3) A Gas Has A Volume Of 100.0 ML At 700mmHg And 10 DC. What Is The New Volume At STP?

3) A Gas Has A Volume Of 100.0 ML At 700mmHg And 10°C. What Is The New Volume At STP?

Understanding how gases behave under varying conditions of temperature and pressure is fundamental in chemistry and physics. When dealing with gases, the ideal gas law provides a powerful tool to predict changes in volume, pressure, and temperature. In this article, we will explore how to determine the new volume of a gas when it is transferred from its initial state to standard temperature and pressure (STP). Using the given initial conditions—volume, pressure, and temperature—we will apply the ideal gas law to find the volume at STP, which is a common reference point in scientific calculations.

Understanding the Problem: Initial Conditions and STP

Before diving into calculations, let's clearly define the problem:

- Initial volume (V_1): 100.0 mL
- Initial pressure (P_1): 700 mmHg
- Initial temperature (T_1): 10°C
- Final conditions: Standard Temperature and Pressure (STP)

What Is Standard Temperature and Pressure (STP)?

Standard Temperature and Pressure (STP) is a set of conditions commonly used as a reference point in chemistry for gases. It allows for consistent comparison of gas volumes and quantities across different experiments and calculations.

Key points about STP:

- Standard Temperature (T_0): 0°C or 273.15 K
- Standard Pressure (P_0): 1 atm or 760 mmHg
- Standard Volume: The molar volume of an ideal gas at STP is approximately 22.4 liters (or 22,400 mL) per mole.

Applying the Ideal Gas Law

The ideal gas law relates pressure (P), volume (V), temperature (T), and the amount of gas in moles (n):

$$ PV = nRT $$

where:

- P: pressure
- V: volume
- n: number of moles
- R: ideal gas constant (8.314 J/mol·K or 0.0821 L·atm/mol·K)
- T: temperature in Kelvin (K)

Since the number of moles (n) remains constant when the gas is not added or removed, we can use the combined gas law to relate the initial and final states:

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

This equation allows us to solve for the final volume V_2:

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

Step-by-Step Calculation of the Final Volume at STP

Let's now proceed step by step to compute the new volume of the gas at STP.

Step 1: Convert all temperatures to Kelvin

- Initial temperature T_1: 10°C

$$ T_1 = 10 + 273.15 = 283.15 \, \text{K} $$

- Final temperature T_2: 0°C

$$ T_2 = 0 + 273.15 = 273.15 \, \text{K} $$

Step 2: Convert pressures to the same units

- Initial pressure P_1: 700 mmHg
- Final pressure P_2: 760 mmHg (at STP)

Since the pressures are in mmHg, no conversion is needed for the ratio, but for clarity, ensure consistent units.

Step 3: Apply the combined gas law

Using the formula:

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

Plugging in the known values:

$$ V_2 = 100.0\, \text{mL} \times \frac{700\, \text{mmHg}}{760\, \text{mmHg}} \times \frac{273.15\, \text{K}}{283.15\, \text{K}} $$

Calculating step-by-step:

1. Pressure ratio:

$$ \frac{700}{760} \approx 0.9211 $$

2. Temperature ratio:

$$ \frac{273.15}{283.15} \approx 0.9649 $$

3. Final volume:

$$ V_2 = 100.0\, \text{mL} \times 0.9211 \times 0.9649 $$

$$ V_2 \approx 100.0 \times 0.8887 $$

$$ V_2 \approx 88.87\, \text{mL} $$

Result: The new volume of the gas at STP is approximately 88.87 mL.

Implications and Practical Applications

This calculation exemplifies how gases respond to changes in temperature and pressure—a crucial concept in various scientific and industrial contexts.

Key applications include:

- Chemical reactions: Knowing the volume change of gases allows chemists to predict product quantities and reaction yields.
- Gas storage: Engineers design storage tanks considering how gases expand or compress under different conditions.
- Environmental science: Monitoring atmospheric gases involves understanding how pressure and temperature variations affect gas volumes.
- Medical field: Gas laws underpin technologies like ventilators and anesthesia delivery systems.

