

INTRODUCTION

The polarity of the water molecule, which makes it a great solvent for ionic compounds, causes water molecules to cling to the structure of solid substances. When this occurs, the trapped water molecules are called water of hydration and they become an integral part of the crystal structure.

There are many compounds that have a tendency to absorb water vapor from the air. These compounds are said to be *hygroscopic*, and can be used as moisture-reducing agents. Other compounds absorb such large quantities of water vapor that they will actually dissolve in their own water of hydration, a property known as *deliquescence*.

In this experiment, you will test a hygroscopic ionic compound containing copper, chlorine, and water molecules locked in the crystal structure of the solid to determine its water of hydration. The general formula for the compound is $\text{Cu}_x\text{Cl}_y \cdot z\text{H}_2\text{O}$. The letters x , y , and z represent integers that will establish the proper chemical formula for this substance. Although the water molecules are securely attached to the ionic solid that you will test, they are susceptible to removal by heat. You will gently heat a sample of the compound to drive off the water of hydration. By measuring the mass of the sample before and after heating, you can determine the amount of water in the sample and calculate its water of hydration.

In the second part of this experiment you will conduct a chemical reaction with the dried sample, which will produce elemental copper. By measuring the mass of copper that forms, you will have the necessary information to determine the moles of copper and chlorine in your sample, and you will be able to establish the proper empirical formula.

John Dalton was an Englishman, a teacher, and an exceptional theoretical chemist. He developed and wrote the modern atomic theory at the turn of the 19th century (documents point to 1803). He was influenced by the experiments of two Frenchmen, Antoine Lavoisier and Joseph Louis Proust. A fundamental component of the modern atomic theory is that the mole ratios of elements in a compound will be small whole numbers (*law of definite proportions*). The whole number mole ratio is commonly referred to as the empirical formula of a compound.

One of the challenges in finding the proper chemical formula for a compound is that there may be more than one plausible mole ratio for the elements in that compound. Dalton called this the law of multiple proportions. For example, if you were testing a compound that contained iron and sulfur, the plausible chemical formula could be FeS or Fe_2S_3 . However, if you determine the mass of iron and the mass of sulfur present in a given mass of the compound, you will be able to establish the true chemical formula of the compound.

OBJECTIVES

In this experiment, you will

- Determine the water of hydration in a copper chloride hydrate sample.
- Conduct a reaction between a solution of copper chloride and solid aluminum.
- Use the results of the reaction to determine the empirical formula of the copper chloride compound.

PreLAD *This must be done before class, and will be turned in.*

1. Read the Procedure and Processing the Data and then make a Data/Results Table on a separate lined piece of paper.

Answer the following questions on another separate piece of paper. Show all work as appropriate.

2. What is the purpose of preheating the crucible and its lid prior to measuring its mass?
3. Washing soda is a hydrated compound whose formula can be written $\text{Na}_2\text{CO}_3 \cdot z\text{H}_2\text{O}$, where z is the number of moles of H_2O per mole of Na_2CO_3 . When a 2.123 g sample of washing soda was heated at 130°C , all of the water of hydration was lost, leaving 0.787 g of anhydrous sodium carbonate. Calculate the value of z .
4. A piece of iron weighing 85.65 g was burned in air. The mass of the iron oxide produced was 118.37 g.
 - a. Calculate the moles of iron in the compound.
 - b. According to the law of conservation of mass, what is the mass of oxygen that reacted with the iron?
 - c. Calculate the number of moles of oxygen in the product.
 - d. Use the ratio between the number of moles of iron and number of moles of oxygen to calculate the empirical formula of iron oxide.

MATERIALS

At Lab bench shared by 2 groups

- crucible and cover x2
- tongs, scoopula, stirring rod & spatula x2
- ring & burner x2
- small beaker x2
- Büchner funnel x2
- filter paper x2
- large watch glass x2
- vial of copper chloride hydrate x1 (~1 g each)
- aluminum wire x2 (~ 10 cm each)
- 6 M HCl solution in dropping bottle
- ethanol in wash bottle
- deionized wash bottle x2

