38 ML Of A Gas Was Collected At 581 Mm Hg And 25 Degrees Celsius. What Would The Volume Be At Standard

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Understanding how gases behave under different conditions is fundamental in chemistry, especially when dealing with gas laws and real-world applications. In this article, we will explore how to determine the volume of a gas under standard conditions, given its initial volume, pressure, and temperature. Specifically, we will analyze a scenario where 38 mL of a gas was collected at 581 mm Hg and 25°C, and we will calculate what its volume would be at standard temperature and pressure (STP).

Introduction to Gas Laws and Conditions

Gases are unique among states of matter because their physical properties are highly sensitive to changes in pressure, temperature, and volume. To predict how a gas's volume changes when these conditions vary, scientists rely on several fundamental gas laws.

Key Gas Laws Involved

The primary gas laws relevant to our calculations include:

- **Boyle's Law:** $P_1V_1 = P_2V_2$ (at constant temperature)
- **Charles's Law:** $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (at constant pressure)
- **Gay-Lussac's Law:** $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ (at constant volume)
- **Combined Gas Law:** $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- **Ideal Gas Law:** $PV = nRT$, where R is the gas constant, n is moles, T is temperature in Kelvin

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Understanding Standard Conditions

Standard Temperature and Pressure (STP) is a reference point used to compare gas volumes under consistent conditions. According to IUPAC:

- **Standard Temperature:** 0°C or 273.15 K
- **Standard Pressure:** 1 atm (760 mm Hg)

At STP, 1 mole of an ideal gas occupies 22.4 liters (or 22,400 mL).

Given Data and Objective

Let's analyze the initial data:

- Initial volume (V_1) = 38 mL
- Initial pressure (P_1) = 581 mm Hg
- Initial temperature (T_1) = 25°C = 298.15 K

Our goal: Determine the volume (V_2) of the gas at standard conditions:

- Standard pressure (P_2) = 760 mm Hg
- Standard temperature (T_2) = 0°C = 273.15 K

Step-by-Step Calculation Using the Combined Gas Law

The combined gas law is ideal for this scenario because it accounts for changes in pressure, volume, and temperature simultaneously:

$$ \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} $$

Rearranged to solve for V_2:

$$ V_2 = V_1 \times \frac{P_1}{P_2} \times \frac{T_2}{T_1} $$

Step 1: Convert all units to consistent measurements

- Pressures are already in mm Hg, which is suitable.
- Temperatures are in Kelvin:

- $T_1 = 25°C + 273.15 = 298.15\, K$
- $T_2 = 0°C + 273.15 = 273.15\, K$

Step 2: Plug the values into the formula

$$ V_2 = 38\, \text{mL} \times \frac{581\, \text{mm Hg}}{760\, \text{mm Hg}} \times \frac{273.15\, K}{298.15\, K} $$

Step 3: Carry out the calculations

- $\frac{581}{760} \approx 0.763$
- $\frac{273.15}{298.15} \approx 0.916$

Now multiply:

$$ V_2 \approx 38 \times 0.763 \times 0.916 $$

Calculations:

- $38 \times 0.763 \approx 28.99$
- $28.99 \times 0.916 \approx 26.58$

Final volume at standard conditions:

$$ V_2 \approx 26.58\, \text{mL} $$

Conclusion: Volume of Gas at Standard Conditions

Given the initial volume of 38 mL of gas collected at 581 mm Hg and 25°C, the volume of this gas at standard temperature and pressure would be approximately 26.58 mL.

Implications and Applications

Understanding how to convert gas volumes under varying conditions is crucial in many scientific and industrial fields. Some key applications include:

- **Laboratory Experiments:** Precise calculations of gas volumes are essential for accuracy in chemical reactions involving gases.
- **Industrial Gas Storage:** Ensuring safe and efficient storage requires knowledge of how gases expand or compress under different conditions.
- **Environmental Monitoring:** Calculating gas emissions and their volumes under different environmental conditions.
- **Medical Applications:** Analyzing the volume of gases in respiratory treatments or diagnostic procedures.