Additional Considerations in Gas Law Calculations

While the ideal gas law provides a good approximation, real gases can deviate due to factors like intermolecular forces and molecular sizes. For most practical purposes at moderate pressures and temperatures, the ideal gas law suffices.

Here are some important notes:

- Assumption of ideality: Gases behave ideally when the pressure is not too high and the temperature is not too low.
- Non-ideal behavior: At very high pressures or low temperatures, corrections using Van der Waals equation or other models may be necessary.
- Moles of gas: When the amount of gas changes, the calculations must account for the change in moles, which is not covered in this scenario as the gas remains unchanged.

Summary: Calculating Gas Volume at STP

To summarize, when given initial conditions of a gas and asked to find its volume at STP, the key steps involve:

1. Converting temperature to Kelvin.
2. Ensuring pressure units are consistent.
3. Applying the combined gas law:

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

4. Plugging in the known values and performing the calculation.

In our specific example, starting with 100.0 mL at 700 mmHg and 10°C, the volume at STP (0°C and 760 mmHg) is approximately 88.87 mL.

Conclusion

Understanding how to manipulate gas laws is essential for students, scientists, and engineers working with gases in various fields. Whether predicting gas behavior in a laboratory, designing industrial processes, or analyzing environmental data, mastering calculations like the one demonstrated here is invaluable. Remember, the ideal gas law is a powerful approximation that simplifies complex behaviors into manageable mathematical relationships, enabling accurate predictions and informed decision-making across scientific disciplines.

Keywords for SEO Optimization:

- Gas law calculations
- Ideal gas law
- Volume at STP
- Gas behavior under different conditions
- How to calculate gas volume change
- Standard Temperature and Pressure (STP)
- Gas pressure and temperature conversion
- Physics and chemistry gas laws
- Practical applications of gas laws
- Gas volume prediction at different conditions

Frequently Asked Questions

What is the initial pressure of the gas given in the problem?

The initial pressure of the gas is 700 mmHg.

What are the initial conditions of the gas before the change?

The initial volume is 100.0 mL, the pressure is 700 mmHg, and the temperature is 10°C.

What is the standard temperature (STP) used for this calculation?

Standard Temperature (STP) is 0°C (273.15 K) and 1 atm pressure (760 mmHg).

Which gas law should be applied to find the new volume at STP?

The combined gas law should be used, which relates pressure, volume, and temperature: (P1 V1)/T1 = (P2 V2)/T2.

What is the calculated volume of the gas at STP?

The new volume at STP is approximately 124.3 mL.

Additional Resources

Gas Behavior and Volume Calculations at Standard Temperature and Pressure (STP)

Understanding the behavior of gases under different conditions is fundamental in chemistry, physics, and various industrial applications. This article explores a practical problem: determining the new volume of a gas when its initial volume, pressure, and temperature are known, and it is then subjected to STP conditions. We will delve into the principles behind the calculations, explain the relevant gas laws, and demonstrate a step-by-step solution to this problem.

Introduction to Gas Laws and Their Significance

Gases are unique in their ability to expand and compress, making their behavior predictable and describable using fundamental laws. These laws relate the pressure (P), volume (V), temperature (T), and amount of gas (n) via mathematical equations.

Key Gas Laws:
- Boyle's Law: At constant temperature and amount, the pressure of a gas is inversely proportional to its volume.
- Charles's Law: At constant pressure and amount, the volume of a gas is directly proportional to its temperature.
- Gay-Lussac's Law: At constant volume and amount, the pressure of a gas is directly proportional to its temperature.
- Combined Gas Law: Combines Boyle's, Charles's, and Gay-Lussac's laws, relating P, V, and T when n is constant.
- Ideal Gas Law: PV = nRT, where R is the ideal gas constant, and n is the number of moles.

In our problem, we are primarily concerned with the combined effect of pressure, volume, and temperature changes, making the Combined Gas Law the most relevant.

The Context of the Problem

Let's restate the problem:

"A gas has a volume of 100.0 mL at 700 mmHg and 10°C. What is its new volume at STP?"

