

## CHEMICAL REACTIONS OF COPPER AND PERCENT YIELD

### Objective

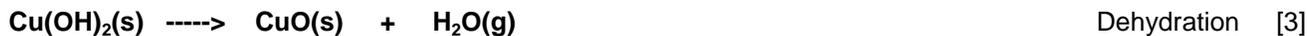
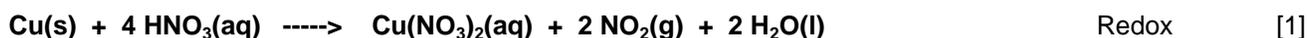
To gain familiarity with basic laboratory procedures, some chemistry of a typical transition element, and the concept of percent yield.

### Apparatus and Chemicals

0.5 g piece of no. 16 or no. 18 copper wire	evaporating dish
250 mL beaker (2)	weighing paper
concentrated HNO <sub>3</sub> (4 – 6 mL)	6.0 M H <sub>2</sub> SO <sub>4</sub> (15 mL)
graduated cylinder	granular zinc
3.0 M NaOH (30 mL)	methanol
carborundum boiling chips	acetone
stirring rod	towel
iron ring and ring stand	balance
wire gauze	aluminum foil cut in 1-inch squares
Bunsen burner	concentrated HCl (drops)

### Discussion

Most chemical synthesis involves separation and purification of the desired product from unwanted side products. Some methods of separation, such as filtration, sedimentation, decantation, extraction, and sublimation were discussed earlier. This experiment is designed as a quantitative evaluation of your individual laboratory skills in carrying out some of these operations. At the same time you will become more acquainted with two fundamental types of chemical reactions -- redox reactions and metathesis (double-displacement) reactions. By means of these reactions, you will finally recover the copper sample with *maximum efficiency*. The chemical reactions involved are the following.



Each of these reactions proceeds to completion. Metathesis reactions proceed to completion whenever one of the components is removed from the solution, such as in the formation of a gas or an insoluble precipitate (driving forces). This is the case for reaction [1], [2], and [3], where in reactions [1] and [3] a gas and in reaction [2] an insoluble precipitate are formed. Reaction [5] proceeds to completion because zinc has a lower ionization energy or oxidation potential than copper.

The objective in this experiment is to recover all of the copper you begin with in analytically pure form. This is the test of your laboratory skills.

The percent yield of the copper can be expressed as the ratio of the recovered weight to initial weight, multiplied by 100:

$$\% \text{ yield} = \frac{\text{recovered wt of Cu}}{\text{initial wt of Co}} \times 100$$

### **Procedure**

- Weight approximately 0.500 g of no. 16 or no. 18 copper wire (1) to the nearest 0.0001 g and place it in a 250 mL beaker. Add 4-5 mL of concentrated  $\text{HNO}_3$  to the beaker, IN THE HOOD. After the reaction is complete, add 100 mL distilled  $\text{H}_2\text{O}$ . Describe the reaction (6) as to color change, evolution of gas, and change in temperature (exothermic or endothermic) in the report sheet.
- Add 30 mL of 3.0 M NaOH to the solution in your beaker and describe the reaction (7). Add two or three boiling chips and carefully heat the solution -- while stirring with a glass stirring rod -- just to the boiling point. Describe the reaction on your report sheet (8). *Remove the boiling chips.*
- Allow the black CuO to settle; then decant the supernatant liquid. Add about 200 mL of very hot distilled water and allow the CuO to settle. Decant once more. What are you removing by washing and decanting (9)?
- Add 15 mL of 6.0 M  $\text{H}_2\text{SO}_4$ . What copper compound is present in the beaker now (10)?

Your teacher will tell you whether you should use Zn or Al for the reduction of Cu (II) in the following step.

#### **A. Zinc**

In the hood, add 2.0 g of 30-mesh zinc metal all at once and stir until the supernatant liquid is colorless. Describe the reaction on your report sheet (11). What is present in solution (12)? When gas evolution has become very slow, heat the solution gently (but do not boil) and allow it to cool. What gas is formed in this reaction (13)? How do you know (14)?

#### **B. Aluminum**

In the hood, add several 1-inch squares of aluminum foil and a few drops of concentrated HCl. Continue to add pieces of aluminum until the supernatant liquid is colorless. Describe the reaction on your report sheet (11). What is present in solution (12)? What gas is formed in this reaction (13)? How do you know (14)?

