# LAD A.1 Formula of a Hydrate

Name___________________Per____

## 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 many solid ionic compounds. When this occurs, the trapped water molecules are called *water of hydration* and they become an integral part of the crystal structure. The resulting compound is called a *hydrate*.

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 drying agents. Look for the drying agent in the bottom of the *desiccator* in this lab. You've seen drying agent in vitamin bottles, leather shoes, and electronics. There are compounds that absorb such large quantities of water vapor that they will actually dissolve in their own water of hydration, a property known as *deliquescence*.

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 $19^{th}$ century (documents suggest he published in 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 mass ratios of elements in a compound will be constant and that the mole ratios of elements in a compound will be *small whole* numbers; this is the *law of constant (definite) composition*, which is sometimes called the *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 determining the proper chemical formula from information in the periodic table for a compound is that there may be more than one plausible mole ratio for the elements in that compound. This occurs because of the ability of elements to exist in more than one *oxidation state*, particularly many of the *transition metals* and many nonmetals when combining with other nonmetals. Dalton called this the *law of multiple proportions*. For example, if you were testing a compound that contained copper and sulfur, the plausible chemical formula could be CuS or $Cu_2S$. If you experimentally determine the mass of copper and the mass of sulfur present in a given mass of the compound, you will be able to establish the empirical chemical formula of that particular compound. You could analyze CuS or $Cu_2S$ to verify the law of constant composition; however, you must study both compounds in order to verify the law of multiple proportions.

## Procedure Overview

In this *gravimetric* (Google this word for a definition) experiment, you will test an 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 $Cu_xCl_y \cdot zH_2O$. The letters $x$, $y$, and $z$ represent integers that will establish the proper chemical formula for this substance.

This experiment is really two separate procedures. Determining the water of hydration, and establishing the chemical formula for the anhydrous copper(?) chloride.

Although the water molecules are attached to the ionic solid that you will test, they are susceptible to removal by heat, this means they are only loosely attached. In the first part of the experiment, 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 after completing part two, you will be able to calculate its water of hydration, the "$z$" value.

In the second part of this experiment you will conduct a chemical reaction with the copper(?) chloride compound, 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 moles of chlorine in your sample, and you will be able to establish the proper empirical formula, the "$x$ and $y$" values.

## PreLAD ***This must be done before class, and this page will be turned in. All work must be shown clearly.***

1. Read the Procedure Overview, the Procedure, and Processing the Data and then make a Data/Results Table − please do it in Google Spreadsheet. Title the document with your LAST name first, and share it with the teacher with full permissions. All other labs in this course will also be in this very same document. You should start setting up formulas for calculations.
2. Read the Post LAD Questions so you know what is coming and so that you can be discussing them with your partners and lab bench neighbors at appropriate times during the LAD.
3. The term “gravimetric” was used in the introduction. Look this word up and jot down a concise definition. (1)
4. The concept of *heating to a constant mass* is used in this lab. What does this mean and why is it necessary / important? (1)
5. Beryllium sulfate is a hydrated compound whose formula can be written $BeSO_4 \cdot zH_2O$, where z is the number of moles of $H_2O$ per mole of $BeSO_4$. When a 3.284 g sample of this hydrate was heated at 130°C, all of the *water of hydration* was lost, leaving 1.336 g of *anhydrous* beryllium sulfate. Calculate the value of z, and write the formula and name of the hydrate. (4)
6. 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. (1)
    b. According to the law of conservation of mass, what is the mass of oxygen that reacted with the iron? (1)
    c. Calculate the number of moles of oxygen in the product. (1)
    d. Use the whole number ratio between the number of moles of iron and number of moles of oxygen to calculate the empirical formula of iron oxide. (2)
    e. Determine the oxidation number of the iron in this compound. (Yikes! a fractional oxidation number − Google *magnetite* and check out Wikipedia for some decent info - We will discuss this briefly in class − take notes here.) (2)

## MATERIALS *on each tray, shared by two lab groups*

At the Lab bench shared by 2 groups

- tongs, forceps, glass rod, & plastic spatula ×2
- ring & burner ×2
- small beaker ×2
- Büchner funnel and filter paper ×2
- large watch glass ×2
- vial of copper chloride hydrate ×1 (~8 g)
- aluminum wire ×2 (~ 20 cm each)
- ~6 M HCl solution in dropping bottle
- tap water wash bottle ×2
- small terra cotta plant pot
- lighter or matches
- tile for cooling evaporating dish
- dessicator