Given Data:
- Initial Volume (V_1) = 100.0 mL
- Initial Pressure (P_1) = 700 mmHg
- Initial Temperature (T_1) = 10°C
- Final Conditions: Standard Temperature and Pressure (STP)

STP Conditions:
- Temperature (T_2) = 0°C = 273.15 K
- Pressure (P_2) = 1 atm = 760 mmHg

The goal is to find the final volume (V_2) when the gas is brought to STP.

Understanding the Variables and Conversions

Before performing calculations, it's essential to ensure all units are consistent.

1. Temperature Conversion:

Convert Celsius to Kelvin:

\[T(K) = T(°C) + 273.15 \]

- Initial Temperature:

\[T_1 = 10 + 273.15 = 283.15\, \text{K} \]

- Final Temperature:

$$ T_2 = 0 + 273.15 = 273.15\, \text{K} $$

2. Pressure Conversion:

While the pressure at initial state is given in mmHg, and STP pressure is in atm, it's preferable to convert all pressures to the same units, typically atmospheres, for consistency with the ideal gas law.

$$ 1\, \text{atm} = 760\, \text{mmHg} $$

- Initial Pressure:

$$ P_1 = \frac{700\, \text{mmHg}}{760\, \text{mmHg/atm}} \approx 0.9211\, \text{atm} $$

- Final Pressure:

$$ P_2 = 1\, \text{atm} $$

Applying the Combined Gas Law

The Combined Gas Law relates the initial and final states of a gas:

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

Rearranged to solve for V_2:

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

This equation accounts for changes in pressure and temperature, assuming the amount of gas remains constant.

Step-by-Step Calculation

Step 1: Substitute known values into the equation:

$$
V_2 = 100.0\, \text{mL} \times \frac{0.9211\, \text{atm}}{1\, \text{atm}} \times \frac{273.15\, \text{K}}{283.15\, \text{K}}
$$

Step 2: Simplify the pressure ratio:

\[

$$
\frac{0.9211}{1} = 0.9211
$$

Step 3: Simplify the temperature ratio:

$$
\frac{273.15}{283.15} \approx 0.9649
$$

Step 4: Calculate V_2:

$$
V_2 = 100.0\, \text{mL} \times 0.9211 \times 0.9649
$$

$$
V_2 \approx 100.0 \times 0.889
$$

$$
V_2 \approx 88.9\, \text{mL}
$$

Result:

The new volume of the gas at STP is approximately 88.9 mL.

Interpreting the Results and Practical Implications

The decrease in volume from 100.0 mL to about 88.9 mL indicates the gas compresses when subjected to higher pressure or lower temperature. In real-world applications, such calculations are vital for:

- Chemical manufacturing: where gases are stored under different conditions.
- Industrial gas handling: ensuring safety and efficiency.
- Laboratory experiments: adjusting gas volumes for reactions.
- Environmental sciences: modeling atmospheric gases under varying conditions.

Understanding how gases respond to changes in pressure and temperature allows scientists and engineers to predict behavior accurately, optimize processes, and ensure safety.

Additional Considerations and Tips

- Always convert units consistently before performing calculations.
- Use Kelvin for temperature calculations to avoid negative or nonsensical results.
- When pressures are given in different units, convert them to atmospheres or

another consistent unit.
- Remember that the ideal gas law assumes ideal behavior; real gases may deviate slightly, especially under high pressure or low temperature.

Summary

To determine the new volume of a gas at STP given initial conditions:

1. Convert all measurements to consistent units (Kelvin for temperature, atm for pressure).
2. Apply the Combined Gas Law:

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

3. Substitute the known values and calculate.

In this example, the gas's volume decreases from 100.0 mL to approximately 88.9 mL when brought from 10°C and 700 mmHg to standard temperature and pressure.

In conclusion, mastering the application of gas laws, especially the combined gas law, is essential for accurately predicting and manipulating gas volumes in various scientific and industrial contexts. This problem exemplifies the importance of dimensional analysis, unit conversions, and understanding the fundamental principles governing gaseous substances.

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