Minneapolis Community and Technical College
Introductory Chemistry Laboratory

Experiment: Empirical Formula of a Compound

Objectives:

- To prepare a compound from a weighed quantity of metal.
- To determine the empirical formula of the compound.

Text references:
Moles, Empirical Formula

Discussion:
Chemical compounds are composed of atoms of two or more elements chemically combined in definite proportions. The total mass of each element in the compound depends on the number of atoms involved, and therefore, the combining elements are in definite proportions by mass. The atoms in a compound are held together by chemical bonds. The ratio of moles of the constituent elements in the compound is nearly always a ratio of small, whole numbers. The formula containing the lowest possible whole number ratio is known as the **empirical formula**.

To find the empirical formula we must combine the elements to generate the compound under conditions that allow us to determine the mass of each element. From these data the moles of each element may be determined. By dividing the moles obtained for each element by the smallest number of moles, we obtain quotients that are in a simple ratio of integers, or are easily changed to such a ratio.

Sample calculations: A strip of aluminum weighing 0.69 g is ignited yielding an oxide that weighs 1.30 g. Calculate the empirical formula of the compound formed.

a. Calculate the mass of oxygen that combined with the aluminum.

oxygen mass = product mass - aluminum mass
= 1.30 g - 0.69 g = 0.61 g oxygen

b. Calculate the moles of each element.

$$\frac{0.69 \text{ g Al} \times 1 \text{ mole Al}}{27.0 \text{ g Al}} = 0.026 \text{ moles Al}$$

$$\frac{0.61 \text{ g O} \times 1 \text{ mole O}}{16.0 \text{ g O}} = 0.038 \text{ moles O}$$

c. Obtain the ratio of atoms by dividing the moles of each by the smallest number of moles.

Oxygen: $\frac{0.038}{0.026} = 1.5$ Aluminum: $\frac{0.026}{0.026} = 1.0$

The ratio is 1.5 atoms O : 1.0 atom Al. Change this ratio to a whole number ratio by multiplying by 2. The empirical formula is Al_2O_3.

Procedure:

In today's experiment, you will determine the empirical formula of the oxide of magnesium formed by heating magnesium metal in air**.**

You will be using an **analytical balance** to weigh all the masses. You must note the balance number and use the same balance for all mass measurements.

You will be using a porcelain crucible (30mL size) to heat the magnesium.

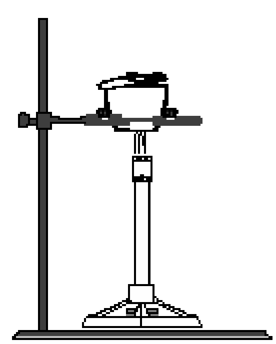
Caution:
a) If the crucible seems dirty, ***do not*** scrub to clean it, as you may accidentally scratch and weaken it.
b) ***Do not*** touch the crucible with your fingers as the oil and dirt from your fingers can add to the mass measurements. ***Always handle the crucible with tongs***.
c) While transporting the crucible, hold it with the tongs, and place it on an evaporating dish, to avoid accidentally dropping it.
d) Always light and adjust the Bunsen burner to a blue flame, prior to placing the crucible into the triangle.
e) ***All heating and cooling must be done in stages, as will be described by your instructor.***

I A. **<u>Cleaning the magnesium/Weighing the magnesium and crucible</u>**:

1) Obtain a piece of magnesium ribbon from your instructor. Clean the magnesium, over a trash bin, with sandpaper to remove any oxide from the surface until the surface appears to be shiny.
2) Make a loose ball of the magnesium and place it at the bottom of the crucible. It should fit into the bottom 2/3 of the crucible (*winding the magnesium metal on a pen or pencil with a pocket clip is a good way to start. Remember your goal is to expose as much of the ribbon to air as possible)*.
3) **Weigh the crucible only and record its mass with all of the digits displayed by the balance.**
4) **Add the magnesium ribbon into the crucible and record their total mass with all of the digits displayed by the balance.**

I B. **<u>Heating the magnesium in air</u>**:

1) Replace the crucible (containing the magnesium ribbon) on the clay triangle with lid at an angle leaving a crack open. During the heating process, observe the magnesium metal through the crack and record your observations. Heat the crucible slowly at first by moving the Bunsen burner underneath the crucible (make sure the flame is blue) and continue to heat strongly for at least 10 minutes.



2) Toward the end of the heating (do not turn off the burner yet), ***carefully*** remove the lid using the tool provided. If the magnesium flares up with a bright yellow flame, the reaction is not complete. Replace the lid and continue to heat until all the metal has been reacted and the reaction appears to be complete. Record your observations.
3) Turn down the flame and after one minute, remove the burner and turn it off.
4) Allow the crucible to cool to room temperature *gradually* while positioned on the clay triangle.

