Two (2) Moles Of An Ideal Gas Are In A Container At 200 Kpa And A Temperature Of 300 K. The Volume Occupied

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Understanding the behavior of gases under various conditions is fundamental in chemistry and physics. When dealing with an ideal gas—a theoretical gas composed of many randomly moving point particles that interact only through elastic collisions—the relationships between pressure, volume, temperature, and amount of substance are elegantly captured by the ideal gas law. In this article, we explore how to determine the volume occupied by 2 moles of an ideal gas contained at a pressure of 200 kPa and a temperature of 300 K. We will delve into the relevant principles, calculations, and practical implications, providing a comprehensive guide suitable for students, educators, and professionals alike.

Understanding the Ideal Gas Law

The ideal gas law is a fundamental equation in thermodynamics that relates the pressure (P), volume (V), temperature (T), and amount of gas (n, in moles). It is expressed as:

$$ PV = nRT $$

Where:
- P is the pressure of the gas (in Pascals, Pa)
- V is the volume (in cubic meters, m^3)
- n is the number of moles of gas
- R is the universal gas constant
- T is the temperature (in Kelvin, K)

This law assumes that the gas particles do not interact with each other except through elastic collisions and that the volume of individual particles is negligible relative to the container's volume.

Key Constants and Units

Before performing calculations, it's essential to understand the constants and units involved:

Universal Gas Constant (R)

- Value: 8.314 J/(mol·K)
- Units: Joules per mole per Kelvin (J/(mol·K))

Pressure Conversion

- Given pressure: 200 kPa
- Conversion to Pascals: $200\, \text{kPa} = 200,000\, \text{Pa}$

Temperature in Kelvin

- The temperature is given directly: 300 K

Calculating the Volume Occupied by the Gas

Using the ideal gas law, we can calculate the volume occupied by 2 moles of the gas at the specified conditions.

Step-by-Step Calculation

1. Identify known parameters:
- $n = 2\, \text{mol}$
- $P = 200,000\, \text{Pa}$
- $T = 300\, \text{K}$
- $R = 8.314\, \text{J/(mol·K)}$

2. Apply the ideal gas law:

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

3. Insert the known values:

$$V = \frac{2 \times 8.314 \times 300}{200,000}$$

4. Perform the calculation:

$$ V = \frac{2 \times 8.314 \times 300}{200,000} = \frac{4,988.4}{200,000} $$

$$ V \approx 0.024942\, \text{m}^3 $$

5. Convert to more practical units (liters):

$$ 1\, \text{m}^3 = 1000\, \text{liters} $$

$$ V \approx 0.024942 \times 1000 = 24.942\, \text{liters} $$

Result: The gas occupies approximately 24.94 liters under the specified conditions.

Implications and Practical Applications

Knowing the volume of a gas under specific conditions has numerous real-world applications, including:

- Chemical engineering: Designing reactors and containers for gases.
- Environmental science: Estimating pollutant dispersion.
- Industrial processes: Calculating storage requirements.
- Thermodynamics education: Demonstrating gas laws with practical examples.

This calculation demonstrates the direct relationship between pressure, temperature, and volume, emphasizing that increasing temperature at constant moles and pressure leads to an increase in volume, and vice versa.

Factors Affecting Gas Behavior in Real-World Contexts

While the ideal gas law provides a good approximation, real gases deviate from ideal behavior under certain conditions. Understanding these factors is essential for accurate modeling:

1. High Pressure

- Gas particles are forced closer together, increasing intermolecular interactions, which the ideal gas law does not account for.

2. Low Temperature

- Reduced kinetic energy leads to stronger intermolecular attractions, causing deviations.

3. Gas Composition

- Real gases may contain polar molecules or complex structures affecting their behavior.

4. Van der Waals Equation

- To account for deviations, the Van der Waals equation introduces correction factors for particle volume and intermolecular forces:

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

Where:
- a and b are substance-specific constants.

Conclusion: Summary of the Key Findings

In summary, using the ideal gas law, 2 moles of an ideal gas at a pressure of 200 kPa and a temperature of 300 K occupy approximately 24.94 liters. This calculation exemplifies the fundamental relationship between pressure, volume, and temperature in gases, serving as a cornerstone for various scientific and engineering applications. Although ideal gas assumptions simplify calculations, real-world scenarios sometimes require correction factors to account for non-ideal behavior, especially at extreme conditions. Understanding these principles equips professionals and students with the tools necessary to analyze and predict gas behavior accurately across diverse contexts.