On center Lab bench

- evaporating dish and cover (dried in oven) ×24
- balances
- drying ovens (set at 110−120ºC)
- side-arm flask, hose and rubber collar
- vacuum pump
- ethanol in wash bottle
- class tray to collect Büchner funnels to dry

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

### *Part A − Determination of the water of Hydration*

*You have done a hydrate lab in first year chemistry, and should be able to write a brief procedure here. This should allow you to write a line item for each data you need to collect into your Google Sheet Data/Results table.*

### *Part B − Determination of the Empirical Formula* ***Goggles and aprons are not an option - Wear them.***

**Observations**: In the space below, comment on the color of the anhydrate, then the color as you begin to dissolve the anhydrate, paying attention to how the color changes as more water is added. (2)

5. Dump your anhydrate into a small beaker. No need to weigh the beaker. Add a small amount of tap water to the evaporating dish, and stir with an stirring rod to completely dissolve the solid that has stuck and pour contents into the small beaker dissolving the anhydrate. Repeat the rinsing process as necessary. (If by chance, the anhydrate is too stuck, you may need to leave the evaporating dish to soak overnight.

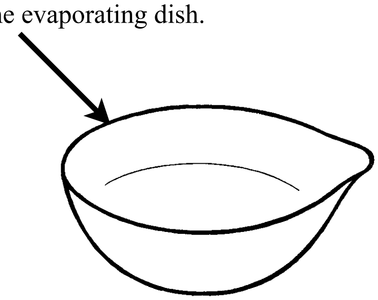
**Check in to see if this will be a stopping point in the lab, to be continued tomorrow.**

6. Take your piece of aluminum foil (no need to weigh the foil) and roll it loosely around a pen or pencil. Stand up one end of the aluminum rolled tube into the beaker. The reaction may take a few minutes to begin, then it will proceed quite rapidly. The reaction will take some time to complete. As the aluminum foil tube reacts, gravity will feed the tube down into the solution.

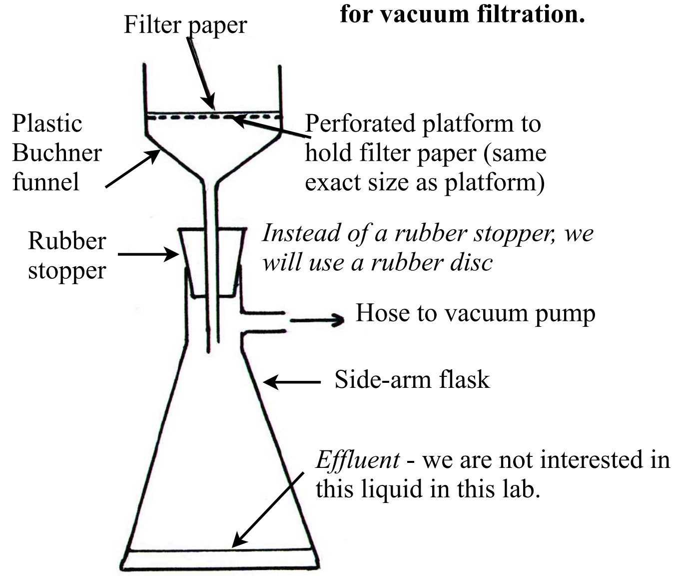
**Observations**: In the space below, comment on observations that give evidence that a reaction is occurring. (2)

7. When the reaction is done, the solution should be colorless, though it may be cloudy. Most of the elemental copper should have fallen to the bottom of the beaker. Shake or use the water bottle to rinse off any stuck copper. If the solution is cloudy, add a squirt of 6 M HCl solution to dissolve any insoluble aluminum salts in the mixture. The acid 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.
8. Use a plastic spatula and forceps to scrape off as much copper as possible from the Al wire. Then rinse off any remaining copper with distilled water. If any of the copper refuses to wash off the aluminum wire, try to wash it off with a bit of 6 M HCl solution. The left-over Al foil should be put into the trash can.
9. Collect and wash the copper produced in the reaction using vacuum filtration.
   a. Prepare a Büchner funnel for vacuum filtration (check out the diagram below) by obtaining a piece of filter paper that fits inside the bottom of the funnel. Record the mass of the filter paper together with a watch glass (on which you will place your filter paper and copper to dry).
   b. Note that the Büchner funnel has two parts, one partner should tightly hold the flask and funnel as demonstrated before class to maintain quality suction, while the other partner does the pouring of the copper onto the filter paper
   c. Take your copper and funnel to the vacuum pump. While drawing "suction" through the funnel, lightly moisten the paper to seal the paper edges to the platform of the funnel. Use small amounts of deionized water to wash all of the copper onto the center of the filter paper in the Büchner funnel. Use the plastic spatula to break up the larger pieces of copper. Rinse the spatula as necessary.
   d. Wash the copper twice more with small amounts of deionized water, and then a small amount of ethyl alcohol to aid in drying.
10. Using tweezers, carefully slide the filter paper out of the Büchner funnel on to a large watch glass (labeled with your name) and set the watch glass on the class tray on center lab bench to dry overnight.
11. Weigh the FP, watch glass, and dried copper all together.
12. Use a sponge as necessary to clean your lab area (sponges in the buckets of warm water on the center lab bench), tidy up the tray and leave all other materials on the lab tray at your lab station. Wash your hands when finished cleaning up.