I.C. <u>Converting any nitride formed to oxide of magnesium</u>:

Since magnesium is an active metal it combines with both oxygen and nitrogen when it burns in air forming both the oxide and the nitride, Mg_3N_2.

The nitride can be converted to the oxide by adding water. The equations for the reactions are:

$$Mg_3N_2(s) + 6H_2O(l) \rightarrow 3Mg(OH)_2(s) + 2\,NH_3(g)$$

$$Mg(OH)_2(s) + \text{heat} \rightarrow MgO(s) + H_2O(l)$$

1) Wet the contents of the crucible by adding about 10 drops of distilled water (from the dropper bottle, NOT the big squeeze bottle!!).
2) Heat gently to vaporize any excess water. Finish heating with a strong flame for 5 to 8 minutes with the lid cracked open.
3) Heat on low for the final minute.
4) Turn off the flame. Allow the crucible to cool completely.
5) **When cool, weigh the mass of the crucible along with the compound formed (record all of the digits displayed by the balance).**

   Caution: *Never weigh any object while it is hot! Never keep the object directly on the pan of the balance. Make sure you place it on a paper and tare the mass of the paper.* Note the balance number and use the same balance for all other mass measurements.
6) Dispose of the solid product in a designated waste container.

II. <u>Calculate the empirical formula</u> from the mass of magnesium and oxygen that was used for the reaction (the latter obtained by the difference in masses). Make sure you follow the rules for significant figures.

Report sheet: Empirical Formula of a Compound

Name________________________________ Date___________ Lab Section_________

Balance number______

I. **<u>Data:</u>**

Record all digits displayed by the balance for mass measurements.
All measurements must have: quantity & units.

a) mass of crucible __________

b) mass of crucible + magnesium ribbon __________

c) mass of crucible + magnesium oxide compound __________
(after converting the nitride to oxide)

Observations of Combustion (What did you see when you peeked inside your crucible?):

II. **<u>Uncertainty</u>**

Because you used an analytical balance for this lab, you were able to measure objects (such as your magnesium ribbon) with more accuracy and certainty than when you've used the top loader balances, in previous labs.

The top loader balances measure with an uncertainty of __________ (include value and units), while the analytical balances measure with an uncertainty of ___________(value and units).

Taking into account the uncertainty of your measurements above, the actual mass of your crucible is likely to fall between what two values? ______________________(range and units).

III. <u>Calculations</u> (show your work, include units & follow the rules for significant figures):

	show your work	final answer
a) mass of magnesium ribbon		
b) mass of magnesium oxide compound formed		
c) mass of oxygen		
d) moles of magnesium		
e) moles of oxygen		
f) ratio of atoms (Mg:O)		
g) empirical formula of compound		

Post-lab Questions

In this lab activity, you utilized laboratory technique and skill to determine the formula of magnesium oxide *experimentally*. However, the end result probably was not a big surprise to you! In fact, it is likely you could have predicted the formula without even setting foot in the lab! Answer the questions below regarding a *theoretical* determination of magnesium oxides formula.

1. Based on their positions in the periodic table:
    a. What is the most likely charge of a magnesium ion?

    b. What is the most likely charge of an oxygen ion?

2. Based on the charges of magnesium and oxygen ions (see #1), what would one predict for the formula of magnesium oxide?

3. A student determined experimentally that the formula of this compound is Mg_3O_2. What might have led to this incorrect determination? Give at least two possible causes.

4. Use the formula of magnesium oxide you derived in Question #2 to write out a **balanced chemical equation** of the burning of magnesium metal in oxygen gas to generate magnesium oxide. Make sure to indicate the physical state (s, l, g, or aq) for each of the substances in the equation.

5. Assign as many classifications as are appropriate to the above reaction. Select from:

acid-base	combustion	combination/synthesis
decomposition	oxidation-reduction	precipitation

<u>Pre-lab exercise</u>: Empirical Formula of a Compound

(Complete and check answers before coming to lab)

1. What are the cautionary measures that you should take in handling the crucible in today's experiment?

2. What type of balance will you be using today, for mass measurements?

3. What cautionary measures do you take in handling the balance?

4. In today's experiment, when magnesium burns in air, in addition to the oxide being formed, what other product will be formed?

5. How do you convert this other compound to oxide?

<u>Show the calculations for the following questions:</u>

6. A 3.70 g sample of sodium is allowed to react completely with sulfur to form a sulfide which weighs 6.30 g. Calculate the following:

   a) mass of sulfur ___________

   b) moles of sulfur ___________

   c) moles of sodium ___________