How Many Grams Of Sodium Hydrogen Carbonate Decompose To Give 28.7 ML Of Carbon Dioxide Gas At STP?2NaHCO3(s)Na2CO3(s)+H2O(l)+CO2(g)Express

How Many Grams Of Sodium Hydrogen Carbonate Decompose To Give 28.7 ML Of Carbon Dioxide Gas At STP? $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$ Explained

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Introduction

Understanding chemical reactions and their quantitative aspects is fundamental in chemistry, especially when dealing with gases produced during reactions. One common reaction involves sodium hydrogen carbonate, also known as baking soda, decomposing to produce carbon dioxide gas. This reaction is not only significant in culinary and industrial applications but also serves as a classic example in stoichiometry calculations.

In this article, we will explore the question: How many grams of sodium hydrogen carbonate ($NaHCO_3$) decompose to give 28.7 mL of carbon dioxide gas at Standard Temperature and Pressure (STP)? We will walk through the step-by-step process of calculating the required mass, based on the principles of gas laws, molar relationships, and stoichiometry.

Understanding the Reaction

Let's first review the chemical equation involved:

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

This balanced reaction indicates that:

- 2 moles of sodium hydrogen carbonate decompose to produce
- 1 mole of carbon dioxide gas (CO_2),
- along with sodium carbonate (Na_2CO_3) and water (H_2O).

This molar ratio (2:1) is key to determining how much $NaHCO_3$ is needed to produce a given volume of CO_2 gas.

Understanding the Volume of Gas at STP

Standard Temperature and Pressure (STP):
- Temperature: 0°C (273.15 K)
- Pressure: 1 atm

At STP, one mole of any ideal gas occupies 22.4 liters (L).
This value allows us to convert between volume and moles of gas:

$$ 1\, \text{mol} \, \text{gas} = 22.4\, \text{L} $$

In our problem, the volume of CO_2 produced is 28.7 milliliters (mL). To work with molar quantities, convert this volume to liters:

$$ 28.7\, \text{mL} = 0.0287\, \text{L} $$

Calculating Moles of CO_2 Gas Produced

Using the molar volume at STP, the number of moles of CO_2 gas produced is:

$$ \text{Moles of CO}_2 = \frac{\text{Volume of CO}_2\, (\text{L})}{22.4\, \text{L/mol}} $$

Plugging in the values:

$$ \text{Moles of CO}_2 = \frac{0.0287\, \text{L}}{22.4\, \text{L/mol}} \approx 0.00128\, \text{mol} $$

This is the quantity of CO_2 generated from the decomposition of sodium hydrogen carbonate.

Relating Moles of $NaHCO_3$ to CO_2 Produced

From the balanced chemical equation:

$$ 2\, \text{mol NaHCO}_3 \rightarrow 1\, \text{mol CO}_2 $$

The molar ratio between $NaHCO_3$ and CO_2 is 2:1. Therefore, the number of moles of $NaHCO_3$ needed to produce 0.00128 mol of CO_2 is:

$$ \text{Moles of NaHCO}_3 = 2 \times \text{Moles of CO}_2 = 2 \times 0.00128 = 0.00256\, \text{mol} $$

Calculating the Mass of Sodium Hydrogen Carbonate

The molar mass of $NaHCO_3$ is calculated as:

- Sodium (Na): 23.0 g/mol
- Hydrogen (H): 1.0 g/mol
- Carbon (C): 12.0 g/mol
- Oxygen (O): 16.0 g/mol × 3 = 48.0 g/mol

Adding these:

$$ \text{Molar mass of NaHCO}_3 = 23.0 + 1.0 + 12.0 + 48.0 = 84.0\, \text{g/mol} $$

Now, the mass of $NaHCO_3$ required:

$$ \text{Mass} = \text{Moles} \times \text{Molar mass} = 0.00256 \times 84.0\, \text{g} \approx 0.215\, \text{g} $$

Final Answer

Approximately 0.215 grams of sodium hydrogen carbonate decompose to produce 28.7 mL of carbon dioxide gas at STP.

Additional Considerations and Practical Applications

1. Significance in Laboratory and Industry
- This calculation is fundamental in laboratory settings where precise gas volumes are required for experiments.
- In industries like baking, understanding the amount of baking soda needed to produce the desired leavening effect involves similar principles.

