What Is The Volume Occupied By 0.897 Mol Of A Gas At 270c (r = 0.08206 L Atm/mol K) And 1.45 Atm?

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Understanding the behavior of gases under different conditions is fundamental in chemistry, physics, and engineering. One of the key aspects of gas behavior is determining the volume that a given amount of gas will occupy when subjected to specific temperature and pressure conditions. This knowledge is crucial for applications ranging from industrial gas storage to chemical reaction design, environmental science, and laboratory experiments.

In this article, we will explore how to calculate the volume occupied by 0.897 mol of a gas at a temperature of 270°C and a pressure of 1.45 atm. We will use the ideal gas law, a cornerstone equation in thermodynamics, to perform this calculation. Along the way, we will explain the relevant concepts, step-by-step procedures, and provide insights into the importance of each parameter involved.

Understanding the Ideal Gas Law

The ideal gas law is an equation that relates the pressure, volume, temperature, and amount of an ideal gas. It is expressed as:

\[PV = nRT \]

Where:

- P = Pressure of the gas (in atmospheres, atm)

- V = Volume of the gas (in liters, L)

- n = Number of moles of the gas (mol)

- R = Ideal gas constant (0.08206 L·atm/mol·K)

- T = Temperature (in Kelvin, K)

This law assumes that the gas particles do not interact with each other and occupy negligible volume compared to the container volume. While real gases deviate from ideal behavior at high pressures and low temperatures, the ideal gas law provides a good approximation under many conditions.

Converting Temperature to Kelvin

Since the ideal gas law requires temperature in Kelvin, we first convert the given temperature from Celsius to Kelvin.

$$
T(K) = T(°C) + 273.15
$$

Given:

- $T(°C) = 270°C$

Calculation:

$$
T = 270 + 273.15 = 543.15\, K
$$

Thus, the temperature in Kelvin is 543.15 K.

Given Data and Parameters

Let's outline all the known parameters:

- Number of moles of gas, $n = 0.897\, \text{mol}$
- Temperature, $T = 543.15\, K$
- Pressure, $P = 1.45\, \text{atm}$
- Gas constant, $R = 0.08206\, \text{L·atm/mol·K}$

Our goal is to find the volume V.

Calculating the Volume Occupied by the Gas

Using the ideal gas law:

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

Substituting the known values:

\[

$$
V = \frac{0.897 \times 0.08206 \times 543.15}{1.45}
$$

Step-by-step calculation:

1. Multiply the constants:

$$
0.897 \times 0.08206 = 0.073557
$$

2. Multiply by temperature:

$$
0.073557 \times 543.15 \approx 40.02
$$

3. Divide by the pressure:

$$
V = \frac{40.02}{1.45} \approx 27.6\, \text{L}
$$

Therefore, the volume occupied by 0.897 mol of the gas under the specified conditions is approximately 27.6 liters.

Significance of the Result and Practical Applications

Understanding how to calculate gas volume based on moles, temperature, and pressure is vital in numerous scientific and industrial contexts:

- Chemical Reaction Planning: Knowing the volume helps in designing reactors and storage tanks.
- Gas Storage and Transportation: Accurate volume estimations ensure safety and efficiency.
- Environmental Science: Modeling atmospheric gases and pollutant dispersion.
- Laboratory Experiments: Precise control over gases during experiments.

Key takeaways:

- The volume of a gas increases with temperature and the number of moles.
- The volume decreases with increasing pressure.
- The ideal gas law provides a straightforward method for these calculations under ideal conditions.

Factors Affecting Gas Behavior and Deviations from Ideal Law

While the ideal gas law is extremely useful, real gases exhibit deviations due to:

- Intermolecular Forces: Attractive or repulsive interactions between molecules.
- Finite Molecular Volume: Gas molecules occupy space, especially at high pressures.

For most practical purposes at moderate temperatures and pressures, the ideal gas law offers accurate predictions. However, at very high pressures or low temperatures, real gas equations such as the Van der Waals equation provide better approximations.

Summary of Calculation Steps

For clarity, here is a concise summary of the steps involved in calculating the volume:

1. Convert temperature from Celsius to Kelvin.
2. Write down the known parameters: n, P, T, R.
3. Apply the ideal gas law formula:

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

4. Substitute values and perform calculations step-by-step.
5. Interpret the result and consider practical implications.

Conclusion

Calculating the volume occupied by a specific amount of gas under given conditions is a fundamental skill in chemistry and physics. Using the ideal gas law, we determined that 0.897 mol of a gas at 270°C and 1.45 atm pressure occupies approximately 27.6 liters. This calculation underscores the importance of understanding thermodynamic principles and accurate unit conversions.

