Lab: Determining Empirical Formula of Sodium Bicarbonate from Percent Composition

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Introduction

When sodium bicarbonate is heated above 176 degrees fahrenheit, it undergoes thermal decomposition. This is a process where a compound breaks down into two or more substances.(Libre Texts) During this thermal decomposition the solid sodium bicarbonate turns into solid sodium carbonate, and the other products like carbon dioxide and water are released as gases. The carbon dioxide and water releasing as gases leads to a decrease in the total mass of the sample. This experiment shows the Law of Conservation of Mass which says that matter cannot be created nor destroyed. According to this law, the total mass of the reactants has to equal the total mass of the products created, so the mass of the sodium carbonate, carbon dioxide, and water created by thermal decomposition has to equal the mass of the original sodium bicarbonate. By measuring the initial mass of sodium bicarbonate and the final mass of the sodium carbonate we can calculate the percent composition and its empirical formula.

Hypothesis

Increasing the temperature of sodium bicarbonate (80°C or 176°F) will lead to a thermal decomposition reaction leading to the formation of sodium carbonate, carbon dioxide, and water vapor. This will result in a total mass loss from the original mass of the sodium bicarbonate due to carbon dioxide and water vapor releasing into the atmosphere. Conversely if the reaction takes place in an airtight container then there would be no loss of mass in the system because the carbon dioxide and water vapor would not be able to escape into the atmosphere.

Variables

Variable	TypeVariable Name	How It Is Measured or Controlled
Initial mass of sodium bicarbonate	Independent Variable	The mass is being measured precisely using an electronic balance.
Final mass of the solid product	Dependent Variable	The mass is being measured using the same electronic balance
Heating	Control Variable	15-18 minutes at (5-6) heat, followed by 3-4 minutes at (6-7).
Materials/Equipment	Control Variable	Using a standard evaporating dish and an electronic balance for every measurement.
Cooling	Control Variable	The dish cools on a heat-resistant surface until cool to the touch (5-6) minutes.

Materials

- Sodium bicarbonate (baking soda) - varying masses from 1.0 g to 5.0 g
- Evaporating dish (heat-resistant)
- Hot plate
- Heat-resistant gloves or tongs
- Electronic balance (±0.01 g)
- Heat-resistant mat

- Stirring rod (glass or heat-resistant)
- Stopwatch or timer

Safety and Disposal Considerations

Wear safety goggles and lab apron throughout the experiment

- Use heat-resistant gloves when handling hot evaporating dishes
- Hot plates remain hot for several minutes after turning off
- Never touch a hot plate surface or evaporating dish with bare hands
- Keep flammable materials away from the hot plate
- Tie back long hair when working with heat sources
- Both sodium bicarbonate and sodium carbonate are safe, non-toxic household chemicals
- Waste can be rinsed down the drain

Procedure

Part A: Preparation

1. Measure and record the mass of a clean, dry evaporating dish
2. Add your assigned mass of sodium bicarbonate to the dish (2.0-5.0 g range)
3. Measure and record the combined mass of evaporating dish and sodium bicarbonate
4. Spread the powder evenly across the bottom of the dish

Part B: Initial Heating

5. Turn the hot plate to medium heat (setting 5-6 out of 10)
6. Place the evaporating dish on the hot plate
7. Heat for 15-18 minutes, stirring gently every 3-4 minutes
8. Watch for bubbling as CO_2 and H_2O are released (this is normal)
9. Continue heating until no more bubbling occurs
10. The powder may clump slightly but should remain white

Part C: Final Heating

11. Increase heat to medium-high (setting 6-7) for 3-4 minutes to ensure complete decomposition
12. Turn off the hot plate
13. Using gloves or tongs, carefully remove the dish and place it on a heat-resistant mat
14. Allow to cool for 5-6 minutes until safe to handle

Part D: Final Mass and Data Sharing

15. Measure and record the final mass of evaporating dish and product
16. Record your data on the class data table for graphing (on Google Sheets)
17. Calculate the mass of sodium carbonate produced

Part E: Cleanup (10 minutes)

18. The product (sodium carbonate) can be rinsed down the drain with water
19. Clean and dry the evaporating dish

Data

Measurement	Value (g)
Mass of evaporating dish	**52.96**
Mass of dish + sodium bicarbonate (before heating)	**58.10**
Mass of dish + product (after heating)	**54.85**
Initial mass of sodium bicarbonate	**3.14**

Observations

Stage	Observations
Initial appearance of $NaHCO_3$	**Fine, white crystalline powder. Has no smell**
During heating	**Remains as a white powder. Visible bubbling. Slightly started to clump**
Final product appearance	**White solid that looks similar to the original. Nondistinguishable from the original visibly.**

