## Objectives

- Observe chemical reactions
- Identify evidence of chemical change
- Complete and balance chemical equations observed reactions
- Classify the types of reactions observed

## Introduction

In this experiment, you will observe **chemical reactions**. Chemistry deals with the study of matter and its properties, its changes, and the energy associated with those changes. Properties are identifying characteristics of matter. Chemical properties are determined from the chemical reactions a substance undergoes.

In a chemical reaction, changes occur in the properties of the reactants as they become new substances. The formation of new substances is called a **chemical change**. Certain changes in properties can be used as evidence that a chemical change has taken place. On the other hand, if new chemicals are not formed, the change is only a **physical change**.

Water boiling into steam is a physical change because steam is the gaseous form of water ($H_2O$). However, if electricity is passed through water, it splits into its component elements, $H_2$ and $O_2$. While these are also gases, they are not the same chemical substance as steam. The electrolysis of water is a chemical change.

| Physical Changes | Chemical Changes |
|---|---|
| Change in state | Temperature increase* |
| Change in size | Formation of gas bubbles* |
| Tearing apart | Permanent color change |
| Breaking into pieces | Formation of precipitate |
| Grinding into powder | Odor change |
| Dissolving | Change in pH |

*without external heating

It is important to record proper descriptions when observing chemical changes. Colors are very important and should be recorded accurately. If a substance has no color and is transparent like water, the proper term is clear colorless.

When a chemical reaction occurs, the atoms in the *reactants* rearrange to produce new combinations of substances that are referred to as products. However, there is no change in the number of atoms initially present in the reactants as they rearrange to form the products. The total number of atoms going into the reaction have to be accounted for in the product. This is known as the **Law of Conservation of Matter**, which states that atoms of matter are not created or destroyed during a chemical reaction. This same law is used to balance chemical equations that use formulas to represent the chemical reactions. Only balanced equations can be used in chemical calculations.

In equations, the reactants are shown on the left side and products are shown on the right. An arrow between sides indicates that a chemical reaction takes place from left to right. Symbols written in parentheses can be used to indicate the physical states of substances in the equation.

$$(s) = \text{solid}, (l) = \text{liquid}, (g) = \text{gas}, (aq) = \text{aqueous (solution in water)}$$

## Gases Encountered in this Experiment

One of the most common evidences of chemical reaction is the formation of a gaseous product. To aid in identifying the gases encountered in this experiment, a few of their significant properties are given below:

1. **Oxygen** ($O_2$) is a colorless, odorless gas that supports combustion. A glowing woodn splint will brighten or burst into flames when inserted into a container of oxygen.
2. **Hydrogen** ($H_2$) is a colorless, odorless gas that burns in air. Hydrogen is less dense than air that can be captured in an inverted vessel, or in a test tube with a paper towel plug. A mixture of hydrogen and air in a test tube will burn with a "pop" when exposed to a lit wooden splint.
3. **Carbon dioxide** ($CO_2$) is a colorless, odorless gas that does not burn in air or support combustion. For that reason, it is used to extinguish fires. When dissolved in water, it forms a mildly acidic solution containing carbonic acid, $H_2CO_3(aq)$. A lit wooden splint will go out when inserted into a container of carbon dioxide.

## Classifying Chemical Reactions

In this experiment, you will learn to differentiate between five general types of chemical reactions. You will carry out certain representative reactions yourself, while other will be demonstrated by your instructor. From your observations, you will attempt to identify the products of each reaction and determine the type of reaction that has taken place. The types of reactions you will consider are listed and described below.

## Types of Chemical Reactions

1. **Combination Reactions**: These are reactions in which two or more substances combine to form a single product. While reactants may be elements or compounds, the product is always a single compound.

   2 Reactants 1 Product

$$\mathbf{A + B \longrightarrow AB}$$

   Example: $4\text{Al} + 3\text{O}_2 \longrightarrow 2\text{Al}_2\text{O}_3$

2. **Decomposition Reactions**: In these reactions, a single substance breaks down into two or more simpler substances. There is always just a single reactance (a compound) in a decomposition reaction.

