Lab 26. Composition of Chemical Compounds: What Is the Empirical Formula of Magnesium Oxide?

Introduction

Chemists can describe the composition of a chemical compound in at least three different ways. The first way is to define the *percent composition* of a compound; this is the percent of each element found in the compound by mass. For example, a chemical compound called acetylene is composed of 92.25% carbon and 7.75% hydrogen by mass. The second way to describe the composition of a compound is to provide its *empirical formula*, which indicates the lowest whole-number ratio of the atoms found within one unit of that compound. The empirical formula of acetylene, for example, is CH. The empirical formula indicates the ratio of atoms in a compound but does not always represent the actual number of each kind of atom found in one unit of that compound. The compound benzene, for example, has the same empirical formula (CH) as acetylene because both acetylene and benzene contain one carbon atom for every atom of hydrogen. The third way to define the percent composition of a compound is to use a *molecular formula*, which indicates the actual number of atoms that are found in a single unit of that compound. The molecular formulas of acetylene and benzene are different even though they share the same empirical formula because each compound contains a different number of carbon and hydrogen atoms. The molecular formula of acetylene is C_2H_2, whereas the molecular formula for benzene is C_6H_6.

Chemists rely on two important principles when they attempt to determine the composition of an unknown compound. The first principle is the *law of definite proportions*, which indicates that a compound is always made up of the exact same proportion of elements by mass. The percent composition of a compound is therefore a constant and does not depend on the amount of a sample. The second principle is the *law of conservation of mass*, which states that mass is neither created nor destroyed during a chemical reaction. These two principles enable chemists to determine the percent composition of an unknown compound. Chemists can then use the percent composition of the compound and some simple mathematics to determine its empirical formula. In this investigation, you will have an opportunity to use these two principles to determine the empirical formula of a compound that you create inside the lab by heating magnesium in the presence of oxygen.

Your Task

Magnesium oxide is a compound that consists of magnesium and oxygen. It is produced when magnesium metal is heated. The heat causes the magnesium to combine with molecules of oxygen found in the air. The magnesium and oxygen may combine in a number of different ratios during this reaction. These ratios include, but are not limited to, MgO, Mg_2O, Mg_3O_2, and Mg_5O_4. Your goal is to determine the percent composition of magnesium oxide and then use this information to calculate its empirical formula.

The guiding question for this lab is, **What is the empirical formula of magnesium oxide?**

Materials

You may use any of the following materials during your investigation:

Consumables	**Equipment**
Magnesium ribbon (3–4 cm long)	• Bunsen burner • Striker • Crucible with lid • Clay triangle • Crucible tongs • Ring stand with metal ring • Wire gauze square • Electronic or triple beam balance • Periodic table

Safety Precautions

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Use caution when working with Bunsen burners. They can burn skin, and combustibles and flammables must be kept away from the open flame. If you have long hair, tie it back behind your head.
- Inspect the crucible for cracks. If it is cracked, exchange it for a new one. Clean the crucible and lid thoroughly before using them.
- Be careful with a crucible after removing it from a flame because it will still be hot.
- Handle all glassware with care.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in your investigation is to determine the percent composition of magnesium oxide. As noted earlier, when magnesium is heated it, combines with oxygen to form magnesium oxide. The law of conservation of mass suggests that the total mass of the products of a chemical reaction must equal the mass of the reactants. The mass of the oxygen in a sample of magnesium oxide will therefore equal the mass of the magnesium oxide minus the mass of the original piece of magnesium that was used in the reaction. You can use this information to determine the percent of oxygen by mass found in magnesium oxide. You will, however, need to first determine what type of data you need to collect and how you will collect the data to be able to make this calculation.

To determine *what type of data you need to collect*, think about the following questions:

- What type of measurements or observations will you need to record during your investigation?
- When will you need to make these measurements or observations?

To determine *how you will collect the data*, think about the following questions:

- What equipment will you need to use to make magnesium oxide?
- How much magnesium will you use to make magnesium oxide?
- How will you know when all the magnesium has been converted to magnesium oxide?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect and how will you organize it?

The second step in your investigation is to calculate the empirical formula for magnesium oxide from its percent composition. This calculation requires two steps. First, you will need to calculate the number of moles of magnesium and oxygen in your sample of magnesium oxide. Next, you will need to use the ratio between the number of moles of magnesium and the number of moles of oxygen to calculate the empirical formula of magnesium oxide. Keep in mind that fractions of atoms do not exist.

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

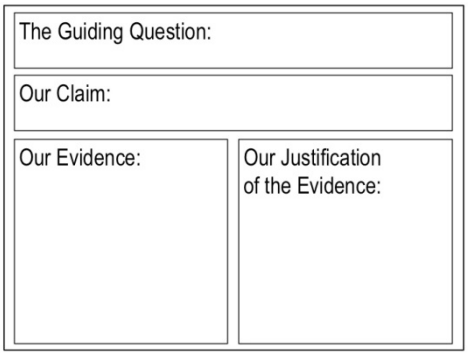
- how scale, proportion, and quantity play a role in science;
- the flow of energy and matter within systems;
- how scientific knowledge can change over time in light of new evidence; and
- the different methods used in scientific investigations.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L26.1.

FIGURE L26.1

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!