Data Processing

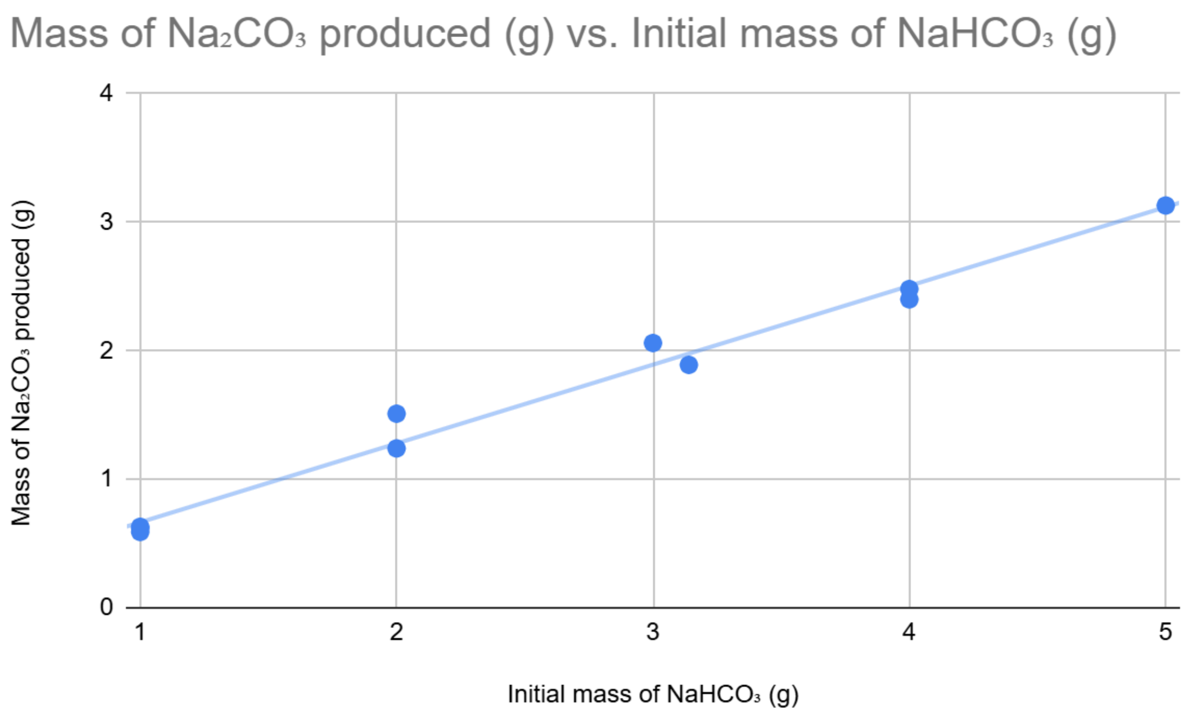
Part 1: Calculate Masses

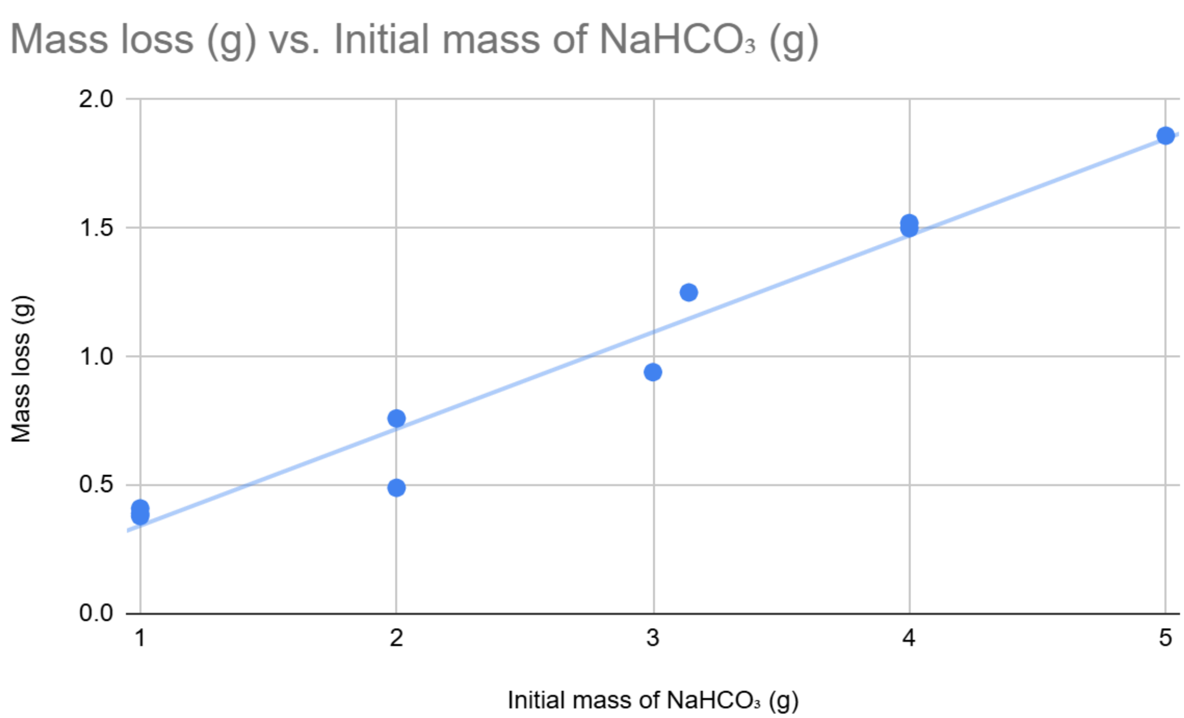
- **Mass of sodium bicarbonate = 3.14 grams**
- **Mass of product = 1.89 grams**
- **Mass loss = 1.25 grams**