Additional Considerations

While the calculations above assume ideal gas behavior, real gases may deviate slightly from ideality, especially under high pressure or low temperature. For most practical purposes at moderate conditions, the ideal gas law provides a good approximation.

Factors Affecting Gas Behavior:

- Intermolecular Forces: Real gases have attractions/repulsions that influence volume and pressure.
- High Pressure: Gases deviate more from ideality at very high pressures.
- Low Temperature: At low temperatures, gases may condense or liquefy, invalidating ideal assumptions.

When to Use Real Gas Laws:

In cases where deviations are significant, the Van der Waals equation offers a correction to the ideal gas law:

$$ (P + \frac{a}{V^2})(V - b) = RT $$

where $ a $ and $ b $ are constants specific to each gas.

Summary

- The initial volume of 38 mL at 581 mm Hg and 25°C corresponds to approximately 26.58 mL at standard temperature and pressure.
- The calculation hinges on the combined gas law, which accounts for changes in pressure and temperature.
- Understanding gas laws is vital across scientific disciplines and real-world applications.

Final Thoughts

Mastering the calculations involving gas laws enables scientists and engineers to predict and manipulate gases effectively. Whether in laboratories, manufacturing, environmental science, or healthcare, these principles are foundational for accurate measurements and safe practices.

References

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- Zumdahl, S. S., & Zumdahl, S. A. (2013). Chemistry. Cengage Learning.
- IUPAC. (Standard Conditions for Gas Calculations). International Union of Pure and Applied Chemistry.

Note: Always double-check units and conditions when performing gas law calculations to ensure accuracy.

Frequently Asked Questions

What is the initial volume of the gas collected?

38 mL

What is the initial pressure of the gas in mm Hg?

581 mm Hg

What is the initial temperature of the gas in Celsius?

25°C

What is the standard pressure in mm Hg used for calculations?

760 mm Hg

What is the standard temperature in Celsius for gas calculations?

0°C

Which gas law is used to find the volume at standard conditions?

Combined Gas Law

How do you convert Celsius to Kelvin?

Add 273.15 to the Celsius temperature (25°C + 273.15 = 298.15 K)

What is the formula to calculate the volume at standard conditions?

V2 = V1 (P1 / P2) (T2 / T1), where V1, P1, T1 are initial volume, pressure, temperature; V2, P2, T2 are standard conditions.

What is the calculated volume of the gas at standard conditions?

Approximately 42.4 mL

Additional Resources

38 mL of a gas was collected at 581 mm Hg and 25°C. What would the volume be at standard conditions? This question exemplifies a common scenario in chemistry involving gas laws and the calculation of gas volumes under different conditions. Understanding how to approach such problems is crucial for students and professionals working in fields like chemistry, environmental science, and engineering. In this detailed guide, we will walk through the principles behind the problem, the relevant gas laws, step-by-step calculations, and key considerations to help you confidently solve similar questions.

Understanding the Problem

Before diving into calculations, it's essential to fully grasp what is being asked:

- Initial Conditions:
- Volume (V_1): 38 mL
- Pressure (P_1): 581 mm Hg
- Temperature (T_1): 25°C

- Final Conditions:
- Standard conditions typically refer to:
- Pressure (P_2): 1 atm (760 mm Hg)
- Temperature (T_2): 0°C (273.15 K)

- Question:
- What will be the volume (V_2) of the gas at standard conditions?

This involves applying the Combined Gas Law, which relates pressure, volume, and temperature before and after a change.

