QUESTION 24 The Density Of N20 At 1.53 Atm And 45.2 C Is = 44.02 G Mol.) G L. (R = 0.08206 L-atm Mol-K

QUESTION 24 The Density Of N2O At 1.53 Atm And 45.2 C Is = 44.02 G Mol.) G L. (R = 0.08206 L-atm Mol-K provides an intriguing scenario for understanding the relationship between the physical properties of gases and the ideal gas law. This problem involves calculating the density of nitrous oxide (N_2O) under specific conditions, which is a fundamental concept in chemistry and physics. To approach this, we need to understand the underlying principles that connect pressure, temperature, molar mass, and volume, especially as they relate to gases.

Understanding Gas Density and Its Significance

What Is Gas Density?

Gas density refers to the mass of a gas per unit volume, typically expressed in grams per liter (g/L). It is an essential parameter because it influences how gases behave under various conditions and impacts applications ranging from industrial processes to environmental science.

Why Is Gas Density Important?

- Chemical Reactions: Knowing the density helps in calculating reactant and product quantities in gaseous reactions.
- Industrial Applications: Design of equipment such as reactors, pipelines, and storage tanks depends on accurate density measurements.
- Environmental Monitoring: Understanding the density of pollutants helps in modeling their dispersion in the atmosphere.
- Thermodynamics: Density links to other thermodynamic properties like pressure, temperature, and molar mass, facilitating the study of gas behavior.

Applying the Ideal Gas Law to Find Density

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

$$PV = nRT$$

Where:
- P = pressure in atm
- V = volume in liters
- n = number of moles
- R = ideal gas constant ($0.08206\ L \cdot atm \cdot mol^{-1} \cdot K^{-1}$)
- T = temperature in Kelvin

To find the density (ρ) of a gas, we need the mass per unit volume:

$$ \rho = \frac{\text{mass}}{\text{volume}} $$

Since the mass of the gas is related to moles and molar mass ($ M $), we have:

$$ \text{mass} = n \times M $$

Combining these, the density becomes:

$$ \rho = \frac{n \times M}{V} $$

From the ideal gas law:

$$ n = \frac{PV}{RT} $$

Substituting into the density equation:

$$ \rho = \frac{PV \times M}{V \times RT} = \frac{PM}{RT} $$

This formula simplifies the calculation of gas density at known pressure, temperature, and molar mass.

Calculating the Density of N_2O

Given:
- $ P = 1.53 $ atm
- $ T = 45.2^\circ C $ (which needs to be converted to Kelvin)
- $ M_{N_2O} = 44.02 $ g/mol
- $ R = 0.08206 $ $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$

First, convert temperature:

$$ T(K) = 45.2 + 273.15 = 318.35\, \text{K} $$

Now, apply the density formula:

$$ \rho = \frac{P \times M}{R \times T} $$

Plugging in the values:

$$ \rho = \frac{1.53 \times 44.02}{0.08206 \times 318.35} $$

Calculating numerator:

$$ 1.53 \times 44.02 \approx 67.26 $$

Calculating denominator:

$$ 0.08206 \times 318.35 \approx 26.11 $$

Finally, the density:

$$ \rho \approx \frac{67.26}{26.11} \approx 2.58\, \text{g/L} $$

However, note that the problem statement mentions a density of 44.02 g/mol, which appears to be a molar mass rather than a density. Based on the calculations, the density of N_2O at the specified conditions is approximately

2.58 g/L.

Understanding the Results and Their Implications

Comparison with Provided Data

The calculated density (around 2.58 g/L) aligns with expectations based on ideal gas behavior. The mention of 44.02 g/mol in the problem is consistent with the molar mass of N_2O, which confirms that the calculation is accurate.

Real-World Applications

- Gas Storage: Knowing the density helps in designing storage tanks and pipelines to safely contain and transport N_2O.
- Environmental Impact: Accurate density measurements assist in modeling the dispersion of nitrous oxide, a potent greenhouse gas.
- Industrial Use: In manufacturing processes, precise gas density calculations ensure optimal operation and safety.

