A Series of Copper Reactions

Objectives: To perform a series of chemical reactions using elemental copper, observe the physical changes associated with those reactions, and end with the recovery of the elemental copper.

Materials: 250-mL beaker, glass rod, ring stand, ring, wire gauze, Bunsen burner, 50-mL graduated cylinder, evaporating dish, copper wire, 15 M HNO_3 (concentrated nitric acid), 3 M NaOH, 6 M H_2SO_4, solid zinc pellets (approx. 30-mesh).

Safety: Concentrated nitric acid (HNO_3) is extremely corrosive and will cause serious burns. It should be used only in the fume hood. Sodium hydroxide (NaOH) and sulfuric acid (H_2SO_4) solutions are also caustic and corrosive and should be handled carefully. **Wear gloves and safety goggles at all times.** Neutralize any spills with sodium bicarbonate before attempting to clean them up. Wash any skin surfaces thoroughly if spattering of solutions occurs. Wash hands and glassware thoroughly after use.

Waste Disposal: All solutions may be washed down the sink with plenty of water. The recovered copper should be placed in the container indicated by the instructor.

INTRODUCTION

Early alchemists were intrigued by the nature of matter and how it changed. However, their investigations were hindered by the lack of instrumentation (except for balances to measure mass), modern atomic theory, and the periodic table to help interpret their results. They relied on *descriptive chemistry*, or simply describing the physical changes that accompany a chemical reaction.

Chemical changes (i.e., reactions) produce physical changes in the substances involved in the reaction. Some reactions, such as combustion, will generate heat and light. Other reactions, such as the reaction of carbonates with acids, will produce bubbles of gas. Still other reactions will result in a change in the color or appearance of the reacting materials. These changes can be used to determine whether or not a chemical reaction has occurred. Modern chemists describe these chemical changes using chemical formulas to describe the starting materials and products and chemical equations to indicate how these substances are changed during the reaction.

In this lab exercise you will start with copper metal and perform a series of reactions, ending with recovery of the copper metal (hopefully!). For each reaction you will record observations of the physical changes and write chemical equations describing the chemical changes involved in each reaction.

Classification of the different reactions in this exercise will vary depending on the textbook you use. Refer to the appropriate chapter and sections in your text for more information regarding the classification of chemical reactions.

Pre-Lab Questions

1. Name *three* physical characteristics that might indicate that a chemical reaction has occurred.

2. Write a balanced chemical equation for the reaction of iron with oxygen to form iron oxide (Fe_2O_3). Then write a description of what you would observe as a piece of iron rusts. Which one is mostly a *chemical* description, and which one is mostly a *physical* description?

3. Define the following terms:

   (a) Oxidation :

   (b) Reduction :

4. For the reaction in question 2, which reactant is oxidized and which is reduced?

5. In the first reaction in this lab you dissolve the copper metal in nitric acid. Why must this reaction be performed in the hood until the reaction is complete?

PROCEDURE

1. Cut a piece of pure copper wire weighing about 0.5 g. Weigh the copper and record the mass on your Data Sheet to the appropriate number of significant figures.

2. Transfer the wire to a 250-mL beaker. Be sure that the copper wire lies flat on the bottom of the beaker. THE NEXT STEP SHOULD BE PERFORMED IN THE HOOD! Add about 4-5 mL of concentrated nitric acid (15 M HNO_3) to the beaker. The copper will dissolve in the acid producing noxious fumes of NO_2 (a brown gas that is involved in smog). Keep the beaker in the hood until the reaction is complete. Record your observations on the Data Sheet. The chemical equation for this reaction is complex, and is already provided for you.

3. When the dissolution reaction is complete you may return to the lab bench. Add distilled water to your beaker to bring the total volume to about 150 mL. Record your observations on your data sheet. Complete the reaction that is provided to obtain a balanced chemical equation that describes what happens.

4. Add 30 mL of 3 M NaOH slowly while stirring with a glass rod. Be sure to keep the glass rod in the beaker to prevent any loss of your copper compounds during this step. Record your observations on the Data Sheet under the section for Reaction 3. Write a balanced chemical equation that describes what happened.

5. Assemble a ring stand, ring, and wire gauze as illustrated in Figure 1. Heat the solution in the beaker gently using a Bunsen burner. You do not need to heat the solution to boiling; a gentle heating will be sufficient.

6. After 5 to 10 minute the reaction should be complete. Complete reaction will be indicated when the solid product is uniform in color and the solution is clear and colorless. Record your observations on the Data Sheet under the section for Reaction 4, and write a balanced chemical equation describing what happened.

