Mass Percent of Carbon in Sodium Bicarbonate

Introduction

The *law of definite proportions* states that a compound always contains two or more elements combined in a fixed (specific) ratio by mass. In this experiment, the mass percent of carbon in sodium bicarbonate (baking soda) will be determined by measuring the mass of carbon dioxide gas produced in the following chemical reaction (equation).

$$NaHCO_3(s) + CH_3COOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l) + CO_2(g)$$

Concepts

- Law of definite proportions
- Law of conservation of matter

Background

The French chemist, Joseph Louis Proust (1754–1826), was one of the first to observe that elements combine with one another in a definite mass ratio. Proust's experimental work helped form the law of definite proportions, (also called the law of definite composition). According to this law, there is a precise quantity of each component required in the formation of a specific compound—the *percent composition* is constant. This, in turn, implies that in the decomposition of a specific compound, a precise quantity of each component will be produced.

Materials

Sodium bicarbonate, $NaHCO_3$, 1.5 g
Vinegar, CH_3COOH, 180 mL
Balance, centigram (0.01-g precision)
Beaker, 250-mL
Spatula
Weighing dish, 3

Safety Precautions

Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Pour 60 mL of vinegar (5% acetic acid, CH_3COOH) into a 250-mL beaker.
2. Place a weighing dish and the beaker containing the vinegar side-by-side on the balance.
3. Record the combined mass of the beaker, vinegar, and weighing dish in the Data Table.
4. Weigh out about 1.5 g (1.4–1.5 g) of sodium bicarbonate on the weighing dish. Record this value in the Data Table. *Note:* The exact amount is not important as long as the precise mass is recorded in step 5.
5. Record the combined mass of the beaker, weighing dish, sodium bicarbonate, and vinegar in the Data Table.
6. Slowly and carefully add the sodium bicarbonate to the vinegar in the beaker in such a way as to prevent any foam produced by the reaction from overflowing the beaker.
7. When all the sodium bicarbonate has been added, gently swirl the beaker to make sure the reaction is complete, and to remove any remaining bubbles in the beaker.
8. Record the mass of the beaker, its contents, and the weighing dish in the Data Table.
9. Repeat steps 1–8 two more times and enter the data in the data table (Trial 2 and Trial 3).

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Data Table

	Trial 1	Trial 2	Trial 3
Mass of beaker, vinegar, and weighing dish (g)			
Mass of beaker, weighing dish, vinegar, and sodium bicarbonate (g)			
Mass of sodium bicarbonate (g)			
Mass of beaker, its contents, and weighing dish after the reaction (g)			
Mass of carbon dioxide produced (g)			
Ratio of the mass of carbon to the mass of carbon dioxide			
Mass of carbon produced (g)			
Percent carbon in sodium bicarbonate sample			

Post-Lab Questions and Calculations *(Show all work on a separate sheet of paper.)*

1. Subtract the combined mass of the weighing dish, beaker, and its contents after the reaction from the combined mass of the beaker, weighing dish, sodium bicarbonate, and vinegar before the reaction to find the mass of carbon dioxide lost to the atmosphere. Record this in the Data Table.
2. Divide the atomic weight of carbon by the molecular weight of carbon dioxide to determine the ratio of the mass of carbon to the mass of carbon dioxide. Record this ratio in the Data Table.
3. Multiply the mass of carbon dioxide by the mass ratio (question 2) to determine the mass of carbon produced in each trial. Record the results in the Data Table.
4. Divide the mass of carbon produced by the mass of sodium bicarbonate to determine the percent carbon in sodium bicarbonate for each trial. Record the results in the Data Table. Calculate the average percent carbon in sodium bicarbonate.
5. Divide the atomic weight of carbon by the molecular weight of sodium bicarbonate and multiply by 100% to determine the theoretical mass percent of carbon in sodium bicarbonate.
6. Compare the average experimental mass percent of carbon in sodium bicarbonate to the theoretical value and calculate the percent error. The equation for percent error is

$$\frac{|\text{theoretical–experimental}|\ \text{mass of carbon in sodium bicarbonate}}{\text{theoretical mass of carbon in sodium bicarbonate}} \times 100\%$$

Disposal

Please consult your instructor for appropriate disposal procedures.