Whether you are designing chemical processes, studying atmospheric phenomena, or conducting laboratory experiments, mastering these calculations enables precise control and understanding of gas behaviors. Always remember to consider the assumptions of the ideal gas law and evaluate when real gas corrections might be necessary.

Keywords: ideal gas law, gas volume calculation, molar volume, gas behavior, thermodynamics, chemistry, pressure, temperature, molar quantity, gas constant

Frequently Asked Questions

How do you calculate the volume occupied by 0.897 mol of a gas at 27°C and 1.45 atm using the ideal gas law?

Use the ideal gas law PV = nRT, where P = 1.45 atm, n = 0.897 mol, R = 0.08206 L·atm/mol·K, and T = 273 + 27 = 300 K. Rearranged as V = nRT / P to find the volume.

What is the formula to determine the volume of a gas given moles, temperature, pressure, and the gas constant?

The formula is V = (nRT) / P, where V is volume, n is moles, R is the gas constant, T is temperature in Kelvin, and P is pressure in atm.

Why is it important to convert Celsius to Kelvin when calculating gas volume?

Because the ideal gas law requires temperature in Kelvin to ensure proper proportionality and accurate calculations; Celsius must be converted by adding 273.

What is the calculated volume occupied by 0.897 mol of gas at 27°C and 1.45 atm?

Using V = (nRT) / P, V = (0.897 mol × 0.08206 L·atm/mol·K × 300 K) / 1.45 atm □ 15.2 liters.

How does an increase in temperature affect the volume of a gas at constant pressure and moles?

Increasing temperature causes the volume to increase proportionally, according to Charles's law.

What role does the gas constant R play in calculating the volume of a gas?

The gas constant R relates pressure, volume, temperature, and moles in the ideal gas law, ensuring units are consistent for calculation.

Can the ideal gas law be used for real gases at all conditions?

While the ideal gas law provides good approximation at low pressure and high temperature, it may be less accurate for real gases under high pressure or low temperature, where deviations occur.

Additional Resources

What Is The Volume Occupied By 0.897 Mol Of A Gas At 270°C (r = 0.08206 L·atm/mol·K) And 1.45 Atm?

Introduction

Understanding the behavior of gases under various conditions is fundamental to both theoretical chemistry and practical applications across industries such as pharmaceuticals, environmental science, and engineering. A common problem encountered involves determining the volume occupied by a specific amount of gas when subjected to given temperature and pressure conditions. This inquiry becomes especially pertinent when precise volume calculations are necessary for process design, safety assessments, or scientific research.

In this comprehensive review, we focus on a specific scenario: calculating the volume occupied by 0.897 mol of a gas at a temperature of 270°C and a pressure of 1.45 atm, utilizing the ideal gas law with the ideal gas constant r = 0.08206 L·atm/mol·K. Despite seeming straightforward, such calculations demand careful attention to units, conversion factors, and underlying assumptions. We will explore the problem step-by-step, delve into the theoretical framework, discuss potential deviations from ideality, and highlight practical implications.

Fundamentals of Gas Behavior and the Ideal Gas Law

The Ideal Gas Law

The ideal gas law is a fundamental equation expressing the relationship among pressure (P), volume (V), temperature (T), and the number of moles (n) of a gas:

$$PV = nRT$$

Where:
- P = pressure (atm)
- V = volume (L)
- n = number of moles (mol)
- R = universal gas constant (L·atm/mol·K)
- T = temperature (Kelvin, K)

This law assumes ideal behavior—particles are point masses with no intermolecular forces, and collisions are perfectly elastic. While real gases deviate from ideality under certain conditions, the ideal gas law provides a reliable approximation in many circumstances, especially at moderate pressures and high temperatures.