1 Reactant 2 Products

$$AB \longrightarrow A + B$$

Example: $Na_2SO_4 \cdot 10H_2O \xrightarrow{\Delta} Na_2SO_4 + 10H_2O$

3. **Single Replacement Reactions**: These reactions involve an element in a compound being replaced (kicked out) by new element that is more reactive than the element being replaced. This type always has two reactants, an element and a compound. There are always two products, a different element and a different compound.

Element Compound Element Compound

$$A + BC \longrightarrow B + AC$$

Example: $Zn + 2AgNO_3 \longrightarrow 2Ag + Zn(NO_3)_2$

4. **Double Replacement Reactions**: In these reactions, the positive ions in two ionic compounds replace each other. These reactions usually occur in aqueous solution and result in the formation of a precipitate or a covalent compound such as a gas or water (which can be written as HOH to aid in balancing the equations).

2 Compounds 2 New Compounds

$$AB + CD \longrightarrow AD + CB$$

5. **Combustion Reactions**: These reactions occur when a substance reacts rapidly with a gas to liberate heat and light energy.

Fuel Oxygen Carbon Dioxide Water

$$C_xH_v + O_2 \longrightarrow xCO_2 + (^y/_2)H_2O$$

Example: $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

Example: Write a balanced equation representing the reaction of magnesium with oxygen gas to produce magnesium oxide.

Write the symbols for the elements Mg and $O_2$ on the left side of the arrow. (Recall that oxygen is diatomic.) These are called the reactants.

$$Mg + O_2 \longrightarrow$$

Next we add the formula for the product to the right of the arrow. Magnesium is in column IIA on the periodic table and has a +2 charge. Oxygen is in column VIA and has a charge of –2. They will combine in a 1:1 ratio to form MgO.

$$Mg + O_2 \longrightarrow MgO$$

A chemical equation must obey the Law of Conservation of Mass. Both sides must contain equal numbers of atoms of each element. Right now, there are two oxygen atoms on the left side of the equation and only one on the right. Unfortunately, the oxygen atom on the right is contained in the compound MgO. To add an oxygen on the right, the entire MgO unit must be added. Do this by placing a 2 in front of the MgO. This causes the Mg to become unbalanced. To balance Mg, place a 2 in front of the Mg on the left side.

$$2Mg + O_2 \longrightarrow 2MgO$$

Now the equation is balanced.



Example: Write the equation for the reaction of hydrochloric acid and calcium metal.

| | | |
|---|---|---|
| 1st step | Skeleton equation | $HCl + Ca \rightarrow CaCl + H$ |
| 2nd step | Write correct compounds | $HCl + Ca \rightarrow CaCl_2 + H_2$ |
| 3rd step | Balance left and right | $2HCl + Ca \rightarrow CaCl_2 + H_2$ |

## *Procedure*

Record your observations in the Data Table and determine the type of reaction in each part. You may do these in any order since they are each independent experiments. The test tubes don't have to be dry except in Reaction III, as requested. Waste liquids should be collected in the Waste beaker and then poured into the waste container in the fume hood. Solids should be thrown into the trash. If liquids and solids are in the same container, carefully pour the liquid off into the Waste container and shake the solids into the trash. Clean the glassware after completing each part.

### Reaction I – Zinc Metal and Copper(II) Sulfate Solution

1. Place ~1 mL (~1/2 inch) of 0.1 M $CuSO_4$(*aq*) (copper(II) sulfate solution) into a small test tube (~4" in size).
2. Add a small piece of zinc metal to the solution.
3. Let it sit for 10 to 15 min, then record your observations.

### Reaction II – Lead(II) Nitrate and Potassium Iodide Solutions

4. Put 1 mL (20 drops) of 0.1 M $Pb(NO_3)_2$(*aq*) (lead(II) nitrate solution) into a small (4") test tube.

> *Caution: Lead is poisonous!*

5. Add 5–10 drops of 0.1 M KI(aq) (potassium iodide solution) to the same test tube and mix.
6. Record your observations.

