How Many Moles Of Gas Dpes Ot Take To Occupy 120 Liters At A Pressure Of 2.3 Atmospheres And 340k

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Understanding the relationship between the amount of gas, its volume, pressure, and temperature is fundamental in chemistry, especially when working with gases. In this comprehensive guide, we will explore how to determine the number of moles of gas required to occupy a specified volume under given conditions of pressure and temperature. Specifically, we will analyze the scenario of occupying 120 liters at a pressure of 2.3 atmospheres and a temperature of 340 Kelvin. By the end of this article, you will have a clear understanding of how to apply the ideal gas law to solve similar problems efficiently.

Introduction to Gas Laws and the Ideal Gas Law

Gases are unique in that their behavior can often be predicted and described mathematically through gas laws. These laws relate the pressure, volume, temperature, and number of moles of gas in a system.

Key Gas Laws

- Boyle’s Law: Pressure and volume are inversely proportional at constant temperature and moles.
- Charles’s Law: Volume and temperature are directly proportional at constant pressure and moles.
- Gay-Lussac’s Law: Pressure and temperature are directly proportional at constant volume and moles.
- Avogadro’s Law: Volume and number of moles are directly proportional at constant temperature and pressure.

The Ideal Gas Law combines these relationships into a single equation:
$$PV = nRT$$
where:
- P = pressure (atm)
- V = volume (liters)
- n = number of moles (mol)
- R = ideal gas constant $(0.0821\, \text{L·atm/(mol·K)})$
- T = temperature (Kelvin)

This law provides a straightforward method to determine the number of moles of gas under specified conditions.

Understanding the Problem

The problem states:

- Volume (V) = 120 liters
- Pressure (P) = 2.3 atmospheres
- Temperature (T) = 340 Kelvin

Our goal: Calculate the number of moles (n) of gas needed to occupy this volume under these conditions.

Before proceeding, it's essential to verify that the ideal gas law applies here. Typically, the law is a good approximation under standard conditions or when gases are not at extremely high pressures or low temperatures.

Applying the Ideal Gas Law to Calculate Moles

Using the ideal gas law:
$$n = \frac{PV}{RT}$$

Step-by-step:

1. Identify known values:
- $P = 2.3\, \text{atm}$
- $V = 120\, \text{L}$
- $T = 340\, \text{K}$
- $R = 0.0821\, \text{L·atm/(mol·K)}$

2. Substitute the known values into the equation:
$$n = \frac{(2.3\, \text{atm}) \times (120\, \text{L})}{0.0821\, \text{L·atm/(mol·K)} \times 340\, \text{K}}$$

3. Calculate numerator:
$$2.3 \times 120 = 276$$

4. Calculate denominator:
$$0.0821 \times 340 \approx 27.914$$

5. Compute n:
$$n = \frac{276}{27.914} \approx 9.88\, \text{mol}$$

Result: Approximately 9.88 moles of gas are needed under the specified conditions to occupy 120 liters.

Additional Considerations and Practical Implications

While the calculation appears straightforward, several factors may influence real-world applications.

Factors Affecting Gas Behavior

- Non-ideal Gas Behavior: At high pressures or low temperatures, deviations from ideality occur. Corrections using Van der Waals equation may be necessary.
- Gas Type: Different gases have different intermolecular forces, affecting their behavior.
- Container Conditions: Real containers may have imperfections or temperature gradients.

Applications of the Calculation

- Chemical Synthesis: Determining reactant quantities.
- Industrial Gas Storage: Estimating storage requirements.
- Laboratory Experiments: Preparing gases at specific conditions.

Summary of Key Steps to Solve Similar Problems

To efficiently determine the number of moles of gas required for a given volume, pressure, and temperature, follow these steps:

1. Write down the known variables: volume, pressure, temperature.
2. Select the appropriate gas law: generally the ideal gas law.
3. Identify the constant \(R \): 0.0821 L·atm/(mol·K).
4. Substitute the known values into the ideal gas law equation.
5. Perform calculations carefully, ensuring units are consistent.
6. Interpret the result in the context of the problem.

Example Applications and Practice Problems

Here are some practice problems to solidify understanding:

- Problem 1: How many moles of oxygen gas are needed to fill a 50-liter tank at 1.5 atm and 298 K?
- Problem 2: If 10 moles of nitrogen gas are at 25°C and occupy 40 liters, what is the pressure?
- Problem 3: How much volume will 5 mol of helium occupy at 2 atm and 300 K?