Teacher's Notes

Mass Percent of Carbon in Sodium Bicarbonate

Materials (for each student group)

Sodium bicarbonate, 4.5 g
Vinegar, 180 mL
Balance, centigram, 0.01-g precision
Beaker, 250-mL
Spatula
Weighing dish

Safety Precautions

Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The waste solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Tips

- Weighing papers or filter paper may be used in place of weighing dishes.
- A larger beaker may be used to prevent foam from flowing out as long as the balance can measure a larger mass.
- This lab can easily be performed in one 50-minute class period, provided enough balances are available.
- Watch significant figures.
- Sources of error include dissolved CO_2, spillage, and moisture.

Sample Data Table *(Student data will vary.)*

	Trial 1	Trial 2	Trial 3
Mass of beaker, vinegar, and weighing dish (g)	*167.37*	*165.34*	*150.40*
Mass of beaker, weighing dish, vinegar, and sodium bicarbonate (g)	*168.89*	*166.85*	*151.91*
Mass of sodium bicarbonate (g)	*1.52*	*1.51*	*1.51*
Mass of beaker, its contents, and weighing dish after the reaction (g)	*168.15*	*166.12*	*151.18*
Mass of carbon dioxide produced (g)	*0.74*	*0.73*	*0.73*
Ratio of the mass of carbon to the mass of carbon dioxide	*3:11*	*3:11*	*3:11*
Mass of carbon produced (g)	*0.20*	*0.20*	*0.20*
Percent carbon in sodium bicarbonate sample	*13*	*13*	*13*

Answers to Post-Lab Questions and Calculations *(Student answers will vary.)*

1. Subtract the combined mass of the weighing dish, beaker, and its contents after the reaction from the combined mass of the beaker, weighing dish, sodium bicarbonate, and vinegar before the reaction to find the mass of carbon dioxide lost to the atmosphere. Record this in the Data Table.

   Trial 1: (168.89 – 168.15)g = 0.74 g

2. Divide the atomic weight of carbon by the molecular weight of carbon dioxide to determine the ratio of the mass of carbon to the mass of carbon dioxide. Record this ratio in the Data Table.

   The ratio of the mass of carbon to the mass of carbon dioxide is 3:11

   $$\frac{12.01\ g\ C}{44.01\ g\ CO_2} = \frac{3}{11}$$

3. Multiply the mass of carbon dioxide by the mass ratio (question 2) to determine the mass of carbon produced in each trial. Record the results in the Data Table.

   Trial 1: $0.74\ g\ CO_2 \times \frac{3}{11} = 0.20\ g\ C$

4. Divide the mass of carbon produced by the mass of sodium bicarbonate to determine the percent carbon in sodium bicarbonate for each trial. Record the results in the Data Table. Calculate the average percent carbon in sodium bicarbonate.

   Trial 1: $\frac{0.20\ g\ C}{1.52\ g\ NaHCO_3} \times 100\% = 13\%$ *Avg. % C* $= \frac{13 + 13 + 13}{3} = 13\%\ C$

   Note: Answer has only two significant figures.

5. Divide the atomic weight of carbon by the molecular weight of sodium bicarbonate and multiply by 100% to determine the theoretical mass percent of carbon in sodium bicarbonate.

   The theoretical mass percent carbon in sodium bicarbonate is 14.30%

   $$\frac{12.01\ g\ C}{84.01\ g\ NaHCO_3} \times 100\% = 14.30\%$$

6. Compare the average experimental mass percent of carbon in sodium bicarbonate to the theoretical value and calculate the percent error. The equation for percent error is

   $$\frac{|\text{theoretical–experimental}|\ \text{mass of carbon in sodium bicarbonate}}{\text{theoretical mass of carbon in sodium bicarbonate}} \times 100\%$$

   Trial 1: $\frac{14.30 - 13}{14.30} \times 100\% = 9.1\%\ error$

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Materials for *Mass Percent of Carbon in Sodium Bicarbonate* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0043	Sodium Bicarbonate, 500 g
V0005	Vinegar, White, 4 L
AP1278	Weighing Dish, 3 1/16″ × 3 1/16″ × 1″
AP1121	Weighing Paper, 3″ × 3″

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.