Experiment

12 Types of Chemical Reactions

Text reference:
Chapter 7, pp. 151–161

Introduction

In this experiment, you will learn to differentiate among five general types of chemical reactions. You will carry out certain representative reactions yourself, while others will be demonstrated by your teacher. From your observations you will attempt to identify the products of each reaction and to determine the type of reaction that has taken place. The types of reaction you will consider are the following: combination reactions, decomposition reactions, single-replacement reactions, double-replacement reactions, and combustion reactions. The majority of common chemical reactions can be classified as belonging to one of these categories. A brief description of each reaction type is provided below.

Combination reactions are reactions in which two or more substances combine to form a single product. The reactants may be elements or compounds, but the product is always a single compound. An example of a combination reaction is the reaction of sulfur trioxide and water to form sulfuric acid.

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Decomposition reactions are reactions in which a single substance breaks down into two or more simpler substances. There is always just a single reactant in a decomposition reaction. An example of a decomposition reaction is the breakdown of calcium carbonate upon heating.

$$CaCO_3(s) + \text{heat} \rightarrow CaO(s) + CO_2(g)$$

Single-replacement reactions are reactions in which an element within a compound is displaced by a separate element. This type of reaction always has two reactants, one of which is always an element. An example of a single-replacement reaction is the reaction of zinc metal with hydrochloric acid.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Double-replacement reactions are reactions in which a positive ion from one ionic compound exchanges with the positive ion of another ionic compound. These reactions typically occur in aqueous solution and result in either the formation of a precipitate, the production of a gas, or the formation of a molecular compound such as water. An example of a double-replacement reaction is the reaction that occurs between aqueous silver nitrate and aqueous sodium chloride. A precipitate of solid silver chloride is formed in this reaction.

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

Combustion reactions are reactions in which an element or a compound reacts rapidly with oxygen gas to liberate heat and light energy. Commonly, the compounds combining with oxygen in these reactions are hydrocarbons, compounds consisting wholly of hydrogen and carbon.

The well-known combustible fuels kerosene and gasoline, for instance, are hydrocarbon mixtures. The complete combustion of a hydrocarbon yields carbon dioxide and water as the reaction products. If insufficient oxygen is available, combustion will not be complete and carbon monoxide and elemental carbon may be obtained as additional products of the reaction. An example of a combustion reaction is the burning of methane gas to give water (in the form of steam), carbon dioxide, heat, and light.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + \text{heat} + \text{light}$$

Objectives

1. To observe chemical reactions in order to determine the reaction type.
2. To write balanced chemical equations for each reaction.

Equipment

Student Experiment

- 2 safety goggles
- 2 small test tubes
- 2 medium test tubes
- 1 large test tube
- 1 test tube holder
- 1 gas burner
- 1 ring stand
- 1 utility clamp
- 1 dropper pipet
- 1 crucible tongs

Teacher Demonstration

- 1 electrolysis apparatus
- 1 rubber stopper, 1-holed
- 1 glass tube, 25-cm length, bent at 90° angle in center

Materials

Student Experiment

- iron filings, Fe
- copper(II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$ [T]
- magnesium, turnings, Mg [F]
- 0.1*M* copper(II) sulfate, $CuSO_4$ [T]
- 0.1*M* lead(II) nitrate, $Pb(NO_3)_2$ [T]
- 0.1*M* potassium iodide, KI [T]
- 3% hydrogen peroxide, H_2O_2
- 6*M* hydrochloric acid, HCl [C] [T]
- wood splint
- matches

Teacher Demonstration

- sodium bicarbonate, $NaHCO_3$
- limewater, saturated solution of calcium oxide, CaO [I]
- 3% sulfuric acid, H_2SO_4 [C] [T]
- wood splints

Safety

1. Wear safety goggles.
2. Hydrochloric acid is corrosive and can cause severe injury. If you spill acid on yourself, immediately flush the affected area with water for

2-3 minutes and notify the teacher. If acid should get into your eyes, begin flushing your eyes with water immediately and continue doing so for at least 20 minutes. If there is an eye wash apparatus with continuous running water in the laboratory, use it.

If acid is spilled on the laboratory bench or on the floor, neutralize the spill with solid sodium bicarbonate, $NaHCO_3$, before wiping it up with sponges or paper towels. The acid will be neutralized when bubbles of gas no longer form after addition of sodium bicarbonate. If you need to dispose of a small quantity of acid, neutralize the sample with sodium bicarbonate before pouring it down the drain.

3. Copper(II) sulfate is an irritant. Avoid skin contact with this chemical. Wash your hands thoroughly after use.

4. Lead and copper compounds are poisonous, bioaccumulative, and are water pollution hazards. However, the small quantities used in this experiment will not contribute significantly to environmental pollution. Use as little of these compounds as practical and rinse small surplus amounts down the drain. Wash your hands thoroughly after use of these compounds.

Procedure

As you perform the experiment, record your observations in Table 12·1, found at the end of the Procedure section.

Part A. Student Experiments

1. Iron metal and copper(II) sulfate solution. Fill a small test tube halfway with copper(II) sulfate solution. Add 2 g (about one-fourth of a small test tube) of iron filings to the solution. Observe the reaction after 5 minutes. Record your observations in Table 12·1. Discard the solid contents of the test tube into the waste container provided. The liquid portion can be poured into the sink.

