A Certain Mass Of Nitrogen Gas Occupies A Volume Of 8.52 L At A Pressure Of 5.06 Atm. At What Pressure

Understanding the Problem: A Certain Mass of Nitrogen Gas Occupies a Volume of 8.52 L at a Pressure of 5.06 atm. At What Pressure?

The scenario presents a common problem in chemistry involving gases: determining the pressure of a gas under specified conditions. Specifically, we are told that a certain mass of nitrogen gas (N_2) occupies a volume of 8.52 liters at an initial pressure of 5.06 atmospheres. The question posed is: what will be the pressure of this nitrogen gas under different conditions or after a change in parameters? To solve such a problem, one must understand the fundamental gas laws and how they relate pressure, volume, temperature, and amount of gas.

Fundamental Concepts in Gas Laws

Ideal Gas Law

The ideal gas law is the cornerstone for solving problems involving gases. It states:

- **PV = nRT**

where:

- **P** = pressure of the gas
- **V** = volume of the gas
- **n** = number of moles of gas
- **R** = ideal gas constant (0.0821 L·atm/(mol·K))
- **T** = temperature in Kelvin

Key Assumptions and Limitations

The ideal gas law assumes:

1. No intermolecular forces exist between gas particles.
2. Gas particles occupy negligible volume compared to the container.
3. Elastic collisions occur between particles.

While these assumptions are idealized, the law provides accurate predictions under many conditions, especially at high temperatures and low pressures.

Step-by-Step Solution Approach

1. Identifying Known and Unknown Variables

From the problem statement, the knowns are:

- Initial volume, $\mathbf{V_1}$ = 8.52 L
- Initial pressure, $\mathbf{P_1}$ = 5.06 atm
- Mass of nitrogen gas (which allows calculation of moles), **m**

The unknown is:

- Final pressure, $\mathbf{P_2}$

2. Calculating the Number of Moles of Nitrogen Gas

To proceed, we need the number of moles of nitrogen present. Since the mass of nitrogen is given or can be assumed, the calculation proceeds as:

1. Use molar mass of nitrogen gas, N_2:

- **Molar mass of N_2** = 28.0134 g/mol

1. Calculate moles:

$n = m / M$

where m is the mass of nitrogen in grams and M is molar mass.

Note: If the mass is not specified, the problem can be approached in terms of molar quantities or assuming the initial conditions correspond to a known number of moles.

3. Applying Gas Laws to Find the Unknown Pressure

Scenario 1: Changing Conditions (Isothermal Process)

If the temperature remains constant during the process, Boyle's Law applies:

- $\mathbf{P_1V_1 = P_2V_2}$

Rearranged to find P_2:

- $\mathbf{P_2 = P_1V_1 / V_2}$

However, if the volume remains fixed and only pressure changes, then additional information or conditions are necessary to determine the new pressure.

Scenario 2: Considering Changes in Temperature or Moles

If temperature or the number of moles changes, the ideal gas law must be used:

- $P_1V_1 / T_1n_1 = P_2V_2 / T_2n_2$

Assuming temperature remains constant and the amount of gas remains unchanged, then the relation simplifies to Boyle's Law.

Calculating the Final Pressure: A Practical Example

Suppose the volume changes to a new value, or the temperature changes, or both.

Let's consider an example where the initial state is given, and the volume is changed to a new volume, V_2. The goal is to find P_2.

1. Using Boyle's Law (Constant Temperature and Moles)

- $P_1V_1 = P_2V_2$

Rearranged:

- $P_2 = P_1V_1 / V_2$

2. Sample Calculation

Assuming the volume doubles (V_2 = 17.04 L):

- P_2 = (5.06 atm) (8.52 L) / (17.04 L)

$P_2 \approx$ 2.53 atm

Important Considerations and Additional Factors

Effect of Temperature

If the temperature changes during the process, the calculation must account for this variation. Using the combined gas law:

- $P_1V_1 / T_1 = P_2V_2 / T_2$

Effect of Moles (Changing Number of Gas Particles)

If the amount of nitrogen gas changes due to addition or removal, then:

- Use the ideal gas law to find moles before and after the change.
- Adjust the calculation accordingly to find the new pressure.

Real-World Applications and Significance

Understanding how to manipulate and calculate the pressure of gases under various conditions is fundamental in fields such as chemical engineering, environmental science, and physiology. For instance, managing nitrogen in industrial processes, calculating pressures in scuba diving tanks, or understanding atmospheric behavior all rely on these gas laws.

Practical Applications

- Designing pressurized containers and tanks.
- Predicting gas behavior in natural and engineered systems.
- Optimizing chemical reactions involving gases.
- Understanding respiratory mechanics and pressures in biological systems.

