How Many Grams Of Sodium Hydrogen Carbonate Decompose To Give 25.0 ML Of Carbon Dioxide Gas At STP? 2NaHCO3(s)Na2CO3(s)+H2O(l)+CO2(g).

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Understanding the relationship between chemical reactions and the amount of gases produced is fundamental in chemistry. Specifically, determining how many grams of sodium hydrogen carbonate (commonly known as baking soda) decompose to produce a specific volume of carbon dioxide (CO_2) at standard temperature and pressure (STP) is a common problem that demonstrates stoichiometry in action. In this article, we'll explore this question step-by-step, providing a comprehensive guide to calculating the mass of sodium hydrogen carbonate required to generate 25.0 mL of CO_2 at STP, based on the balanced chemical equation:

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

Understanding the Chemical Reaction

Before diving into calculations, it's essential to understand the reaction involved and the significance of each component.

The Balanced Equation

The chemical equation for the decomposition of sodium hydrogen carbonate is:

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

This indicates that:

- 2 moles of sodium hydrogen carbonate decompose to produce
- 1 mole of sodium carbonate,
- 1 mole of water,
- 1 mole of carbon dioxide gas.

Implications for Stoichiometry

From the balanced equation, we see that:

- 2 moles of $NaHCO_3$ produce 1 mole of CO_2.
- Therefore, the molar ratio of $NaHCO_3$ to CO_2 is 2:1.

Calculating the Moles of CO_2 at STP

The first step involves converting the given volume of CO_2 to the number of moles.

Volume of CO_2 at STP

Standard Temperature and Pressure (STP) conditions are:

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

At STP, 1 mole of any ideal gas occupies 22.4 liters (L).

Given:

- Volume of CO_2 = 25.0 mL

Convert this volume to liters:

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25.0 mL × (1 L / 1000 mL) = 0.025 L
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Calculate moles of CO_2:

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Number of moles = Volume / Molar volume at STP = 0.025 L / 22.4 L/mol ≈
0.00111607 mol
```

Relating Moles of CO_2 to Moles of Sodium Hydrogen Carbonate

Using the molar ratio from the balanced equation:

- 2 mol $NaHCO_3$ produce 1 mol CO_2.

Therefore:

```
Number of moles of NaHCO₃ = 2 × (moles of CO₂) = 2 × 0.00111607 mol ≈
0.00223214 mol
```

This is the amount of sodium hydrogen carbonate required to produce 25.0 mL of CO_2 at STP.

Calculating the Mass of Sodium Hydrogen Carbonate Needed

Next, determine how many grams of $NaHCO_3$ correspond to this number of moles.

Molar Mass of Sodium Hydrogen Carbonate

Calculate the molar mass:

- Sodium (Na): 22.99 g/mol
- Hydrogen (H): 1.008 g/mol
- Carbon (C): 12.01 g/mol
- Oxygen (O): 16.00 g/mol

Sum:

```
Molar mass of NaHCO₃ = 22.99 + 1.008 + 12.01 + (3 × 16.00)
= 22.99 + 1.008 + 12.01 + 48.00
= 84.008 g/mol
```

Mass Calculation

Multiply moles by molar mass:

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Mass = moles × molar mass ≈ 0.00223214 mol × 84.008 g/mol ≈ 0.1874 g
```

Therefore, approximately 0.187 grams of sodium hydrogen carbonate decompose to produce 25.0 mL of CO_2 at STP.

Summary of the Calculation

Step	Description	Result
1	Convert volume of CO_2 to moles at STP	0.001116 mol
2	Use molar ratio from balanced equation	0.002232 mol $NaHCO_3$
3	Calculate mass of $NaHCO_3$	≈ 0.187 g

Additional Considerations

While the calculation above provides an accurate estimate under ideal conditions, real-world factors such as impurities, reaction completeness, and measurement precision can influence the actual amount needed.

Practical Applications

This calculation is useful in various contexts:

- Baking: understanding how much baking soda to use for a specific leavening effect.
- Laboratory experiments: designing reactions that produce controlled amounts of CO_2.
- Environmental studies: estimating gas emissions from decomposition processes.