Additional Resources for Further Learning

- Textbooks:
- "Thermodynamics: An Engineering Approach" by Yunus Çengel and Michael Boles
- "Physical Chemistry" by Peter Atkins and Julio de Paula

- Online Tools:
- Gas law calculators

- Interactive simulations on gas behavior (e.g., PhET simulations)

- Research Articles:
- Studies on deviations from ideal behavior
- Applications of the Van der Waals equation

By mastering the principles outlined here, readers can confidently perform gas calculations and deepen their understanding of thermodynamic systems, ensuring accurate analysis and efficient design in scientific and industrial pursuits.

Frequently Asked Questions

What is the initial volume occupied by 2 moles of an ideal gas at 300 K and 200 kPa?

To find the initial volume, we use the ideal gas law: $PV = nRT$. Substituting $P = 200{,}000$ Pa, $n = 2$ mol, $R = 8.314$ J/(mol·K), $T = 300$ K, we get $V = (nRT)/P = (2 \times 8.314 \times 300) / 200{,}000 \approx 0.0249$ m³.

How does the volume of the gas change if the temperature increases to 400 K at constant pressure?

Since pressure and amount of gas are constant, the volume is directly proportional to temperature (Charles's Law). Therefore, new volume $V_2 = V_1 \times (T_2 / T_1) = 0.0249 \text{ m}^3 \times (400 / 300) \approx 0.0332 \text{ m}^3$.

What is the significance of using the ideal gas law in this problem?

The ideal gas law allows us to relate pressure, volume, temperature, and amount of gas mathematically, assuming the gas behaves ideally, which simplifies calculations for gases under typical conditions.

If the pressure is doubled while keeping the temperature and moles constant, what will be the new volume?

Using Boyle's Law (PV = constant), doubling the pressure halves the volume. So, new volume $V_2 = V_1 / 2 \approx 0.0249 \text{ m}^3 / 2 \approx 0.01245 \text{ m}^3$.

How can we determine the work done during an isothermal expansion of this ideal gas?

The work done during an isothermal process is $W = nRT \ln(V_2 / V_1)$. To calculate this, you'd need the initial and final volumes. For example, if the volume doubles, work = 2 mol × 8.314 J/(mol·K) × 300 K × ln(2) ≈ 1729 J.

What assumptions are made when applying the ideal gas law to this problem?

The main assumptions are that the gas molecules do not interact with each other and occupy negligible volume compared to the container, which is valid at low pressures and high temperatures.

Additional Resources

Two (2) Moles of an Ideal Gas Are in a Container at 200 kPa and a Temperature of 300 K. The Volume Occupied

Understanding the behavior of gases under various conditions is fundamental in thermodynamics and chemical engineering. When dealing with a specified amount of an ideal gas, such as two moles, in a confined environment, the ability to determine the volume occupied by the gas under given pressure and temperature conditions becomes crucial. This scenario provides an excellent opportunity to explore the ideal gas law, analyze the factors influencing gas volume, and understand the practical applications of these principles in real-world systems.

Introduction to the Ideal Gas Law

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

$$PV = nRT$$

where:

- P = pressure of the gas (in Pa or kPa)
- V = volume of the gas (in m^3 or liters)
- n = number of moles of gas
- R = universal gas constant (8.314 J/mol·K)
- T = absolute temperature (in Kelvin)

This law assumes that gas particles are point masses with no intermolecular forces and that collisions are perfectly elastic. Although real gases deviate from this behavior at high pressures or low temperatures, the ideal gas law provides an excellent approximation under many conditions, including the scenario at hand.

Given Conditions and Objective

In this specific problem, we are provided with:

- Number of moles (n): 2 mol
- Pressure (P): 200 kPa
- Temperature (T): 300 K

The goal is to determine the volume (V) occupied by the gas under these conditions.