Attempting these problems using the ideal gas law will reinforce your understanding and ability to apply the concepts accurately.

Conclusion

Calculating the number of moles of gas required to occupy a specific volume under certain pressure and temperature conditions is a fundamental skill in chemistry. By utilizing the ideal gas law, you can solve such problems efficiently and accurately. In the scenario of occupying 120 liters at 2.3 atm and 340 Kelvin, approximately 9.88 moles of gas are needed. Remember to consider the limitations of the ideal gas law and the specific properties of gases in real-world applications. Mastery of these calculations enhances your ability to work in laboratory settings, industrial processes, and academic research involving gases.

Keywords: ideal gas law, moles of gas, gas law calculations, pressure, volume, temperature, chemistry, gas behavior, molar calculations, gas law applications

Frequently Asked Questions

How many moles of gas occupy 120 liters at 2.3 atm and 340 K?

Approximately 4.2 moles of gas occupy 120 liters under those conditions, based on the ideal gas law.

What is the ideal gas law formula used to calculate moles in this scenario?

PV = nRT, where P is pressure, V is volume, n is moles, R is the gas constant, and T is temperature in Kelvin.

What is the value of the gas constant R used in these calculations?

R = 0.0821 L·atm/(mol·K).

How do you rearrange the ideal gas law to solve for the number of moles, n?

n = PV / RT.

What is the calculation for the number of moles at given conditions (P=2.3 atm, V=120 L, T=340 K)?

n = (2.3 atm × 120 L) / (0.0821 L·atm/(mol·K) × 340 K) ≈ 4.2 mol.

Are real gases likely to deviate from ideal behavior at these conditions?

At high pressures and lower temperatures, real gases can deviate from ideal behavior, but at 2.3 atm and 340 K, the ideal gas law provides a good approximation.

How does increasing temperature affect the number of moles calculated for a fixed volume and pressure?

Increasing temperature increases the number of moles, assuming pressure and volume are constant, as per the ideal gas law.

What units are important for the pressure, volume, and temperature in this calculation?

Pressure in atmospheres (atm), volume in liters (L), and temperature in Kelvin (K).

If the pressure was doubled, how would that affect the number of moles needed to occupy the same volume at the same temperature?

Doubling the pressure would double the number of moles required, since n is directly proportional to P in the ideal gas law.

What assumptions are made when using the ideal gas law for this calculation?

Assumes the gas behaves ideally, with negligible interactions between particles and particles occupying no volume.

Additional Resources

Calculating the number of moles of gas required to occupy a specific volume under given pressure and temperature conditions is a fundamental application of the ideal gas law, a cornerstone concept in chemistry and physics. In this comprehensive review, we examine the process of determining how many moles of gas are needed to fill a volume of 120 liters at a pressure of 2.3 atmospheres and a temperature of 340 Kelvin. This analysis not only demonstrates the practical application of theoretical principles but also explores the nuances, assumptions, and potential real-world implications of such calculations.

Introduction to Gas Laws and Their Significance

Understanding how gases behave under various conditions is vital across multiple scientific and industrial domains, including chemical manufacturing, environmental science, and engineering. Gases are highly compressible and expand to fill their containers uniformly, making their behavior predictable through mathematical relationships known as gas laws.

Key Gas Laws:
- Boyle's Law: Describes the inverse relationship between pressure and volume at constant temperature.
- Charles's Law: Addresses the direct relationship between temperature and volume at constant pressure.
- Gay-Lussac's Law: Relates pressure and temperature at constant volume.
- Ideal Gas Law: Combines the above relationships into a single equation, PV = nRT, where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature in Kelvin

The ideal gas law provides the most comprehensive framework for solving problems involving gases under various conditions.

Understanding the Ideal Gas Law

The ideal gas law is expressed as:

PV = nRT

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

This equation assumes gases behave ideally—meaning particles have negligible volume and no intermolecular forces. While real gases deviate from ideal behavior under high pressure or low temperature, at moderate conditions such as those specified in our problem, the ideal gas law provides a reliable approximation.

Applying the Ideal Gas Law to the Problem

Our goal is to determine n, the number of moles of gas, required to occupy 120 liters at 2.3 atm and 340 K.

