Empirical Formula of a Compound

Suggested reading: *Chang* text – pages 84 - 90

Cautions Magnesium ribbon is flammable.
Ammonia gas is toxic and harmful.
Hot ceramic crucible and metal items can produce a severe burn.

Purpose

The purpose will be to determine the empirical formula of magnesium oxide by burning pure magnesium metal in air.

Introduction

The simplest whole number ratio of moles of the elements in a compound is known as the **Empirical Formula**. This can be determined experimentally if a chemical compound can be synthesized from an element. This process requires three steps:

1. Determine the mass of each element in the compound
2. Calculate the number of moles of each element in the sample.
3. Express the molar ratio of each element as the smallest whole number.

An example would be the chemical analysis of a solid sample was found to have 1.76 grams of Aluminum and 1.57 grams of Oxygen. The simplest whole number ratio is found to be 2 to 3 (see example calculations below); therefore the empirical formula is Al_2O_3 for aluminum oxide.

$$\frac{1.76}{26.98} = 0.0652 \text{ moles of Al} \qquad \frac{1.57}{16.00} = 0.0981 \text{ moles of O}$$

Mole Ratio

$$\text{mole ratio of Al} = \frac{0.0652}{0.0652} = 1.00 \qquad \text{mole ratio of O} = \frac{0.981}{0.652} = 1.50$$

Simplest Whole Number Ratio

$1.00 : 1.50$ becomes $2.00 : 3.00$

Molecular oxygen is very reactive whether it is a pure element or found in a mixture such as air. Nitrogen, the major component of air, is typically un-reactive. When an element reacts with oxygen in a process known as combustion, an oxide will be formed. In air, nitrogen is also available, and thus some nitrides may also form. The oxide is usually more likely to form compared to the nitride due to oxygen's greater reactivity.

In today's experiment a piece of magnesium ribbon and air will be reacted to form magnesium oxide. The empirical formula of the magnesium oxide will be determined using the initial mass of metal and the final mass of the metal oxide

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Procedure

To complete 2 trials in one lab period, your instructor may require you to perform both trials simultaneously.

1. Obtain a crucible and lid. Clean the crucible and check for any stress cracks, fractures, or fissures. These types of defects are common in used crucibles. If the crucible is dirty then move the apparatus to a hood and add 1-2 mL of 6M HNO_3 and gently evaporate to dryness then inspect the crucible after cooling for any defects. If no defects are found the crucible and lid should be supported on a clay triangle.
2. Heat the crucible with a gentle flame for 5 minutes before heating with an intense flame. Continue heating for 10 to 12 minutes with an intense flame after the bottom of the crucible has become red. Allow the crucible to cool by placing it on a wire pad. Do not set the crucible on the bench top or touch it with your hands due to possible contamination or cracking.
3. Determine the mass of the "fired" cool crucible with lid and record.
4. Repeat step 2 and 3 until you have two crucible and lid mass readings that differ by no more than 10 mg.
5. Obtain a magnesium ribbon that weighs between 0.17 and 0.23 grams. Form the ribbon into a loose ball or coil so it rests in the bottom of the crucible. If the ribbon is not bright and shiny, clean the surface with a piece of sandpaper or steel wool to remove any impurities. **DO NOT SAND DIRECTLY ON THE DESKTOP!**
6. Add the clean coiled magnesium ribbon to your crucible. Weigh the crucible containing the metal with the lid.
7. Return the crucible and lid containing the metal to the clay triangle support. Initially heat the sample gently for 2 to 3 minutes, gradually intensify the heat, and continue heating for three minutes.
8. Using the crucible tongs, slightly lift one edge of the lid to allow air inside of the crucible. DO NOT REMOVE THE LID. When done correctly, the metal will begin to glow. If the metal ignites into a flame, quickly cover the crucible with the lid. Heat the crucible for approximately 3 minutes.
9. Repeat step 8 several times until no glowing metal is seen or remains upon the entrance of the air. Then remove from the heat source, cover with the lid, and cool to room temperature.
10. To the cooled crucible with no remaining magnesium metal, add 3 drops of distilled water. The smell of ammonia may be evident.
11. Position the crucible lid slightly off to the side to allow the evolving water molecules to escape during heating. Initially heat the sample slowly and gradually intensify the heat. Be careful not to let the crucible become very hot too fast or liquid will splatter out of the crucible. Heat the sample at a high temperature for 15 to 17 minutes.
12. Allow the crucible and the metal oxide to cool. Determine the mass of the crucible, lid, and metal oxide using the same balance as used in the earlier steps.
13. Reheat the sample for an additional 5 minutes with high heat. Measure the combined mass of the crucible, lid, and metal oxide; repeat this process until you obtain 2 concurrent readings within 10 mg of each other.
14. Repeat this entire procedure with a new sample of magnesium metal for Trial 2.

Waste Disposal Place the product metal oxide in the appropriate container.

Clean-Up Clean the crucible of any metal oxide residue. Wash the crucible with soap then rinse 3 times with tap water, and once with deionized water.

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Data Sheet

Name: _____ **Lab Partner:** _____

	UNITS	TRIAL 1	TRIAL 2
Mass of Crucible and Lid			
Before Heating			
After 1st Heating			
After 2nd Heating			
After 3rd Heating			
After 4th Heating			
Mass of Crucible, Lid, and Metal			
Mass of Metal			
Mass of Crucible, Lid, and Metal Oxide after 1st heating			
2nd Heating Mass Measurement			
3rd Heating Mass Measurement			
4th Heating Mass Measurement			
Mass of Metal Oxide			

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	UNITS	TRIAL 1	TRIAL 2
Mass of Metal Oxide (from page 3)			
Mass of Metal in the Compound (from page 3)			
Number of Moles of Metal in the Compound (using sig. figs.)			
Mass of Oxygen in the Compound			
Number of Moles of Oxygen in the Compound (using sig. figs.)			
Simplest Whole Number Ratio of Oxygen to Metal			
Empirical Formula for the Compound using Whole Numbers			

Empirical Formula of a Compound

Calculations:

Show all work clearly when performing calculations.

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Post-lab Assignment

Name: _____

1. If you did not heat the crucible and its contents following the reaction to a constant mass you may have affected the ratio of oxygen to magnesium. How will this error affect the empirical formula determination if some magnesium metal remains unreacted? Explain.

2. Based upon your knowledge of nomenclature, what is the empirical formula of magnesium oxide?

3. Compare your empirical formula with the standard of magnesium oxide. What are the most likely sources of experimental error and what could have been done to prevent them?

Challenge Question

If there is an insufficient amount of oxygen (from the air) some magnesium nitride (Mg_3N_2) will form. If this is not converted to magnesium oxide, will the ratio of oxygen to magnesium be high or low? Explain your answer in detail.

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Pre-lab Assignment

Name: _____

1. Define in your own words the term “empirical formula” and explain how it differs from a molecular formula.

2. Determine the empirical formulas of the following compounds:
   a. Benzene, C_6H_6
   b. Dinitrogen tetroxide, N_2O_4
   c. Calcium oxide, CaO
   d. Fructose, $C_6H_{12}O_6$

3. A substance was found to have contained 65.95% barium and 34.05% chlorine upon analysis. What is the empirical formula of the compound?

4. An oxide of mercury will thermally decompose when heated. A 0.204 g sample of the mercury oxide is heated to form 0.189 g of mercury. What is the empirical formula of the mercury oxide?