EXPERIMENT # 10
COMBINATION AND DECOMPOSITION REACTIONS

Purpose:

1. To identify the reactants and products in a combination and a decomposition reaction and to describe their properties.
2. To observe and describe a chemical event.
3. To write word equations and balanced chemical equations for chemical reactions studied in this experiment.

Introduction:

A chemical reaction involves a reorganization of atoms or molecules to form new substances. The starting materials are called reactants and new substances that form as a result of a chemical reaction are called products.

For example, by passing an electric current through water containing a compound that is able to conduct electricity, water can be decomposed into the elements it contains, hydrogen and oxygen. This process is commonly called the electrolysis of water and can be schematically represented by the following word equation:

$$Water \xrightarrow{electrolysis} Hydrogen + Oxygen$$ (Word Equation)

$$colorless\ liquid \rightarrow colorless\ gas + colorless\ gas$$

To simplify the writing of the names of the elements and compounds, symbols and formulas are used, and the resulting equation is referred to as a chemical equation.

$$H_2O \rightarrow H_2 + O_2$$ (Unbalanced Chemical Equation)

A given symbol used in a chemical equation represents 1 atom of that element. Thus H_2O represents a molecule of water which contains 2 atoms of H and 1 atom of O; H_2 represents a molecule of hydrogen containing 2 atoms of hydrogen, and O_2 represents a molecule of oxygen containing 2 atoms of oxygen.

The chemical equation should also take into account the principle of conservation of mass; that atoms are neither created nor destroyed in a chemical reaction. The process of accounting for all the atoms present in a chemical reaction by the use of **coefficients placed in front of the formulas** is called balancing the equation and results in what is commonly referred to as a balanced chemical equation.

$$2H_2O \rightarrow 2H_2 + O_2$$ (Balanced Chemical Equation)

Many simple equations may be balanced by Inspection but correct balancing requires attention and patience. There are 3 important rules which must be followed in balancing equations:

1. We cannot change the formula of a compound, but must instead use numerical coefficients to balance the equation.
2. The coefficients should be Integral numbers.
3. The coefficients should be the smallest set of Integers which provides the balanced equation.

In order to write the equations, we must know the symbols and formulas of all the elements and compounds present as reactants and compounds.

In this experiment, the formulas for some compounds are given and for the others the correct name of the compound will provide sufficient information from which the correct formula can be derived. You should also keep in mind that most of the common gases, such oxygen, nitrogen and hydrogen and some of the nonmetals such as iodine exist as diatomic molecules in their free or uncombined state and their formulas are written O_2, N_2, H_2 and I_2 respectively. Two of the simplest types of chemical reactions which will be performed and observed in this experiment are combination and decomposition reactions.

A **combination reaction** always has a single product. In a combination reaction, two or more substances (elements or compounds) react to form a single product. You may think of a combination reaction as putting together several parts to from a single product. The general form of a combination reaction is:

$$A + B \rightarrow AB \quad \text{(Combination Reaction)}$$

Specific examples:

$$2Na + Cl_2 \rightarrow 2NaCl$$

$$2CO + O_2 \rightarrow 2CO_2$$

A **decomposition reaction** produces several products (elements or simpler compounds) from the breakdown of a single compound. There is a single reactant and two or more products. The general form of a decomposition reaction is:

$$AB \rightarrow A + B \quad \text{(Decomposition Reaction)}$$

Specific examples:

$$2H_2O \rightarrow 2H_2 + O_2$$

$$2CaCO_3 \rightarrow CaO + CO_2$$

Procedure:

I. COMBINATION REACTIONS:

1. The reaction of **aluminum** with **iodine** (Instructor's Demonstration)
   - Prepare approximately 5 grams of Iodine flakes and an equal volume of aluminum powder on two different watch glasses.
   - Observe and describe the properties of the two elements.
   - Mix well the elements with a spatula in a crucible.
   - Place the crucible in a clay triangle supported by a ring under the fume hood.
   - Let a few drops of water fall on the mixture. (The water is added only to speed the reaction, but it does not experience a permanent change during the reaction and hence it is not a reactant. Such a substance is referred to as a catalyst.)
   - Observe and describe the chemical reaction and the properties of the product.

2. The reaction of **zinc** with **sulfur** (Instructor's Demonstration)
   - Prepare 4 grams of zinc powder and 2 grams of Flowers of sulfur on two different watch glasses.
   - Observe and describe the properties of the two elements.
   - Mix well the two elements in a mortar.
   - Make a small cone of the mixture on wire gauze.
   - Place the wire gauze with the mixture supported by a ring under the fume hood.
   - Holding the Bunsen burner by the base, play the tip of the flame on base of the cone.
   - Observe and describe the chemical reaction and the properties of the product.

