A Gas Occupies 300.0 ML At 30.00C And 70.00 KPa. What Will The Volume Be At SC?

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Understanding the behavior of gases under different conditions is fundamental in chemistry and physics. When dealing with gases, temperature, pressure, and volume are interrelated through the ideal gas law. In this article, we will explore how to determine the volume of a gas at standard conditions (SC) given its initial conditions. Specifically, we focus on the problem: A gas occupies 300.0 mL at 30.00°C and 70.00 kPa. What will its volume be at standard conditions?

This comprehensive guide will walk you through the concepts, formulas, and calculations necessary to solve such problems, ensuring you understand the principles behind gas law applications.

Understanding the Problem Statement

The problem provides initial conditions of a gas sample:
- Initial volume (V□): 300.0 mL
- Initial temperature (T□): 30.00°C
- Initial pressure (P□): 70.00 kPa

The goal:
- Find the volume (V□) of the same gas at standard conditions (SC), which are typically:
- Temperature (T□): 0°C (273.15 K)
- Pressure (P□): 101.3 kPa (standard atmospheric pressure)

Fundamentals of Gas Laws

To solve this problem, it's essential to understand the relationship between pressure, volume, and temperature of gases. The ideal gas law provides a mathematical model:

$$PV = nRT$$

Where:

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

Since the amount of gas (n) remains constant, the combined gas law is more applicable:

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

This equation relates the initial and final states of the gas when the amount of gas is unchanged.

Step-by-Step Calculation of Final Volume at Standard

Conditions

Let's go through the process systematically:

1. Convert Temperatures to Kelvin

The ideal gas law and combined gas law require temperatures in Kelvin.

- T_1 = 30.00°C + 273.15 = 303.15 K
- T_2 = 0°C + 273.15 = 273.15 K

2. Write Down Known Values

- P_1 = 70.00 kPa
- V_1 = 300.0 mL
- T_1 = 303.15 K
- P_2 = 101.3 kPa (standard pressure)
- T_2 = 273.15 K

3. Apply the Combined Gas Law

Using:

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

Solve for V_2:

$$V_2 = V_1 \left(P_1 / P_2\right) \left(T_2 / T_1\right)$$

4. Plug in the Values

V_2 = 300.0 mL (70.00 kPa / 101.3 kPa) (273.15 K / 303.15 K)

Calculations:

- Pressure ratio: 70.00 / 101.3 ≈ 0.691
- Temperature ratio: 273.15 / 303.15 ≈ 0.901

Therefore,

V_2 ≈ 300.0 mL 0.691 0.901 ≈ 300.0 mL 0.623 ≈ 186.9 mL

Final Answer and Interpretation

The volume of the gas at standard conditions (0°C and 101.3 kPa) will be approximately 186.9 mL.

This calculation demonstrates how gases behave under changing conditions and how the combined gas law allows us to predict volume changes accurately.

Additional Considerations in Gas Law Calculations

While the ideal gas law provides a good approximation, real gases may deviate under certain conditions. Here are some factors to consider:

1. Deviations from Ideal Gas Behavior

- At high pressures or low temperatures, gases may not follow ideal behavior.
- Van der Waals equation can be used to account for interactions and volume occupied by gas particles.

2. Standard Conditions Variations

- Standard temperature and pressure (STP) are sometimes defined differently (e.g., 0°C and 1 atm).
- Always verify the standard conditions relevant to your context.

3. Converting Units Consistently

- Ensure pressure, volume, and temperature are in compatible units.
- Convert temperature to Kelvin.
- Use consistent pressure units (kPa, atm, etc.).

Practical Applications of Gas Law Calculations

Understanding how to manipulate gas laws is critical in various fields:

- Chemistry: Determining gas volumes in reactions.
- Engineering: Designing pressurized systems.
- Environmental Science: Modeling gas exchange in atmospheres.
- Medicine: Calculating gas flows in respiratory devices.

Summary of Key Steps for Gas Volume Calculations

To summarize, here are the essential steps when solving similar problems:

1. Convert all temperatures to Kelvin.
2. Identify initial and standard conditions for pressure and temperature.
3. Use the combined gas law to relate initial and final states.
4. Plug in the known values and perform calculations.
5. Interpret the result in the context of the problem.

Conclusion

Predicting the volume of a gas at different conditions is a fundamental skill in science and engineering. Using the combined gas law, we determined that a gas occupying 300.0 mL at 30.00°C and 70.00 kPa would occupy approximately 186.9 mL at standard conditions of 0°C and 101.3 kPa. Mastery of these calculations enhances your understanding of gas behavior and supports practical applications across various disciplines.

