Calculate The Number Of Liters Of Carbon Dioxide Measured At STP That Could Be Produced From 6.71 G Of

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Understanding the relationship between mass, molar volume, and gases is fundamental in chemistry, especially when dealing with gaseous products like carbon dioxide (CO_2). Whether you're a student preparing for exams, a professional conducting experiments, or simply an enthusiast interested in chemical calculations, knowing how to determine the volume of CO_2 produced from a given mass is a crucial skill. In this guide, we'll walk you through the process of calculating the volume of CO_2 at Standard Temperature and Pressure (STP) that can be generated from 6.71 grams of a substance—most likely a carbonate or bicarbonate compound—based on the chemical reaction involved.

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Understanding The Context and The Reaction

Before diving into calculations, it’s important to understand the chemical reaction that produces carbon dioxide. Common reactions include:

- The reaction of acids with carbonates/bicarbonates:

$$
\text{M}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{MCl} + \text{CO}_2 + \text{H}_2\text{O}
$$

- The thermal decomposition of carbonates:

$$
\text{M}_2\text{CO}_3 \xrightarrow{\text{heat}} \text{M}_x\text{O}_y + \text{CO}_2
$$

- The combustion of fossil fuels, which releases CO_2.

For our calculation, let's assume the scenario involves the reaction of a carbonate compound, such as sodium carbonate (Na_2CO_3), with an acid like hydrochloric acid (HCl), which is a common laboratory reaction.

Step 1: Identifying the Substance and Its Molar Mass

To proceed, we need to know the chemical formula of the compound involved. Assuming the compound is sodium carbonate (Na_2CO_3), the molar mass calculation is as follows:

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

Calculating molar mass of Na_2CO_3:

$$
\text{Molar mass of Na}_2\text{CO}_3 = (2 \times 22.99) + 12.01 + (3 \times 16.00) = 45.98 + 12.01 + 48.00 = 105.99 \text{ g/mol}
$$

This value will be used to convert the given mass to moles.

Step 2: Converting Mass to Moles

Given mass of the compound:

$$
6.71\, \text{g}
$$

Calculate the number of moles:

$$
\text{Moles of Na}_2\text{CO}_3 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{6.71\, \text{g}}{105.99\, \text{g/mol}} \approx 0.0633\, \text{mol}
$$

This is the amount of sodium carbonate available to react and produce CO_2.

Step 3: Understanding the Stoichiometry of the

Reaction

From the balanced chemical equation:

$$
\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}
$$

The molar ratio of sodium carbonate to carbon dioxide is 1:1. This means:

- 1 mol of Na_2CO_3 produces 1 mol of CO_2.

Therefore, the moles of CO_2 produced are equal to the moles of Na_2CO_3 reacted, which we calculated as approximately 0.0633 mol.

Step 4: Calculating the Volume of CO_2 at STP

At Standard Temperature and Pressure (STP), which is defined as:

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

1 mol of any ideal gas occupies 22.4 liters.

Thus, the volume of CO_2 that can be produced is:

$$
\text{Volume} = \text{Number of moles} \times 22.4\, \text{L/mol}
$$

Calculating:

$$
0.0633\, \text{mol} \times 22.4\, \text{L/mol} \approx 1.42\, \text{L}
$$

Answer: Approximately 1.42 liters of CO_2 measured at STP can be produced from 6.71 grams of sodium carbonate reacting with sufficient acid.

Additional Considerations

While the above calculation assumes ideal conditions and a specific compound, real-world scenarios may vary due to factors such as:

- Impurities in reactants
- Non-ideal gas behavior
- Variations in temperature and pressure

To account for these, more advanced calculations or experimental measurements may be necessary.

Practical Applications of Calculating Gas Volumes

Understanding how to perform these calculations has multiple real-world applications:

1. **Laboratory Experiments:** Predict the amount of gas produced during titrations or gas-evolution reactions.

2. **Environmental Science:** Estimate emissions of CO_2 from industrial processes.

3. **Industrial Processes:** Design reactors and safety measures based on gas production volumes.

4. **Educational Purposes:** Enhance students' understanding of stoichiometry and gas laws.

Summary of Key Points

- Identify the chemical formula and molar mass of the reactant compound.

- Convert the given mass to moles using molar mass.

