**Stoichiometry Lab**

**CHEMICAL REACTIONS OF COPPER AND PERCENT YIELD**

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

**Discussion:**
Most chemical syntheses involve separation and purification of the desired product from unwanted side products. Common methods of separation are filtration, sedimentation, decantation, extraction, and sublimation. This experiment is designed to be a quantitative evaluation of your individual laboratory skills in carrying out some of these operations. At the same time, you will become acquainted with two fundamental types of chemical reactions, called redox reactions and metathesis reactions. By means of these reactions, you will carry out several chemical transformations involving copper, and you will finally recover the copper sample with maximum efficiency. The chemical reactions involved are the following:

\[
\text{Cu(s)} + 4\text{HNO}_3(aq) \rightarrow \text{Cu(NO}_3)_2(aq) + 2\text{NO}_2(g) + 2\text{H}_2\text{O(l)} \quad \text{Redox [1]}
\]

\[
\text{Cu(NO}_3)_2(aq) + 2\text{NaOH(aq)} \rightarrow \text{Cu(OH)}_2(s) + 2\text{NaNO}_3(aq) \quad \text{Metathesis [2]}
\]

\[
\text{Cu(OH)}_2(s) \rightarrow \text{CuO(s)} + \text{H}_2\text{O(g)} \quad \text{Dehydration[3]}
\]

\[
\text{CuO(s)} + \text{H}_2\text{SO}_4(aq) \rightarrow \text{CuSO}_4(aq) + \text{H}_2\text{O(l)} \quad \text{Metathesis [4]}
\]

\[
\text{CuSO}_4(aq) + \text{Zn(s)} \rightarrow \text{ZnSO}_4(aq) + \text{Cu(s)} \quad \text{Redox [5]}
\]

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. This is the case for reactions [1], [2], and [3], where in reactions [1] and [3] a gas and in reaction [2] an insoluble precipitate are formed. (Reactions [5] and [6] proceed to completion because copper is more difficult to oxidize than either zinc or aluminum.

The object of this experiment is to recover all of the copper with which you began. This is the test of your laboratory skills.

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

\[
\% \text{ yield} = \frac{\text{recovered mass of Cu}}{\text{initial mass of Cu}} \times 100
\]

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**Apparatus**

<table>
<thead>
<tr>
<th>Balance</th>
<th>Bunsen burner and hose</th>
<th>Boiling chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>250-mL beakers (2)</td>
<td>100 mL graduated cylinder</td>
<td>Drying oven</td>
</tr>
<tr>
<td>Evaporating dish</td>
<td>Weighing paper</td>
<td>Stirring rod</td>
</tr>
</tbody>
</table>

**Chemicals**

| 0.5-g piece of granular copper | Conc, HNO₃ | Acetone | Zinc |
| 6 M H₂SO₄ | 6 M NaOH | Methanol |

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Procedure:

Weigh your granular copper piece and record its mass (1). It should be approximately 0.500 g. Place it in a 250-mL beaker. **IN THE HOOD** add 4 or 5 mL of concentrated HNO₃ to the beaker. **(CAUTION:** Be careful not to get any of the nitric acid on yourself. If you do, wash it off immediately with copious amounts of water. The gas produced in this reaction is toxic, and the reaction must be performed in the hood.) Slowly warm your copper solution on a hot plate. After the reaction is complete, add 100 mL of distilled H₂O. Describe the reaction as to color change, evolution of a gas, and change in temperature (exothermic or endothermic) on the report sheet(6).

Add 30 mL of 6.0 M NaOH to the solution in your beaker and describe the reaction of the report sheet (7). Add **two or three boiling chips** and carefully heat the solution - while stirring with a stirring rod - just to the boiling point. Describe the reaction on your report sheet (8).

Allow the black CuO to settle, then decant the supernatant liquid. Add about 200 mL of very hot distilled water, stir, and then allow the CuO to settle. Decant once more. What are you removing by the washing and decantation (9)?

Add 15 mL of 6.0 M H₂SO₄. What copper compound is present in the beaker now (10)?

Your will use zinc for the reduction of Cu(II) in the following step.

Reduction with 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)?

When gas evolution has ceased, decant the solution and transfer the precipitate to a preweighed porcelain evaporating dish and record its mass on the report sheet (3). Wash the precipitated copper with about 5 mL of distilled water, allow it 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. **(CAUTION: Keep the methanol away from flames - it is flammable! Methanol is also extremely toxic. Avoid breathing the vapors as much as possible.)** Allow the precipitate to settle and decant the methanol. Finally wash the precipitate with about 5 mL of acetone. **(CAUTION: Keep the acetone away from flames - it is extremely flammable!!)** Allow the precipitate to settle, and decant the acetone from the precipitate. Label your evaporating dish and place it in the drying oven.

When dry, wipe the bottom of the evaporating dish with a towel, remove the boiling chips, weigh the evaporating dish plus copper, and record its mass (2). **Calculate the final mass of copper (4). Compare the mass with your initial mass 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).**

Dispose of the chemicals in the designated receptacles.
Stoichiometry Lab

CHEMICAL REACTIONS OF COPPER AND PERCENT YIELD

PRE-LAB QUESTIONS

Before beginning this experiment in the laboratory, you should be able to answer the following 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 five methods of separating materials.

5. Give criteria in terms of temperature changes for exothermic and endothermic reactions.

6. If 3.40 g of Cu(NO₃)₂ are obtained from allowing 2.09 g of Cu to react with excess HNO₃, what is the percent yield of the reaction?

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

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

9. When Cu(OH)₂(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.
REPORT SHEET

Chemical Reactions of Copper and Percent Yield

1. Initial mass of copper
2. Mass of copper and evaporating dish
3. Mass of evaporating dish
4. Mass of recovered copper
5. Percent yield (show calculations)
6. Describe the reaction Cu(s) + HNO₃ (aq) →
7. Describe the reaction Cu(NO₃)₂ (aq) + NaOH(aq) →
8. Describe the reaction Cu(OH)₂(s) →
9. What are you removing by this washing?
10. What copper compound is present in the beaker?
11. Describe the reaction CuSO₄(aq) + Zn(s), or CuSO₄(aq) + Al(s)
12. What is present in solution?
13. What is the gas?
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.
QUESTIONS

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, \( CH_4 \):

\[ CH_4 (g) + 2O_2 (g) \rightarrow CO_2(g) + 2H_2O (g) \]

Suppose 2.5 moles of methane are allowed to react with 3 moles of oxygen.
(a) What is the limiting reactant, \( CH_4 \) or \( O_2 \)? (Show work)

(b) How many moles of \( CO_2 \) can be made from this mixture? (remember to use limiting reactant to solve, show work)

(c) How many grams of \( CO_2 \)? (show work)

3. Suppose 8.00 g of \( CH_4 \) is allowed to burn in the presence of 6.00 g of oxygen. How much (in grams) \( CH_4 \), \( O_2 \), \( CO_2 \), and \( H_2O \) remain after the reaction is complete?
(a) Start by determining the limiting reactant, \( CH_4 \) or \( O_2 \)? (Show work)

(b) How many grams of \( CH_4 \) remain after the reaction is complete? (show work)

(c) How many grams of \( O_2 \) remain after the reaction is complete? (show work)

(d) How many grams of \( CO_2 \) remain after the reaction is complete? (show work)

(e) How many grams of \( H_2O \) remain after the reaction is complete? (show work)

4. If 3.00 g of Zn is allowed to react with 1.75 g of \( CuSO_4 \) according to Equation [5], how many grams of Zn will remain after the reaction is complete? (show work, hint-determine limiting reactant first)