Chemical Transformations of Copper

Introduction:

Copper was one of the first metals to be isolated, due to the ease of separating it from its ores. It is believed that the process was known (**metallurgy**) as early as 4500 BC. It is a ductile, malleable metal and is easily pounded and/or drawn into various shapes for use as wire, ornaments and implements of various types. Alloys of copper (bronze, brass) were discovered quite early in history and were among the first impetuses for international trade. Pure copper is the best electrical conductor of the more abundant metals. It has a good thermal conductivity and is corrosion resistant. Copper as a metal is second in commercial importance only to iron.

In this experiment, a weighed amount of copper metal is transformed, through a series of reactions, into other copper-containing compounds, and is eventually returned to the metal state. The series involves the use of reactions classified as metathesis, decomposition, displacement and oxidation-reduction reactions. The following equations (unbalanced) outline the series of transformations to be performed:

A. $Cu_{(s)} + HNO_3\ _{(aq)} \rightarrow Cu(NO_3)_2\ _{(aq)} + NO_2\ _{(g)} + H_2O_{(l)}$

B. $Cu(NO_3)_2\ _{(aq)} + NaOH_{(aq)} \rightarrow Cu(OH)_2\ _{(s)} + NaNO_3\ _{(aq)}$

C. $Cu(OH)_2\ _{(s)} \rightarrow CuO_{(s)} + H_2O_{(l)}$

D. $CuO_{(s)} + H_2SO_4\ _{(aq)} \rightarrow CuSO_4\ _{(aq)} + H_2O_{(l)}$

E. $CuSO_4\ _{(aq)} + Zn_{(s)} \rightarrow Cu_{(s)} + ZnSO_4\ _{(aq)}$

This series of reactions begins and ends with copper metal. Since no copper is added or removed between Reactions A and E, and since each reaction nearly goes to completion, you should be able to quantitatively recover all the copper metal you started with. The sequence of reactions also shows the wide variety of colors observed for inorganic compounds.

Experimental Procedure:

Part A: Preparation of Copper(II) Nitrate Solution

> **NOTE: T*his reaction should be carried out in a well-ventilated area (preferably a hood).***

Place about 100 mg of copper wire (about 1 cm of 18 gauge wire), weighed to the nearest mg, in a 10 mL beaker. In the **HOOD**, add 2 mL of 6M nitric acid to the beaker and warm the contents on a hot plate. Continue heating until the copper wire has completely dissolved and the evolution of brown fumes of nitrogen dioxide is no longer observed. If necessary, you may cautiously add more nitric acid in 2 mL increments, but only add sufficient nitric acid to complete the reaction. Avoid adding a significant excess. The nitrogen dioxide should appear as a brown haze over the surface of the solution.

Allow the resulting blue solution of copper(II) nitrate to cool to room temperature. This cooling process may be hastened by placing the beaker cautiously in an ice bath for a few minutes. When the solution has cooled, add 2 mL of distilled water to the blue solution.

Part B: Preparation of Copper(II) Hydroxide

Add a magnetic stirring bar to the beaker and place the flask on a microscale magnetic stirrer. At room temperature, with stirring, carefully add 6M NaOH solution dropwise until the solution is basic to red litmus paper. Use a capillary tube to remove sample for pH testing. A light blue precipitate of copper(II) hydroxide is formed as this reaction is carried out. **Make sure the litmus paper has actually changed from red to blue, rather than simply being colored blue by the blue precipitate.**

Part C: Preparation of Copper(II) Oxide

Set the hot plate for a moderate heat setting, and while stirring heat the beaker using a temperature of 110^{o}-115^{o}C. A setting of 3 on most hot plates will work. If a reaction has not occurred after 5 minutes, turn up the heat.

> **NOTE:** ***Stirring is essential to prevent bumping of the mixture and thus loss of CuO.***

During this time, the copper(II) hydroxide is transformed into copper(II) oxide (or cupric oxide), which appears as a black precipitate. When no more blue precipitate is present, allow the mixture to cool to room temperature and remove the magnetic stirring bar using forceps. If necessary, rinse the bar with a small amount of water, collecting the rinse in the beaker. Isolate the black solid by suction filtration using a Hirsch funnel. Rinse the beaker with 1 - 2 mL of

distilled water to make the transfer complete. **Discard the filtrate in the heavy metal waste container.** Wash the collected filter cake with an additional 1 - 2 mL of distilled water.