Take a close look at the rim of the evaporating dish.



**Büchner Funnel Set-up for vacuum filtration.**



## PROCESSING THE DATA

***All of the calculations below should be line items in your data/results table. Since # 8 is the grand result of this lab, be sure you have room to report it below your data/results table.***

- You (or your partner) must enter your measured data (with partner's name) to the Lab data collection form on the website.
- Be sure that you have a second column in your data/results table with the SAMPLE DATA.

1. Calculate the final constant mass of your anhydrate (by subtracting the empty dish)
2. Calculate the mass of water removed from the hydrate
   a. Calculate the number of moles of water were in your sample of copper chloride hydrate.
3. Calculate the mass of copper that was in your sample of copper chloride.
   a. Calculate the number of moles of copper that were in your sample of copper chloride.
4. Using the Part B anhydrate, calculate the mass of chlorine were in your part B sample of copper chloride.
   a. Calculate the number of moles of chlorine were in your sample of copper chloride.
5. Calculate the Cl/Cu mole ratio. Round to one decimal place.
6. Calculate the moles of anhydrate.
7. Calculate the mole water/mole anhydrate (part A) ratio.
8. Write the proper chemical formula and name for the original hydrated compound that you tested.
9. Using the mass of the **hydrate** calculate the theoretical yield of copper.
10. Calculate the percent yield of copper actually produced in this experiment.

## POST LAD QUESTIONS − *To be completed on this page. Clear, concise, complete answers − full sentences are not 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)

2. During part B of the lab, the copper chloride anhydrate was dissolved in water. Draw a particulate sketch of the dissolved copper chloride in the box on the left. In the box on the right, sketch at least four or five water molecules as they would arrange around a single dissolved copper chloride unit.Indicate the partial charges of the water molecules $\delta+$ or $\delta-$
In the space below each drawing, make a bullet list of a few key points that each model attempts to display. (7)

3. Due to the arrangement of particles demonstrated in the box on the right, some water molecules are ripped apart due to their close association with the copper ions. The copper ions are acting as a Lewis acid. Look up the definition of Lewis acid on the bottom of page 649 in your textbook. Rewrite that definition below. (1)

4. In the “Hydrolysis of Metal Ions” section on page 650 in your text book, you will see a reaction representing the interaction of iron(III) ions with water. This is a hydrolysis reaction. Rewrite that balanced equation below, substituting copper ions (from this lab) for the iron ions. (2)

5. 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 a balanced net ionic redox reaction that occurs between aluminum metal and acid ions. (2)

6. Did you notice that the rim of the porcelain evaporating dish is unglazed? Observe what water will do to the unglazed terra cotta plant pot on your tray. What is the purpose of preheating the evaporating dish prior to measuring its mass? Would the experimentally determined moles of water in the hydrate appear to be larger, smaller, or the same on a humid day if the evaporating dish had not been heated before the initial weighing? Justify your answer. (4)

7. Why should objects be cooled before their mass is determined on a sensitive balance? (More than one answer would be appropriate, and do NOT answer that the hot dish will not break the balance, because in fact a hot dish will NOT break or damage the balance.) (2)

8. After removing the water from the hydrated sample a student fails to cool the evaporating dish in the desiccator. This might be a problem on a humid day in September since our lab is not air conditioned. Would this oversight cause the experimentally determined mole ratio of the water /anhydrate to be larger, smaller, or remain the same. Justify your answer. (3)

# **Scoring Rubric** (out of 100 pts)

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|---|---|
| 5 | PreLab Data Table done BEFORE Lab day |
| 5 | PreLab Questions done BEFORE Lab day |
| 4 | Observations |
| 13 | PreLab Questions |
| 23 | PostLab Questions |
| 40 | Data Table (What makes a good data table? Be sure and read the this document to find out) Stapled to the END of this lab sheet. |
| 10 | Anything else… |