CHM 2045 LAB 5: DETERMINING THE FORMULA OF A HYDRATE
BACKGROUND INFORMATION FOR THE TOPICS INVESTIGATED IN THIS LAB

A hydrate is an ionic compound that has a definite amount of water molecules attached to its crystalline structure. The ratio of water molecules to the anhydrous salt is constant. Many compounds exist as hydrates. Some examples are copper (II) sulfate, sodium sulfate, nickel (II) sulfate, iron (II) sulfate, cobalt (II) chloride, magnesium sulfate, sodium carbonate, calcium sulfate, sodium acetate, and barium chloride.

The hydrate $Na_2S_2O_3 \cdot 5\ H_2O$ is used in photography to fix negatives during the development of photographs. Five water molecules are attached to every sodium thiosulfate molecule. Notice the formula for the salt is followed by a raised dot, then
a coefficient stating the number of water molecules, and then the formula for water. The raised dot means that the water molecules are loosely attached to the ionic compound. This hydrate $Na_2S_2O_3 \cdot 5\ H_2O$ is named sodium thiosulfate pentahydrate. The name of the anhydrous salt is followed by a prefix indicating the number of water molecules followed by the word hydrate.

In this experiment the hydrates of copper(II) sulfate, $CuSO_4 \cdot \boldsymbol{x}\ H_2O$, and magnesium sulfate, $MgSO_4 \cdot \boldsymbol{x}\ H_2O$, will be studied. The water molecules are loosely attached to the salt and can be removed upon heating yielding the anhydrous salt (salt without water). The mass of water lost during heating can be determined and the coefficient ***x*** can be calculated from the ratio of moles of anhydrous salt to moles of water.

Hydrate ---Δ---> anhydrous salt + water

The symbol Δ represents heat. Sometimes a color change occurs when a colored hydrate is heated. However a color change does not usually occur for white crystalline hydrates.

This experiment will also illustrate the law of conservation of mass and the law of definite proportions. The law of conservation of mass states that the total mass remains constant during a chemical change or chemical reaction. Atoms are not destroyed, created, or broken down during a chemical reaction. A chemical reaction only rearranges the combination of atoms. The total mass remains constant.

Mass of substances <u>before</u> reaction = Mass of substances <u>after</u> reaction

In this experiment:

mass of Hydrate = mass of H_2O lost + mass of anhydrous salt after heating

The law of definite proportions or constant composition states that the elements in a pure compound are present in a definite constant mass. For example, every molecule of water has 2 hydrogen atoms for every one oxygen atom OR a mole of H_2O has 2.016 grams hydrogen for every 16.00 grams oxygen. The hydrate $Na_2S_2O_3 \cdot 5\ H_2O$ has a constant composition of 5 moles H_2O for every 1 mole $Na_2S_2O_3$.

Objectives:

1. Calculate the molar mass of a compound
2. Convert grams to moles
3. Determine the formula of a hydrate
4. Determine the mass percentage of water in a hydrate
5. Understand the law of definite composition and law of conservation of mass

Prior to lab read the sections in Chapter 6 that discuss the topics: moles, molar mass, hydrates, percent composition, and the law of definite composition.

Chemicals:
Hydrates: $CuSO_4 \cdot x\ H_2O$ and $MgSO_4 \cdot x\ H_2O$

Equipment:
crucible, crucible tongs, clay triangle Ring clamp, thin spatula, butane burner, tile, analytical balance

Sample Calculation:

A 3.255 gram sample of cobalt (II) chloride hydrate $CoCl_2 \cdot x\ H_2O$ was heated carefully. After heating, 1.776 grams of the anhydrous salt $CoCl_2$ remained.

a) What is the formula of the hydrate?

First determine mass H_2O, next calculate moles H_2O, then calculate moles of anhydrous salt

Mass of H_2O = mass hydrate - mass anhydrous salt
= 3.255g – 1.776 g = 1.479 grams H_2O

Molar mass of H_2O = [2 H x 1.01] + [1 oxygen x 16.00]

= 2.02 + 16.00 = 18.02 g/mole H_2O

Moles H_2O $= 1.479\ g\ H_2O \times \frac{1\ mole\ H_2O}{18.02\ g\ H_2O} = 0.08208\ mole\ H_2O$

Molar mass of $CoCl_2$ = [1 Co x 58.93] + [2 Cl atoms x 35.45]

= 58.93 + 70.90 = 129.83 g/mole $CoCl_2$

Moles of $CoCl_2$ = $1.776\ g\ CoCl_2 \times \frac{1\ mole\ CoCl_2}{129.83\ g\ CoCl_2} = 0.01368\ mole\ CoCl_2$

Ratio moles H_2O to moles $CoCl_2$
$= \frac{0.08208\ mole\ H_2O}{0.01368\ mole\ CoCl_2} = 6$
This represents 1 mole $CoCl_2$ to 6 mole H_2O so the formula of hydrate is $CoCl_2 \cdot \mathbf{6}\ H_2O$

b) What is the mass percent of H_2O in the hydrate?

$$Percent\ H_2O\ = \frac{mass\ H_2O}{mass\ hydrate\ (CoCl_2 \cdot 6\ H_2O)} \times 100$$

$$Percent\ H_2O\ = \frac{1.479\ g\ H_2O}{3.255\ g\ CoCl_2 \cdot 6\ H_2O} \times 100\ = 45.44\%\ H_2O$$

This experiment contains several parts. Each part is described in the instructions. An Excel spreadsheet will be used to enter collected data and calculations.