Step-by-Step Calculation Process

1. Converting Temperature from Celsius to Kelvin

Temperature must be expressed in Kelvin for the ideal gas law:

$$ T(K) = T(°C) + 273.15 $$

Given $T = 270°C$:

$$ T = 270 + 273.15 = 543.15\,K $$

2. Applying the Ideal Gas Law

Using the given values:

- $n = 0.897\,mol$
- $R = 0.08206\,L\,atm/(mol\,K)$
- $P = 1.45\,atm$
- $T = 543.15\,K$

The volume V can be calculated as:

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

Substituting the known values:

$$ V = \frac{0.897\,mol \times 0.08206\,L\,atm/(mol\,K) \times 543.15\,K}{1.45\,atm} $$

Calculating numerator:

$$ 0.897 \times 0.08206 \times 543.15 \approx 0.897 \times 44.612 \approx 40.055\,L\,atm $$

Dividing by pressure:

$$ V \approx \frac{40.055}{1.45} \approx 27.65\,L $$

Result: The gas occupies approximately 27.65 liters under the specified conditions.

Deep Dive: Assumptions, Limitations, and Real-World Considerations

1. Validity of the Ideal Gas Approximation

While the ideal gas law offers a convenient model, real gases exhibit deviations due to intermolecular forces and finite molecular sizes. These deviations become significant at high pressures or low temperatures. At 1.45 atm and 543.15 K, the pressure is moderate, and the temperature is relatively high, making the ideal gas approximation reasonably valid.

However, for precise applications, consider:

- Van der Waals Equation adjustments
- Real gas behavior data
- Compressibility factors (Z)

2. Effect of Temperature and Pressure

- Temperature: The high temperature (270°C) increases molecular kinetic energy, reducing intermolecular attractions and favoring ideal behavior.
- Pressure: Moderate pressure (1.45 atm) is unlikely to cause significant deviations but should be monitored in sensitive calculations.

3. Gas Identity and Specific Properties

The calculation assumes a generic gas with molar volume behavior similar to an ideal gas. Different gases may have unique properties affecting volume:

- Polar gases tend to deviate more due to intermolecular forces.
- Lighter gases (e.g., helium) generally adhere more closely to ideal behavior.

Without specific gas identity, the calculation remains an approximation.

Practical Applications and Implications

1. Industrial Gas Storage and Transport

Knowing the volume that a given amount of gas occupies under specific conditions informs storage tank design, safety protocols, and transportation logistics.

2. Chemical Reaction Stoichiometry

Accurate volume calculations allow chemists to determine reactant quantities and optimize reaction conditions, especially in industrial synthesis.

3. Environmental and Atmospheric Science

Estimations of gas volumes at varying temperatures and pressures are crucial for modeling atmospheric phenomena, pollutant dispersion, and climate modeling.

Alternative Approaches and Advanced Considerations

1. Use of Van der Waals Equation

For more precise calculations, especially at higher pressures or lower temperatures, the Van der Waals equation:

$$\left(P + a \frac{n^2}{V^2} \right) (V - nb) = nRT$$

can be employed, where:
- a and b are substance-specific constants accounting for intermolecular forces and finite molecular size, respectively.

2. Corrections for Non-Ideal Behavior

Empirical correction factors or equations of state (e.g., Redlich-Kwong, Peng-Robinson) provide improved accuracy for real gases.

Summary and Conclusions

In the given scenario, the volume occupied by 0.897 mol of a gas at 270°C and 1.45 atm, calculated via the ideal gas law, is approximately 27.65 liters. This calculation hinges on fundamental assumptions of ideality, which are often valid under moderate conditions, but must be scrutinized in precise or extreme cases.

Understanding the interplay between temperature, pressure, and molar quantity through the ideal gas law forms the cornerstone of many scientific and engineering calculations. While approximations suffice in many contexts, awareness of deviations and advanced models ensures more accurate and reliable results.

Final Remarks

The calculation presented exemplifies the utility and limitations of the ideal gas law. As scientific investigations and industrial processes demand ever-increasing precision, chemists and engineers must judiciously choose appropriate models, consider real gas effects, and leverage empirical data when necessary. Mastery of these concepts enables informed decision-making and fosters innovation across disciplines relying on gas behavior understanding.

References

- Atkins, P., & de Paula, J. (2010). Physical Chemistry (9th ed.). Oxford University Press.
- Levine, I. N. (2014). Quantum Chemistry (7th ed.). Pearson.
- Yaw, J. (2011). "Application of the Van der Waals Equation in Real Gas Calculations," Journal of Chemical Education, 88(7), 944–948.
- CRC Handbook of Chemistry and Physics, 97th Edition, CRC Press.

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