

Classifying Chemical Reactions

Objectives: To perform a series of chemical reactions; to write balanced chemical equations for these reactions based on observations; to classify each reaction as one of four general types

Materials: Magnesium ribbon; 0.10 M HCl; 0.10 M CuSO₄; 0.10 M NaOH; CuSO₄·5H₂O; steel wool; (NH₄)₂CO₃; litmus paper

Equipment: Bunsen burner; 15 x 100 mm test tubes; spatula; stirring rod; watch glass; test tube holder

Safety: HCl and NaOH solutions are caustic and corrosive, and can cause burns. Handle hot glassware with tongs or test tube holder. Hydrogen gas is explosive, so avoid open flames for those portions of the lab that produce hydrogen. Ammonia fumes are toxic and irritating—work in a fume hood for those portions of the lab that produce ammonia vapors. Safety goggles should be worn at all times.

Waste Disposal: All waste materials from the copper reactions should be placed in the inorganic waste container. All other materials may be flushed down the drain with plenty of tap water.

Review: You should be familiar with techniques for measuring solution volumes, understand the difference between elements and compounds, and know how to use equations to represent chemical reactions.

INTRODUCTION

Chemistry is defined as the study of matter and the changes that matter undergoes. These changes are represented by chemical reactions or equations that indicate the starting materials, or **reactants**, and the resulting materials, or **products**. Reaction equations also indicate the phases of the reactants and products as solid (s), liquid (l), gas (g), or aqueous solution (aq).

There are thousands of chemical reactions, but we can sort these reactions into general classifications based on the nature of the transformations involved, or similarities in the types of products that are formed. The classification scheme presented in this lab sorts reactions into four types, which are described in the following sections.

Type I: Combination or Synthesis Reactions

A **combination** or **synthesis** reaction occurs when two substances are combined to form a new substance. The reactants are often substances in their elemental form. A generalized combination reaction is shown in Equation 1, and a specific example is provided in Equation 2.



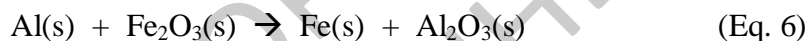
Type II: Decomposition Reactions

A **decomposition** reaction occurs when one compound breaks down into two or more products. The products may be elements or compounds. A generalized decomposition reaction is shown in Equation 3, while a specific example is provided in Equation 4.



Type III: Single Displacement Reactions

A **single displacement** reaction occurs when one element replaces another element in a compound to form a new compound. Equation 5 shows a generalized single displacement reaction, and a specific example is provided in Equation 6.



Type IV: Double Displacement Reactions

In a **double displacement** reaction elements in two different compounds switch places to form two new compounds. A generalized double displacement reaction is shown in Equation 7, and a specific example is provided in Equation 8.

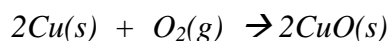


Double displacement reactions are also characterized by the nature of the products formed. Typically, one of the products is a solid, a gas, or water. When a solid product is formed, such as in Equation 8, the solid is called a **precipitate**.

Most chemical reactions can be identified by the formation of solids or gases, or by a color change in the solution. Reactions are also characterized by the exchange of heat with their surroundings. **Exothermic** reactions release heat to their surroundings, while **endothermic** reactions absorb heat from their surroundings. Therefore, a change in temperature in the reaction system can also be an indication that a chemical reaction has occurred.

Example: When elemental copper is heated in a crucible a crumbly black solid is formed. How would you classify this reaction? Write a balanced chemical equation representing this reaction.

Solution: We started with a pure element (Cu) and a new substance was formed. We can assume that the copper was converted into a compound by combining with a component of air. Therefore, this is a combination or synthesis reaction. If we assume that the copper reacted with oxygen from the air, then the new substance would be copper oxide. We can represent this reaction as:



In this exercise we will observe several chemical reactions. Based on your observations, you will classify each of the reactions and write chemical equations for these reactions. The names and chemical formulas of the substances used in this exercise are summarized in Table 1.

