Lab 27. Stoichiometry and Chemical Reactions: Which Balanced Chemical Equation Best Represents the Thermal Decomposition of Sodium Bicarbonate?

Introduction

The *law of conservation of mass* states that mass is conserved during a chemical reaction. The *law of definite proportions* states that a compound is always made up of the exact same proportion of elements by mass. John Dalton was able to explain these two fundamental laws of chemistry with his *atomic theory*, which states that a chemical reaction is simply the rearrangement of atoms with no atoms being destroyed and no new atoms being produced during the process. Chemists use a balanced chemical equation to represent what happens on the submicroscopic level during a chemical reaction.

The *stoichiometric coefficient* is the number written in front of atoms, ions, or molecules in a chemical equation. These numbers are used to balance the number of each type of atom found on both the reactant and product sides of the equation. Stoichiometric coefficients are also useful because they identify the mole ratio between reactants and products. The mole ratio is important because it allows chemists to determine how many moles of a product will be produced from a specific number of moles of a reactant or how many moles of reactant are needed to produce a specific amount of a product.

Molar mass serves as a bridge between the number of moles of a substance and the mass of a substance. The molar mass is the mass of a given substance divided by one mole of the substance. The molar mass of a given substance can be calculated by summing the atomic mass for each atom found in a molecule of that substance. For example, the atomic mass of hydrogen is 1.01 g/mol, and the atomic mass of oxygen is 15.99 g/mol, so the molar mass of H_2O is 18.01 g/mol (1.01 g/mol + 1.01 g/mol + 15.99 g/mol). Once the molar mass of a substance is known, the mass of a sample can be used to determine the number of moles of a substance or the moles of substance can be used to determine the mass of a sample. For example, a 40-gram sample of H_2O consists of 2.2 mol of H_2O (40 g of H_2O ÷ 18.01 g/mol = 2.2 mol of H_2O) and a 3.0 mol sample of H_2O has a mass of 54.03 g (3.0 mol of H_2O x 18.01 g/mol = 54.03 g of H_2O). In this investigation, you will have an opportunity to use atomic theory, molar mass, and stoichiometry to determine how atoms are rearranged during a chemical reaction.

Your Task

There are at least four different balanced chemical equations that could explain how atoms are rearranged during the thermal decomposition of sodium bicarbonate ($NaHCO_3$). The first potential explanation is that the sodium bicarbonate decomposes into sodium hydroxide (NaOH) and carbon dioxide (CO_2) when it is heated. The balanced chemical equation for this reaction is

$$NaHCO_3(s) \rightarrow NaOH(s) + CO_2(g)$$

The second potential explanation is that the sodium bicarbonate decomposes into sodium carbonate (Na_2CO_3), carbon dioxide (CO_2), and water when it is heated. The balanced chemical equation for this reaction is

$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

The third potential explanation is that the sodium bicarbonate decomposes into sodium oxide (Na_2O), carbon dioxide, and water when it is heated. The balanced chemical equation for this potential reaction is

$$2NaHCO_3(s) \rightarrow Na_2O(s) + 2CO_2(g) + H_2O(g)$$

The fourth potential explanation is that the sodium bicarbonate decomposes into sodium hydride (NaH), carbon monoxide (CO), and oxygen when it is heated. The balanced chemical equation for this potential reaction is

$$NaHCO_3(s) \rightarrow NaH(s) + CO(g) + O_2(g)$$

Your goal is to determine which of these four balanced chemical equations best represents how atoms are rearranged during the thermal decomposition of sodium bicarbonate.

The guiding question of this investigation is, **Which balanced chemical equation best represents the thermal decomposition of sodium bicarbonate?**

Materials

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

Consumable	**Equipment**
Solid $NaHCO_3$	• Bunsen burner • Striker • Ring stand with metal ring • Crucible with lid • Crucible tongs • Pipe-stem triangle • 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.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

As part of your investigation, you will need to use a Bunsen burner and a crucible (see Figure L27.1) to increase the temperature of sodium bicarbonate enough for it to decompose. The thermal decomposition of sodium bicarbonate will occur rapidly at 200°C, but the product of the decomposition reaction will begin to decompose at temperatures over 850°C.

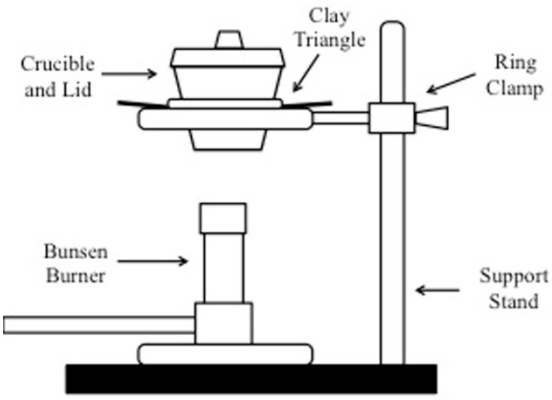
To answer the guiding question, you will also need to determine what type of data you will need to collect during your investigation, how you will collect the data, and how you will analyze the data.

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

- How much $NaHCO_3$ will you need to use?
- What will you need to measure?

FIGURE L27.1

How to heat sodium bicarbonate using a crucible and a Bunsen burner



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

- How long will you need to heat the $NaHCO_3$?
- How will you empirically determine when the decomposition of the $NaHCO_3$ is complete?
- How will you reduce error?

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

- What type of calculations will you need to make?
- How will your group take into account the precision of the balance in your analysis?

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

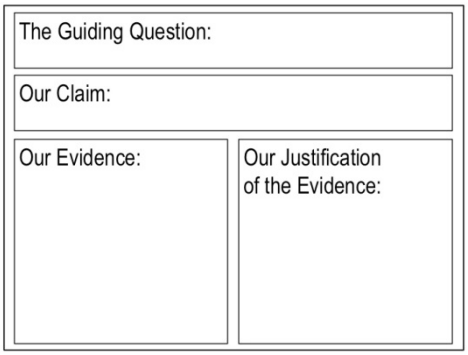
- the importance of identifing the underlying cause for observed phenomena,
- how models are used to study natural phenomena,
- the difference between data and evidence in science, and
- the nature and role of experiments in science.

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 L27.2.

FIGURE L27.2

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?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data, and why did you decide to do it that way? Did you check your calculations?
- 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!