Experiment 6

Determining the Empirical Formula of a Compound

Pre-Lab Assignment

Before coming to lab:
- Read the lab thoroughly.
- Answer the pre-lab questions that appear at of this lab exercise.

Objectives
- Learn the techniques of weighing accurately and quickly.
- Understand the concept of moles and how to use it as a conversion factor to determine the mass of a sample.
- Learn a method for calculating the formula of a compound from experimental data.

Purpose

In today's experiment, you will prepare a compound from known amounts of reactants through a direct combination reaction of two elements. The compound will form when a weighted amount of magnesium placed into a clean and pre-weighed crucible is heated. Oxygen gas from the air will react with the magnesium metal to produce magnesium oxide, a white-grey powdery substance as shown in the following balanced equation (Eqn. 1).

$$2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s) \qquad \text{Eqn. 1}$$

The magnesium metal will also react with nitrogen gas in the air to form a small amount of magnesium nitride as shown in equation 2. To remove any nitride product, water is added and the product is reheated. Any nitride product is converted to magnesium oxide and ammonia as shown in equation 3. The formation of the nitride product is minimal and so we will ignore it.

$$3\ Mg\ (s) + N_2\ (g) \rightarrow Mg_3N_2\ (s) \qquad \text{Eqn. 2}$$

$$Mg_3N_2\ (s) + 3\ H_2O\ (l) \rightarrow 3\ MgO\ (s) + 2\ NH_3\ (g) \qquad \text{Eqn. 3}$$

When the reaction reaches completion, the mass of the oxygen gas that combined with the magnesium metal to produce the magnesium oxide product is determined by subtracting the known mass of the crucible and the known mass of the magnesium metal from the mass of the crucible and new product. By knowing the mass of each reactant, we can calculate the moles of each and also the mole ratio of magnesium and oxygen, which is the formula of the compound.

Background

Chemical formulas express the exact ratio of atoms that compose a particular compound. For example, CO_2 contains carbon and oxygen atoms combined in a 1:2 ratio. Atoms are very small to be dealt with individually so chemists work with the mass of a larger unit of atoms known as moles. A mole of atoms contains 6.022×10^{23} atoms and provides a way of dealing with atoms despite their very small size. The mass of a mole of atoms of a particular element (in grams) equals the molar mass of that element; which can be used as a conversion factor to calculate the moles of a given mass and vice versa.

Let us consider calcium (Ca), which has an atomic mass of approximately 40. This means that 6.022×10^{23} atoms of calcium, which represent 1 mole of calcium, have a mass of 40 grams. If we have 6.2 grams of calcium, then we have 6.2/40. = 0.16 mole of calcium or

$$6.2\ g\ Ca \times \frac{1\ mol\ Ca}{40.g\ Ca} = 0.16\ mol\ Ca \qquad \text{Example 1}$$

Example Problem: Finding the Empirical Formula of barium oxide.

If 14.42 g sample of barium reacts exactly with 1.68 g of oxygen, find the empirical formula of the barium oxide product formed.

Step 1: Find the moles of barium that reacted

$$14.42 \text{ g Ba} \times \frac{1 \text{ mol Ba}}{137.3 \text{ g Ba}} = 0.1050 \text{ mol Ba}$$

Step 2: Find the moles of oxygen that reacted

$$1.68 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.105 \text{ mol O}$$

Step 3: Find the molar ratio by dividing by smallest number of moles

$$\frac{0.1050 \text{ Ba O}}{0.105 \text{ mol}} = 1 \text{ mol Ba} \qquad \frac{0.105 \text{ mol O}}{0.105 \text{ mol}} = 1 \text{ mol O}$$

Step 4: Write the empirical formula showing the calculated molar ratio
Since the molar ratio is one to one, the formula of the product is BaO.

Determining the masses of two elements that react to form a product allows for the determination of the formula of that product. Once the masses of the reactants have been determined, their moles are easily calculated by dividing the mass of each reactant by its molar mass (example 1). Comparing the moles of the reactants then allows to determine the molar ratio, that is, the relationship between the number of moles each reactant is contributing to the formation of the product.

Procedure

IMPORTANT: Work in pairs and perform two trials. While one crucible is heating, clean the other crucible and clean the magnesium strip. Or while on crucible is cooling, go ahead and heat the other.

1. Clean two crucibles thoroughly. Use steel wool to remove any rust as loss of any rust flakes will introduce substantial error.

