Determinant 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

Concepts

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

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 (1754-1826), 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 oceanshore, 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. 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 – C₂H₂ and C₆H₆ 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

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:

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

Pre-Lab Questions

A piece of iron weighing 85.65g was burned in air. The mass of the iron oxide produced was 118.37g.
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 1/2, 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\(_2\)O).

Materials

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver oxide samples, 0.5 g</td>
<td>Balance, milligram (0.001-g precision)</td>
</tr>
<tr>
<td>Crucible and crucible lid, 15- or 30-mL</td>
<td>Clay pipe stem triangle</td>
</tr>
<tr>
<td>Crucible tongs</td>
<td>Wire gauze with ceramic center</td>
</tr>
<tr>
<td>Bunsen burner</td>
<td>Wash bottle and water</td>
</tr>
<tr>
<td>Ring stand and ring clamp</td>
<td>Watch glass (optional)</td>
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</tbody>
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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. Wash hands thoroughly with soap and water before leaving the laboratory.

Procedure

Note: This procedure does not indicate the data that must be collected in order to successfully complete the lab. You should determine what data needs to be collected, and make the appropriate data tables in your lab notebook.

1. Set up a Bunsen burner on a ring stand beneath a ring clamp holding a clay pipe stem 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 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 proper transfer techniques, add approximately 0.5 grams of silver oxide to the crucible.
5. 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.
6. Place the burner on the ring stand and gently heat the crucible for an additional 10 minutes.
7. 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.
8. After 10 minutes, turn off the gas source and remove the burner.
9. 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)
10. Allow the crucible and its contents to cool completely on the bench top for at least 10 minutes.
11. Dump 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.
12. Dump the entire contents of the crucible into the waste container provided by the instructor. Carefully clean the crucible and crucible lid.
13. Repeat steps 4 to 14 for trial #2.

Discussion and Calculations

Create a 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 molar mass of silver, the mole ratio of Ag/O in silver oxide, and finally, the empirical formula of silver oxide. You should calculate percent error for all quantities where there is a theoretical value.