- Use stoichiometry to determine moles of CO_2 produced.

- Apply the molar volume at STP (22.4 L/mol) to find the volume of CO_2.

- Remember that real-world conditions may cause deviations from ideal calculations.

Final Thoughts

Calculating the volume of carbon dioxide produced from a specific mass of a compound is a foundational skill in chemistry that combines knowledge of molar mass, stoichiometry, and gas laws. Whether for academic purposes, industrial applications, or environmental assessments, mastering these calculations enables better understanding and control of chemical reactions involving gases. Always ensure to verify the chemical reaction involved and adjust calculations accordingly for different compounds and conditions.

If you want to perform similar calculations with other compounds or under different conditions, remember to adjust molar masses, reaction ratios, and gas volumes accordingly. With practice, these calculations will become an intuitive part of your chemistry toolkit.

Frequently Asked Questions

How do I calculate the volume of CO_2 produced at STP from 6.71 g of a given substance?

First, determine the molar mass of the substance and find the number of moles by dividing 6.71 g by its molar mass. Then, use the molar volume of gases at STP (22.4 L per mole) to find the volume: multiply the moles by 22.4 L.

What is the molar mass needed to convert 6.71 g of a substance into liters of CO_2 at STP?

The molar mass depends on the specific compound involved. To convert grams to liters of CO_2, you need the molar mass of the substance that produces CO_2 upon reaction. Once known, divide 6.71 g by this molar mass to find moles, then multiply by 22.4 L.

If 6.71 g of a carbon-containing compound produces CO_2, how many liters of CO_2 are generated at STP?

Calculate the number of moles of the compound by dividing 6.71 g by its molar mass. Then, multiply the moles by 22.4 L to find the volume of CO_2 at STP.

Why is 22.4 liters used in calculating the volume of gases at STP?

22.4 liters is the molar volume of an ideal gas at standard temperature and pressure (0°C and 1 atm), representing the volume occupied by one mole of gas.

Can I determine the volume of CO_2 produced from 6.71 g of any substance directly?

No, you need to know the specific chemical formula and the reaction involved to determine how much CO_2 is produced. The molar mass and the reaction stoichiometry are essential for accurate calculation.

How does the chemical formula of the substance affect the calculation of CO_2 volume at STP?

The chemical formula determines the molar mass and the ratio of CO_2 produced per mole of the substance. This information is necessary to convert grams to moles and then to volume at STP.

Additional Resources

Calculate The Number Of Liters Of Carbon Dioxide Measured At STP That Could Be Produced From 6.71 G Of Substance

Understanding the relationship between mass, molar quantities, and gas volume is fundamental in chemistry, especially when dealing with gases under standard conditions. In this comprehensive analysis, we explore how to determine the volume of carbon dioxide (CO_2) produced from a given mass of a substance—presumably a carbonate or other CO_2-generating compound—by applying stoichiometric principles at standard temperature and pressure (STP). This process involves several key steps, including calculating the molar mass, molar ratios from balanced equations, and volume conversions, all of which will be elaborately discussed to provide clarity and insight.

Introduction to Gas Volume Calculations and STP

Before delving into calculations, it’s crucial to understand the foundational concepts underpinning gas volume determination.

What is STP?

Standard Temperature and Pressure (STP) is a standardized set of conditions used in chemistry to compare gas quantities. Typically, STP is defined as:
- Temperature: 0°C (273.15 K)
- Pressure: 1 atm
- Molar volume of an ideal gas: approximately 22.4 liters per mole

These conditions assume ideal gas behavior, which is a good approximation for most gases under typical laboratory conditions.

The Significance of Molar Volume

Molar volume is the volume occupied by one mole of gas at STP. For calculations involving gases, once the number of moles is known, the volume can be directly computed using this constant (22.4 L/mol).

Identifying the Substance and the Chemical Reaction

The initial step involves clarifying what substance is providing the carbon dioxide upon reaction. Typically, the scenario involves a carbonate salt or similar compound reacting with an acid, such as:

Example Reaction:
$$ \text{M}_x \text{CO}_y + \text{acid} \rightarrow \text{CO}_2 + \text{other products} $$

A common example is the reaction of calcium carbonate with hydrochloric acid:
$$ \text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O} $$

For the purpose of this calculation, let's assume the primary compound is calcium carbonate (CaCO_3), which is a typical source of CO_2 in laboratory and industrial reactions.