Frequently Asked Questions (FAQs)

Q1: Why do we convert temperatures to Kelvin in gas law calculations?
A1: Kelvin is the absolute temperature scale; gas laws are based on absolute temperatures because they directly relate to the kinetic energy of gas particles.

Q2: Can I use the ideal gas law for real gases?
A2: Yes, but with caution. The ideal gas law approximates behavior well at high temperatures and low pressures. For more accurate results at high pressures or low temperatures, consider real gas equations like Van der Waals.

Q3: What are standard conditions?
A3: Standard conditions typically refer to 0°C (273.15 K) and 101.3 kPa (1 atm). However, definitions may vary depending on the context.

Q4: How does pressure affect gas volume?
A4: According to Boyle's law, at constant temperature, pressure and volume are inversely proportional: increasing pressure decreases volume, and vice versa.

Q5: Is the amount of gas always constant in these calculations?
A5: Yes. These calculations assume no gas is added or removed; the number of moles remains constant.

By mastering the principles and calculations outlined in this article, you will be well-equipped to analyze and predict gas behaviors under various conditions, an essential skill in scientific and engineering endeavors.

Frequently Asked Questions

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

The initial volume of the gas is 300.0 mL.

What are the initial temperature and pressure conditions of the gas?

The initial temperature is 30.00°C and the initial pressure is 70.00 kPa.

What does 'SC' stand for in the context of gas volume measurements?

'SC' stands for Standard Conditions, typically 0°C (273.15 K) and 100 kPa.

Which gas law is used to relate initial and final conditions to find the volume at standard conditions?

The Combined Gas Law, which relates pressure, volume, and temperature, is used.

How do you convert the initial temperature from Celsius to Kelvin?

Add 273.15 to the Celsius temperature: 30.00°C + 273.15 = 303.15 K.

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

$V_2 = (P_1 V_1 T_2) / (P_2 T_1)$, where P_1, V_1, T_1 are initial conditions and P_2, T_2 are standard conditions.

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

The volume at standard conditions is approximately 1248 mL.

Additional Resources

Understanding Gas Behavior: Calculating Volume at Standard Conditions

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Introduction: The Fundamentals of Gas Laws

Gases are unique among the states of matter because their properties are highly dependent on temperature, pressure, and volume. The behavior of gases can be accurately described and predicted using fundamental gas laws—namely Boyle's Law, Charles's Law, Gay-Lussac's Law, and the combined gas law. These laws are based on the ideal gas model, which idealizes gases as particles that do not interact and occupy no volume themselves.

In the problem at hand, we are given a specific amount of gas occupying a volume of 300.0 mL at a temperature of 30.00°C and a pressure of 70.00 kPa. The goal is to determine what the volume of this same gas would be at standard conditions (SC), which are typically defined as 0°C (273.15 K) and 1 atm (101.325 kPa).

Understanding the Given Data

Before diving into calculations, it is vital to understand and organize the data provided:

- Initial Volume (V_1): 300.0 mL
- Initial Temperature (T_1): 30.00°C
- Initial Pressure (P_1): 70.00 kPa
- Standard Conditions:
- Temperature (T_2): 0°C (273.15 K)
- Pressure (P_2): 1 atm (101.325 kPa)
- Volume (V_2): Unknown — to be calculated

Note: The unit of volume is milliliters, but for gas law calculations, it's often preferable to convert to liters for consistency, as 1 liter = 1000 mL.

Converting Units for Consistency

To ensure calculations are straightforward and adhere to standard conventions, convert all measurements to SI units:

- Volume:
- V_1 = 300.0 mL = 0.300 L
- Temperatures:
- T_1 = 30.00°C = 30.00 + 273.15 = 303.15 K
- T_2 = 0°C = 273.15 K
- Pressures:
- P_1 = 70.00 kPa
- P_2 = 101.325 kPa (since 1 atm = 101.325 kPa)

Applying the Ideal Gas Law and Combined Gas Law

The core principle to solve this problem is the Combined Gas Law, which relates pressure, volume, and temperature for a fixed amount of gas:

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

Since the amount of gas remains constant, this law allows us to find the unknown volume at standard conditions:

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

Note: This formula assumes ideal gas behavior, which is generally acceptable at standard conditions and moderate pressures.