3. The reaction of red **phosphorus** with **oxygen** **(Do this in the hood)**
   - Place a small spatula full of red phosphorus in a deflagrating spoon.
   - Observe and describe the appearance of the red phosphorus.
   - Ignite the red phosphorus with a Bunsen burner.
   - The white smoke that formed is not a gas but small particles of tetraphosphorus decaoxide (P_4O_{10}).
   - Observe and describe the chemical reaction and the properties of the product.

4. The reaction of **copper** with **oxygen**
    - Examine a clean piece of copper foil and describe it.
    - Hold one end of the copper foil with the crucible tongs and place the copper foil in the outer cone of the Bunsen burner flame for about one minute.
    - Let the copper foil cool and examine the foil using your spatula.
    - Scrape some of the scale formed on the surface or the metal and describe it. (This scale is copper (II) oxide and is the product of the reaction.)

5. The reaction of **magnesium** with **air**.
    - Obtain a two-inch length of magnesium ribbon.
    - Hold the metal with your crucible tongs and ignite it with your Bunsen flame. **WARNING:** *Do not look directly at the ribbon while it burns.*
    - Examine the material that remains after burning and describe it.
    - Magnesium combines with both the nitrogen and oxygen from air to form a mixture of magnesium oxide and magnesium nitride.
    - Write separate reactions for magnesium with **oxygen** and with magnesium with **nitrogen.**

II. DECOMPOSITION REACTIONS:

1. Electrolysis of **water** (Instructor's Demonstration)
    - Set up an electrolysis apparatus as shown in **Figure 1**.
    - Note that the water contains a little sulfuric acid to act as a catalyst.
    - Apply power and observe the activity at each electrode.
    - Collect the inverted test tube with the larger volume of gas as shown in **Figure 2**.
    - Thrust a glowing splint into this test tube of gas to identify it. (You should hear a faint 'popping' sound as hydrogen burns violently in air.)
    - Collect the inverted test tube with the smaller volume of gas as shown in **Figure 2**.
    - Thrust a glowing splint into this test tube of gas to identify it. (You should see the splint reignite as oxygen supports combustion and burns more violently in oxygen than in air.)

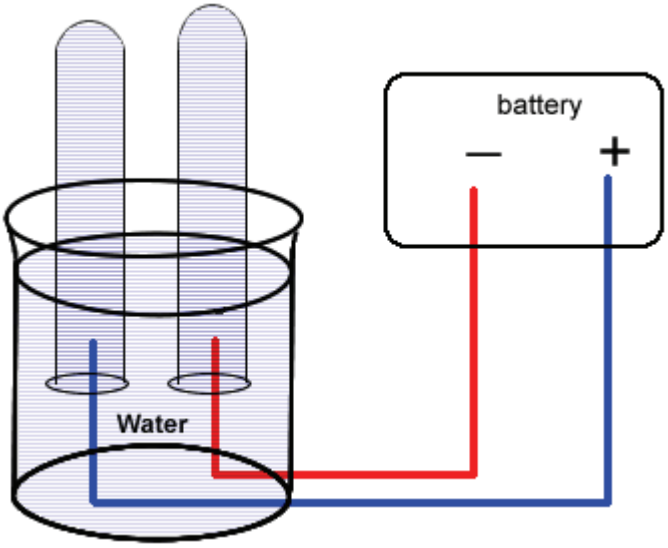

Figure 1

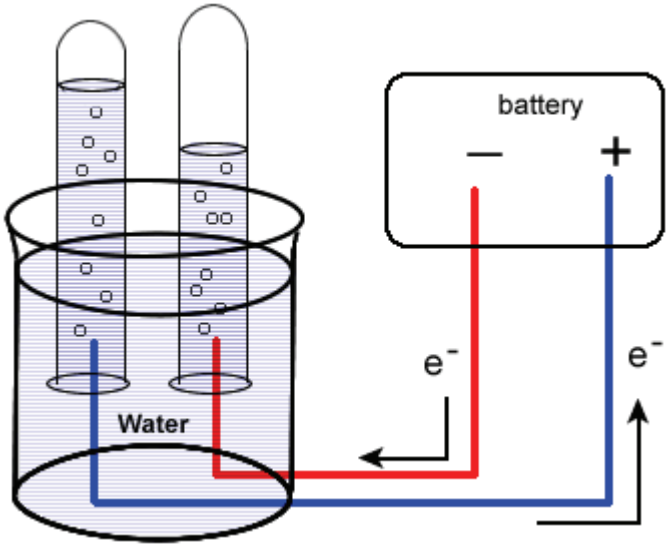

Figure 2

2. Decomposition of **mercury (II) oxide** (Instructor's Demonstration)
    - Place about one gram of mercury (II) oxide into a dry test tube.
    - Note the color of mercury (II) oxide.
    - Heat the test tube gently to about 200°C for a few minutes.
    - Note the color of the solid which forms in the test tube. This solid is mercury (I) oxide and is one of the intermediary products of the decomposition of mercury (II) oxide. The other product is a gas which may be identified by inserting a glowing split into the test tube while continuing to heat the tube. (You should see the splint reignite.)