Table 1. Names and formulas for substances involved in this experiment

<i>Chemical Name</i>	<i>Chemical Formula</i>
Ammonia	NH ₃
Ammonium carbonate	(NH ₄) ₂ CO ₃
Carbon dioxide	CO ₂
Copper	Cu
Copper(II) sulfate	CuSO ₄
Copper (II) sulfate pentahydrate	CuSO ₄ ·5H ₂ O
Hydrochloric acid	HCl
Iron	Fe
Iron(II) sulfate	FeSO ₄
Magnesium	Mg
Sodium hydroxide	NaOH

Pre-Lab Questions

1. Describe the hazards associated with each of the materials listed below, and the precautions recommended in this lab.

a) Heated $(\text{NH}_4)_2\text{CO}_3$

b) 0.10 M HCl

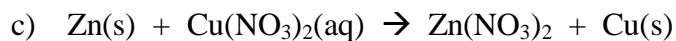
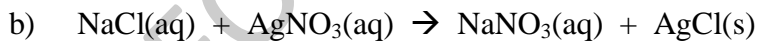
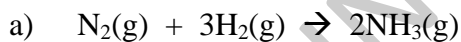
c) 0.10 M NaOH

2. Distinguish between:

a) Exothermic and endothermic reactions

b) Single and double displacement reactions

3. Identify the general reaction type for each of the following reactions:



PROCEDURE

Observe all safety precautions when working with reagents and performing reactions.

I. Reacting Mg with 0.10 M HCl

Caution: HCl solution is corrosive! The reaction of Mg with HCl produces a gas that is flammable. Be sure there are no Bunsen burner flames in the area where you are performing this reaction.

1. Transfer a 0.5 cm piece of Mg ribbon to a clean test tube.
2. Record your descriptions of the Mg ribbon and the HCl solution on your Data Sheet.
3. Holding the bottom of the test tube containing the Mg ribbon, transfer 2 mL of 0.10 M HCl to the test tube. Observe the reaction mixture for evidence of a chemical reaction. Record all observations on your Data Sheet.
4. Dispose of the reaction mixture down the sink. Rinse and dry your test tube.

II. Reacting 0.10 M CuSO₄ with 0.10 M NaOH

Caution: CuSO₄ solutions are toxic. NaOH solutions are toxic and caustic.

5. Record your descriptions of 0.10 M CuSO₄ and 0.10 M NaOH solutions on your Data Sheet.
6. Transfer 10 drops of the 0.10 M CuSO₄ solution to a clean, dry test tube. Add 2 drops of 0.10 M NaOH solution and mix thoroughly. Observe the reaction mixture for evidence of a chemical reaction. Record your observations on your Data Sheet.
7. Dispose of your reaction mixtures in the waste beaker provided by the lab TA.

III. Reacting CuSO₄·5H₂O with heat and water

8. Record your description of the CuSO₄·5H₂O on your Data Sheet.
9. Transfer enough CuSO₄·5H₂O to fill the end of a micro-spatula into a clean, dry test tube.
10. Use a test tube holder to grasp the test tube. Heat the test tube strongly with a Bunsen burner until you notice a change in the appearance of the solid. Be careful keep the test tube pointed away from yourself or other students while heating.
11. Allow the test tube and contents to cool. Record your observations on your Data Sheet.
12. Add 1 drop of distilled water to the solid residue in the test tube. Record your description of the solid after addition of water.
13. Dispose of your reaction mixture as you did in Part II.

IV. Reacting 0.10 M CuSO₄ with steel wool (Fe)

14. Record your description of the steel wool and 0.10 M CuSO₄ solution on your Data Sheet.

15. Obtain a small piece of steel wool about the size of a pencil eraser. Use a glass rod to slide the steel wool to the bottom of a clean, dry test tube.
16. Add 2 mL of 0.10 M CuSO_4 solution to the test tube. Stir the contents of the test tube with your stirring rod for 2-3 min.
17. Observe the appearance of the steel wool and the CuSO_4 solution. Record your observations on your Data Sheet.
18. Remove the remaining steel wool and dispose of in the trash can. Dispose of your reaction solution as indicated in Parts II and III.