Additional Factors Affecting Gas Density

While the ideal gas law provides a good approximation, real gases may deviate due to interactions between molecules, especially at high pressures or low temperatures. Factors include:

- **Van der Waals Forces**: Attractive or repulsive forces between molecules can alter gas behavior.
- **Temperature and Pressure Deviations**: Extreme conditions may require corrections to the ideal model.
- **Impurities and Mixtures**: Presence of other gases can influence the overall density.

In such cases, more advanced models like the Van der Waals equation can be used to refine the calculations.

Conclusion: Mastering Gas Density Calculations

Understanding how to calculate the density of gases like N_2O under varying conditions is vital for chemists, engineers, and environmental scientists. By leveraging the ideal gas law and knowing the molar mass, one can accurately determine the density, which in turn informs practical applications ranging from industrial design to environmental monitoring. The calculations demonstrate the interplay between pressure, temperature, and molar mass, emphasizing the importance of precise measurement and understanding of thermodynamic principles in real-world scenarios.

Key Takeaways:
- Gas density can be calculated using \(\rho = \frac{PM}{RT} \).
- Accurate temperature conversion to Kelvin is essential.
- Real-world factors may require adjustments beyond the ideal gas law.
- Knowledge of gas properties underpins various scientific and industrial fields.

By mastering these concepts, professionals can effectively analyze and manipulate gaseous substances, ensuring safety, efficiency, and environmental responsibility.

Frequently Asked Questions

How do you calculate the density of N_2O using the ideal gas law?

Density can be calculated using the formula: density = (P × M) / (R × T), where P is pressure, M is molar mass, R is the gas constant, and T is temperature in Kelvin.

Given the pressure, temperature, and molar mass of N_2O, how is the density determined at 1.53 atm and 45.2°C?

Convert temperature to Kelvin (45.2°C + 273.15 = 318.35 K), then apply the formula: density = (1.53 atm × 44.02 g/mol) / (0.08206 L·atm/mol·K × 318.35 K), resulting in approximately 44.02 g/L.

Why is the ideal gas law applicable for calculating the density of N_2O in this scenario?

Because the conditions are close to ideal, with low pressure and moderate temperature, making the gases behave ideally and the law applicable for precise calculations.

What is the significance of the gas constant R in the density calculation?

The gas constant R relates pressure, volume, temperature, and amount of gas; in density calculations, it helps convert molar quantities into mass per unit volume.

How does temperature affect the density of N_2O at constant pressure?

As temperature increases at constant pressure, the density decreases because the gas expands, increasing volume and reducing mass per unit volume.

Additional Resources

QUESTION 24 The Density Of N_2O At 1.53 Atm And 45.2°C Is = 44.02 G Mol.) G L. (R = 0.08206 L-atm Mol-K

In the realm of physical chemistry, understanding the behavior of gases under varying conditions is fundamental. One such intriguing scenario involves determining the density of nitrous oxide (N_2O) when subjected to specific pressure and temperature conditions. The question at hand states: "The density of N_2O at 1.53 atm and 45.2°C is 44.02 g/mol·L." While this may seem straightforward, it opens up a pathway to explore the principles of gas laws, the ideal gas law, and how thermodynamic parameters influence gas density. This article delves into the methodology of calculating gas density, interpreting the given data, and understanding the broader implications for scientific and industrial applications.

Understanding Gas Density and Its Significance

What Is Gas Density?

Gas density refers to the mass of a gas per unit volume, typically expressed in grams per liter (g/L). It is a crucial parameter in fields such as chemical engineering, environmental science, and physics because it influences how gases behave in different environments. For example, density affects buoyancy, diffusion rates, and reaction kinetics.

Why Is Gas Density Important?

- Design of Chemical Processes: Accurate density measurements are essential when designing reactors, pipelines, and storage systems.
- Environmental Monitoring: Understanding pollutant dispersal relies on knowledge of gas densities.
- Aerospace and Atmospheric Science: Gas density impacts aircraft lift, weather modeling, and climate studies.
- Industrial Applications: Gas density determines flow rates and efficiency in manufacturing and energy sectors.

Analyzing the Given Data

The problem specifies:
- Pressure (P) = 1.53 atm
- Temperature (T) = 45.2°C
- Density (D) = 44.02 g/mol·L
- Gas constant (R) = 0.08206 L·atm/(mol·K)

At first glance, the notation "44.02 g mol." appears to suggest a molar mass, but context indicates it's the density in grams per liter (g/L). Clarifying this is vital for correct calculations.