Common Mistakes to Avoid

- Forgetting to convert volume to moles at STP.
- Using incorrect molar volume (some resources cite 22.4 L/mol, but at non-STP conditions, volume changes).
- Mixing units or neglecting significant figures.

Conclusion

In summary, to produce 25.0 mL of carbon dioxide gas at STP via the decomposition of sodium hydrogen carbonate, approximately 0.187 grams of $NaHCO_3$ are required. This calculation hinges on understanding the balanced chemical equation, converting gas volume to moles, applying stoichiometry, and then translating moles back to mass using molar mass. Mastery of these steps empowers chemists and students alike to predict reaction outcomes accurately, optimize laboratory procedures, and deepen their understanding of chemical principles.

Final Note

Always remember to verify conditions and units in your calculations, and consider practical factors that may influence real-world reactions. With this methodology, you can confidently determine the amount of sodium hydrogen carbonate needed for various gas production scenarios, making your chemistry experiments more precise and effective.

Frequently Asked Questions

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

The balanced equation is 2NaHCO3(s) → Na2CO3(s) + H2O(l) + CO2(g).

How do you determine the amount of sodium hydrogen carbonate that decomposes to produce a specific volume of CO_2 at STP?

Use the molar volume of gases at STP (22.4 L/mol), relate the volume of CO_2 to moles, then use the mole ratio from the balanced equation to find the amount of $NaHCO_3$ in grams.

What is the molar volume of a gas at STP, and why is it important in this calculation?

The molar volume of a gas at STP is 22.4 liters per mole, and it allows us to convert the volume of CO_2 gas into moles for stoichiometric calculations.

How many moles of CO_2 are generated from 25.0 mL at STP?

Moles of CO_2 = 25.0 mL × (1 L / 1000 mL) ÷ 22.4 L/mol ≈ 0.001116 moles.

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

$NaHCO_3$ has a molar mass of approximately 84.01 g/mol.

How do you calculate the grams of $NaHCO_3$ needed to produce 25.0 mL of CO_2?

First, determine moles of CO_2 (≈0.001116 mol), then use the mole ratio from the balanced equation (2 mol $NaHCO_3$ per 1 mol CO_2) to find moles of $NaHCO_3$, and multiply by its molar mass: (0.001116 mol × 2) × 84.01 g/mol ≈ 0.188 g.

What is the final answer for the grams of sodium hydrogen carbonate decomposing to produce 25.0 mL of CO_2 at STP?

Approximately 0.188 grams of $NaHCO_3$ decompose to produce 25.0 mL of CO_2 at STP.

Why is it necessary to use the ideal gas law or molar volume in this calculation?

Because it allows us to convert the volume of gas at STP into moles, which is essential for stoichiometric calculations involving mass of reactants.

Can this calculation be used for gases at conditions other than STP?

No, because gas volumes vary with temperature and pressure; for non-STP conditions, you'd need to use the ideal gas law (PV=nRT) to account for actual conditions.

Additional Resources

Sodium Hydrogen Carbonate Decomposition: Calculating the Grams Needed to Generate 25.0 mL of CO_2 at STP

Understanding the precise amount of a chemical needed to produce a specific volume of a gas is fundamental in chemistry, especially in contexts ranging from laboratory experiments to industrial applications. Today, we delve into a detailed analysis of how many grams of sodium hydrogen carbonate ($NaHCO_3$) are required to release exactly 25.0 mL of carbon dioxide (CO_2) gas at Standard Temperature and Pressure (STP). This exploration combines stoichiometry, gas laws, and chemical understanding to provide a comprehensive answer.

Introduction to the Chemical Reaction

The decomposition of sodium hydrogen carbonate, commonly known as baking soda, is a well-known chemical process with both scientific and practical significance. The reaction can be represented as:

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

This balanced equation indicates that two moles of sodium hydrogen carbonate produce one mole of carbon dioxide, along with sodium carbonate and water.

Key points:
- The reaction is a decomposition, often triggered by heating.
- The molar ratio of $NaHCO_3$ to CO_2 is 2:1.
- The process is used in baking, fire extinguishers, and chemical experiments.

Understanding the Conditions: STP and Gas Volume

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

At STP, gases behave ideally, and molar volume (the volume occupied by 1 mole of gas) is approximately 22.4 liters (or 22,400 mL).