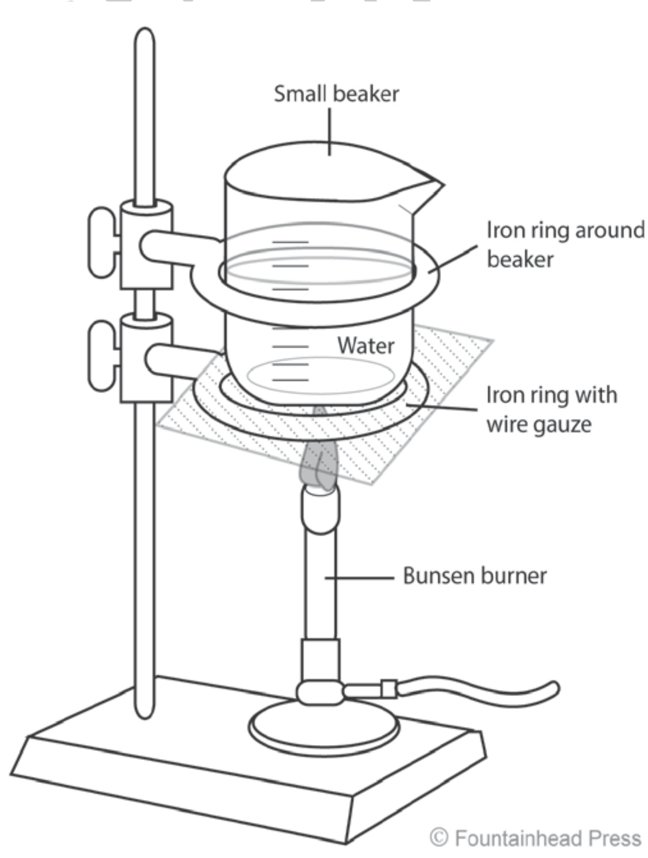

Figure 1. Ring stand and beaker

7. Remove the beaker from the wire gauze and replace it with a clean beaker with 150 mL of distilled water (no stirring rod). Heat the water until it is close to boiling.

8. Allow the solution from Reaction 4 to settle. Decant the *supernatant solution* (i.e., the liquid above the solid), and discard the supernatant down the drain with plenty of water. Be careful not to lose any of the solid CuO that has formed.

9. When the water in step 7 is hot, turn off the Bunsen burner and pour the hot water into the beaker with the solid CuO. Stir briskly to wash any unreacted NaOH from the solid. Allow the solid to settle, and decant the supernatant as you did in step 8. Be careful not to lose any of the solid CuO.

10. Slowly add 15 mL of 6 M H_2SO_4 to the solid CuO while stirring with a glass rod. Record your observations on the Data Sheet under the section for Reaction 5. Write a balanced chemical equation to describe this reaction.

11. RETURN TO THE HOOD TO PERFORM THIS NEXT STEP. Weigh 2.0 g of 30-mesh zinc metal in a weigh boat or small beaker. Add the zinc to the solution all at once. Stir until the solution is colorless and the evolution of gas ceases, and then continue stirring for 2 to 5 more minutes. Record your observations on the Data Sheet. There are two different reactions occurring in this step – Reactions 6 and 7. Write balanced chemical equations to describe the reactions that occur in this step.

12. Preweigh a clean, dry porcelain evaporating dish. Record the mass on your Data Sheet to the appropriate number of significant figures.

13. Decant the supernatant solution and discard. Wash the copper metal with about 5 mL of distilled water to remove any unreacted acid from the copper. Decant the wash solution, and repeat the wash step with two more 5 mL shots of distilled water. When you are confident that you have removed all the acid from the copper, transfer the solid copper to the porcelain evaporating dish. Place the evaporating dish in the oven and allow to dry.

14. When the copper is dry, record the final mass of copper and calculate your percent recovery.

CALCULATIONS

There are many points in the procedure where you may lose some of the copper due to incomplete reaction, solubility of the product, or incomplete transfer of product between beakers. You can evaluate your lab technique by how much of the original copper was recovered after all the reactions were complete. Percent recovery is calculated as

$$\% \text{ recovery} = \frac{\text{final mass of copper}}{\text{initial mass of copper}} \times 100$$

Series of Copper Reactions
Data Sheet

Initial mass of copper wire: ____________________ g

Observations and Chemical Equations

Record all your observations below. Then write balanced chemical equations for each step. Write the equation in the space provided. The equation for Reaction 1 has been provided for you. (Hint: If you are not sure what the product is in a given step, look at the starting materials in the next step!)

Reaction 1: $Cu + HNO_3 \rightarrow$

$Cu(s) + 4\ HNO_3(aq) \rightarrow Cu(NO_3)_2\ (aq) + 2\ H_2O(l) + 2\ NO_2(g)$

Observations:

Reaction 2: $Cu(NO_3)_2\ (aq) + H_2O\ (l) \rightarrow$

Observations:

Reaction 3: $Cu(H_2O)_6^{2+}(aq) + NaOH(aq) \rightarrow$

Observations:

Reaction 4: $Cu(OH)_2(s)$ (+ heat) $\rightarrow$

Observations:

Reaction 5: $CuO(s) + H_2SO_4(aq) \rightarrow$

Observations:

Reaction 6: $CuSO_4(aq) + Zn(s) \rightarrow$

Observations:

Reaction 7: $Zn(s) + H_2SO_4(aq) \rightarrow$

Observations:

Mass of porcelain evaporating dish: ____________________ g

Mass of dish + copper: ____________________ g

Mass of copper (final): ____________________ g

% Recovery:

(Show your work!)

Post-Lab Questions

1. Which of the major physical laws of chemistry are you testing when you calculate the percent recovery? Explain.

2. The mass of recovered copper can be greater or less than the amount at the beginning.

   (a) Give at least one reason why the mass of recovered copper might be greater than the initial mass of copper, and one reason why it might be less than the initial mass.

   (b) What steps could be taken to minimize these sources of error in the experiment?

3. In this experiment, reactions 1, 6, and 7 are of the same classification. What type of reaction do they represent? Explain your choice by writing one of the reaction equations and identifying the reactants according to their behavior.

4. Show by calculation that the 2.0 g of zinc used in reaction 6 is enough to completely react with the mass of copper that you started with.

5. The Statue of Liberty is made of bronze, but exhibits a green surface, or "patina." What is bronze? Based on the composition of bronze, suggest a chemical reason for the green color and write a chemical reaction to illustrate.