CHEM 109
Introduction to Chemistry
Revision 1.0

Laboratory Exercise: Illustration of the Law of Multiple Proportions

In this exercise we will illustrate the Law of Multiple Proportions by examining the elemental composition of two Bromides of Copper, Cupric Bromide and Cuprous Bromide, a black powder and a dark green powder respectively, whose compositions can be readily determined. This compositional information can then be used to form the following mass ratio, which, accordingly, is consistent with Dalton's Law.

$$\frac{\left(\frac{Mass\ Br\ in\ Cupric\ Bromide}{Mass\ Cu}\right)}{\left(\frac{Mass\ Br\ in\ Cuprous\ Bromide}{Mass\ Cu}\right)}$$

Cuprous Bromide
(Dark Green Powder)

Cupric Bromide
(Black Powder)

Specifically we will determine the composition of Cupric Bromide by decomposing the compound, driving off the Bromine and leaving behind Copper. This will allow us to determine the relative mass of Copper in the compound and thus will allow us to calculate the percentage Copper in the compound. For the sake of time we will use literature data for the composition of Cuprous Bromide.

Heating Cupric Bromide will lead to its decomposition:

$$\text{Cupric Bromide} \longrightarrow \text{Cuprous Bromide} + \text{Bromine Gas}$$

The resulting Cuprous Bromide is then treated with Nitric Acid, which will release the remaining Bromine and leave us with the Oxide:

Cuprous Bromide + Nitric Acid $\longrightarrow$ Cupric Oxide

Other by-products of this reaction are driven off by heating the system. The Oxide can now be reduced to elemental Copper by heating it in the presence of a Carbon source in the presence of limited Oxygen. Our source of organic Carbon will be the Natural Gas (Methane) that fuels our Bunsen burners.

Cupric Oxide + Methane $\longrightarrow$ Copper + Carbon Dioxide

By knowing the masses of the starting Cupric Bromide and the ending Copper, we can determine the composition of the compound:

$$\% \text{ Copper} = \frac{Mass\ Copper}{Mass\ Cupric\ Bromide}\ x\ 100$$

%Br = 100% - % Copper

A similar experiment will yield the following results for Cuprous Bromide:

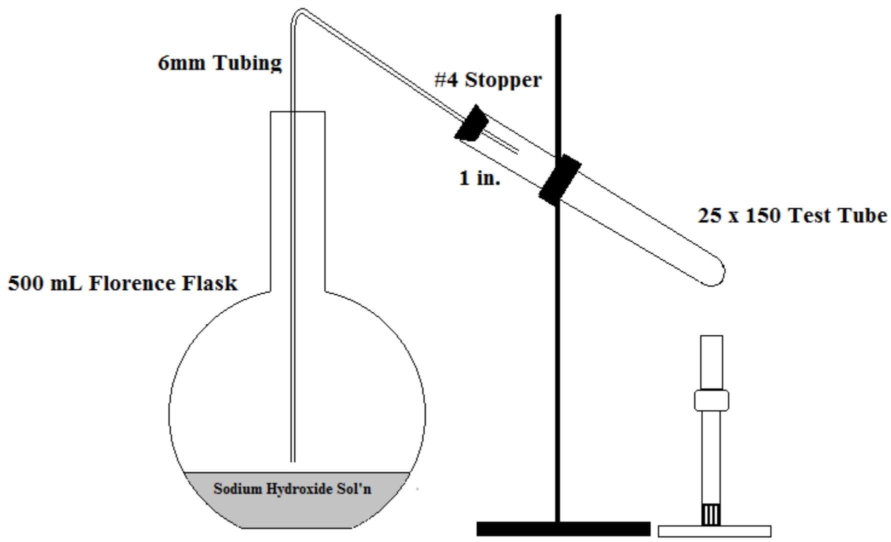
% Cu = 44.30%
% Br = 55.70%

This data for the two Bromides can now be used to illustrate the Law of Multiple Proportions. Employing Dalton's Law of Greatest Simplicity will allow for a subsequent assignment of chemical formulas top these compounds. Additional data can be marshalled to demonstrate these formulas are indeed correct.

Procedure

Conversion of the Bromide to the Oxide

1. **In the fume hood,** construct the following apparatus:



2. Accuratly weigh the large test tube on an analytical balance. Add ~0.5g of Cupric Bromide to the test tube and re-weigh it accurately. Clamp the test tube into place using a metal clamp.

3. Add about 50 mL of 0.1M Sodium Hydroxide solution the the 500 mL Florence flask. (This solution will absorb the Bromine vapors.) Arrange things such that the exhaust tube from the test tube is about 1 inch above the Hydroxide solution.