### Reaction III – Action of Heat on Copper(II) Sulfate Pentahydrate

7. Add about a pea-sized amount of solid $CuSO_4•5H_2O$ to a small, dry test tube.
8. Hold the test tube sideways near the top with a test tube holder, with the open end angled up a little.
9. Using proper techniques, thoroughly heat the end with the $CuSO_4$ over a Bunsen burner for about half a minute.
10. Allow it to cool on a ceramic hot pad for a few minutes and record your observations, including the presence of any condensate (fog or dew) in the upper part of the test tube.
11. The solids are water soluble and can be rinsed down the drain. Watch as you add the first rinse water. Did a color change occur again?

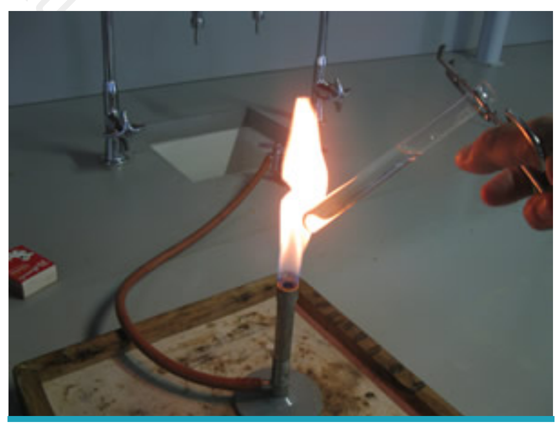

Figure 1 Heating a Test Tube placeholder art

> *Caution: Do not point the mouth of the test tube toward you or anyone else!*

## Reaction IV – Magnesium Ribbon and Oxygen

*Complete this part in the fume hood!*

12. In the fume hood, turn the blower on, but leave the light off.
13. Obtain a small strip of magnesium metal ribbon from your tray.
14. Using crucible tongs or a test tube holder, hold the tip of the magnesium ribbon in the hottest part of a Bunsen burner flame. As soon as the magnesium ignites, look away to avoid eye damage.
15. When the reaction is complete, examine the residue and record your observations.
16. Clean up the mess (trash).

## Reaction V – Magnesium Turnings and Hydrochloric Acid

17. Place about half an inch of 3.0 M hydrochloric acid (HCl) in a small to medium size test tube.
18. Prepare a small wad of dry paper towel the right size to snugly stopper the test tube.

*Caution: Hydrochloric acid is corrosive!*

19. With the test tube in the test tube rack, add 3-4 pieces of magnesium metal turnings (little curls) to the HCl in the test tube.
20. Immediately plug the test tube with the paper towel wad. This keeps the gas inside until you are ready to test it.
21. Record your observations.
22. Light a wooden splint and hold it next to the top of the test tube.
23. Remove the paper towel plug and immediately move the lit end of the splint into the top of the test tube. Do not dip the splint into the solution.
24. Record your additional observations.



## Reaction VI – Reaction of Sodium Hydrogen Carbonate with Hydrochloric Acid

25. Add about 4 mL of 3 M HCl to a 50-mL beaker (not larger).
26. Obtain a watch glass from your basket. Add a small scoop of solid $NaHCO_3$ (sodium hydrogen carbonate) to the beaker and immediately cover it with the watch glass. This will contain the gas until you are ready to test it.
27. Record your observations.
28. As soon as the reaction settles down: light a wooden splint, remove the watch glass, and lower the lit end of the splint down into the gas in the beaker. DO NOT dip the splint into the solution.

29. Record what happened to the flame.

## Reaction VII – Calcium Metal and Water

30. Fill a medium to large size test tube about one fourth (1/4) full of water and place the test tube in your test tube rack.
31. Using forceps, take a small piece of calcium metal from the container on your tray. Make sure it's hard and metallic gray and not white and crumbly.
32. Add it to the water and allow it to stand for a few minutes. (If it starts to froth up to the top of the test tube, try testing the froth with a lit wooden splint.)
33. When the reaction subsides, test the mixture with a piece of red litmus paper or pH paper.
34. Record all of your observations.

> *Caution: The white material is calcium hydroxide, which can damage the skin.*

Name________________________________________________ Section_____________

Partner______________________________________________ Date______________

## Types of Chemical Reactions Report Sheet

Record your observations for each chemical reaction in the table.

| Reaction | Observations |
|---|---|
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