V. Heating $(\text{NH}_4)\text{CO}_3$

Caution: The vapors created by heating $(\text{NH}_4)\text{CO}_3$ are toxic and irritating. The heating of this substance should be performed in the fume hood.

19. Transfer an amount of $(\text{NH}_4)_2\text{CO}_3$ that fills the end of a micro-spatula to a clean, dry test tube. Record your observations of the appearance of the sample on your Data Sheet.
20. Moisten a piece of litmus paper with 1-2 drops of distilled water and place on a watch glass. The wet litmus paper should adhere to the surface of the watch glass. Record the appearance of the litmus paper on your Data Sheet.
21. In the fume hood, strongly heat the bottom of the test tube containing your sample. Observe both the solid and the inner walls near the open end of the test tube.
22. Holding the test tube about 6 in. from your face, carefully waft the fumes from the end of the test tube toward your nose (see Figure 1.) **DO NOT HOLD THE TEST TUBE DIRECTLY UNDER YOUR NOSE!** Note the odor of the vapors, and record your observations on your Data Sheet.
23. Invert the watch glass and position it so that the dampened litmus paper covers the open end of the test tube. Observe the color of the litmus paper. Record your observations on the Data Sheet.
24. Dispose of the litmus paper and the residue in the test tube in the trash can.



Figure 1. Proper technique for detecting vapors/odors from test tube.

Data Sheet

I. Reacting Mg with 0.10 M HCl

	<i>Appearance of Reactants</i>	<i>Appearance of Products</i>	<i>Other Observations (if any)</i>
Mg			
0.10 M HCl			

II. Reacting 0.10 M CuSO₄ with 0.10 M NaOH

	<i>Appearance of Reactants</i>	<i>Appearance of Products</i>	<i>Other Observations (if any)</i>
0.10 M CuSO ₄			
0.10 M NaOH			

III. Reacting $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ with heat and water

	<i>Appearance of Reactants</i>	<i>Appearance of Products</i>	<i>Other Observations (if any)</i>
1. Adding heat $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (before heating)			
2. Adding water Product of heated $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$			

IV. Reacting 0.10 M CuSO_4 with steel wool (Fe)

	<i>Appearance of Reactants</i>	<i>Appearance of Products</i>	<i>Other Observations (if any)</i>
0.10 M CuSO_4			
Fe			

V. Heating $(\text{NH}_4)_2\text{CO}_3$

	<i>Appearance of Reactants</i>	<i>Appearance of Products</i>	<i>Other Observations (if any)</i>
$(\text{NH}_4)_2\text{CO}_3$			
Moistened litmus paper			

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Reactions and Conclusions

Write your conclusions in the spaces provided.

I. Reacting Mg with 0.10 M HCl

Evidence of a chemical reaction:

Chemical equation for the reaction:

General reaction type:

II. Reacting 0.10 M CuSO₄ with 0.10 M NaOH

Evidence of a chemical reaction:

Chemical equation for the reaction:

General reaction type:

III. Reacting CuSO₄·5H₂O with heat and water

Evidence of a chemical reaction:

Chemical equation for the reaction:

General reaction type:

IV. Reacting 0.10 M CuSO₄ with steel wool (Fe)

Evidence of a chemical reaction:

Chemical equation for the reaction:

General reaction type:

V. Heating (NH₄)₂CO₃

Evidence of a chemical reaction:

Chemical equation for the reaction:

General reaction type:

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Post-Lab Questions

1. What evidence did you list to indicate that chemical reactions had occurred?

2. List each of the reactions you observed under the appropriate type in the space below:

Combination:

Decomposition:

Single Displacement:

Double Displacement:

3. First generation automobile air bags contain a mixture of sodium azide (NaN_3), potassium nitrate (KNO_3), and silicon dioxide (SiO_2).

a) The chemical reaction responsible for inflating this type of air bag is shown below:



Classify this reaction as one of the four types studied in this lab.

b) The sodium formed when the airbags fill with nitrogen reacts with KNO_3 as shown in the reaction below:



Classify this reaction as one of the four types. (**NOTE:** Ignore the K_2O when considering your classification; it is a simple byproduct of the primary reaction.)