A Cycle of Copper Reactions

EQUIPMENT

You will need one 250 mL beaker, one hot plate, a magnetic stirrer, a magnetic stir bar, beaker tongs, a 50 mL graduated cylinder, a stirring rod, a wash bottle full of D.I. water, a pair of disposable protective gloves, and a 600 mL beaker for waste.

CHEMICALS

Approximately 1 gram Cu(s), 5 mL 16M HNO_3, 15 mL 6M NaOH, 30 mL 3M H_2SO_4, about 3 grams granular zinc, and 10 mL 12M HCl.

WASTE DISPOSAL

Any copper (II) must go in the copper waste container. You can tell if there is copper (II) in a solution because if there is the solution will be blue. Solid copper can go in the trash.

SAFETY

Concentrated acids must be dealt with very carefully! You absolutely must wear your goggles the entire time! Wear protective gloves when handling concentrated acids. All concentrated acids must remain in the hoods. Your reaction vessel must remain in the hood while there is any concentrated acid in it. Copper(II) is toxic, do not ingest it. Sodium hydroxide (NaOH) is a strong base and can cause burns. Avoid contact with all body tissue. Hydrogen gas is generated in **reaction f**. Hydrogen gas is flammable, keep all heat and flames away from your reaction vessel and the hydrogen gas.

INTRODUCTION

In this experiment you will attempt to verify the law of conservation of mass for a series of chemical reactions involving copper. To do this you will start with a sample of copper metal and perform a series of chemical reactions that convert that copper into a series of different chemical compounds and finally back to copper. You will determine if the mass of copper you started with is close to the mass of copper you recover after the series of chemical reactions.

The series of chemical reactions is as follows:

$Cu(s) + 4H^+(aq) + 2NO_3^-(aq) \longrightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$ (a)

$Cu^{2+}(aq) + 2\ OH^-(aq) \longrightarrow Cu(OH)_2(s)$ (b)

$2\ Cu(OH)_2(s) \longrightarrow 2\ CuO(s) + 2H_2O(l)$ (c)

$CuO(s) + H^+(aq) + HSO^-_4(aq) \longrightarrow Cu^{2+}(aq) + SO^{2-}_4(aq) + H_2O(l)$ (d)

$Cu^{2+}(aq) + Zn(s) \longrightarrow Cu(s) + Zn^{2+}(aq)$ (e)

$Zn(s) + 2\ H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$ (f)

PROCEDURE

Weigh a 250 mL beaker and record its mass in your data table. Tare the beaker, then add about 0.9 gram of copper metal to the beaker and record the mass of the copper in your data table.

Put the beaker with the copper in it in the fume hood. Put on a pair of protective gloves. Make sure to bring about 10 mL of D.I. water with you.

DO NOT REMOVE THE BEAKER FROM THE HOOD UNTIL YOU HAVE ADDED THE 10 mL OF D.I. WATER!!!

CAREFULLY add about 5 mL of concentrated nitric acid (16 M) to the copper**(reaction a)**.

CAUTION!!! CAUTION!!! THIS IS CONCENTRATED ACID! BE CAREFUL NOT TO GET IT ON YOU OR ANYONE ELSE! DO NOT BREATH IN THE FUMES!

Continue to swirl the beaker occasionally as the reaction progresses. Record your observations in your data table. The reaction is complete when there is no more solid copper left in the beaker. Make sure all of the copper solid has dissolved.

THE BEAKER MUST STILL BE IN THE HOOD!

Next add about 10 mL of D.I. water carefully to the beaker and swirl the beaker.

You can **now** remove the beaker from the hood and bring it to your lab bench.

Slowly add about 15 mL of 6 M NaOH while continuing to swirl **(reaction b)**. Record your observations in your data table.

Add about 50 mL of D.I. water to the beaker, and place the beaker on a hot plate-stirrer with a magnetic stir bar in the beaker.

IMPORTANT!!! STIR THE SOLUTION CONTINUOSLY FROM THIS POINT UNTIL YOU REMOVE THE BEAKER FROM THE HOT PLATE!!!