- Continue heating the test tube and note the appearance of all deposit on the side of the test tube. Silvery droplets of liquid indicate the formation of mercury which is one of the products of the decomposition of black mercury (I) oxide now present in the test tube.
- One more time insert a glowing splint into the test tube while continuing to heat the test tube. (You should see the splint reignite.)

3. Decomposition of **sugar**
   - Regular household sugar is a chemical compound (sucrose) whose chemical formula is $C_{12}H_{22}O_{11}$.
   - Place about one gram of sugar in a test tubs and heat it gently with a Bunsen burner until a black sticky solid remains in the test tube.
   - When heating the test tube, keep it in an inclined position (almost horizontal), so to keep the mouth of the test tube relatively cool.
   - Note any deposition the colder, upper portion of the test tube and record your observations. Do not attempt to clean the test tube. When the test tube has cooled, discard it in the broken glass container.

4. Dehydration of **bluestone algicide** (root eater)
   - Bluestone algicide or root eater is a chemical compound used as an agricultural poison and as algicide in water purification. Its chemical name is copper (I) sulfate pentahydrate or $CuSO_4 \cdot 5H_2O$.
   - Place about two grams of medium sized crystals of copper (II) sulfate pentahydrate in a test tube.
   - Heat the sample of copper (II) sulfate pentahydrate holding the test tube at an angle, test tube mouth downward.
   - Note any deposit on the colder portion of the test tube and any change in appearance of the solid left in the test tube.

5. Decomposition of **malachite**
   - Malachite is a naturally occurring green mineral used for ornamental objects. The most familiar form of malachite is the green coating that forms on copper objects as the result of prolonged weathering. The chemical name of malachite is basic copper (II) carbonate, and its formula is $CuCO_3 \cdot Cu(OH)_2$.
   - Place about one gram of malachite in a clean dry test tube.
   - Heat the test tube at an angle (keep its upper part relatively cool) and when you notice that a change starts to take place, insert a burning wood splint into the upper, cooler part of the test tube.
   - Continue heating the test tube until the change is complete and note any deposit on the colder upper portion of the test tube.
   - The substance which remains in the test tube (the residue) is copper (II) oxide. The other products formed are carbon dioxide and water.

6. Decomposition of hydrated **iron (III) nitrate** **(Do this In the hood)**
   - Place a few small crystals of hydrated iron (III) nitrate, $Fe(NO_3)_3 \cdot 9H_2O$, in a clean, dry test tube and note the color of the crystals.
   - Heat gently at first and then more strongly. (Water vapor escapes during the initial heating.)
   - Continue heating until no further change takes place (a solid residue should remain in the test tube) and observe the color of the gas evolved. The gas we are able to see escaping is nitrogen dioxide. Oxygen gas is also liberated when the iron (III) nitrate decomposes. The solid residue which remains in the test tube is iron (III) oxide.

7. Decomposition of **ammonium dichromate**
   - In a clean, dry evaporating dish make a conical pile from about **one gram or less** of ammonium dichromate.
   - Make a fuse from a one cm piece of filter paper.
   - Wet the fuse with alcohol and then insert it into the cone of ammonium dichromate.
   - Light the fuse and observe the change which takes place.
   - The formula of the original ammonium dichromate is $(NH_4)_2Cr_2O_7$.
   - The residue remaining is chromium (III) oxide and the gases given off in the reaction are nitrogen and water vapor.