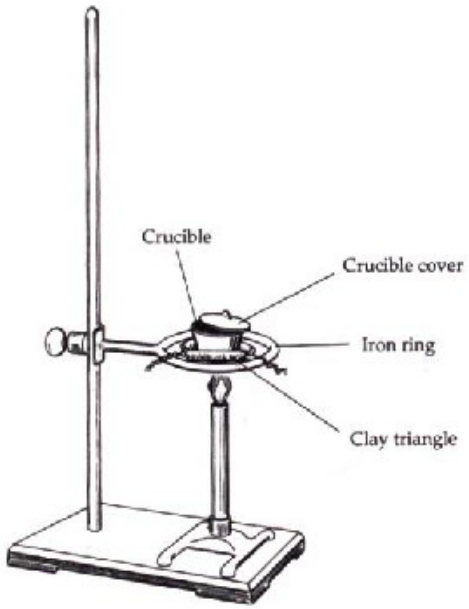
The parts to the experiment are:

1. Safety precautions
2. Preparing the crucible
3. Heating the hydrate
4. Lab Cleanup

Download the Data Spreadsheet Safety precautions:
Wear safety goggles.
Do not touch the hot crucible or iron ring with your hands. Always use tongs.
Do not set a hot dish on the table, set it on tile.
When working with the butane burner, tie back long hair. Secure loose clothing such as drawstrings from sweatshirts.

Procedure:
Preparing the crucible:

1. Wash the crucible with soap and water. Rinse with distilled water. Dry with paper towels.
2. Prepare the setup as shown below inside the fume hood. [The ring clamp and clay triangle should be a few inches above the butane burner.] Place the clean crucible on the clay triangle.



3. Using the hottest part of the flame, heat the empty clean crucible for 5 minutes.
4. Do not touch the hot crucible with your hands. With the tongs, remove the dish and place it on a tile. Cool for 5 minutes.
5. Mass the cooled crucible and record the mass. WRITE ALL of the digits from the balance reading. The mass of the empty crucible is CRITICAL to the results. If there is any doubt as to whether the crucible is completely dry, repeat the heating, cooling, and massing.

Heating the copper (II) sulfate hydrate:

1. Use the SAME analytical balance for the entire experiment. Place a small scoop of the blue copper(II) sulfate •hydrate into the crucible and record the mass.
2. Place the crucible containing the hydrate on the clay triangle.
3. Heat strongly for 5 minutes or longer until the blue color disappears.
   During this heating process, use the tongs to remove the crucible and place the crucible onto a tile. While holding the crucible with the tongs, use a thin spatula to break up any clumps so the 'trapped' water molecules can evaporate. Do not remove any of the solid with the spatula. If the edges of the hydrate begin to yellow or brown, remove the heat momentarily. Heat again at a gentler rate.
4. When you see no remaining blue color to the solid, stop heating (do not ask Professor if you're done heating, you will need to determine this with your partner).
5. With the tongs, remove the crucible and place it on a triangle. Allow the crucible and cool to touch (3-5 minutes).
6. Record the mass of the crucible and anhydrous salt (1^{st} heating).
7. Heat again for 5 minutes. If the edges of the hydrate begin to yellow or brown, remove the heat momentarily. Heat again at a gentler rate.
8. With tongs, place it on a tile and cool to touch (3-5 minutes).
9. Record the mass of the crucible and anhydrous salt (2^{nd} heating).
10. If the masses after the first and second heating do not agree to within $^{+}/_{-}$ 0.020 grams, heat a third time, cool, and mass again. If mass increased, do not heat a third time.

Heating the magnesium sulfate hydrate:

1. Clean and prepare a second crucible by washing it, drying it, and heating it as described in the section above titled "**Preparing the crucible**".
2. Record the mass of the clean crucible under the heading for "$MgSO_4$ Hydrate".
3. Repeat the entire experiment and record the data using magnesium sulfate •hydrate (known as Epsom salt), instead of copper (II) sulfate •hydrate. Follow the procedure listed above for heating the hydrate and record the mass after each heating. There will not be a color change but instead a crystallized material will change to a powder.

Lab Cleanup:

1. Let the iron ring and clay triangle cool till the end of lab and then put them away.
2. Observe the color of the anhydrous salt. Did it change color? What does the color indicate?
3. Using a water bottle, spray a few drops of water on the copper sulfate hydrate. Observe what happens.
4. Discard the product in the metal waste container located in the back of the lab.
5. Wash the crucibles and spatulas and put away.
6. Clean balance, fume hood, tile, lab table and put everything away to the proper location.