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Determination of the Formula Weight of a Copper Compound

Purpose

The objectives of this lab were to perform measurements, and observe a chemical reaction to determine the formula weight of a copper compound in an unknown substance.

Introduction

I worked with an unknown compound that contained one copper atom per molecule. The compound was dissolved in hydrochloric acid, and I observed a single replacement reaction using Magnesium (Mg) as demonstrated below:

$$\text{Cu compound} + 2\ HCl \rightarrow CuCl_2 + \text{H compound}$$

$$CuCl_2 + Mg \Rightarrow Cu + MgCl_2$$

Because the reaction was in an acid solution, we observed a second reaction:

$$Mg + 2\ HCl \Rightarrow MgCl_2 + H_2$$

As result of hydrogen gas being released in the second reaction, I performed the experiment under the hood. As soon as the reaction was completed the metallic copper was filtered from the acid solution, dried in an oven, and weighed.

Procedure

1) Obtain a vial of an unknown compound
2) Weigh the vial with the cap in place
3) Pour half of the contents of the vial into beaker number 1
4) Reweigh vial with cap in place
5) Pour the remaining contents into beaker number 2
6) Reweigh vial with cap in place to determine weight of both vial and compound
7) Add 50 ml of H_2O to each beaker
8) Place both beakers under hood
9) Add 6 ml of HCl to each beaker, stir until the solid dissolves
10) Add 0.5 g of Magnesium turnings to each beaker and stir well
    a) Reaction is complete when solution is clear
    b) Add a couple more Magnesium turnings if solution is still colored but not bubbling
11) When solution is colorless add 2ml of HCl to dissolve remaining Magnesium

12) Label and weigh 2 pieces of filter paper
13) Filter solution #1 through filter paper #1
    a) Repeat following steps for solution #2 and filter paper #2
14) Use 25ml of H_2O to transfer copper to filter paper and to wash filter paper
15) After H_2O has drained wash filter paper and copper with 5 ml of Ethyl Alcohol
16) After Ethyl Alcohol has drained wash filter paper and copper with 5 ml of Acetone
17) Remove filter paper and spread on watch glass
18) Place in oven to dry for approximately 10 minutes
19) Weigh filter paper and record results

Data and Observations

Sample ID #: 484
Sample appeared light blue and powdery

Table 1: Mass of Vial and Compound

Mass of vial and unknown compound (g)	14.13
Mass of vial and half of unknown compound (g)	12.32
Mass of vial and no compound (g)	9.80

Table 2: Initial Mass of Filter Paper

Filter Paper #1 (g)	1.05
Filter Paper #2 (g)	1.04

Table 3: Final Mass of Filter Paper and Copper Metal

Filter Paper #1 (g)	1.71
Filter Paper #2 (g)	1.91

Analysis

Part 1: Mass of Unknown Compound Calculation

Initial mass – Final mass = 14.13 g – 12.32 g = 1.81 g

Table 4:Mass of Unknown Compound

Sample	1	2
Mass of Unknown (g)	1.81	2.52

Part 2: Mass of Copper Calculation

Mass of Filter Paper and Copper Metal – Mass of Filter Paper = 1.71 g – 1.05 g = 0.66 g

Table 5: Mass of Copper

Sample	1	2
Mass of Cu (g)	0.66	0.87

Part 3: Moles of Copper Calculation

Moles of a substance calculation:

$$0.66 \text{ g of Cu}\left(\frac{1 \text{ mole Cu}}{63.55\ g}\right) = 0.01 \text{ moles of Cu}$$

Table 6: Moles of Copper

Sample	1	2
Moles of Cu (mol)	0.01	0.01

Part 4: Formula Weight Calculation

Calculation of formula weight of unknown

Grams of sample ÷ moles of unknown = 0.66 g ÷ 0.01 mol= 66 g/mol

Table 7: Formula Weight

Sample	1	2
Formula Weight (g/mol)	66	87

The average of the two samples are:

(66 g/mol + 87 g/mol) ÷ 2 = 76.5 g/mol

Part 5: Analysis of Error

Average deviation:

$$\delta = \frac{\sum|x_i - x_{\text{mean}}|}{\text{n}} = \frac{|66 - 76.5| + |87 - 76.5|}{2} = \frac{21}{2} = 10.5\ \%$$

Relative STD:

$$\text{relative STD} = \frac{\text{STD}}{\text{mean}} \times 100 = \frac{10.5}{76.5} \times 100 = 13.73\%$$

The relative standard deviation is greater than 3-5% so an error must have been made somewhere

A graph of formula weight vs. mass of unknown is attached in Appendix A. The slope was determined to be: $\frac{2.52 \text{ g} - 1.81 \text{ g}}{87 \text{ (g/mol)} - 66 \text{ (g/mol)}} = .0338$

Conclusion

In this lab I determined the mass of copper in an unknown compound by using a single replacement reaction. I dissolved the unknown compound in HCl, and added Magnesium to the solution. Then I waited for the reaction to replace the Cu in the compound with Mg. After that I filtered out the Copper metal and weighed it to determine the mass of copper in the unknown compound.

There were many places where error could have occurred. First I should have more carefully measured an equal quantity of the unknown compound in the 2 beakers, instead of "eyeballing it". I should have also measured the additional quantities of Magnesium and Hydrochloric Acid to complete the reaction. And in an effort to keep more accurate scientific records I should have noted the times that I started the reaction, added more Mg or HCl to the solutions, and when the reaction was complete. Also by only repeating the experiment twice I really didn't gather sufficient data to correctly determine either the precision or the accuracy of the results.

By looking at the graphical analysis of the data, it seems that the percentage of error was very small. Because the data points did not fall very far from the regression line. However I am not certain that I am graphing the correct relationship of data.

Finally this lab gave me experience in taking measurements, performing calculations, observing chemical reactions, and practicing laboratory safety.

Appendix A: Graph of formula weight vs. mass of unknown substance