2. Place the cleaned crucible on a clay triangle and heat with the tip of the inner blue flame of a Meeker Burner, moving the flame around to heat the crucible evenly. This will drive off moisture and any other volatile deposits that might be lost during the experiment. Allow to cool to room temperature. (Hot objects appear to weigh less because of rising warm air currents).

IMPORTANT: Heating a metal crucible in just one spot until it is red hot may cause the metal at that spot to oxidize and flake off. Heating a ceramic crucible similarly may cause it to crack. Needless to say, this will ruin your mass change data. In this experiment, always move the flame around to prevent any one spot from being overheated.

3. Cool and weigh the crucible. (Move with tongs, or folded paper towel, not with fingers. Carry in a clean evaporating dish).

4. Use steel wool to thoroughly clean the coating off of an approximate 4 inch strip of magnesium ribbon, then wipe the ribbon with a clean dry cloth to remove loose particles. This cleaning step is vital for you to achieve good results. Coil the ribbon so that it will fit into the crucible.

5. Weigh the metal and crucible together and determine the exact weight of metal.

6. Heat the crucible containing magnesium with a Meeker Burner, leaving the cover propped open a bit. When the magnesium ignites, immediately close the crucible cover completely. Do not look directly at it, as considerable UV light is emitted which can damage your eyes.

7. Every 2 minutes or so, check the progress of the magnesium combustion by removing the crucible cover and peeking at the sample. If the magnesium continues to flare up, immediately re-place the crucible cover back on top of the crucible. When the magnesium no longer flares up, remove the cover and heat 5 more minutes. The sample should be white ash.

8. Allow the crucible to cool to warm to the touch.

9. Add 10 drops of water to decompose any magnesium nitride formed in the experiment and heat again for 10 minutes.

10. Allow the crucible to cool completely and then determine the mass.

Name: ____

Experiment #: Report Sheet

Experimental Data

		Trial 1	Trial 2
1	Metal used		
2	Weight of crucible and lid (g)		
3	Weight of crucible, lid and metal (g)		
4	Weight of crucible, lid and compound (g) after heating		

Calculations (Show work for all steps for one trial)

7	Weight of Mg (g) *Show calculation:*		
8	Weight of oxygen that has combined with Mg *Show calculation:*		
9	Moles of Mg *Show calculation:*		
10	Moles of oxygen that has combined with Mg *Show calculation:*		
11	Experimental ratio of moles Mg to moles of oxygen *Show calculation:*		
12	Formula of the compound from experimental data		
13	Known ratio of moles Mg to moles oxygen		

Name: ______________________________

Post-Lab Assignment

1. If not all the magnesium burned, how would that affect the Mg:O ratio? Would the ratio become larger or smaller than the true value? Explain.

2. An experiment similar to this one yielded the following data:

1	Weight of crucible and lid (g)	48.0271
2	Weight of crucible, lid and aluminum (g)	48.5084
3	Weight of crucible, lid and aluminum sulfide (g)	49.3908

Calculate the following (make sure to show all steps)

a. Moles of aluminum.

b. Moles of combined sulfur.

c. Mole ratio (Al:S).

d. Formula of aluminum sulfide.

3. A 2.3814 g sample of a particular compound was found to contain 0.8735 g of potassium, 0.7931 g of chlorine with the remaining mass being oxygen. Calculate the empirical formula of the compound.

4. A compound is analyzed and found to be 27.06 % sodium, 16.47 % nitrogen, and 56.47 % oxygen. What is the empirical formula of this substance?

5. A sample of a hydrocarbon (which contains only C and H) weighs 0.234 g. It is analyzed and found to contain 0.201 g of carbon and the rest is hydrogen.
   a. What is the empirical formula of this substance?

   b. If the molar mass of the substance is 56 g/mol, what is the molecular formula?

Name: ___________________________________

Pre-Lab Assignment for Determining the Empirical Formula of a Compound

1. Why is it important to scour the magnesium strip with steel wool at the start of the experiment?

2. Why must the heated crucible be cooled to near room temperature before weighing?

3. Should the Bunsen burner flame be kept heating one area of the crucible? Explain why or why not.

4. Should you stare at the magnesium ribbon if it flares up? Explain.

5. Based on your knowledge of the charges of magnesium and oxygen, what is the formula for magnesium oxide?