Implication for Our Calculation:
Knowing the molar volume allows us to convert between moles of gas and volume at STP, which is essential for our problem.

Step-by-Step Calculation Strategy

To determine how many grams of $NaHCO_3$ are needed to produce 25.0 mL of CO_2 at STP, we will follow these steps:

1. Convert the gas volume to moles of CO_2.
2. Use the stoichiometry of the balanced reaction to find moles of $NaHCO_3$ required.
3. Convert moles of $NaHCO_3$ to grams using molar mass.

Step 1: Converting Volume of CO_2 to Moles

Given:
- Volume of CO_2 = 25.0 mL
- Molar volume at STP = 22,400 mL/mol

Calculation:
$$ \text{Moles of CO}_2 = \frac{\text{Volume of CO}_2}{22,400 \text{ mL/mol}} $$

$$ \text{Moles of CO}_2 = \frac{25.0 \text{ mL}}{22,400 \text{ mL/mol}} $$

$$ \text{Moles of CO}_2 \approx 0.00111607 \text{ mol} $$

Rounded for simplicity:
$$ \boxed{\text{Moles of CO}_2 \approx 1.12 \times 10^{-3} \text{ mol}} $$

Step 2: Applying the Stoichiometry of the Reaction

From the balanced chemical equation:

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

- 2 moles of $NaHCO_3$ produce 1 mole of CO_2.

Therefore:

$$ \text{Moles of NaHCO}_3 = 2 \times \text{Moles of CO}_2 $$

$$ \text{Moles of NaHCO}_3 = 2 \times 1.12 \times 10^{-3} $$

$$ \boxed{\text{Moles of NaHCO}_3 \approx 2.24 \times 10^{-3} \text{ mol}} $$

Step 3: Converting Moles of $NaHCO_3$ to Grams

Molar mass of $NaHCO_3$:
- Na: 23.00 g/mol
- H: 1.008 g/mol
- C: 12.01 g/mol
- O: 16.00 g/mol (three oxygens)

Calculating:

$$ \text{Molar mass} = 23.00 + 1.008 + 12.01 + (3 \times 16.00) $$

$$ \text{Molar mass} = 23.00 + 1.008 + 12.01 + 48.00 $$

$$ \text{Molar mass} = 84.02 \text{ g/mol} $$

Mass of $NaHCO_3$ required:

$$ \text{Mass} = \text{Moles} \times \text{Molar mass} $$

$$ \text{Mass} = 2.24 \times 10^{-3} \times 84.02 $$

$$ \text{Mass} \approx 0.188 \text{ grams} $$

Final answer:

$$
\boxed{
\text{Approximately 0.188 grams of NaHCO}_3 \text{ are needed}
}
$$

Discussion and Practical Implications

This calculation provides a precise quantitative measure crucial for laboratory preparations, educational demonstrations, or industrial processes involving gas generation. It emphasizes several core principles:

- Stoichiometry's importance in predicting reactant quantities for a desired product.
- Gas laws' utility in translating between volume and moles under known conditions.
- The balance of chemical equations as an essential tool for accurate calculations.

Practical considerations:

- Purity of reactants: Real-world sodium hydrogen carbonate may contain impurities, affecting the actual amount needed.
- Reaction conditions: Heating or other factors may influence the efficiency of CO_2 release.
- Measurement accuracy: Small volumes like 25.0 mL require precise measurement tools for reliable results.

Summary of Key Points

- To produce 25.0 mL of CO_2 at STP, approximately 0.188 grams of sodium hydrogen carbonate are required.
- The calculation hinges on understanding the molar volume of gases, stoichiometry of the reaction, and molar masses.
- This process underscores the importance of fundamental chemistry principles in practical applications.

In essence: Whether you're a student conducting a classroom experiment or a professional designing a process, knowing how to connect gas volumes to reactant masses is invaluable. This detailed approach ensures accuracy, efficiency, and a solid understanding of the underlying chemistry.

Final note: Always double-check measurements and consider experimental conditions that might cause deviations from ideal behavior. Proper lab techniques and precise calculations are the cornerstones of successful chemical work.

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