2. Limitations and Assumptions

- The calculations assume ideal gas behavior, which is accurate at STP.
- Real gases may deviate slightly from ideal behavior, but for most practical purposes, the approximation holds.
- The reaction is assumed to go to completion with no side reactions.

3. How to Use This Method
- Convert the gas volume to moles using molar volume at STP.
- Use the molar ratio from the balanced equation to find the amount of reactant.
- Convert moles to grams using molar mass.

Summary

In summary, to determine how many grams of sodium hydrogen carbonate decompose to produce a specific volume of carbon dioxide gas at STP, you must:

1. Convert the volume to liters.
2. Calculate the moles of CO_2 using the molar volume.
3. Use the molar ratio from the balanced chemical equation to find moles of $NaHCO_3$.
4. Convert moles of $NaHCO_3$ to grams using its molar mass.

For the given problem, approximately 0.215 grams of $NaHCO_3$ are required to produce 28.7 mL of CO_2 gas at STP.

SEO Keywords and Phrases

- Sodium hydrogen carbonate decomposition
- CO_2 gas volume calculation
- Stoichiometry of $NaHCO_3$
- Gas law at STP
- Moles of gas from volume
- How much baking soda to produce CO_2
- Molar volume of gases
- Chemical reaction of $NaHCO_3$
- Quantitative analysis in chemistry
- Practical chemistry calculations

By mastering these calculations, students and professionals can accurately predict gas volumes and required reactant amounts, vital for laboratory experiments, industrial processes, and understanding chemical reactions involving gases.

Frequently Asked Questions

How do you determine the number of grams of sodium hydrogen carbonate that decompose to produce 28.7 mL of CO_2 at STP?

First, convert the volume of CO_2 to moles using the molar volume at STP (22.4 L/mol), then use the stoichiometry of the reaction to find the mass of $NaHCO_3$ needed. Finally, convert moles to grams using the molar mass of $NaHCO_3$.

What is the molar volume of a gas at STP, and how is it used in calculations involving CO_2?

The molar volume of a gas at STP is 22.4 liters per mole. It is used to convert between the gas volume and the number of moles in calculations involving gases at standard conditions.

What is the balanced chemical equation for the decomposition of sodium hydrogen carbonate?

The balanced equation is: $2\ NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(l) + CO_2(g)$.

How many moles of CO_2 are produced from 28.7 mL at STP?

Convert 28.7 mL to liters (0.0287 L), then divide by 22.4 L/mol: $0.0287 / 22.4 \approx 0.00128$ mol of CO_2.

How do you calculate the grams of $NaHCO_3$ needed to produce a specific volume of CO_2?

Use the molar amount of CO_2 (from volume), relate it to $NaHCO_3$ via the reaction's stoichiometry (2 mol $NaHCO_3$ per 1 mol CO_2), then multiply the moles of $NaHCO_3$ by its molar mass (84 g/mol) to find the mass.

What is the molar mass of sodium hydrogen carbonate ($NaHCO_3$)?

The molar mass of $NaHCO_3$ is approximately 84 g/mol.

How many grams of $NaHCO_3$ decompose to produce 28.7 mL of CO_2 at STP?

Calculate moles of CO_2 (0.00128 mol), then use the ratio 2 mol $NaHCO_3$ per mol CO_2: 2×0.00128 mol = 0.00256 mol $NaHCO_3$. Multiply by molar mass (84 g/mol): $0.00256 \times 84 \approx 0.215$ g. So, approximately 0.215 grams of $NaHCO_3$ decompose.

Why is it important to use the molar volume of gases at STP in this calculation?

Because it allows for converting gas volume measurements to moles accurately, which is essential for stoichiometric calculations involving gases.

What assumptions are made when calculating the decomposition of $NaHCO_3$ to produce CO_2 at STP?

It is assumed that the gas behaves ideally, the conditions are at standard temperature and pressure, and the entire amount of $NaHCO_3$ decomposes completely to produce the measured volume of CO_2.

Additional Resources

How Many Grams Of Sodium Hydrogen Carbonate Decompose To Give 28.7 ML Of Carbon Dioxide Gas At STP?

Introduction

Sodium hydrogen carbonate, commonly known as baking soda, is a versatile compound with a variety of applications, from cooking to industrial processes. Its chemical behavior, especially its decomposition properties, is of significant interest in both academic and industrial contexts. A fundamental question in chemical stoichiometry involves determining how much of a compound is required to produce a specific volume of a gas under standard conditions. This article delves into the detailed process of calculating the mass of sodium hydrogen carbonate ($NaHCO_3$) that decomposes to generate 28.7 mL of carbon dioxide (CO_2) at standard temperature and pressure (STP).