At center Lab bench

- balances
- drying ovens
- vacuum pump

PROCEDURE ***Goggles and aprons are not an option - Wear them.***

1. Be sure and use the same balance throughout the LAD. Do NOT change midway through. Measure and record the mass of a clean, preheated crucible and cover. Obtain about 1 g of the unknown copper chloride hydrate and place it in the crucible. Use a spatula to break up any large pieces of the substance by pressing the pieces against the wall of the crucible. Measure and record the exact mass of the crucible with compound and its cover.
2. Set up a ring stand, ring, and clay triangle for heating the sample. Rest the crucible on the clay triangle. Set up a lab burner and ignite the burner away from the crucible. Adjust the burner to get a small flame.
3. Hold the burner in your hand and move the flame slowly back and forth underneath the crucible to GENTLY heat the sample. DO NOT OVERHEAT the compound. Note the color change, from blue-green to brownish, as the water of hydration is driven out of the crystals. When the sample has turned brown, gently heat the crucible for two more minutes.
4. Remove and turn off the burner. Cover the crucible and allow the sample to cool for about ten minutes. Mass the crucible, crucible lid and sample.
5. Reheat the crucible, crucible lid and sample until constant mass is achieved.
6. Once the sample has achieved constant mass, transfer the brown solid to a clean and empty 50 mL beaker. Rinse out the crucible with two 8 mL aliquots of distilled water and pour the water into the 50 mL beaker. Gently swirl the beaker to completely dissolve the solid. Note that the color of the solution is green as the copper ions are rehydrated.
7. Make the aluminum wire into a flat spiral that and then sit on the bottom of the beaker so that it is completely immersed in the copper chloride solution. Note that the reaction produces a gas, elemental copper is forming on the surface of the aluminum wire, and the color of the solution is fading. The reaction will take about 30 minutes to complete. Go to Step 10 and pre-mass the filter paper.
8. When the reaction is done, the solution will be colorless, though it may be cloudy. Most of the elemental copper will be on the aluminum wire. Add 5 drops of 6 M HCl solution to dissolve any insoluble aluminum salts in the mixture, which should make the solution clear. CAUTION: Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin.
9. Use a glass stirring rod to scrape off as much copper as possible from the Al wire. Slide the wire up the wall of the beaker and out of the solution with the glass stirrer and rinse off any remaining copper with distilled water. If any of the copper refuses to wash off the aluminum wire, wash it with one or two drops of 6 M HCl solution. Leave the AL wire on the center lab bench on the tray.

10. Collect and wash the copper produced in the reaction using vacuum filtration.
 - a. Prepare a Büchner funnel for vacuum filtration by obtaining a piece of filter paper that fits inside the bottom of the funnel. Measure and record the mass of the filter paper, and then place the filter paper on the funnel. Moisten the paper to seal its edges to the funnel.
 - b. Take your copper and funnel to the vacuum pump. Use small amounts of distilled water to wash all of the copper onto the filter paper in the Büchner funnel. Use the glass stirring rod to break up the larger pieces of copper.
 - c. Wash the copper twice more with small amounts of distilled water.
 - d. Take your Büchner funnel off the side arm flask and return to your lab station. Add 10 mL of 95% ethanol to the copper on the filter paper and let it sit for about 1 minute. Return to the vacuum pump and let the vacuum filtration run for about five minutes.
11. Measure and record the mass of a clean, dry watch glass. Transfer the filter paper with the copper to the watch glass. Make sure that you have scraped all of the copper onto the watch glass.
12. Dry the watch glass of copper on the filter paper in a drying oven for five minutes. When the watch glass is cool enough to touch, measure the mass of the watch glass plus copper and filter paper. Repeat the drying and weighing of the copper until you achieve a constant mass.
13. Leave all materials on the Lab Tray at your lab station.

PROCESSING THE DATA - To be completed on the bottom of your data/Results Table. Show all work.

1. If you did not type it into the spreadsheet in class, you must email your measured data (with partner's name) to Biggs before 10 pm.
2. How many moles of water were in your sample of copper chloride hydrate?
3. How many moles of copper were in your sample of copper chloride?
4. How many moles of chlorine were in your sample of copper chloride?
5. Write the proper chemical formula and name for the compound that you tested.

POST LAD QUESTIONS - To be completed on the back of your data/Results Table. Show all work as necessary.

1. Now that you know the formula and therefore the charge on the copper in the copper chloride, write a balanced net ionic equation to represent the redox reaction between the aluminum metal and the copper chloride solution.
2. Recall that you may have seen bubbles of gas forming during the redox reaction. These bubbles are due to a side reaction between some of the aluminum wire and acid (H^+ ions) formed by the hydrolysis of the copper ions. Write net ionic redox reaction that occurs between aluminum metal and acid ions.
3. Use stoichiometry to calculate the theoretical yield of copper in this experiment based on the initial mass of your sample.
4. Calculate the percent yield of copper actually produced in this experiment.
5. Why must objects be cooled before their mass is determined on a sensitive balance?
6. A student fails to place the lid on the crucible during the initial heating of the hydrated sample and some of the solid spatters out. What effect does this error have on the calculated mass of the water lost by the hydrate? Justify your answer.