Rearranged form of the ideal gas law:

n = PV / RT

Substituting known values:

- $P = 2.3$ atm
- $V = 120$ L
- $R = 0.082057$ L·atm/(mol·K)
- $T = 340$ K

Calculating:

$$n = (2.3 \text{ atm}) \times (120 \text{ L}) / (0.082057 \text{ L·atm/(mol·K)} \times 340 \text{ K})$$

$$n = (276 \text{ atm·L}) / (27.89638 \text{ L·atm/mol})$$

$$n \approx 9.89 \text{ mol}$$

Thus, approximately 9.89 moles of gas are needed to occupy 120 liters under the specified conditions.

Deeper Analysis and Implications

While the calculation appears straightforward, several factors influence the accuracy and applicability of this result.

Assumptions Underlying the Calculation

- Ideal Behavior: The calculation assumes the gas behaves ideally. Real gases exhibit deviations, especially at high pressures or low temperatures. However, at moderate pressure (2.3 atm) and high temperature (340 K), these deviations are minimal.
- Uniform Conditions: The gas is assumed to be at uniform pressure and temperature throughout the container.
- No Gas Mixture Effects: The calculation presumes a pure gas. Mixtures may require partial molar calculations.

Potential Deviations in Real-World Scenarios

- Non-Ideal Gas Behavior: Under certain conditions, intermolecular forces cause deviations from ideality. These are often corrected using equations like Van der Waals equation.
- Container Effects: The physical characteristics of the container, such as surface interactions and material, can influence behavior.
- Measurement Uncertainties: Pressure and temperature measurements have inherent uncertainties, affecting the molar calculation.

Extended Considerations and Applications

Understanding the number of moles needed for a particular volume under specified conditions is crucial for various practical applications.

Industrial Gas Storage and Transportation

Knowing the molar quantities allows engineers to design storage tanks and transportation methods that optimize space and safety. For example:

- Gas Liquefaction: To liquefy gases, they must be cooled and compressed, requiring knowledge of molar quantities to determine the amount of cooling and compression needed.
- Pressure Vessel Design: Ensuring that containers withstand the internal pressure generated by a given amount of gas.

Chemical Reaction Stoichiometry

Quantifying gases in molar terms is essential for:

- Calculating reactant and product quantities.
- Designing reactors where gases are involved.
- Ensuring safety protocols when handling hazardous gases.

Environmental Monitoring and Atmospheric Science

Understanding molar quantities helps in:

- Modeling atmospheric gas concentrations.
- Predicting the behavior of pollutants.
- Designing emission control systems.

Further Analytical Perspectives

Beyond straightforward calculations, several advanced considerations can refine understanding.

Using Real Gas Equations

For situations where deviations from ideality are significant, the Van der Waals equation is employed:

$$(P + a(n/V)^2)(V - nb) = nRT$$

Where a and b are gas-specific constants accounting for intermolecular forces and particle volume, respectively.

Calculating with these parameters provides more accurate molar estimates under non-ideal conditions.

Impact of Temperature Variations

Temperature profoundly affects gas behavior:

- Higher Temperatures: Increase molecular motion, potentially increasing the volume for a given pressure.
- Lower Temperatures: Can lead to condensation or liquefaction, invalidating ideal gas assumptions.

In our problem, 340 K is relatively high, minimizing these concerns.

Pressure Limitations and Safety Considerations

Pressures exceeding certain thresholds require special materials and safety protocols. Knowing the precise molar amount helps in:

- Ensuring pressure vessels are within safety limits.
- Avoiding over-pressurization that could lead to rupture.

Conclusion: Synthesis of Findings and Practical Relevance

The calculation demonstrates that approximately 9.89 moles of an ideal gas are necessary to fill 120 liters at 2.3 atm and 340 K. This quantitative insight is fundamental in fields ranging from chemical engineering to environmental science, underpinning processes such as storage, reaction design, and atmospheric modeling.

While the ideal gas law offers a robust foundation for such calculations, real-world applications must consider deviations, measurement uncertainties, and safety factors. The precise determination of molar quantities ensures efficient, safe, and environmentally responsible management of gaseous systems.

In essence, this analysis underscores the power of fundamental physical laws to inform practical decisions and innovations. As technology advances, integrating these principles with sophisticated models will continue to enhance our capacity to manipulate and understand gaseous systems in diverse contexts.

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