Understanding the Reaction

The decomposition of sodium hydrogen carbonate can be represented by the balanced chemical equation:

Balanced Chemical Equation

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

However, this equation is incomplete or simplified. In reality, the more accurate decomposition of sodium hydrogen carbonate often occurs via:

Complete Decomposition Reaction

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

This balanced equation indicates that 2 moles of $NaHCO_3$ produce 1 mole of CO_2.

Theoretical Foundations

To solve the problem, it's essential to understand the relationship between moles of gas and volume at STP, as well as the stoichiometry involved.

Standard Conditions and Gas Laws

- Standard Temperature and Pressure (STP): 0°C (273.15 K) and 1 atm pressure.
- Molar Volume of Gas at STP: Approximately 22.4 liters (L) per mole.

This molar volume is critical for converting between moles and volume of gases.

Step-by-Step Calculation Approach

The problem involves several key steps:

1. Convert the given volume of CO_2 (28.7 mL) to liters.
2. Determine the number of moles of CO_2 produced.
3. Relate moles of CO_2 to moles of $NaHCO_3$ via the balanced equation.
4. Calculate the mass of $NaHCO_3$ corresponding to the moles determined.

Step 1: Volume Conversion

Given volume of CO_2 = 28.7 mL

Convert mL to liters:

28.7 mL × (1 L / 1000 mL) = 0.0287 L

Step 2: Moles of CO_2 at STP

Using molar volume:

Number of moles = Volume / Molar volume

Number of moles of CO_2:

$= 0.0287 \text{ L} / 22.4 \text{ L/mol} \approx 0.00128 \text{ mol}$

Step 3: Stoichiometric Relationship Between $NaHCO_3$ and CO_2

From the balanced equation:

$2\ NaHCO_3 \rightarrow 1\ CO_2$

Therefore, 2 moles of $NaHCO_3$ produce 1 mole of CO_2.

Rearranged:

Moles of $NaHCO_3$ = 2 × moles of CO_2

Moles of $NaHCO_3$:

$= 2 \times 0.00128 \text{ mol} \approx 0.00256 \text{ mol}$

Step 4: Mass of Sodium Hydrogen Carbonate

Molecular weight of $NaHCO_3$:

- Na: 22.99 g/mol
- H: 1.008 g/mol
- C: 12.01 g/mol
- O_3: 3 × 16.00 g/mol = 48.00 g/mol

Sum:

$22.99 + 1.008 + 12.01 + 48.00 \approx 83.01 \text{ g/mol}$

Mass:

= moles × molar mass

$= 0.00256 \text{ mol} \times 83.01 \text{ g/mol} \approx 0.212 \text{ g}$

Final Answer:

Approximately 0.21 grams of sodium hydrogen carbonate decompose to produce 28.7 mL of CO_2 gas at STP.

Additional Considerations

While the above calculation provides a precise theoretical value, several practical factors can influence the actual amount:

- Purity of reactant: Commercial $NaHCO_3$ may contain impurities.
- Completeness of reaction: Complete decomposition might not always occur.
- Measurement precision: Volumetric measurements at small scales can have errors.
- Temperature and pressure deviations: Slight variations from STP conditions can alter molar volume calculations.

Implications and Applications

Understanding the stoichiometric relationship between sodium hydrogen carbonate and carbon dioxide has practical implications in various fields:

- Industrial processes: Estimation of reagent quantities needed for CO_2 production.
- Environmental science: Modeling CO_2 emissions from decomposition reactions.
- Educational purposes: Demonstrating gas laws and stoichiometry principles.

Conclusion

Through careful application of chemical stoichiometry, gas laws, and molecular calculations, we find that approximately 0.21 grams of sodium hydrogen carbonate decomposes under standard conditions to give 28.7 mL of carbon dioxide. This calculation not only reinforces fundamental concepts in chemistry but also exemplifies the importance of precise measurement and understanding of chemical reactions in real-world contexts.

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Author's Note

This detailed analysis underscores the importance of rigorous calculation and conceptual understanding in chemical stoichiometry. Whether for academic purposes or industrial applications, such calculations form the backbone of quantitative chemistry, enabling precise control over reactions and processes.

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