Calculating the Volume of the Gas

Step-by-Step Calculation

Applying the ideal gas law:

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

Convert all units to SI for consistency:

- R = 8.314 J/mol·K
- P = 200 kPa = 200,000 Pa
- n = 2 mol
- T = 300 K

Substituting:

$$ V = \frac{2 \times 8.314 \times 300}{200,000} $$

Calculating numerator:

$$ 2 \times 8.314 \times 300 = 2 \times 2494.2 = 4988.4 \text{ J} $$

Now, dividing by pressure:

$$V = \frac{4988.4}{200,000} = 0.024942 \text{ m}^3$$

Expressed in liters:

$$1 \text{ m}^3 = 1000 \text{ liters}$$

$$V \approx 24.94 \text{ liters}$$

Therefore, the gas occupies approximately 24.94 liters under the specified conditions.

Analysis of the Result

This calculation underscores how the ideal gas law provides a straightforward method to determine the volume of a given amount of gas at specified pressure and temperature. The volume of roughly 25 liters indicates that two moles of an ideal gas at 300 K and 200 kPa occupy this amount of space, a useful figure in designing chemical reactors, storage tanks, or understanding natural systems.

Factors Affecting Gas Volume

While the ideal gas law offers a simplified model, real-world gases are influenced by additional factors, which can be summarized as follows:

Pressure

- Increasing pressure compresses the gas, reducing its volume.
- At very high pressures, gas particles are forced closer together, leading to deviations from ideality.

Temperature

- Increasing temperature causes particles to move faster, increasing the volume if pressure is constant.
- Temperature changes can significantly affect gas behavior, especially near phase transition points.

Intermolecular Forces

- Attractive or repulsive forces between particles influence volume, especially at high pressures or low temperatures.
- Ideal gas law assumes no intermolecular forces, which is an approximation.

Number of Moles

- More moles of gas occupy a larger volume at constant pressure and temperature.

Features and Practical Significance

Understanding the volume occupied by gases under specific conditions has several practical implications:

- Design and optimization of industrial processes: Accurate volume calculations ensure proper sizing of containers, reactors, and piping systems.
- Safety considerations: Knowing the volume helps assess the potential for overpressure scenarios.
- Environmental modeling: Gas volumes relate to atmospheric studies, pollution dispersion, and climate modeling.
- Laboratory experiments: Precise calculations enable reproducibility and safety.

Limitations of the Ideal Gas Law

While the ideal gas law is highly useful, it has its limitations:

- High pressure conditions: Deviations become significant as gases deviate from ideality.
- Low temperature conditions: Approaching condensation points, gases behave less ideally.
- Real gases: Exhibit intermolecular forces and finite particle sizes, making real gas equations (like Van der Waals) more accurate in certain scenarios.

Advanced Considerations and Corrections

For more precise calculations under non-ideal conditions, corrections are applied:

- Van der Waals Equation:

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

where:

- a: accounts for attractive forces
- b: accounts for finite particle volume

These corrections become significant at high pressures or low temperatures.

Applications in Real-World Scenarios

The principles demonstrated here are foundational in various fields:

- Chemical engineering: Reactor design, gas storage, and process optimization rely on accurate volume estimations.
- Environmental science: Estimating pollutant dispersion involves understanding gas volumes at different atmospheric conditions.
- Aerospace: Calculating the volume of gases in spacecraft life support systems.
- Medical fields: Understanding gas volumes in respiratory systems or medical equipment.

Conclusion

Determining the volume occupied by two moles of an ideal gas at 200 kPa and 300 K illustrates the practical utility of the ideal gas law. The calculation reveals that under these conditions, the gas occupies approximately 24.94 liters. While the ideal gas law simplifies many aspects of gas behavior, understanding its assumptions and limitations is essential for accurate application in real-world contexts. Whether designing industrial equipment, modeling environmental phenomena, or exploring fundamental physics, the ability to relate pressure, volume, temperature, and amount of gas remains a vital skill in science and engineering.

Summary of Key Points

- The ideal gas law provides a simple yet effective way to calculate gas volume.
- Under specified conditions, 2 mol of an ideal gas occupies about 25 liters.
- Real gases deviate from ideality at high pressures and low temperatures, requiring corrections.
- Practical applications span multiple industries and scientific disciplines.
- Understanding the principles behind gas behavior informs safe, efficient, and innovative system design.

In essence, mastering the relationship between pressure, volume, temperature, and moles allows engineers and scientists to predict and manipulate the behavior of gases effectively, enabling advancements across technology, industry, and environmental management.

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