Assumption: The given density is approximately 44.02 g/L, a typical value for N_2O under the specified conditions.

Note: The units of the given data seem to have a typographical inconsistency. Usually, molar mass is expressed in g/mol, and density in g/L. Here, the figure 44.02 likely corresponds to density (g/L), not molar mass.

Applying the Ideal Gas Law to Find Gas Density

The ideal gas law provides a fundamental equation:

$$ PV = nRT $$

Where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature (in Kelvin)

To relate this to density, recall:

$$ \text{Density} (\rho) = \frac{\text{Mass}}{\text{Volume}} $$

Since:

$$ \text{Mass} = n \times M $$

where M is the molar mass of N_2O (~44.013 g/mol), then:

$$ \rho = \frac{n \times M}{V} $$

From the ideal gas law:

$$ n = \frac{PV}{RT} $$

Substituting:

$$ \rho = \frac{PV \times M}{V \times RT} = \frac{P \times M}{RT} $$

This formula allows us to compute the gas density directly from pressure, molar mass, temperature, and the gas constant.

Step-by-step Calculation:

1. Convert temperature to Kelvin:

$$ T = 45.2^\circ C + 273.15 = 318.35\, K $$

2. Use the known constants:

- $P = 1.53\, atm$
- $M = 44.013\, g/mol$
- $R = 0.08206\, L\, atm/(mol\, K)$

3. Plug into the formula:

$$ \rho = \frac{P \times M}{R \times T} $$

$$ \rho = \frac{1.53 \times 44.013}{0.08206 \times 318.35} $$

Calculate numerator:

$$ 1.53 \times 44.013 \approx 67.278 $$

Calculate denominator:

$$ 0.08206 \times 318.35 \approx 26.112 $$

Finally:

$$ \rho = \frac{67.278}{26.112} \approx 2.577\, g/L $$

Result: Under ideal conditions, the expected density of N_2O at 1.53 atm and 45.2°C is approximately 2.58 g/L.

Reconciling with the Given Data

The initial statement indicates a density of 44.02 g/mol·L, which is inconsistent with typical gas densities and units. This discrepancy suggests a typographical error or misinterpretation.

- If the value is 44.02 g/L, it aligns closely with the molar mass of N_2O, implying perhaps the data intended to communicate molar mass rather than density.
- Alternatively, if the original data was a misprint, the correct density at the specified conditions is approximately 2.58 g/L, based on calculations.

Implication: For accurate scientific analysis, clarity of units and data is vital. Assuming the goal was to find the density, the calculated value reflects the expected physical property of N_2O under the specified conditions.

Broader Implications and Applications

Understanding the density of gases like N_2O at given pressures and temperatures has numerous practical applications:

Industrial Gas Handling and Storage

- Ensuring safe and efficient storage of N_2O cylinders requires knowledge of its density.
- Dosing and delivery systems in medical or industrial settings depend on precise gas quantities, which rely on accurate density data.

Environmental and Atmospheric Studies

- N_2O is a potent greenhouse gas. Quantifying its concentration in the atmosphere involves understanding its behavior under varying environmental conditions.
- Density calculations help model dispersion, diffusion, and environmental impact assessments.

Process Engineering and Combustion

- N_2O is utilized as an oxidizer in rocket propulsion and welding. Its density influences flow rates and combustion efficiency.
- Accurate density data inform the design of equipment and safety protocols.

Conclusion: The Significance of Accurate Gas Property Calculations

The exercise of calculating the density of N_2O at specific pressure and temperature conditions exemplifies the importance of fundamental principles like the ideal gas law in practical chemistry. While the initial data presented some ambiguities, applying established formulas clarifies the expected physical properties of gases under given conditions.

In professional practice, meticulous attention to units, accurate data interpretation, and understanding the underlying physics enable chemists, engineers, and environmental scientists to make informed decisions. Whether designing industrial processes, monitoring environmental gases, or conducting research, the ability to compute and interpret gas densities remains a cornerstone of scientific competency.

Ultimately, such calculations underscore the interconnectedness of thermodynamics, material properties, and real-world applications, highlighting the elegance and utility of physical chemistry in solving complex problems.

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