Part D: Preparation of Copper(II) Sulfate Solution

Place 6 mL of 3M sulfuric acid in a 50 mL beaker. Using a spatula, transfer the black copper oxide and filter paper to the acid solution. Stir the mixture with a glass stirring rod until the black solid has **completely** dissolved. Remove the filter paper from the solution, as soon as it is clean, using forceps. Gently rinse the filter paper with 1 - 2 mL of water. Add the rinse to the blue copper(II) sulfate solution. If residual traces of the CuO remain on the Hirsch funnel, rinse or dissolve this material (holding the funnel over the beaker), using the solution in the beaker. Once the transfer is complete, rinse the funnel with 1 - 2 mL of water. This rinse is also added to the beaker.

Part E: Regeneration of Copper Metal

Place the beaker containing the blue copper(II) sulfate solution in the **HOOD** and add, in small portions, about 600 **mg**(0.600 g) of zinc powder. Stir the mixture with a glass rod, until evolution of bubbles ceases. The blue color should now be gone. A metallic precipitate of copper metal forms during this period. Vigorous evolution of hydrogen gas is also observed during the addition.

NOTE: ***The absence of any remaining copper(II) ions left in the solution can be verified by adding a drop of the reaction solution to 1 mL of concentrated ammonia in a small test tube. If a deep midnight-blue color of*** $Cu(NH_3)_4^{+2}$ ***forms, the reaction is not yet complete.***

After the reaction is complete, add 5 mL of 6M HCl solution and stir the mixture with a glass rod. This process removes any unreacted zinc metal. The copper metal does not react under these conditions. You will again see bubbling of H_2. Wait till any bubbling has stopped and then add 1 mL of the HCl solution to make sure no more bubbling is occurring. Repeat this until the addition of HCl does not produce any bubbling.

Allow the copper precipitate to settle, decant the aqueous solution and **discard in the heavy metal waste container.** Wash the solid 3 times with 2 mL portions of distilled water. Decant and discard the rinse solution between washings. Repeat this process using acetone as the wash solvent. Discard the acetone washings in the appropriate waste container. Spread the copper solid on a pre-weighed glassine weighing paper, place the paper with its precipitate on a watch glass and place in a drying oven for 5 - 10 minutes. Pressing and pulling a flat spatula across the Cu will polish it so that it looks more like the Cu metal students are familiar with. Weigh the copper and weighing paper, calculate the mass of the recovered copper and determine the percentage recovery.

Remember to discard all heavy metal wastes and organic wastes in the appropriate container. Your instructor will provide specific instructions for today's lab.

Data Sheet

Name _____ Section _____

Chemical Transformations of Copper

1. Initial mass of copper wire _____

2. Mass of Copper + weighing paper _____

3. Mass of weighing paper _____

4. Mass of copper recovered _____

5. Percentage recovery (show calculation) _____

6. In Part E of the experiment, the zinc metal is added to undergo a redox reaction with the copper(II):

$$Zn + Cu^{+2} \rightarrow Cu + Zn^{+2}$$

Hydrogen gas is also generated in this step. How is the hydrogen gas formed?

7. Why is a large excess of zinc added in the reaction of Part E?

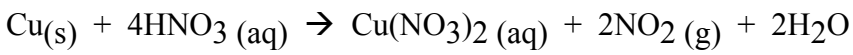
Lab #6

PRESTUDY

Name _____ Section _____

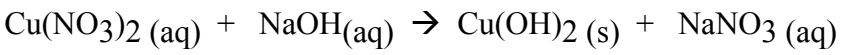
Chemical Transformations of Copper

1.(4 points) The first reaction in today's experiment follows the following balanced equation:



$$Cu_{(s)} + 4HNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + 2NO_{2\,(g)} + 2H_2O$$

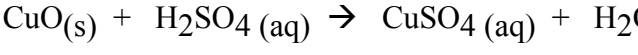
The remaining 4 reactions follow the following equations: Balance each of these:

A. 

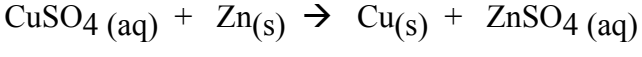
$$Cu(NO_3)_{2\,(aq)} + NaOH_{(aq)} \rightarrow Cu(OH)_{2\,(s)} + NaNO_{3\,(aq)}$$

B.

$$Cu(OH)_{2\,(s)} \rightarrow CuO_{(s)} + H_2O$$

C. 

$$CuO_{(s)} + H_2SO_{4\,(aq)} \rightarrow CuSO_{4\,(aq)} + H_2O$$

D. 

$$CuSO_{4\,(aq)} + Zn_{(s)} \rightarrow Cu_{(s)} + ZnSO_{4\,(aq)}$$

2.(4 points) Classify the above 4 reactions as to type: (substitution, decomposition, etc.)

3.(2 points) Based on the balanced equations of Question 1, if you used 94.5 mg of copper in the initial reaction, calculate the exact amount of zinc required to complete the reaction in equation D.