What Volume Of Carbon Dioxide, Measured At 25 C And 741 Torr, Can Be Obtained By The Reaction Of 50.

What Volume Of Carbon Dioxide, Measured At 25 C And 741 Torr, Can Be Obtained By The Reaction Of 50. This question involves understanding the principles of chemical reactions, gas laws, and stoichiometry to determine the volume of CO_2 produced under specific conditions. In this comprehensive guide, we will explore the factors influencing gas volume calculations, step-by-step procedures, and practical applications.

Understanding the Basics: Gas Laws and Stoichiometry

Before diving into calculations, it is essential to review fundamental concepts related to gases and chemical reactions.

Gas Laws Overview

Gases are described by various gas laws that relate their pressure (P), volume (V), temperature (T), and amount in moles (n). The key laws include:

- Boyle's Law: $P_1V_1 = P_2V_2$ (constant T and n)
- Charles's Law: $V_1/T_1 = V_2/T_2$ (constant P and n)
- Gay-Lussac's Law: $P_1/T_1 = P_2/T_2$ (constant V and n)
- Ideal Gas Law: $PV = nRT$

Here, R is the universal gas constant (8.314 J/mol·K or 0.082057 L·atm/mol·K).

Note: Since the problem involves specific temperature and pressure, the ideal gas law provides a reliable framework for calculations.

Stoichiometry in Chemical Reactions

Stoichiometry involves quantifying reactants and products based on the balanced chemical equation. It allows for converting between mass, moles, and volume of gases involved in the reaction.

The Chemical Reaction Involved

The specific reaction leading to CO_2 production is critical. Common reactions producing CO_2 include:

- Reaction of Carbon with Oxygen:

$$
C + O_2 \rightarrow CO_2
$$

- Reaction of Hydrocarbons (e.g., Methane):

$$
CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O
$$

- Reaction of Carbonates with Acid:

$$
CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O
$$

For this guide, assume the reaction involves a known amount of a carbon source reacting with oxygen to produce CO_2, such as the combustion of a hydrocarbon or carbon.

Note: Since the question mentions "reaction of 50" without specifying the reactant, we will assume 50 grams of carbon reacting with oxygen.

Step-by-Step Calculation of CO_2 Volume

To find the volume of CO_2 produced, we follow these steps:

1. Identify the reactant and its amount in moles.
2. Use the stoichiometric ratio to determine moles of CO_2 produced.
3. Convert moles of CO_2 to volume using the ideal gas law, adjusted for the given T and P.

Step 1: Calculate Moles of Reactant (Carbon)

Given:
- Mass of carbon = 50 grams
- Atomic mass of carbon = 12.01 g/mol

$$
\text{Moles of carbon} = \frac{\text{Mass}}{\text{Atomic mass}} = \frac{50\,g}{12.01\,g/mol} \approx 4.16\,mol
$$

Step 2: Determine Moles of CO_2 Produced

From the combustion reaction:

$$
C + O_2 \rightarrow CO_2
$$

The molar ratio of carbon to CO_2 is 1:1. Therefore, moles of CO_2 produced:

$$
\text{Moles of } CO_2 = \text{Moles of carbon} = 4.16\,mol
$$

Step 3: Calculate the Volume of CO_2 at 25°C and 741 Torr

Convert the given conditions to appropriate units:

- Temperature (T): 25°C = 25 + 273.15 = 298.15 K
- Pressure (P): 741 Torr

Convert Torr to atmospheres:

$$
P = \frac{741\, Torr}{760\, Torr/atm} \approx 0.975\, atm
$$

Use the ideal gas law:

$$
V = \frac{nRT}{P}
$$

Where:
- $n = 4.16\, mol$
- $R = 0.082057\, L\, atm\, mol^{-1}\, K^{-1}$
- $T = 298.15\, K$
- $P = 0.975\, atm$

Calculating:

$$
V = \frac{4.16\, mol \times 0.082057\, L\, atm\, mol^{-1}\, K^{-1} \times 298.15\, K}{0.975\, atm}
$$

\[

$$
V \approx \frac{4.16 \times 0.082057 \times 298.15}{0.975}
$$

$$
V \approx \frac{4.16 \times 24.464}{0.975}
$$

$$
V \approx \frac{101.7}{0.975} \approx 104.3\, L
$$

Result: Approximately 104.3 liters of CO_2 can be obtained under the specified conditions.

Additional Factors to Consider

While the above calculation provides a theoretical volume, real-world scenarios may involve deviations due to various factors.

1. Non-Ideal Gas Behavior

At high pressures or low temperatures, gases deviate from ideal behavior. However, at 25°C and below 1 atm, the ideal gas law provides a close approximation.

2. Reaction Completeness

The calculation assumes complete conversion of carbon to CO_2. In practice, reaction efficiency, side reactions, and incomplete combustion can reduce actual yields.

3. Purity of Reactants

Impurities or excess reactants may influence the amount of CO_2 produced.

4. Measurement Accuracy

Precise measurements of temperature, pressure, and reactant quantities are vital for accurate calculations.