4. Heat the Bromide using the a mild flame from the Bunsen burner. After a few minutes, increase the quality of the burner's flame and heat the sample strongly. (Do not heat the sample to a Red Heat as this will cause the sample to decompose uncontrollably.) As the Bromine vapors form, play the flame along the test tube to drive them out. (Avoid heating in the region near the rubber stopper.)

5. When Bromine vapors are no longer formed in significant quantities, allow the system to cool. Remove the stopper from the test tube and again heat the tube to drive away the remaining Bromine.

6. Allow the test tube to cool completely.

7. Now, be ready to reassemble the apparatus. Add 1 mL of Concentrated Nitric Acid. Rapidly reassemble the apparatus. (The reaction will begin almost immediately upon addition of the acid.)

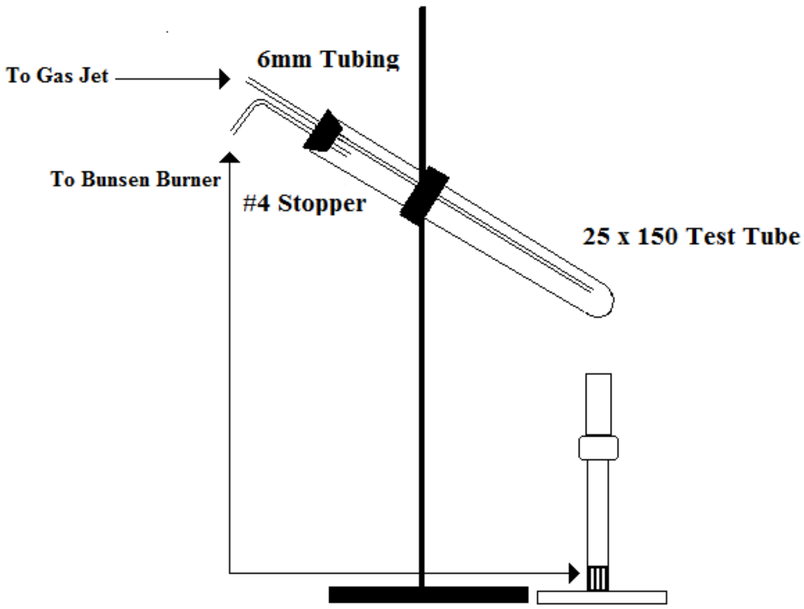
8. Begin heating the sample slowly, playing the flame over the length of the test tube.

9. Again, once it appears Bromine is no longer being produced, allow the system to cool, remove the stopper, and heat the tube until only the black Oxide of Copper remains.

10. Allow the test tube to cool. Seal the tube with a small piece of Parafilm. Store your sample until the laboratory session.

Conversion of the Oxide to Copper

1. **In the fume hood,** construct the following apparatus:



   Use rubber tubing to connect the system to the Natural Gas jet and the system to the Bunsen burner. Make sure everything is connected tightly.

2. Close off the Air vents to the burner. Light the burner and let it burn until the flame becomes luminous. (When this happens, there is no more Air in the test tube. If Air remains in the test tube, it can form an explosive mixture with the Natural Gas when heated.)

3. Adjust the burner to produce a hot, non-luminous flame and begin heating the sample.

4. The black Copper Oxide will be converted into metallic Copper. It should take about 10 minutes for this conversion to be complete. Continue heating the sample for about 5 additional minutes. Again, play the flame along the test tube.

5. When the reaction is complete, move the still burning burner off to the side and allow the test tube to cool. Turn of the burner and disassemble the apparatus.

6. Re-weigh the test tube with the Copper product.

Data Sheet

Mass Test Tube ____________________

Mass Tube + Bromide ____________________

Mass Tube + Copper ____________________

Observations:

Name: ______________________________ Date: ____________________

Signature: ______________________________

Data Analysis

1. Determine the mass of the Cupric Bromide Used.

2. Determine the mass of the elemental Copper metal produced.

3. Determine the elemental composition of Cupric Bromide; % Cu and % Br.

4. Determine the mass Bromine needed to form Cupric Bromide if 1.00g of Copper is formed as above.

5. Using the composition of Cuprous Bromide presented above, determine the mass Bromine needed to form this compound if 1.00g of Copper present in the compound.

6. Use this data to illustrate the Law of Multiple Proportions by forming the mass ratios as above.

7. Suggest reasonable chemical formulas for both of the Bromides of Copper. (Apply Dalton's Rule of Greatest Simplicity to determine the formula for Cuprous Bromide.)

Post Lab Questions:

1. How will the percentage Copper in the compound be affected if the rubber stopper is heated and some sticks to the test tube?

2. During the conversion of the Oxide to Copper, why do we allow the Natural Gas to continue to burn while the test tube cools in step 5 of the procedure?

3. How would this experiment have differed if we had started with Cuprous Bromide instead of Cupric Bromide?