Determination of the Empirical Formula of Silver Oxide

Introduction

There is an official database that keeps track of the known chemical compounds that exist in nature or have been synthesized in the lab. The database, called the chemical abstracts database, is updated daily. Currently, over 20 million different inorganic and organic compounds have been recognized. Twenty million compounds! How is it possible to identify so many different compounds and tell them all apart?

Concepts

- Percent composition
- Empirical formula
- Law of conservation of mass
- Molecular formula
- Percent yield

Background

The composition of a chemical compound—what it is made of—can be described at least three different ways. The *percent composition* gives the percent by mass of each element in the compound and is the simplest way experimentally to describe the composition of a substance. According to the law of definite proportions, which was first formulated in the early 1800s by Joseph Proust, the elements in a given compound are always present in the same proportion by mass, regardless of the source of the compound or how it is prepared. Calcium carbonate, for example, contains calcium, carbon, and oxygen. It is present in eggshells and seashells, chalk and limestone, minerals and pearls. Whether the calcium carbonate comes from a mineral supplement on a drugstore shelf or from seashells on the ocean shore, the mass percentage of the three elements is always the same: 40% calcium, 12% carbon, and 48% oxygen.

The percent composition of a compound tells us what elements are present in the compound and their mass ratio. In terms of understanding how elements come together to make a new compound, however, it is more interesting and more informative to know how many atoms of each kind of element combine with one another. Since all the atoms of a given element in a compound have the same average atomic mass, the elements that are present in a fixed mass ratio in a compound must also be present in a fixed number ratio as well. The *empirical formula* describes the composition of a compound in terms of the simplest whole-number ratio of atoms in a molecule or formula unit of the compound. Empirical means experimentally determined. When an experiment is carried out to determine the composition of a compound, only the empirical formula can be obtained from this information. An additional experiment is needed to determine the molecular formula. For example, finding the molecular mass would allow the molecular formula to be calculated. The empirical formula gives the ratio of atoms in a compound and does not necessarily represent the actual number of atoms in a molecule or formula unit. It is possible, in fact, for different compounds to share the same empirical formula.

The organic compounds acetylene and benzene, for example, have the same empirical formula, CH—one hydrogen atom for every carbon atom. These two compounds, however, have very different properties and different molecular formulas—C_2H_2 and C_6H_6 for acetylene and benzene, respectively. Notice that in both cases, the molecular formula is a simple multiple of the empirical formula. The *molecular formula* of a compound tells us the actual number of atoms in a single molecule of a compound. In order to find the molecular formula of a compound whose empirical formula is known, the molar mass of the compound must also be determined.

Experiment Overview

In this experiment, the percent composition and empirical formula of silver oxide will be determined. Silver oxide decomposes to silver metal and oxygen when strongly heated. Heating silver oxide causes the oxygen to be driven off, leaving only the silver metal behind. According to the law of conservation of mass, the total mass of the products of a chemical reaction must equal the mass of the reactants. In the case of the decomposition of silver oxide, the following equation must be true:

$$\text{Mass of silver oxide} = \text{Mass of silver metal} + \text{Mass of oxygen}$$

If both the initial mass of silver oxide and the final mass of the silver metal are measured, the decrease in mass must correspond to the mass of oxygen that combined with silver. The percent composition and empirical formula of silver oxide can then be calculated, based on the combining ratios of silver and oxygen in the reaction.

Pre-Lab Questions *(Use a separate sheet of paper to answer the following questions.)*

A piece of iron weighing 85.65 g was burned in air. The mass of the iron oxide produced was 118.37 g.

1. Use the molar mass of iron to convert the mass of iron used to moles.
2. According to the law of conservation of mass, what is the mass of oxygen that reacted with the iron?
3. Calculate the number of moles of oxygen in the product.
4. Use the ratio between the number of moles of iron and number of moles of oxygen to calculate the empirical formula of iron oxide. *Note:* Fractions of atoms do not exist in compounds. In the case where the ratio of atoms is a fractional number, such as ½, the ratio should be simplified by multiplying all the atoms by a constant to give whole number ratios for all the atoms (e.g., $HO_{1/2}$ should be H_2O).

Materials

Chemicals

Silver oxide, 1.5 g

Equipment

Balance, 0.001-g or 0.0001-g precision

Bunsen burner

Clay pipestem triangle

Crucible and crucible lid, 15- or 30-mL

Crucible tongs

Ring stand and ring clamp

Watch glass (optional)

Wire gauze with ceramic center

Safety Precautions

Silver oxide is slightly toxic and is a fire risk when in contact with organic material or ammonia. Handle the crucible and its lid only with tongs. Do not touch the crucible with fingers or hands. There is a significant burn hazard associated with handling a hot crucible—remember that a hot crucible looks exactly like a cold one. Always keep your face at arm's length from the crucible. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

1. Set up a Bunsen burner on a ring stand beneath a ring clamp holding a clay pipestem triangle. Place the crucible in the clay triangle (See Figure 1.) Do NOT light the Bunsen burner.
2. Adjust the height of the ring clamp so that the bottom of a crucible sitting in the clay triangle is about 1 cm above the burner. This will ensure that the crucible will be in the hottest part of the flame when the Bunsen burner is lit.
3. Light the Bunsen burner and brush or gently heat the bottom of the crucible with the burner flame for about one minute. Turn off the Bunsen burner and allow the crucible to cool.
4. Using crucible tongs to handle the crucible, measure the mass of a clean, dry, empty crucible and its lid to the nearest 0.001 g. Record the mass in the Data Table.