The Gas Laws: A Quick Recap

1. Boyle's Law
- States that, at constant temperature, pressure and volume are inversely proportional:

$P_1V_1 = P_2V_2$ (when T is constant)

2. Charles's Law
- States that, at constant pressure, volume and temperature are directly proportional:

$V_1 / T_1 = V_2 / T_2$ (when P is constant)

3. Gay-Lussac's Law
- States that, at constant volume, pressure and temperature are directly proportional:

$P_1 / T_1 = P_2 / T_2$ (when V is constant)

4. Combined Gas Law
- Integrates Boyle's, Charles's, and Gay-Lussac's laws:

$(P_1V_1) / T_1 = (P_2V_2) / T_2$

Step-by-Step Solution

Step 1: Convert all units to appropriate standards

- Temperature: Convert Celsius to Kelvin:

$T_1 = 25°C + 273.15 = 298.15$ K

$T_2 = 0°C + 273.15 = 273.15$ K

- Pressure: Convert mm Hg to atm:

$P_1 = 581$ mm Hg × (1 atm / 760 mm Hg) ≈ 0.763 atm

$P_2 = 1$ atm (standard pressure)

Step 2: Write down known values

Parameter	Initial	Final
Pressure (atm)	0.763 atm	1 atm
Volume (mL)	38 mL	V_2 (unknown)
Temperature (K)	298.15 K	273.15 K

Step 3: Apply the Combined Gas Law

$$
\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}
$$

Rearranged to solve for V_2:

$$
V_2 = V_1 \times \frac{P_1}{P_2} \times \frac{T_2}{T_1}
$$

Step 4: Plug in the known values

$$
V_2 = 38\, \text{mL} \times \frac{0.763\, \text{atm}}{1\, \text{atm}} \times \frac{273.15\, \text{K}}{298.15\, \text{K}}
$$

Calculate each component:

- Pressure ratio: 0.763 / 1 = 0.763
- Temperature ratio: 273.15 / 298.15 ≈ 0.916

Now, multiply:

$$
V_2 = 38 \times 0.763 \times 0.916 \approx 38 \times 0.699 \approx 26.56\, \text{mL}
$$

Final Answer:

The volume of the gas at standard conditions would be approximately 26.56 mL.

Key Concepts and Considerations

1. Standard Conditions
- Standard temperature and pressure (STP) are conventionally 0°C (273.15 K) and 1 atm pressure.
- These conditions are used as a reference point to compare gas behaviors.

2. Importance of Units

- Always convert pressure to atmospheres (or the same units).
- Convert temperature to Kelvin for calculations involving gas laws.
- Use consistent units throughout.

3. Real vs. Ideal Gas Behavior
- Gas laws assume ideal behavior, which is a close approximation under many conditions.
- Deviations can occur at high pressures or low temperatures.

Additional Tips for Gas Law Problems

- Always identify initial and final conditions clearly.
- Convert units first to avoid errors.
- Use the combined gas law when multiple variables change.
- Double-check calculations for unit consistency and accuracy.
- Remember the significance of temperature in Kelvin—never use Celsius directly in gas law calculations.

Common Mistakes to Avoid

- Forgetting to convert pressure units.
- Using Celsius instead of Kelvin for temperature.
- Mixing up initial and final conditions.
- Not simplifying fractions properly, leading to calculation errors.
- Assuming ideal gas behavior at conditions where deviations are significant.

Practical Applications

Understanding how to calculate gas volumes under different conditions has numerous practical uses:

- Laboratory analysis: Adjusting gas sample volumes to standard conditions for comparison.
- Industrial processes: Designing systems that account for gas expansion or compression.
- Environmental science: Modeling the behavior of atmospheric gases.
- Medical applications: Calculating the volume of anesthetic gases or respiratory gases.

Conclusion

In this comprehensive guide, we explored how to determine the volume of a gas at standard conditions given an initial volume, pressure, and temperature. By understanding the core principles of gas laws and carefully applying the combined gas law, you can confidently solve similar problems. Remember to always convert units appropriately, double-check your calculations, and keep in mind the assumptions inherent in ideal gas behavior. Mastery of these concepts not only enhances your problem-solving skills but also deepens your understanding of the fundamental behaviors of gases in various scientific and engineering contexts.

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