Step-by-Step Calculation

Let's substitute the known values into the formula:

$$
V_2 = 0.300 \text{ L} \times \frac{70.00 \text{ kPa}}{101.325 \text{ kPa}} \times \frac{273.15 \text{ K}}{303.15 \text{ K}}
$$

Calculating each component:

1. Pressure ratio:

$$
\frac{70.00}{101.325} \approx 0.691
$$

2. Temperature ratio:

$$
\frac{273.15}{303.15} \approx 0.902
$$

3. Combine all:

$$
V_2 = 0.300 \times 0.691 \times 0.902 \approx 0.300 \times 0.623 \approx 0.187 \text{ L}
$$

To express this in milliliters:

$$
V_2 = 0.187 \text{ L} \times 1000 = 187.0 \text{ mL}
$$

Final Answer and Interpretation

The volume of the gas at standard conditions (0°C and 1 atm) is approximately 187.0 mL.

This indicates that when the gas is brought from a state of 30°C and 70 kPa to 0°C and 101.3 kPa, it contracts from 300 mL to about 187 mL, consistent with the expectations based on the ideal gas law.

Deeper Analysis and Considerations

While the straightforward calculation above provides a good estimate, there are several key points and nuances to consider when working with real gases and different conditions:

1. Ideal Gas Assumption
- The calculations assume ideal behavior. Real gases deviate from ideality at high pressures and low temperatures.
- For most gases at moderate conditions, the ideal gas law provides a close approximation.

2. Standard Conditions Variability
- The definition of standard conditions can vary:
- Standard Temperature: 0°C (273.15 K)
- Standard Pressure: 1 atm (101.325 kPa)
- Sometimes, standard conditions are taken as 25°C and 1 atm, or other variations, depending on the context.

3. Impact of Gas Type
- The actual volume change depends on the amount of gas, which is related to moles via the ideal gas law:

$$
PV = nRT
$$

- Since the amount (n) remains constant, the calculations hold, but for real gases, factors like the van der Waals equation may be used for more accuracy.

4. Temperature Conversion Accuracy
- Always convert Celsius to Kelvin to avoid errors in calculations involving temperature ratios.

5. Pressure Units
- Be consistent with units.
- When using the ideal gas law, pressure should be in atmospheres or Pascals, but as long as units are consistent, the ratios remain valid.

Additional Methods and Considerations

While the combined gas law is the most straightforward method here, other approaches and considerations include:

- Using the Ideal Gas Law directly:
- Calculate the number of moles at initial conditions:

$$
n = \frac{P_1 V_1}{RT_1}
$$

- Then, find the volume at standard conditions:

$$
V_2 = \frac{nRT_2}{P_2}
$$

- This method confirms the previous calculation and is particularly useful if the amount of gas is unknown or if more complex calculations are needed.

Example:

Calculating moles:

$$
n = \frac{70.00 \text{kPa} \times 0.300 \text{ L}}{8.314 \text{ J/(mol·K)} \times 303.15 \text{ K}}
$$

Note: 1 kPa·L = 1 J, so the units are compatible.

$$
n = \frac{70.00 \times 0.300}{8.314 \times 303.15} \approx \frac{21}{2518} \approx 0.00833 \text{ mol}
$$

Then, at standard conditions:

$$
V_2 = \frac{nRT_2}{P_2} = \frac{0.00833 \times 8.314 \times 273.15}{101.325} \approx \frac{18.89}{101.325} \approx 0.186 \text{ L} = 186 \text{ mL}
$$

This aligns closely with the previous result, reaffirming the calculation accuracy.

Implications and Practical Applications

Understanding how gases behave under different conditions has numerous practical applications:

- Chemical Engineering: Design of reactors and gas storage systems relies on precise volume calculations at varying pressures and temperatures.
- Environmental Science: Modeling atmospheric gases and pollutants requires understanding gas volume changes.
- Medicine: In respiratory therapy, gas law principles govern the delivery and measurement of gases.
- Aerospace: Fuel and oxygen storage calculations depend on accurate gas volume predictions under different conditions.

Limitations and Real-World Deviations

While ideal gas law calculations are invaluable, real-world gases sometimes deviate from ideal behavior due to:

- Intermolecular forces: Attractive or repulsive interactions.
- Finite molecular volume: Gas particles occupy space.
- High-pressure and low-temperature conditions: Gases may liquefy or solidify.

In such cases, corrections like the van der Waals equation or real gas models are employed for more precise calculations.

Conclusion: Bringing It All Together

Through a detailed exploration of the gas law principles, unit conversions, and calculations, we've determined that a gas occupying 300.0 mL at 30.00°C and 70.00 kPa would occupy approximately 187.0 mL at standard conditions of 0°C and 1 atm.

This problem exemplifies the importance of understanding fundamental gas laws, the necessity of unit consistency, and

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