2. Lead(II) nitrate and potassium iodide solutions. Put 2 mL of lead(II) nitrate solution in the test tube. Add 5 to 10 drops of potassium iodide solution. Record your observations. Discard the contents of the test tube into the sink and rinse the tube with water.

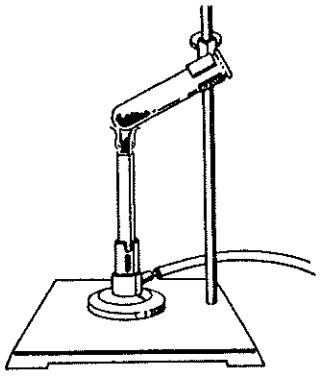

Figure 12·1

3. Action of heat on copper(II) sulfate crystals. Put one or two pea-sized crystals of copper(II) sulfate pentahydrate into a large, dry test tube.

CAUTION: *Do not point the open mouth of the tube at yourself or anyone else.* (See Figure 12·1.) Make observations as you *gently* heat the crystals in a burner flame for approximately 30 seconds. Heat only the bottom of the tube, where the crystals are located. When the test tube has cooled, discard its contents into the waste container provided.

4. Magnesium metal and hydrochloric acid. Fill one small test tube halfway with 3*M* hydrochloric acid. **CAUTION:** *Hydrochloric acid is corrosive.* Place the test tube in a test tube rack. Put one magnesium piece into the acid solution. If you observe a gas forming, test for its identity by holding a burning wood splint at the mouth of the test tube. Do not put the splint into the solution. Record your observations. Decant the liquid portion of the test tube contents into the sink; discard the solid into the waste container provided.

Put test tube over reaction to collect gas

Table 12·1 Observations

	Reaction	Observations		Reaction Type
1.	Fe and $CuSO_4$	Day 1 (give color of solid and liquid)	Day 2	
2.	$Pb(NO_3)_2$ and KI			
3.	$CuSO_4 \cdot 5H_2O$ and heat	note color change of crystal and anything else on inside of test tube		
4.	Mg and HCl		Gas – How identified –	
5.	H_2O_2		Gas – How identified	
6.	electrolysis of H_2O		Gas – How identified	
7.	$NaHCO_3$ and heat		Gas – How identified	

5. Action on hydrogen peroxide. Add of the 3% hydrogen peroxide solution to a large test tube. (about ¼). Using the wooden splint, add a tiny amount of MnO_2. This is a catalyst to speed up the reaction, it is not part of balanced equation. If you observe a gas forming, test for its identity by inserting a glowing wood splint into the mouth of the test tube. Do not put the splint into the solution. Record your observations. Rinse the contents of the test tube into the sink.

Part B. Teacher Demonstrations

6. Action of electricity on water (Electrolysis). Water can be broken down to its component elements by passing electricity through it. This process is called *electrolysis*. The apparatus used for this demonstration will be explained by your teacher (see Figure 12·2). Make observations of the reaction at several intervals during a period of 5–10 minutes.

7. Action of heat on sodium bicarbonate. Solid sodium bicarbonate will be heated strongly in a test tube for 2 minutes. The gas that is given off will be tested by exposing it to a burning splint, and by bubbling it through limewater (a saturated solution of calcium oxide, CaO). Record your observations of these tests.

Data Analysis

1. Decide which type of reaction is represented by each reaction observed in this experiment. Record your answers in Table 12·1.

Name _____ Class _____ Date _____

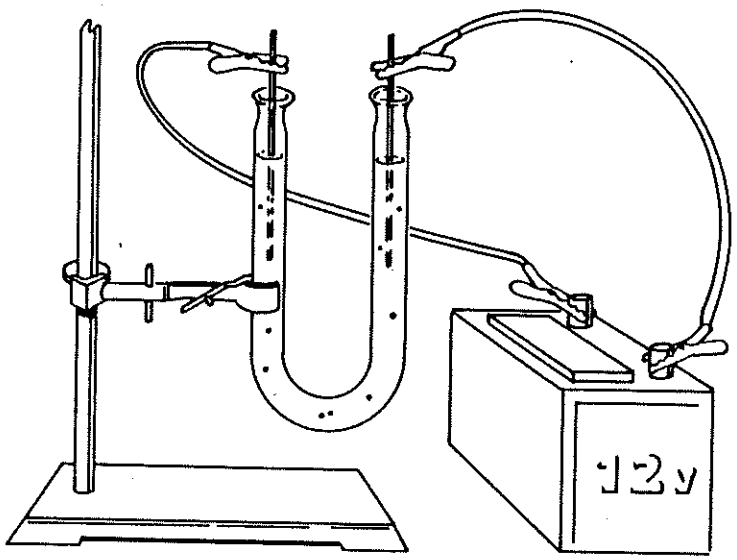

Figure 12·2

2. Write a balanced chemical equation for each reaction observed.

1) _____

2) _____

3) _____

4) _____

5) _____

6) _____

7) _____

3. No combination reactions were described in the Procedure section for this experiment. Give an example of a combination reaction from an earlier experiment. Write the balanced equation for the reaction. (Use any equation from a previous worksheet)

4. Although no combustion reactions were described in the Procedure section, one combustion reaction did occur in the course of this experiment. What was this reaction? Write its balanced equation below. (see page 86)

Results and Conclusions

1. Describe in your own words the five types of chemical reactions that were discussed in the introduction to this experiment. Explain how each type of reaction can be identified.

2. List the 3 ways that were used in this experiment to identify gases. Be specific, how do you recognize oxygen, hydrogen and carbon dioxide?