

Chemical Reactions: Introduction to Reaction Types

Introduction:

In this experiment, you will observe (on video and in lab) examples of the six basic types of chemical reactions which are described below. You will write your observations of the reactions. Based on those observations and the given word equations, you will write complete, balanced chemical equations to effectively communicate the chemistry of the reactions.

Six Reaction Types:

1. Combination: $A + B \rightarrow AB$

In a combination reaction, a new compound can be formed in one of three ways, by combining: **a)** 2 elements, **b)** 1 element and 1 binary compound (consisting of 2 elements), or **c)** 2 binary compounds. The following are examples of combination reactions:

The rusting of iron: $4\text{Fe (s)} + 3\text{O}_2 \text{ (g)} \rightarrow 2\text{Fe}_2\text{O}_3 \text{ (s)}$

The formation of one kind of acid rain: $\text{SO}_3 \text{ (g)} + \text{H}_2\text{O (l)} \rightarrow \text{H}_2\text{SO}_4 \text{ (aq)}$

2. Decomposition: $AB \rightarrow A + B$

In a decomposition reaction, a compound is broken down into two or more substances. In general, decomposition reactions occur when a solid compound is heated. This type of reaction almost always produces a gas. The following are examples of decomposition reactions:

Heating mercury (II) oxide produces oxygen gas: $2\text{HgO (s)} \rightarrow 2\text{Hg (l)} + \text{O}_2 \text{ (g)}$.

Leaving the cap off the carbonated soft drink bottle allows the carbonic acid to release carbon dioxide: $\text{H}_2\text{CO}_3 \text{ (aq)} \rightarrow \text{H}_2\text{O (l)} + \text{CO}_2 \text{ (g)}$.

3. Single Replacement: $A + BC \rightarrow AC + B$

In this type of reaction, a more “active metal” displaces another element in solution. These reactions can be further classified as a solid metal reacting with **a)** a metal ion solution, **b)** an acid solution, or **c)** water. An example of each is provided below:

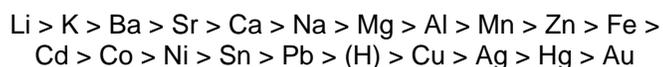
a) **When a solid metal reacts with a metal solution**, the solid metal’s ions go into solution while the metal ions originally in solution plate out onto the surface of solid metal—e.g., $\text{Zn (s)} + \text{CuSO}_4 \text{ (aq)} \rightarrow \text{ZnSO}_4 \text{ (aq)} + \text{Cu (s)}$.

b) **When a solid metal reacts with an acid**, the metal replaces hydrogen in the acid to produce hydrogen gas while the metal ion goes into solution with the anion from the acid—e.g., $\text{Mg (s)} + 2\text{HCl (aq)} \rightarrow \text{H}_2 \text{ (g)} + \text{MgCl}_2 \text{ (aq)}$.

c) **When a solid metal reacts with water**, the metal replaces hydrogen in the water to produce hydrogen gas while the metal ion goes into solution with hydroxide ion—e.g., $\text{Ca (s)} + 2 \text{H}_2\text{O (aq)} \rightarrow \text{H}_2 \text{ (g)} + \text{Ca(OH)}_2 \text{ (aq)}$.

To predict whether or not a single-replacement reaction will occur, we refer to the Activity Series for Metals (shown on the next page).

Activity Series for Metals



If a solid metal is “more active” – i.e., higher on the Activity Series – than the metal ion in solution or hydrogen for acids, the more active metal will displace the less active ion, so a reaction occurs. The more active metal goes into solution while the less active ion either plates out for a metal ion or bubbles out as a gas for hydrogen ion. If the solid metal is less active than the metal ion or hydrogen in the compound, then no reaction occurs. Only six metals (Li, K, Ba, Sr, Ca, and Na) – called “active metals” – react directly with water to produce hydrogen gas and a metal hydroxide solution. These active metals are the first six metals in the Activity Series.

4. Double Replacement/Precipitation: $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$

These reactions involve the mixing of two aqueous ionic compounds to produce a **precipitate**, an insoluble ionic compound. The products of a double-replacement/precipitation reaction can be predicted by switching the cations of the two compounds and using the Solubility Rules (see below) to determine if the compounds produced are soluble or insoluble.