Turn on the magnetic stirrer so that there is a whirlpool, but not so vigorously that solution splashes out of the beaker. Turn on the hot plate a little more than halfway. Heat the solution until all of the blue color is gone. Rinse down the sides of the beaker with D.I. water to ensure that all of the product is in solution.

Turn off the hot plate and remove the beaker carefully from the hot plate using **beaker tongs (reaction c)**. Turn off the magnetic stirrer. Record your observations in your data table.

Allow the brown solid to settle to the bottom of the beaker.

Next, decant (pour off) the liquid into another beaker (your waste beaker). Be careful not to lose any of the solid! Some water will remain with the product.

Add about 25 mL of D.I. water to the solid in the 250 mL beaker and swirl to rinse it off. Decant this liquid into your waste beaker. This is called **washing**.

Do not remove the magnetic stir bar yet! You will need it for reaction (e).

Wash the solid with another 25 mL of D.I. water, decanting into your waste beaker after rinsing the solid in your 250 mL beaker.

After the final washing, pour your waste down the drain in a large sink.

Add about 30 mL of 3 M H_2SO_4 to the solid in your 250 mL beaker. Swirl gently. When the solid completely reacts, leaving a clear blue solution, the reaction is done **(reaction d)**. Record your observations in your data table.

Add about one spoon of granular zinc to your 250 mL beaker that has the clear blue solution in it. You will see solid copper metal begin to fall out of solution.

Place the beaker on a magnetic stirrer. Turn on the stirrer and wait for the reaction to be complete. The reaction is complete when there is no blue color left in the solution. DO NOT USE HEAT DURING THIS STEP!

Hold a piece of white paper behind the beaker to see if the solution is clear (no hint of color). If the zinc is gone and there is still some blue left add some more zinc. Continue stirring on the magnetic stirrer until the solution has no blue at all.

(reaction e). It does not matter if there are still bubbles, once the blue is all gone move on to the next step.

Remove the magnetic stir bar using a noodle. Make sure to wash off the magnetic stir bar thoroughly with D.I. water before returning it!

Decant the solution into your waste beaker, being careful to leave all of the solid in the 250 mL beaker.

Move to a hood and add about 10 mL of concentrated HCl (12 M) to your 250 mL beaker **(reaction f)**.

The beaker must stay in the hood until the zinc is gone!

You can tell when this happens because there will be no more bubbles or gas evolved.

CAUTION!!! THIS IS CONCENTRATED ACID! BE CAREFUL NOT TO GET IT ON YOU OR ANYONE ELSE!

Record your observations in your data table.

Wash the solid in your 250 mL beaker **at least five times**, each time with 50 mL of D.I. water. Decant each washing into your waste beaker. Empty your waste beaker down the drain.

MAKE SURE TO WASH ALL OF THE HCl OFF OF YOUR COPPER! IF YOU LEAVE EVEN A LITTLE, IT WILL CAUSE THE COPPER TO REACT WITH THE AIR AND ULTIMATELY FORM COPPER (II) CHLORIDE, A GREEN SUBSTANCE EASILY RECOGNIZED. THIS WILL AFFECT YOUR PERCENT RECOVERY!

Label your beaker with your name and what it contains (copper). Place the beaker with the copper in it into an oven set at 50 °C to dry until the next lab period.

The next lab period weigh the 250 mL beaker with the dry copper in it and record that mass in your data table. Record your observations in your data table.

Calculations

Calculate the initial mass of copper before the chemical reactions and the final mass of copper after all of the reactions. Calculate your percent recovery. Percent recovery is given by:

$$\% \text{ Recovery } = \frac{\text{Experimental Yield}}{\text{Theoretical Yield}} \times 100$$

Here Experimental Yield is the mass of copper you recovered and theoretical yield is the initial mass of copper (how much you started with).

Conclusion

In your conclusion give your initial mass of copper, your recovered mass of copper, and your percent recovery.

Determine and analyze one potential source of experimental error. Please make sure to read "How to Determine and Analyze a Source of Experimental Error" to understand what you are to do.