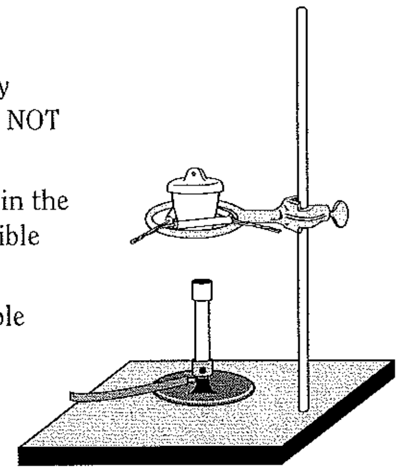

Figure 1.

5. Using proper transfer techniques, add approximately 0.5 grams of silver oxide sample to the crucible. Measure the combined mass of the crucible, crucible lid, and silver oxide to the nearest 0.001 g. Record the mass in the Data Table.
6. Place the crucible with its lid on the clay triangle as shown in Figure 2. Light the Bunsen burner again and slowly heat the crucible by brushing the bottom of the crucible with the Bunsen burner flame for 2–3 minutes.
7. Place the burner on the ring stand and gently heat the crucible for an additional 10 minutes.

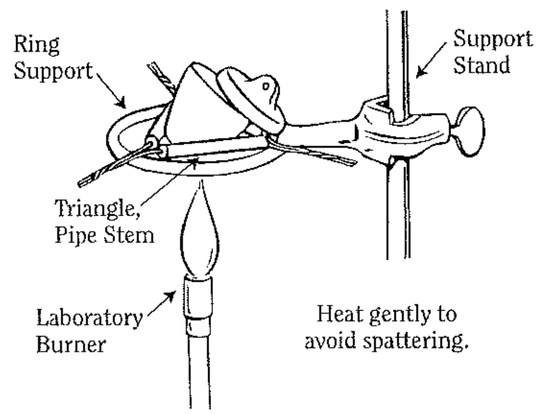

Figure 2.

8. After 10 minutes, adjust the burner to maximize the flame temperature. Heat the crucible with the most intense part of this flame for 10 minutes. *Caution:* Do not inhale the smoke! Do not lean over the crucible. Keep the crucible at arm's length at all times.
9. After 10 minutes, turn off the gas source and remove the burner.
10. Using tongs, remove the crucible lid and place it on a wire gauze on the bench top. With the tongs, remove the crucible from the clay triangle and place it on the wire gauze as well. (See Figure 3.)
11. Allow the crucible and its contents to cool completely on the benchtop for at least 10 minutes.
12. Measure the combined mass of the crucible, crucible lid, and silver metal product. Record the mass in the Data Table.

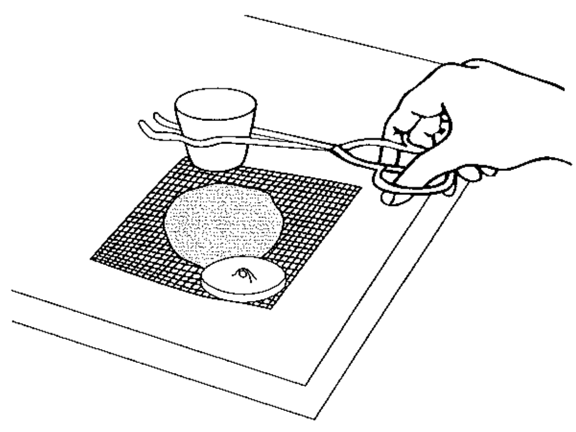

Figure 3.

13. *(Optional)* If time permits, pour the contents of the crucible onto a watch glass. Note the appearance and consistency of the product. Is any unreacted silver oxide still present? Record all observations in the Data Table.
14. Dump the entire contents of the crucible into the waste container provided by the instructor. Carefully clean the crucible and crucible lid.
15. Repeat steps 4 to 14 for trials #2 and #3.

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

Data Table

	Trial #1	Trial #2	Trial #3
Mass of crucible and lid, g			
Mass of crucible, lid, and silver oxide, g			
Mass of crucible, lid, and silver metal, g			
Appearance of product			

Post-Lab Calculations and Analysis

(Use a separate sheet of paper to answer the following questions.)

Create a Data Results Table for each trial with the following categories: the mass of silver oxide in grams, the mass of silver metal produced in grams, the mass of oxygen gas produced in grams, the percent composition of silver, the percent composition of oxygen, the moles of oxygen in the silver oxide sample, the moles of silver in the silver oxide sample, the mole ratio of Ag/O in silver oxide, and finally, the empirical formula of Ag_xO_y.

1. Calculate the mass of silver oxide and the mass of the silver metal product. Use the law of conservation of mass to calculate the mass of oxygen produced with the silver. Enter the answers in the Data Results Table.
2. What is the percent composition of silver and oxygen in silver oxide? Enter the answers in the Data Results Table.
3. Use the molar masses of silver and oxygen to calculate the number of moles of each product. Enter the answers in the Data Results Table.
4. Calculate the ratio between the number of moles of silver and the number of moles of oxygen in the product. What is the empirical formula of silver oxide? Enter the answers in the Data Results Table.
5. Write a balanced chemical equation for the decomposition of silver oxide to form silver metal and oxygen.
6. The *theoretical yield* of a product in a chemical reaction is the maximum mass of product that can be obtained, assuming 100% conversion of the reactant(s). Calculate the theoretical yield of silver metal in this experiment. *Hint:* Calculate the molar mass of silver oxide.
7. The percent yield reflects the actual amount of product formed versus the maximum that might have been obtained. Use the following equation to calculate the percent yield of silver metal produced in this experiment.

$$\%\text{ yield} = \frac{\text{actual mass of product (g)}}{\text{theoretical mass (g)}} \times 100\%$$

8. Discuss sources of error in this experiment that might account for a percent yield lower or higher than 100%. Be specific!