Solubility Rules for Ionic Compounds in Water

The **compound is SOLUBLE** if it has:

1. Li^+ , Na^+ , K^+ , or NH_4^+ ion (**ALWAYS!**)
2. $\text{C}_2\text{H}_3\text{O}_2^-$, NO_3^- , ClO_4^-
3. Cl^- , Br^- , or I^- , **except compounds with Ag^+ , Pb^{+2} , Cu^{2+} , and Hg_2^{+2} are insoluble**
4. SO_4^{2-} **except compounds with Ag_2SO_4 , CaSO_4 , SrSO_4 , BaSO_4 , PbSO_4 , and Hg_2SO_4 are insoluble**

The **compound is INSOLUBLE** if it has:

5. CO_3^{2-} , CrO_4^{2-} , PO_4^{3-} , **except compounds with Li^+ , Na^+ , K^+ , NH_4^+ are soluble**
 6. S^{2-} , **except compounds with Li^+ , Na^+ , K^+ , NH_4^+ , Ca^{+2} , Sr^{+2} , Ba^{+2} are soluble**
 7. Hydroxide ion, OH^- , **except compounds with Li^+ , Na^+ , K^+ , NH_4^+ are soluble**
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Soluble ionic compounds will dissolve in water, so their physical states are indicated as aqueous, (aq), while insoluble ionic compounds will not dissolve in water, so their physical states are indicated as solid, (s). For a precipitation reaction to occur, at least one of the products must be insoluble; if both products are soluble, then no reaction occurs. The presence of a precipitate is observed in the lab as a cloudy mixture that results when two solutions are mixed. The following is an example of a double-replacement/precipitation reaction: $\text{Pb}(\text{NO}_3)_2 (\text{aq}) + \text{K}_2\text{CrO}_4 (\text{aq}) \rightarrow 2\text{KNO}_3 (\text{aq}) + \text{PbCrO}_4 (\text{s})$

5. Acid-Base Neutralization: $\text{HX} (\text{aq}) + \text{YOH} (\text{aq}) \rightarrow \text{H}_2\text{O} (\text{l}) + \text{XY} (\text{aq})$

These reactions occur between an acid and a base. In general, **acids** are compounds that **produce hydrogen ions (H^+)**, also called **protons**, when dissolved in water. The chemical formulas for acids are most often given with the H's at the beginning, so acids are usually easy to recognize. A few common acids are hydrochloric acid, $\text{HCl}(\text{aq})$, nitric acid, $\text{HNO}_3(\text{aq})$, and sulfuric acid, $\text{H}_2\text{SO}_4(\text{aq})$. **Bases** are compounds that **produce hydroxide ions (OH^-)** when dissolved in water. A few common bases are sodium hydroxide, NaOH , potassium hydroxide, KOH , calcium hydroxide, $\text{Ca}(\text{OH})_2$, and barium hydroxide, $\text{Ba}(\text{OH})_2$. Other types of bases contain carbonate ion, CO_3^{2-} , and hydrogen carbonate (or bicarbonate) ion, HCO_3^- .

The two types of acid-base neutralization reactions involve **a**) an acid reacting with a base (containing

the hydroxide ion (OH^-) to produce water and a salt (an ionic compound) or **b**) an acid reacting with a base containing carbonate (CO_3^{-2}) or hydrogen carbonate ion (HCO_3^-) to produce water, carbon dioxide gas, and a salt. An example of each is provided below:

a) When **an acid reacts with a base containing hydroxide ion (OH^-) to produce water and a salt**, the hydrogens from the acid combine with the hydroxide from the base to form water while the salt is formed by combining the cation from the base with the anion from the acid. The following is an example of this type of reaction: **$\text{HCl (aq)} + \text{NaOH (aq)} \rightarrow \text{H}_2\text{O (l)} + \text{NaCl (aq)}$** .

b) When **an acid reacts with a base containing carbonate (CO_3^{-2}) or hydrogen carbonate ion (HCO_3^-) to produce water, carbon dioxide gas, and a salt**, the hydrogens from the acid combine with the carbonate or hydrogen carbonate from the base to form water and carbon dioxide gas while the salt is formed by combining the cation from the base combining with the anion from the acid—e.g., **$\text{HCl (aq)} + \text{NaHCO}_3 \text{ (aq)} \rightarrow \text{H}_2\text{O (l)} + \text{CO}_2 \text{ (g)} + \text{NaCl (aq)}$** .

6. Combustion Reactions: Hydrocarbon (C_xH_y) + $\text{O}_2 \text{ (g)} \rightarrow \text{CO}_2 \text{ (g)} + \text{H}_2\text{O (g)}$

In a combustion reaction, a hydrocarbon (composed of C and H) or a hydrocarbon derivative (composed of C, H, and O) is burned in oxygen to produce carbon dioxide gas and steam. One example is the combustion of methane (natural gas): **$\text{CH}_4 \text{ (g)} + 2 \text{ O}_2 \text{ (g)} \rightarrow \text{CO}_2 \text{ (g)} + 2 \text{ H}_2\text{O (g)}$**