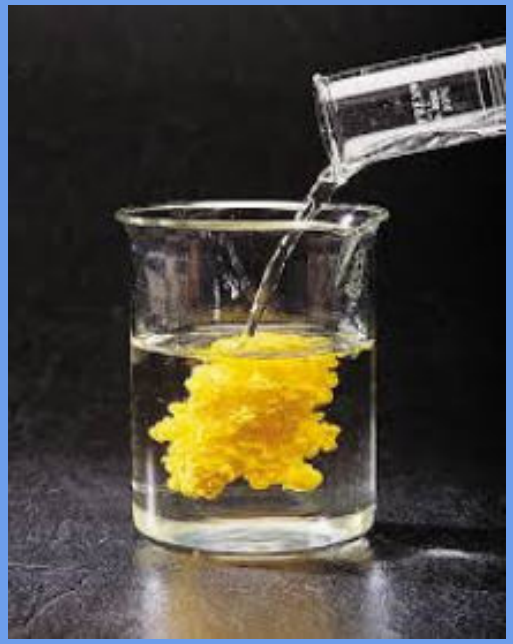


# A Double Replacement Reaction is like swapping partners at a square dance.



# Double Replacement Reaction



# Neutralization

A **Neutralization Reaction** **is** a special kind of double replacement reaction in which an acid reacts with a base to form an ionic salt and water.