EXPERIMENT #10

Name:_____

Date:_____

Partner:_____

I. COMBINATION REACTIONS

1. The combination of **aluminum** with **iodine** (The answers are provided so you will know how to answer the remaining questions. The answers are *highlighted* below.)

   a. Evidence of reaction:

   A flash of light and blue smoke was produced.

   b. Write a word equation for this reaction and briefly describe both the reactants and the products *(show the state designations)*:

   aluminum (solid) + *iodine* (solid) → *aluminum iodide* (solid)

   silver powder *dark purple crystals* *purple smoke*
   solid *soil* *solid*

   c. Write a balanced chemical equation for the combination of aluminum and iodine:

$$2Al_{(s)} + 3I_{2(s)} \rightarrow 2AlI_{3(s)}$$

2. The combination of **zinc** with **sulfur**

   a. Evidence of reaction:

   b. Write a word equation for this reaction and briefly describe both the reactants and the products:

   _____ + _____ → _____

   c. Write a balanced chemical equation for the combination of zinc with sulfur *(show the state designations)*:

3. The reaction of red **phosphorus** with **oxygen**

   a. Evidence of reaction:

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ + _____ → _____

_____ _____ _____

_____ _____ _____

c. Write a balanced chemical equation for the combination of red phosphorus with oxygen *(show the state designations)*:

4. The reaction of **copper** with **oxygen**

a. Evidence of reaction:

_____

_____

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ + _____ → _____

_____ _____ _____

_____ _____ _____

c. Write a balanced chemical equation for the combination of copper with oxygen *(show the state designations)*:

5. The reaction of **magnesium** with **air**

a. Evidence of reaction:

_____

_____

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ + _____ → _____ + _____

_____ _____ _____ _____

_____ _____ _____ _____

c. Write a balanced chemical equation for the combination of magnesium with **oxygen** *(show the state designations)*:

d. Write a balanced chemical equation for the combination of magnesium with **nitrogen** *(show the state designations)*:

II. DECOMPOSITION REACTIONS

1. Electrolysis of **water**

   a. Describe the test used to identify the presence of hydrogen:

   b. Write a balanced chemical equation which represents the reaction used to identify the presence of hydrogen *(show the state designations)*:

   c. Describe the test used to identify the presence of oxygen:

   d. Write a balanced chemical equation which represents the reaction used to identify the presence of oxygen *(show the state designations)*:

2. Decomposition of **mercury (II) oxide** (2 steps). Step one, the decomposition of mercury (II) oxide to form mercury (I) oxide:

   a. Evidence of reaction:

   b. What happened to the burning splint when it was inserted into the test tube?

   c. What does this suggest about the gaseous product formed?

d. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____ + _____

_____ _____ _____

_____ _____ _____

e. Write a balanced chemical equation for the decomposition of mercury (II) oxide *(show the state designations)*:

Step two, the decomposition of **mercury (I) oxide**:

f. Evidence of reaction:

g. What happened to the burning splint when it was inserted into the test tube?

h. What does this suggest about the gaseous product formed?

i. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____ + _____

_____ _____ _____

_____ _____ _____

j. Write a balanced chemical equation for the decomposition of mercury (I) oxide *(show the state designations)*:

3. Decomposition of **sugar**

a. Evidence of reaction:

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____ + _____

_____ _____ _____

_____ _____ _____

c. Write a balanced chemical equation for the decomposition of sugar *(show the state designations)*:

4. Dehydration of **bluestone algicide** (copper (II) sulfate pentahydrate)

a. Evidence of reaction:

_____

_____

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____ + _____

_____ _____ _____

_____ _____ _____

c. Write a balanced chemical equation for the decomposition of copper (II) sulfate pentahydrate *(show the state designations)*:

5. Decomposition **malachite** (basic copper (II) carbonate or $CuCO_3 \cdot Cu(OH)_2$)

a. Evidence of reaction:

_____

_____

b. What happened to the burning splint when it was inserted into the test tube?

_____

_____

c. What does this suggest about the gaseous product formed?

_____

_____

d. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____+ _____ + _____

_____ _____ _____ _____

_____ _____ _____ _____

e. Write a balanced chemical equation for the decomposition of $CuCO_3 \cdot Cu(OH)_2$ *(show the state designations)*:

6. Decomposition of **hydrated (III) iron (III) nitrate** (**$Fe(NO_3)_3 \cdot 9H_2O$**)

a. Evidence of reaction:

_____

_____

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____+ _____ + _____ + _____

_____ _____ _____ _____ _____

_____ _____ _____ _____ _____

c. Write a balanced chemical equation for the decomposition of $Fe(NO_3)_3 \cdot 9H_2O$ *(show the state designations)*:

7. Decomposition of **ammonium dichromate** (**$(NH_4)_2Cr_2O_7$**)

a. Evidence of reaction:

_____

_____

b. Write a word equation for this reaction and briefly describe both the reactants and the products:

_____ → _____+ _____ + _____

_____ _____ _____ _____

_____ _____ _____ _____

c. Write a balanced chemical equation for the decomposition of $(NH_4)_2Cr_2O_7$ *(show the state designations)*: