Discovery of the Amount of Hydrated Chemical Compound and its Empirical Formula

Group Members:
Ashu Yalamarty
Jonathan Wang
Leon Fu
Vasanth Rajasekaran

Contributions:
Ashu Yalamarty: Data Table & Post Lab Questions
Jonathan Wang: Background of Lab
Leon Fu: CER
Vasanth Rajasekaran: CER

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Background of Lab

Materials

- Crucible
- Unknown solid copper chloride hydrate
- Crucible tongs
- 20 cm aluminum wire
- 6 M hydrochloric acid, HCl, solution
- Ring stand, ring, and clay triangle
- 95% ethanol solution
- Lab burner
- Distilled water
- 50 mL beaker
- Büchner funnel and filter flask balance
- Filter paper for Büchner funnel
- Glass stirring rod
- Watch glass
- Heat lamp

Background

The purpose of this lab is to determine the percent water in the copper chloride hydrate and the empirical formula of the compound. Stoichiometry can help in calculating empirical formulas. By gently heating an ionic compound and measuring its mass before and after heating, we can determine the amount of hydrate, or the water evolved, within the copper chloride compound. Water of hydration refers to water molecules trapped in solid compounds due to water's strong polarity. In this lab, we refer to it as water evolved. Since water is a good solvent for ionic compounds, it becomes an integral part of the compound's structure. Compounds that absorb water from the air are called hygroscopic. (Contributors:, Flowers, P., Theopold, K., Langley, R., Key, J. A., Ball, D. W., Soderberg, T., Wacowich-Sgarbi, S., & Department, L. C. (n.d.). 5.4 determining empirical and molecular formulas. CHEM 1114 Introduction to Chemistry. https://pressbooks.bccampus.ca/chem1114langaracollege/chapter/3-2-determining-empirical-and-molecular-formulas/)

By gently heating the compound, we remove the water of hydration or water evolved. The process will allow us to calculate the amount of water present in the copper chloride hydrate. The reaction between copper chloride and solid aluminum will help separate the copper and chlorine elements, allowing us to determine the mass and moles of each. Aluminum assists in this reaction by helping to isolate the copper and chlorine from the compound(Pauller, N. (2014b, May 20). How can I calculate the percent composition of water in a hydrate?: Socratic.

Socratic.org.https://socratic.org/questions/how-can-i-calculate-the-percent-composition-of-water-in-a-hydrate)

Using the masses of the copper chloride sample and the water lost, we can calculate the empirical formula of the copper chloride hydrate. The empirical formula represents the simplest whole-number ratio of elements in a compound, which in this case, can be determined based on the reaction and mass changes observed during the lab.

Lab Results

Data Table of Masses Recorded Throughout Copper Chloride Hydrate Lab:

Mass of Crucible(g)	**31.21 grams**
Mass of Crucible and Hydrated Sample(g)	**32.21 grams**
Mass of Hydrated sample(g)	**32.21 - 31.21 = 1.00 grams** **Mass of Crucible and Hydrated Sample - Mass of Crucible**
Mass of Crucible and Dehydrated Sample(g)	**First Heating: 31.98 grams** **Second Heating: 31.98 grams** **Third Heating: 31.98 grams**
Mass of Water Evolved(g)	**1.00g - 0.77g=0.23g** **Mass of Hydrated Sample - Mass of Dehydrated Sample**
Mass of Empty Watch Glass(g)	**45.71g**
Mass of watch glass, copper, and filter paper(g)	**46.30g**
Mass of Copper(g)	**46.30 - (0.25g + 45.71g) = 0.34g** **Mass of Watch Glass, Copper- and filter paper - (Mass of Empty Watch Glass + Mass of Filter Paper)**
Mass of Filter Paper(g)	**0.25g**

Post Lab Questions

1. Why must objects be cooled before their mass is determined on a sensitive balance?

Objects must be cooled before heating due to the convection currents that they create causing the scale to display an inaccurate measurement of the mass. Another reason why objects are cooled before they are measured is so that the measurement tools are not damaged due to the heat transfer.

2. How many moles of water were in your sample of Copper Chloride Hydrate?

Post Lab Questions

2. Mass of dehydrated sample: 31.98g − 31.21g = 0.77 g

Mass of water = mass of Hydrated sample − Dehydrated sample

= 1.00g − 0.77g = 0.23g

$$0.23g\,H_2O \left(\frac{1\text{ mol }H_2O}{18.02g\,H_2O}\right) = \boxed{0.013\text{ mol }H_2O}$$

$\boxed{0.013\text{ moles}}$ of H_2O were present in the CopperChloride Hydrate

3. How many moles of Copper were in your sample of Copper Chloride?

3. Mass of copper: 46.30g − 0.25g − 45.71g = 0.34g

$$0.34g\,Cu \left(\frac{1\text{ mol Cu}}{63.55g\,Cu}\right) = \boxed{0.0054\text{ mol Cu}}$$

$\boxed{0.0054\text{ moles}}$ of Copper were present in the CopperChloride sample

4. How many moles of Chlorine were in your sample of Copper Chloride?

4. Mass of Chlorine: Mass of dehydrated Sample − Mass of Copper
Mass of dehydrated Sample: 31.98g − 31.21g = 0.77g
Mass of Copper: 0.34g Cu
Mass of Chlorine: 0.77g − 0.34g = 0.43g Cl

$$0.43\text{g Cl}\left(\frac{1\text{ mol Cl}}{35.45\text{g Cl}}\right) = \boxed{0.012\text{ mol Cl}}$$

$\boxed{\text{0.012 moles}}$ of Chlorine were present in the Copper chloride Sample

5. Write the proper chemical formula and name for the compound that you tested

5. 0.012 mol Cl ÷ 0.0054 = 2
0.0054 mol Cu ÷ 0.0054 = 1

Empirical Formula: $\boxed{\text{CuCl}_2 \text{ - Copper (II) Chloride}}$ Anhydrous Sample

$$0.77\text{g CuCl}_2\left(\frac{1\text{ mol CuCl}_2}{134.45\text{g}_{\text{CuCl}_2}}\right) = 0.0057\text{ mol CuCl}_2$$

moles of H_2O: 0.013 mol H_2O

$CuCl_2$	H_2O
$\frac{0.0057}{0.0057}$	$\frac{0.013}{0.0057}$
1	2.328
·2	·2

$\boxed{CuCl_2 \cdot 2H_2O \text{ — Copper (II) Chloride dihydrate}}$

6. Use stoichiometry to calculate the theoretical yield of Copper in this experiment based on the initial mass of your sample.

6 $CuCl_2 \cdot 2H_2O \rightarrow Cu_{(s)} + 2Cl_{(s)} + 2H_2O_{(g)}$

$$1.00\text{g } CuCl_2 \cdot 2H_2O \left(\frac{1 \text{ mol } CuCl_2 \cdot 2H_2O}{170.49\text{g } CuCl_2 \cdot 2H_2O}\right)\left(\frac{1 \text{ mol Cu}}{1 \text{ mol } CuCl_2 \cdot 2H_2O}\right)\left(\frac{63.55\text{g Cu}}{1 \text{ mol Cu}}\right) = \boxed{0.372\text{g Cu}}$$

7. Calculate the percent yield of Copper actually produced in this experiment.

7. $$\frac{0.34\text{g}}{0.372\text{g}} \times 100 = \boxed{91\%}$$

8. 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

If the original hydrated mass of the sample is 1.00 grams but some of the sample spatters out during heating, this will cause the mass of the dehydrated sample to be less than expected. In this experiment, the mass of the dehydrated sample was 0.77 grams. Meaning that there was 0.23 grams of water. But if some of the sample spattered out this would cause the dehydrated sample to be less this will cause the mass of water to increase. For example, if 0.10 grams of the dehydrated sample was lost this would cause the mass of water to evolve to become 1.00 - 0.67 = 0.33 grams of water causing water's mass to be higher than it should be.

CER

Claim:

The empirical formula of the copper chloride hydrate can be discovered by heating the substance in a crucible and its reaction with an aluminum wire.

Evidence:

This is done by measuring the sample before and after heating. In a case where the initial mass of a hydrated sample was 1.00 grams, this was determined by subtracting the mass of the crucible which is 31.21g from the mass of the crucible + hydrated sample 32.21g to get a perfect mass of 1.00g. By heating the sample to such a temperature that it evaporated to get rid of the water of hydration, the crucible mass plus the dehydrated sample obtained constant mass at 31.98 g and the mass of the dehydrated sample was 0.77g or 31.98 g - 31.21 g. The mass of water of hydration lost upon heating can be calculated now by subtracting the dehydrated sample from the hydrated sample which gives a mass of 0.23g 1.00g - 0.73g. After dehydration, the compound was dissolved and reacted with aluminum wire creating elemental copper. The mass of the elemental copper was determined by subtracting the masses of the filter paper and the watch glass from the total mass. The clean watch glass had a mass of 45.71 g, while the watch glass, filter paper, and copper had a combined mass of 46.30 g. The mass of the filter paper was taken to be 0.25g and the mass of copper was calculated by subtracting the mass of the paper and watch glass from the total mass, 46.30g - 45.71g - 0.25g, giving us the mass of copper produced to be 0.34g. The measurements produced will now be used to calculate the moles of water, copper, and chlorine. These measurements are necessary in deducing the empirical formula of the compound.