Step-by-Step Calculation Process

The calculations involve several key steps:

1. Determine the molar mass of the compound (e.g., calcium carbonate).
2. Calculate the number of moles of the compound from its given mass.
3. Use the molar ratio from the balanced reaction to find the moles of CO_2 produced.
4. Convert the moles of CO_2 to volume at STP.

Each step will be elaborated with detailed explanations.

Step 1: Calculate the Molar Mass of Calcium Carbonate ($CaCO_3$)

The molar mass is calculated by summing the atomic masses of all atoms in the formula:

Element	Atomic Mass (g/mol)	Number of Atoms	Total Mass Contribution (g/mol)

Calcium (Ca)	40.08	1	40.08
Carbon (C)	12.01	1	12.01
Oxygen (O)	16.00	3	48.00

Total molar mass of $CaCO_3$:
$$ 40.08 + 12.01 + 48.00 = 100.09 \, \text{g/mol} $$

This value indicates that 1 mol of calcium carbonate weighs approximately 100.09 grams.

Step 2: Calculate Moles of Calcium Carbonate in 6.71 g

Using the molar mass:

$$
\text{Moles of CaCO}_3 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{6.71 \, \text{g}}{100.09 \, \text{g/mol}} \approx 0.067 \, \text{mol}
$$

This calculation reveals the amount of calcium carbonate involved in the reaction.

Step 3: Determine Moles of CO_2 Produced

From the balanced chemical equation:
$$ \text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O} $$

The molar ratio of calcium carbonate to carbon dioxide is 1:1. Therefore, 1 mol of $CaCO_3$ produces 1 mol of CO_2.

$$
\text{Moles of CO}_2 = \text{Moles of CaCO}_3 \times 1 = 0.067 \, \text{mol}
$$

Step 4: Convert Moles of CO_2 to Volume at STP

Using the molar volume of an ideal gas at STP (22.4 L/mol):

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

$$
= 0.067 \times 22.4 \approx 1.501 \, \text{liters}
$$

Result:
Approximately 1.50 liters of carbon dioxide gas measured at STP can be produced from 6.71 grams of calcium carbonate reacting completely with acid.

Implications and Broader Context

This calculation exemplifies fundamental stoichiometry principles crucial in various scientific and industrial applications, including:

- Environmental Science: Estimating CO_2 emissions from mineral deposits or industrial processes.
- Chemical Manufacturing: Designing processes where CO_2 generation is a byproduct or desired product.
- Laboratory Analysis: Quantitative analysis of carbonate content in mineral samples.

Furthermore, understanding the conversion from mass to gas volume at STP enables scientists and engineers to model and optimize reactions, ensuring safety, efficiency, and compliance with environmental standards.

Factors Affecting Accuracy and Real-World Considerations

While theoretical calculations are insightful, real-world scenarios involve several factors that can affect the actual volume of CO_2 produced:

- Gas Non-Ideal Behavior: At high pressures or low temperatures, gases deviate from ideal behavior, slightly altering volume estimations.
- Incomplete Reactions: Not all reactant molecules may react completely, reducing the actual CO_2 yield.
- Purity of Reactants: Impurities can lead to side reactions or reduced efficiency.
- Measurement Uncertainties: Precise weighing and controlled reaction conditions are vital for accurate results.

In laboratory settings, corrections and calibrations are performed to account for these factors, ensuring the reliability of measurements.

Conclusion

Calculating the volume of carbon dioxide produced from a given mass of a compound involves a systematic approach grounded in stoichiometry, molar mass calculations, and gas laws. Using calcium carbonate as an example, we demonstrated that 6.71 grams could theoretically produce approximately 1.50 liters of CO_2 at STP. Such calculations are instrumental across scientific disciplines, enabling accurate predictions, process optimization, and environmental impact assessments. Mastery of these concepts enhances our ability to analyze chemical reactions quantitatively, fostering advancements in research, industry, and environmental stewardship.

Note: If the original substance was different from calcium carbonate, the same approach applies—identify the molar mass, write the balanced reaction, and proceed through the steps accordingly.

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