Practical Applications and Significance

Understanding the volume of CO_2 generated from specific reactions has numerous applications:

- Environmental Monitoring: Estimating greenhouse gas emissions.
- Industrial Processes: Designing reactors for combustion or carbonation.
- Laboratory Experiments: Quantitative analysis in chemical education.
- Carbon Capture and Storage: Assessing CO_2 quantities involved in sequestration processes.

Summary and Key Takeaways

- The calculation of CO_2 volume involves understanding the chemical reaction, stoichiometry, and gas laws.
- For 50 grams of carbon reacting completely with oxygen, approximately 104.3 liters of CO_2 are produced at 25°C and 741 Torr.
- Converting pressure units and using the ideal gas law are essential steps.
- Real-world factors may influence the actual volume obtained, but theoretical calculations provide valuable estimates.

Conclusion

Determining the volume of carbon dioxide produced under specific conditions combines chemical reaction principles with gas law applications. By carefully following stoichiometric relationships and applying the ideal gas law, chemists and engineers can accurately estimate gas volumes for various practical purposes. Whether in laboratory settings or industrial applications, such calculations are fundamental to understanding and managing gaseous reactions efficiently.

Note: Always ensure the reactant quantities, reaction conditions, and assumptions are clearly specified when performing real calculations to ensure accuracy and relevance.

Frequently Asked Questions

What is the chemical reaction involved when 50 grams of a substance reacts to produce carbon dioxide at 25°C and 741

Torr?

The specific reaction depends on the reactant, but a common example is the combustion of a hydrocarbon, such as methane: $CH4 + 2O2 \rightarrow CO2 + 2H2O$.

How do I calculate the volume of CO_2 produced from 50 grams of a reactant at 25°C and 741 Torr?

You can use stoichiometry to determine moles of CO_2 produced from the reactant, then apply the ideal gas law ($PV = nRT$) to find the volume under the given conditions.

What is the ideal gas law constant R used for calculations at 25°C and 741 Torr?

The ideal gas constant R is approximately 0.0821 L·atm/(mol·K). Since 741 Torr is less than 1 atm, convert pressure to atm: 741 Torr ÷ 760 Torr/atm ≈ 0.975 atm.

How do I convert pressure from Torr to atm for the calculation?

Divide the pressure in Torr by 760: 741 Torr ÷ 760 = approximately 0.975 atm.

What is the molar volume of an ideal gas at 25°C and 741 Torr?

Using the ideal gas law, the molar volume at these conditions is approximately $V = (RT)/P = (0.0821 \times 298) / 0.975 \approx 25.1$ liters per mole.

How much CO_2 (in grams) can be produced from 50 grams of the reactant?

This depends on the molar mass of the reactant and the balanced chemical equation. First, calculate moles of reactant, then use stoichiometry to find moles of CO_2, and finally convert moles to grams using the molar mass of CO_2 (44 g/mol).

If the reaction involves 50 grams of a hydrocarbon like methane, what volume of CO_2 can be obtained at 25°C and 741 Torr?

For methane (molar mass 16 g/mol), 50 g corresponds to 3.125 mol. From the reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, 1 mol of CH_4 produces 1 mol of CO_2. Therefore, 3.125 mol of CO_2 can be produced, which occupies about 78.4 liters at the given conditions.

What factors can affect the accuracy of calculating CO_2

volume at these conditions?

Factors include deviations from ideal gas behavior, impurities in reactants, measurement errors, and temperature or pressure fluctuations during the reaction.

Additional Resources

What Volume Of Carbon Dioxide, Measured At 25 °C And 741 Torr, Can Be Obtained By The Reaction Of 50

In the realm of chemistry, understanding the quantifiable aspects of gas production during chemical reactions is fundamental. Whether for industrial applications, laboratory experiments, or academic pursuits, accurately determining the volume of gases like carbon dioxide (CO_2) generated under specific conditions is crucial. Today, we explore a common yet instructive scenario: calculating the volume of CO_2 obtained at a temperature of 25 °C and a pressure of 741 Torr, resulting from the reaction involving 50 units of a particular reactant. This analysis will delve into the theoretical principles, the steps involved, and the practical considerations to ensure precise measurements.

Understanding the Context and the Reaction

Before embarking on calculations, it is essential to clarify the specifics of the reaction in question. While the prompt mentions “the reaction of 50,” it likely refers to a known chemical process where a specific reactant (possibly a solid or a liquid) reacts to produce CO_2. For illustration purposes, let us consider a common reaction:

Calcium Carbonate Decomposition:

$$\mathrm{CaCO_3 (s)} \rightarrow \mathrm{CaO (s)} + \mathrm{CO_2 (g)}$$

This reaction is widely studied and serves as a typical example for CO_2 generation. Alternatively, in the context of organic chemistry, the reaction of an acid with a carbonate or bicarbonate to produce CO_2 is common:

Acid-Carbonate Reaction:

$$\mathrm{NaHCO_3 (s)} + \mathrm{HCl (aq)} \rightarrow \mathrm{NaCl (aq)} + \mathrm{H_2O (l)} + \mathrm{CO_2 (g)}$$

For the sake of a detailed calculation, let us assume that the “50” refers to 50 grams of sodium bicarbonate ($NaHCO_3$), a typical reactant used in laboratory demonstrations of CO_2 production.