Reasoning:
The mass of copper can be found by subtracting the mass of the watch glass, copper, and filter paper(g) by the mass of the empty watch glass (g) = resulting in the mass of copper in grams which is 0.34 grams. Dividing the mass of copper (0.34 grams) by the molar mass of copper (63.55 grams), results in the moles of copper which is 0.0054 moles of copper. This means that 0.0054 moles of copper were present in the copper chloride sample. The mass of copper can help determine the amount of chloride in the sample. But the first step to finding the moles of chloride is to find the mass of chloride, which can be done by subtracting the mass of the dehydrated sample (0.77 grams) from the mass of copper (0.34) resulting in the 0.43 grams of chlorine. The grams of chlorine can then be converted to moles of chlorine by dividing the mass of chlorine (0.43 grams) by the molar mass of (35.45 grams), which results in 0.012 moles of chlorine present in the copper chloride sample. Next to find the empirical formula the moles of chlorine (0.012 moles chlorine) and moles of copper (0.0054 moles copper) need to be divided by the smallest amount of moles, which is 0.0054 moles of copper. Dividing 0.012 moles of chlorine by 0.0054 moles of copper equals 2, and 0.0054 moles of copper divided by 0.0054 moles of copper equals 1. The values are the amount of chlorine and copper in the empirical formula, resulting in the empirical formula being $CuCl_2$ which is Copper (II) Chloride. Next to find the empirical of water present in the sample, divide the mass of $CuCl_2$(0.77 grams) by the molar mass of $CuCl_2$ (134.45 grams) equalling 0.0057 moles of $CuCl_2$. The mass of the dehydrated sample, which is 0.77g can be used to determine the moles of water present in the sample. The mass of water can be found by subtracting the hydrated sample (1.00g) from the dehydrated sample (0.77g) = 0.23 g, which equals the mass of water present in the hydrate. Using the mass of water, the moles of water can be calculated by dividing the mass of water by the molar mass of water. Resulting in 0.013 moles of H_20. The next step is to divide the moles of H_20 and moles of $CuCl_2$ by the smallest amount of moles, which is 0.0057 grams. Resulting in a coefficient of 1 for $CuCl_2$ and 2 for H_20. Ending with the final empirical formula of $CuCl_2 + 2H_20$. The empirical formula that was determined reinforces the claim by showing that the empirical formula of the copper chloride hydrate can be discovered by heating the substance in a crucible and its reaction with an aluminum wire. To calculate the theoretical yield now, the moles of copper in the original sample have to be determined. Based on the empirical formula, for every mole of the compound, there is 1 mole of Cu based on the ratios. The molar mass of the empirical formula can be calculated

with Cu(63.55g/mol) + 2Cl(2*35.45g/mol) + 2H2O(2* 18.02g/mol) = 170.48g/mol. Now, the equation 1.00g/170.48g/mol can be used to get moles of the empirical formula, totaling 0.00587 mols. Since there is 1 mole of Cu per mole, 0.00587 mols is correct. Now, to calculate theoretical yield the equation 0.00587 mol * 63.55 g/mol = 0.373g. Now to calculate the percent yield, the actual yield is taken (0.34g) divided by the theoretical yield(0.373g), and multiplied by 100 to get 91.2%. Therefore, the percent yield of copper in this experiment is 91.2%. While the collection of data was occurring, an error of incomplete reactions due to chemical limitations could be found. Not all copper(II) ions fully reacted with the aluminum wire to produce copper. This error is caused by some of the ions remaining in the solution due to reaction time, or due to different reactions that prevented the full response with copper ions. This error leads to a lower yield of the copper, which affects the accuracy of the percent yield calculation. A possible explanation that would fix this error would be to extend the reaction time, allowing it to run for a longer period. This gives the copper(II) ions more time to fully react with the aluminum. A possible follow-up experiment would be to investigate the percent yield of copper using different metals instead of reacting with copper chloride. This allows the exploration of different elements to see which is most effective at reducing the copper ions to elemental copper and how the efficiency is affected.

Citations APA Format

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