Part 2: Empirical Formula Determination

1. **Mass percent of sodium in sodium carbonate - 1.89 x 0.4338**
    - **0.82 grams of Na**
2. **Mass of carbonate portion:**
    - **1.89 - 0.82 = 1.07 grams**
3. **Convert to moles:**
    - **Moles of Na = 0.82/22.99 g/mol = 0.036 moles**
    - **Moles of CO2 = 1.07/66.01 g/mol = 0.016 moles**
4. **Find mole ratio:**
    - **0.036/0.016 ≈ 2**
    - **0.016/0.016 = 1**
5. **Na_4CO_3**

Data Analysis





Interpretation

- For the first graph it is apparent that as the initial mass of sodium bicarbonate increased that the mass of sodium carbonate also increases
- For the second graph it is apparent that as the initial mass of sodium bicarbonate increases the total mass lost in the reaction also increases

Conclusion

This experiment successfully demonstrated the thermal decomposition of sodium bicarbonate and allowed for the empirical formula of the product which was sodium carbonate to be found by using mass loss. The data for our group showed the initial mass of sodium bicarbonate at **3.14 g** and the mass of sodium carbonate produced at **1.89 g.** This means the mass of carbon dioxide and water vapor lost was **1.25 g.** Observing the reaction showed the white powder slightly bubbling, but other than that nothing seemed to change visually. Based on our group's data (3.14 sodium bicarbonate creating 1.89 sodium carbonate) the mole ratio for sodium to carbonate was 2.01 to 1. This gave us the empirical formula of Na_2CO_3 for the product of the reaction. This result is most likely correct because of how close it is to the ratio 2 to 1. The deviation of 0.01 is probably due to the random error in the experiment. The class data was plotted to see the relationship between the initial mass of sodium bicarbonate and the mass of the products. The linear relationships in both graphs shows that the reaction follows a consistent pattern. For graph 1 the theoretical slope is 0.631 which is very close to the class slope in the graph; this verifies and confirms that approximately 63.1% of the original mass should stay as sodium carbonate. For graph 2 the theoretical slope should be 0.369 which is also similar to the class slope on the graph; this also confirms that 36.9% of the mass was turned into carbon dioxide and water vapor. Using different initial masses of sodium bicarbonate as the independent variable was a needed element in this experiment. Because by putting the data together across the class and looking at the consistent linear correlation we confirmed that the decomposition reaction stays the same. The variation in the mass by using different groups allowed us to confirm again that the chemical equation and ratios of the substance does not change based on the amount used. These results align with the Law of Conservation of Mass which states that mass in a system can neither be created nor destroyed if the system is enclosed. In this case it was a open system so the carbon dioxide and water vapor escaped into the atmosphere, but the total mass of the sodium carbonate, carbon dioxide, and water vapor is still equal to the mass of the sodium bicarbonate. These results also align with (LibreTexts) experiment on the thermal decomposition of sodium bicarbonate. Both our experiment and (LibreTexts) experiment are very similar in the procedure of heating, cooling, measuring, and observing the sample. This experiment mirrors real world applications like fire extinguishers which rely on thermal decomposition of the sodium bicarbonate leading to the release of carbon dioxide to extinguish the fire.

Evaluation

This experiment included many sources of error, some include the following: Incomplete decomposition or not heating it long enough for it to fully decompose. This led to the calculated mass of sodium carbonate being too high because some of the sodium bicarbonate stays undecomposed which means the final mass will have undecomposed material inside it leading to a higher mass because it has a higher mass than pure sodium carbonate. Another source of error was loss of the product while stirring leading to the calculated mass being too low. This is because when we stirred the product it might have been flicked out or spilled. Some improvements to the methods used could first be using a more efficient method for heating to have complete decomposition such as repeating the heating and cooling process multiple times to confirm that the entire sample is decomposed. Another improvement would be using a larger, deeper evaporating dish to ensure that the powder is not spilled or flicked out while stirring.

Sources

https://chem.libretexts.org/Courses/Triton_College/Fundamentals_of_Chemistry_(Lab_Manual)/09%3A_Decomposition_of_Baking_Soda#:~:text=As%20the%20food%20item%20is,as%20shown%20in%20Example%201.