Key Assumption:

- Reactant: 50 grams of sodium bicarbonate ($NaHCO_3$)
- Reaction: $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$
- The reaction is complete and yields CO_2 proportional to the amount of $NaHCO_3$ reacted.

Calculating the Moles of Reactant Reacted

The first step involves converting the mass of the reactant into moles, which provides a basis for stoichiometric calculations.

Molecular weight of $NaHCO_3$:

- Na: 22.99 g/mol
- H: 1.008 g/mol
- C: 12.01 g/mol
- O: 16.00 g/mol (three oxygens)

Total:

$$ 22.99 + 1.008 + 12.01 + (3 \times 16.00) = 22.99 + 1.008 + 12.01 + 48.00 = 83.998 \text{ g/mol} $$

Number of moles in 50 grams:

$$ \text{Moles} = \frac{\text{Mass}}{\text{Molecular weight}} = \frac{50\, \text{g}}{83.998\, \text{g/mol}} \approx 0.595\, \text{mol} $$

This indicates that 50 grams of $NaHCO_3$ corresponds to approximately 0.595 moles of reactant.

Stoichiometry and Gas Yield

The reaction between $NaHCO_3$ and HCl produces CO_2 in a 1:1 molar ratio—each mole of sodium bicarbonate reacting with one mole of acid generates one mole of CO_2.

Therefore:

$$ \text{Moles of CO}_2 = \text{Moles of NaHCO}_3 \approx 0.595\, \text{mol} $$

Assuming an excess of HCl, the limiting reactant is $NaHCO_3$, and all of it reacts to produce CO_2.

Applying Gas Laws to Determine Volume at Given Conditions

The core of the calculation involves converting the moles of CO_2 into a volume under specified temperature and pressure conditions. The ideal gas law is the primary tool here:

$$ PV = nRT $$

Where:

- P = pressure in atm
- V = volume in liters
- n = number of moles
- R = ideal gas constant, 0.082057 L·atm/(mol·K)
- T = temperature in Kelvin

Converting the conditions:

- Pressure: 741 Torr

$$1\, \text{atm} = 760\, \text{Torr} \Rightarrow P = \frac{741}{760} \approx 0.975\, \text{atm}$$

- Temperature: 25 °C

$$T = 25 + 273.15 = 298.15\, \text{K}$$

- Number of moles of CO_2: 0.595 mol (from earlier)

Calculating volume:

$$V = \frac{nRT}{P}$$

$$V = \frac{0.595 \times 0.082057 \times 298.15}{0.975}$$

Calculating numerator:

$$0.595 \times 0.082057 \times 298.15 \approx 14.55\, \text{L·atm}$$

Dividing by pressure:

$$V \approx \frac{14.55}{0.975} \approx 14.93\, \text{L}$$

Result:

Under the specified conditions, approximately 14.93 liters of CO_2 can be obtained from 50 grams of sodium bicarbonate reacting completely with excess acid.

Practical Considerations and Error Margins

While the above calculation provides a theoretical maximum volume, real-world factors can influence actual measurements. These include:

- Gas Purity: The calculated volume assumes pure CO_2 without contamination or absorption.
- Reaction Completeness: Any incomplete reaction reduces yield.
- Temperature and Pressure Variations: Fluctuations from the assumed conditions can alter gas volume.
- Measurement Accuracy: Precision in weighing reactants and controlling reaction conditions impacts the final result.
- Gas Collection Method: Techniques such as displacement of water or gas syringes may introduce

measurement errors.

To mitigate these issues:

- Use calibrated measurement instruments.
- Conduct reactions in controlled environments.
- Account for deviations by applying correction factors where necessary.

Broader Applications and Significance

Understanding the volume of CO_2 produced under specific conditions has broad implications:

- Industrial Processes: Carbon capture, fermentation, and carbonation processes depend on precise gas measurements.
- Environmental Monitoring: Quantifying CO_2 emissions from various reactions aids in evaluating their environmental impact.
- Educational Demonstrations: Accurate calculations enhance learning and comprehension in chemistry education.
- Research and Development: Developing new materials or reactions requires precise gas quantification for validation.

Conclusion: From Theory to Practice

Calculating the volume of carbon dioxide generated from a known quantity of reactant at specified temperature and pressure involves a clear understanding of chemical stoichiometry and gas laws. In our example, reacting 50 grams of sodium bicarbonate with excess acid produces approximately 14.93 liters of CO_2 at 25 °C and 741 Torr. This process underscores the importance of precise measurements, careful conversion of units, and the application of ideal gas law principles.

Such calculations are not only academic exercises but also practical tools for scientists and engineers engaged in designing processes, conducting experiments, or monitoring environmental impacts. By mastering these fundamental concepts, practitioners can confidently predict gas outputs, optimize reactions, and interpret results with greater accuracy.

In essence, the ability to determine the volume of gases like CO_2 under various conditions forms a cornerstone in the intersection of chemistry, environmental science, and industrial technology.

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