When gas evolution has ceased, decant the solution and transfer the precipitate to a preweighed porcelain evaporating dish (3). Wash the precipitated copper with about 5 mL of distilled water, allow to settle, decant the solution, and repeat the process. What are you removing by washing (15)? Wash the precipitate with about 5 mL of methanol (**KEEP THE METHANOL AWAY FROM FLAMES \_ IT IS FLAMMABLE!**) Allow the precipitate to settle, and decant the methanol. (**METHANOL IS ALSO EXTREMELY TOXIC: AVOID BREATHING THE VAPORS AS MUCH AS POSSIBLE.**) Finally, wash the precipitate with about 5 mL of acetone (**KEEP THE ACETONE AWAY FROM FLAMES - IT IS EXTREMELY FLAMMABLE!**), allow the precipitate to settle, and decant the acetone from the precipitate. Prepare a steam bath as illustrated and dry the product on your steam bath for at least 5 minutes.

Wipe the bottom of the evaporating dish with a towel, remove the boiling chips and weigh the evaporating dish plus copper (2). Calculate the final weight of copper (4). Compare the weight with your initial weight and calculate the percent yield (5). What color is your copper sample (16)? Is it uniform in appearance (17)? Suggest possible sources of error in this experiment (18).

***Pre-lab (Review Questions)***

1. Give an example, other than the ones listed in this experiment, of redox and metathesis reactions.
2. When will reactions proceed to completion?
3. Define percent yield in general terms.
4. Name six methods of separating materials.
5. Give criteria in terms of temperature changes for exothermic and endothermic reactions.
6. If 1.65 g of  $\text{Cu}(\text{NO}_3)_2$  are obtained from allowing 0.93 g of Cu to react with excess  $\text{HNO}_3$ , what is the percent yield of the reaction?

## Prelab – Chemical Reactions of Copper and Percent Yield

7. What is the maximum percent yield in any reaction?

8. What is meant by the terms *decantation* and *filtration*?

9. When  $\text{Cu}(\text{OH})_2(\text{s})$  is heated, Copper (II) oxide and water are formed.

Write a balanced equation for the reaction.

10. When sulfuric acid and copper (II) oxide are allowed to react, copper (II) sulfate and water are formed.

Write a balanced equation for this reaction.

11. When copper (II) sulfate and aluminum are allowed to react, aluminum sulfate and copper are formed.

What kind of reaction is this? Write a balanced equation for this reaction.

## REPORT SHEET

### Chemical Reactions of Copper and Percent Yield

1. Weight copper initial \_\_\_\_\_
2. Weight of copper and evaporating dish \_\_\_\_\_
3. Weight of evaporating dish \_\_\_\_\_
4. Weight of copper final \_\_\_\_\_
5. % Yield (show calculations) \_\_\_\_\_

6. Describe the reaction  $\text{Cu(s)} + \text{HNO}_3(\text{aq}) \rightarrow$

7. Describe the reaction  $\text{Cu(NO}_3)_2(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow$

8. Describe the reaction  $\text{Cu(OH)}_2(\text{s}) \rightarrow$

9. What are you removing by this washing (be specific)?

10. What copper compound is present in the beaker?

11. Describe the reaction  $\text{CuSO}_4(\text{aq}) + \text{Zn(s)}$ , or  $\text{CuSO}_4(\text{aq}) + \text{Al(s)}$

12. What is present in solution (aqueous)?

**Chemical Reactions of Copper and Percent Yield**

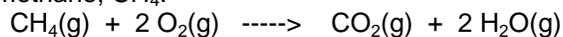
13. What is the gas? Hint: Where did the  $\text{HCl}(aq)$  go? Why did you have to do this reaction in the fume hood?
  
  
  
  
  
  
  
  
  
  
14. How do you know?
  
  
  
  
  
  
  
  
  
  
15. What are you removing by washing?
  
  
  
  
  
  
  
  
  
  
16. What color is your copper sample?
  
  
  
  
  
  
  
  
  
  
17. Is it uniform in appearance?
  
  
  
  
  
  
  
  
  
  
18. Suggest possible sources of error in this experiment.

## POST LAB QUESTIONS

Name \_\_\_\_\_

1. If your percent yield of copper was greater than 100%, what are two plausible errors you may have made?

2. Consider the combustion of methane, CH<sub>4</sub>:



Suppose 2 mole of methane is allowed to react with 3 mol of oxygen.

a) What is the limiting reagent? (show work)

b) How many moles of CO<sub>2</sub> can be made from this mixture? How many grams of CO<sub>2</sub>?

3. Suppose 8.00 g of CH<sub>4</sub> is allowed to burn in the presence of 6.00 g of oxygen.

How much (in grams) CH<sub>4</sub>, O<sub>2</sub>, CO<sub>2</sub>, and H<sub>2</sub>O remain after the reaction is complete?

4. How many milliliters of 6.0 M  $\text{H}_2\text{SO}_4$  are required to react with 0.80 g of CuO according to Equation [4]?

5. If 2.00 g of Zn is allowed to react with 1.75 g of  $\text{CuSO}_4$  according to Equation [5], how many grams of Zn will remain after the reaction is complete?

6. What is meant by the term limiting reagent? Explain