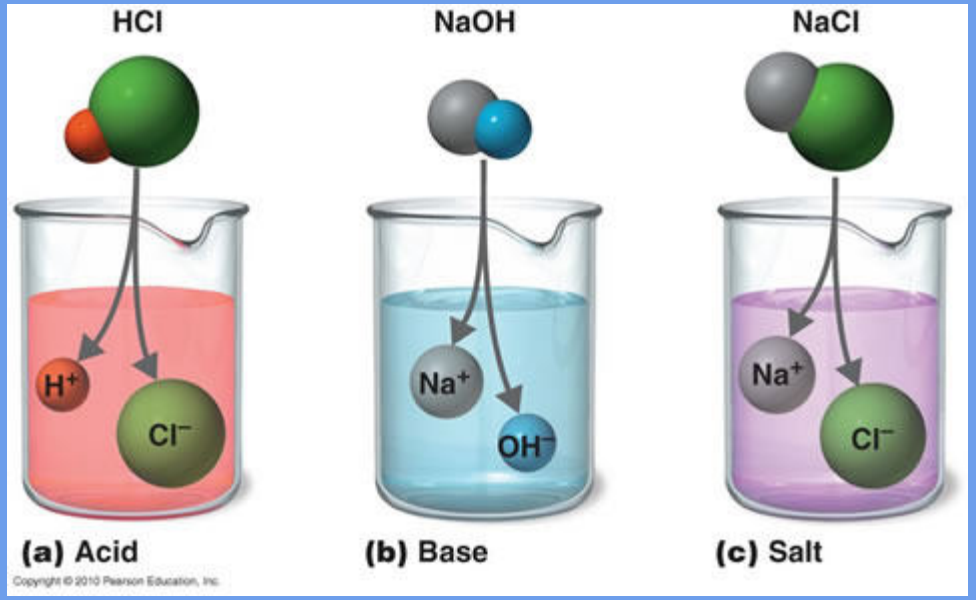
**Example #1:**

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$$

**Example #2:**

$$2\ H_3PO_4\ (aq) + 3\ Ca(OH)_2\ (aq) \rightarrow Ca_3(PO_4)_2 + 6\ H_2O\ (l)$$

# Neutralization Reaction



# Common Acids & Bases

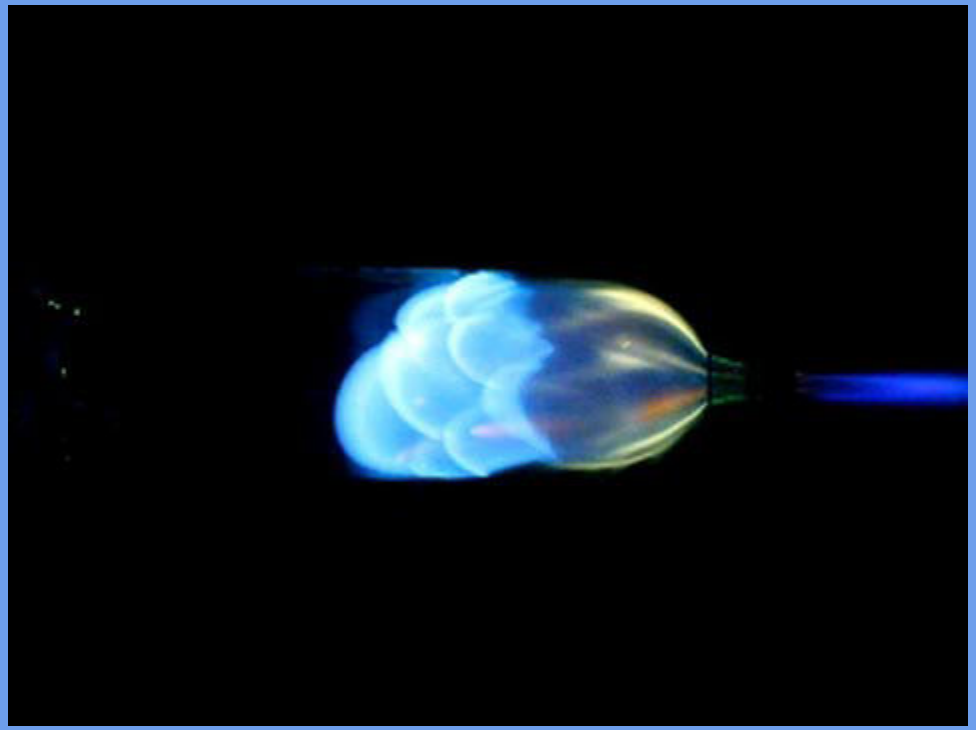
| | | | |
|---|---|---|---|
| $HCl$ | **hydrochloric acid** | $NaOH$ | **sodium hydroxide** |
| $HNO_3$ | **nitric acid** | $KOH$ | **potassium hydroxide** |
| $H_2SO_4$ | **sulfuric acid** | $Ca(OH)_2$ | **calcium hydroxide** |
| $H_3PO_4$ | **phosphoric acid** | $Al(OH)_3$ | **aluminum hydroxide** |

# Combustion

A **Combustion Reaction** is an oxidation reaction of an organic compound that releases heat. It occurs when a **hydrocarbon** burns in the presence of oxygen to form carbon dioxide and water.

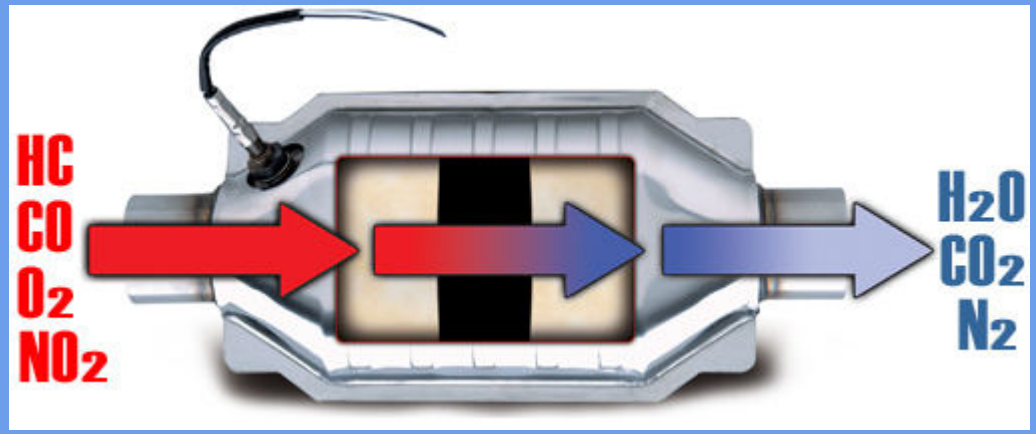
**Example:** $2\ C_4H_{10}\ (g) + 13\ O_2\ (g) \rightarrow 8\ CO_2\ (g) + 10\ H_2O\ (g)$

# Combustion Reaction



# Incomplete Combustion

**Incomplete Combustion** occurs when there is limited **oxygen**, and the reaction produces carbon monoxide or carbon instead of carbon dioxide.

# Incomplete Combustion