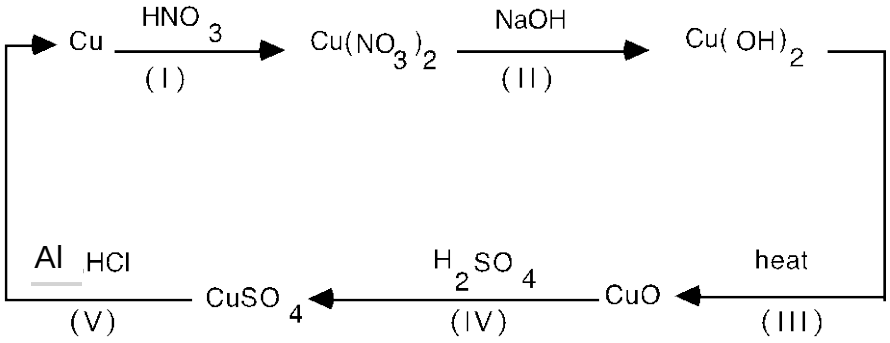
REACTIONS OF COPPER

Copper will undergo many types of reactions. In this experiment you will observe a sequence of copper reactions. The sequence begins with copper metal and ends with copper metal, so it is called a cycle of copper reactions. Observations will be made for each reaction.
Since no copper is added or removed between the initial and final reaction steps, copper can be quantitatively recovered. In other words, to recover the same amount of copper metal that you started with, this will require careful work. The success of the copper metal recovery will be shown by calculating the percent yield. The diagram below shows (in an abbreviated form) the cycle of copper reactions.



The following are the completed but **unbalanced** equations. Each equation is numbered to match each step of the cycle:

I. $HNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + 2H_2O(l) + 2\,NO_2(g)$ (oxidation-reduction)

II $Cu(NO_3)_2(aq) + NaOH(aq) \rightarrow Cu(OH)_2(s) + NaNO_3(aq)$

III. $Cu(OH)_2(s) \rightarrow CuO(s) + H_2O(l)$

IV. $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

V. $CuSO_4(aq) + Al(s) \rightarrow Al_2(SO_4)_3(aq) + Cu(s)$

It is useful to classify reactions into different types, because products of reactions can then be predicted.
No one classification scheme can accommodate all known reactions but you will classify the reactions in your experiment based on ideas of double exchange, combination, decomposition, and replacement.

Throughout the experiment careful observations and recordings must be made. Determine the colors of the solids as well as the color of ions in solution. In order to have a good percent yield, it is important to prevent loss by avoiding spattering while boiling, leaving product on sides of beakers, and spilling of product. Purify precipitates by washing efficiently and then drying completely before weighing.

1. Safety goggles **must** be worn at all times
2. Concentrated nitric acid, HNO_3, is hazardous. It produces severe burns on the skin and the vapor is a lung irritant. Any acid spilled on the skin or splashed into your eyes must be rinsed with a large volume of water for 15 minutes. While handling nitric acid you must wear gloves. Rinse your hands with tap water after handling HNO_3.
3. NaOH solutions are corrosive to the skin.
4. Dissolution of the copper wire with concentrated HNO_3 should be carried out in the fume hood. The brown NO_2 gas that is evolved is very irritating to the lungs.
5. Dilute hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) can harm eyes, skin, and clothing. Handle with care. Any acid spilled on the skin or splashed into your eyes must be rinsed with a large volume of water.

PROCEDURE

PART A

[Remember: DO NOT PUT ANY EXCESS REAGENTS BACK INTO THE REAGENT BOTTLES!]

Step I

1. Weigh a clean and dry evaporating dish to the nearest .1 mg. Record the mass on the data sheet (Page 5)

2. Obtain a piece of copper wire. Weigh the copper plus an evaporating dish to the nearest 0.1 milligram, recording the mass on the data sheet (page 5)

3. Place the copper into a 250 mL beaker; and place it under the fume hood. Your instructor will put on a pair of rubber gloves and will carefully add 4.0 ml of 16M nitric acid, HNO_3 concentrated.

4. Record your observations on the report sheet, page5. After the copper has dissolved swirl the solution to remove the brown NO_2 gas (What is in the solution when the reaction is complete?).

5. After the copper has dissolved, carefully (slowly!) add approximately 100 ml distilled water to your copper solution.

6. Make and record your observations on page 5

Step II (Conducted at your lab bench)

1. While stirring the solution with a glass rod, slowly add 15 mL of Dil (6 M) NaOH to precipitated $Cu(OH)_2$. It is important to add the NaOH slowly, because you are adding a base to an acid. (This type of reaction generates a lot of heat). If your mixture warms up too much, you will skip step II and form the CuO directly-Step III.)

4. Start to preheat your hot plate

3. The solution should be alkaline (basic) after the addition. A drop of solution touched to red litmus paper, using a glass stirring rod, turns it blue. If the solution is not basic, add an additional 5 mLs of NaOH. Wait until the precipitate settles slightly and look at the clear top part of the mixture. There should be no blue color left in the top clear solution. (What ion gives the blue color?)

4. Record your observations

Step III

1. Ask instructor to add 2 or 3 boiling chips to the $Cu(OH)_2$ solution. Heat the mixture just barely to the boiling point using a **hot-plate**, while stirring continuously gently with a glass rod to prevent "bumping" (a phenomenon caused by the formation of a large steam bubble in a locally overheated area of the beaker)

2. Continue to heat gently while stirring to better coagulate the CuO .

3. When the transformation is complete, remove the hot solution from the hotplate to cool, **continue stirring for a minute or two**. Remove the boiling chips then allow the CuO to settle.

4. Record your observations.

5. Carefully decant as much solution as possible without losing precipitate.

6. Now filter the solution using a clean 125 mL Erlenmeyer flask and filter paper. Then, rinse the black solid thoroughly three times using 7 mL of DI water.

Step IV

NOTE: Do not start steps IV and V unless you have at least 45 minutes left in the lab period!!

1. Place a clean 125 mL Erlenmeyer flask under the stem of the funnel. Slowly pour 5 mL of **3 M** H_2SO_4. Repeat this step if black solid remains. If the entire solid is not dissolved, ask instructor for help. (What is in the solution now?).

2. Transfer dissolved black solid solution into a clean 250 mL beaker and place it into the hood.

3. Record your observations.

Step V

This part of the experiment is to be conducted in the fume hood.

1. While in the hood, place two 1 in. squares of aluminum foil into the solution. Ask instructor to add 4-5 drops concentrated HCl to your solution. Immediately start to stir for 1 min. (What happens? - What gas is produced?).

2. Cover your solution with a watch glass and store it in the designated cabinet under the Fume Hood on top of a paper towel with your name until the next lab period.

3. Check to see that the solution is colorless.

4. Record your observations

5. Wash the solid with two separate 50 mL portions of distilled water, decanting carefully after each washing.

6. Transfer all the copper to the evaporating dish using a little water to wash all the copper from the beaker. Decant the water used in transferring.

6. Place the evaporating dish with the copper on a steam bath to **dry to constant mass-** within 5 mg**.** (What color is the metal?)

8. After the evaporating dish has cooled to room temperature, weigh the dish plus the copper metal.

9. Give your instructor your copper sample in a clean, labeled, and corked test tube.

Report Sheet Name_____
Last First
Instructor's initial_____

Experiment: Reactions of Copper

DATA AND CALCULATIONS

1. Mass of the empty evaporating dish _____

2. Initial mass of copper wire plus the evaporating dish _____

Data approval_____

3. Calculate initial mass of Copper wire

Setup:

_____

4. Final mass of recovered copper

Mass of evaporating dish plus dry copper #1 _____

#2 _____

#3 _____

Data approval_____

5. Mass of recovered copper _____
Setup:

6 Percentage recovery (show calculations)
Setup:

_____

EQUATIONS AND OBSERVATIONS

For each step of the cycle, write the products of the reaction and balance the chemical equations. Classify each reaction. Also, record your observations of what happens at each step and answer the questions posed earlier in the Experimental Procedure.

STEP I

$Cu + HNO_3 \rightarrow$

What ions are in the solution after the reaction is complete? _____

Observations:

1.

2.

3.

Data approval_____

STEP II

$Cu(NO_3)_2$ + NaOH →

Reaction type _____

HNO_3 + NaOH →

Reaction type _____

The gelatinous precipitate is $Cu(OH)_2$.

What ions are in solution? _____

Observations:

1.

2.

Data Approval_____

STEP III

$Cu(OH)_2 \xrightarrow{heat}$

Reaction type _____

Observations:

Data Approval_____

STEP IV

CuO + H_2SO_4 →

Reaction type _____

Observations:

1.

2.

Data approval_____

STEP V

Al + $CuSO_4$ →

Reaction type _____

Al + H_2SO_4 →

Reaction type _____

Al + HCl →

Reaction type _____

Observations:

1.

2.

3.

4.

What gas is produced in the reaction?_____

What ions are removed by the washing and decantation near the end of STEP V?

_____

What is the color of recovered copper?_____

Data approval_____

QUESTIONS:

1. Give possible reasons why the percentage recovery might be low.

   a.

   b.

   c.

2. Give possible reasons why the percentage recovery might be over 100%.

a.

b.

c.

3. How many milliliters of 3.0 M NaOH are required to react with 4.0 mL of 16.0 M HNO_3?

Equation:

Answer_____

4. How many milliliters of 3.0 M NaOH are required to react with 0.50 g of Cu^{2+} to form $Cu(OH)_2$?

Equation:

Answer_____

5. What is the theoretical percentage copper in $Cu(OH)_2$?

Setup:

Answer_____

6. What theoretical weight of CuO can be obtained from 2.00 g of Cu?

Setup:

Answer_____

7. Iron is obtained from iron ore according to the following reaction:

Fe_2O_3 + 3 CO ----> 2 Fe + 3 CO_2 (unbalanced)

a. Assuming the blast furnace is 90.0 % efficient in recovering the iron, what is the actual mass of iron obtainable from a ton of ore?

1 ton = 2000.0 lb 1 lb = 453.6 g

Answer_____

Problem #7 continued on next page

Problem #7 continued

b. What is theoretical yield of iron if 200.0 g of Fe_2O_3 reacts with 100.0 g of CO?

Answer_____

c.How many grams of excess reactant are left at the end of the reaction?

Answer_____