Summary and Final Remarks

The problem of determining the pressure of a gas under specified conditions is a classic example of applying the ideal gas law and related principles like Boyle's law. The key steps involve identifying known variables, calculating the amount of gas in moles if necessary, and applying the appropriate gas law equations based on the process's conditions (constant temperature, volume, or moles). For the scenario provided, if the volume or temperature changes, the pressure can be calculated accordingly. The fundamental understanding of these relationships enables scientists and engineers to predict and control gas behavior in countless practical situations.

In conclusion, knowing how to manipulate and apply the ideal gas law is essential for solving real-world problems involving gases, including nitrogen, which is abundant and widely used in various industries. Mastery of these principles allows for accurate predictions and safe, efficient design of systems involving gases.

Frequently Asked Questions

How do you calculate the pressure of nitrogen gas when given its volume, amount, and temperature?

You can use the ideal gas law $PV = nRT$, rearranged to solve for pressure: $P = (nRT)/V$, where n is moles, R is the gas constant, T is temperature in Kelvin, and V is volume.

What is the significance of knowing the volume and initial pressure of nitrogen gas in calculating its current pressure?

Knowing the initial volume and pressure allows you to apply the ideal gas law to determine the amount (moles) of gas or to find the new pressure under different conditions, assuming temperature remains constant.

If the volume of nitrogen gas is 8.52 L at a pressure of 5.06 atm, how can I find the pressure if the volume changes to 10 L at the same temperature and amount?

Using Boyle's Law ($P_1V_1 = P_2V_2$), you can solve for the new pressure: $P_2 = (P_1 \times V_1) / V_2$. Substituting the values gives $P_2 = (5.06 \text{ atm} \times 8.52 \text{ L}) / 10 \text{ L}$.

What assumptions are made when applying the ideal gas law to determine the pressure of nitrogen gas?

The ideal gas law assumes that the gas particles do not interact and occupy negligible volume compared to the container, which is a good approximation at high temperatures and low pressures.

How does temperature influence the pressure calculation of nitrogen gas in this scenario?

Temperature directly affects pressure in the ideal gas law. An increase in temperature, assuming constant volume and amount of gas, results in a proportional increase in pressure.

Additional Resources

A Certain Mass Of Nitrogen Gas Occupies A Volume Of 8.52 L At A Pressure Of 5.06 Atm. At What Pressure is a classic problem encountered in the realm of gas laws, particularly ideal gas law calculations. Such questions are fundamental in understanding how gases behave under different conditions, which has applications ranging from industrial processes to scientific research. This type of problem is a textbook example used to demonstrate the application of the ideal gas law $PV = nRT$, where pressure (P), volume (V), amount of gas in moles (n), the universal gas constant (R), and temperature (T) are interconnected. The challenge often involves solving for an unknown pressure, given certain parameters, which requires a clear understanding of the relationships and the ability to manipulate the equation accurately.

Understanding the Problem

The problem states that a certain mass of nitrogen gas occupies a volume of 8.52 liters at a pressure of 5.06 atmospheres. The question is to find the pressure under different or new conditions, or to determine the pressure when some parameters change. Often, such problems involve assuming constant temperature (isothermal conditions) or constant amount of gas, which simplifies the calculations. To proceed effectively, it’s essential to analyze what is given and what is asked.

Key Data:
- Volume (V): 8.52 L
- Pressure (P_1): 5.06 atm
- Gas: Nitrogen (N_2)
- The problem: Find the new pressure (P_2) under different conditions or confirm the existing pressure based on the given data.

Assumptions:
- The gas behaves ideally.
- Temperature remains constant unless specified otherwise.
- The amount of nitrogen (mass or moles) is known or can be calculated.

Fundamental Concepts and Equations

The Ideal Gas Law

The ideal gas law is the foundation for solving problems like this:

$$PV = nRT$$

where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant ($0.0821 \, \text{L·atm/(mol·K)}$)
- T = temperature in Kelvin

Since the problem involves determining pressure, knowing or calculating the number of moles of nitrogen gas becomes crucial.

Calculating the Moles of Nitrogen Gas

If the mass of nitrogen is known, the moles can be calculated using:

$$ n = \frac{m}{M} $$

where:
- m = mass of nitrogen in grams
- M = molar mass of nitrogen (~28.0134 g/mol for N_2)

In many problems, the mass is given or can be inferred, but if not, the focus shifts to the proportional relationship between pressure, volume, and temperature.

Applying the Ideal Gas Law

Given the initial conditions, the number of moles can be expressed as:

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

Since R is constant and assuming the temperature remains the same (isothermal condition), the combined gas law simplifies to:

$$ \frac{P_1 V_1}{T} = \frac{P_2 V_2}{T} $$

or, with constant temperature:

$$ P_1 V_1 = P_2 V_2 $$

This relation is known as Boyle's Law, which states that pressure and volume are inversely proportional at constant temperature.

Calculating the Unknown Pressure

Suppose the question involves finding the pressure P_2 when the volume changes to a different value V_2 or under different conditions. The steps are:

1. Identify the known values.
2. Determine whether temperature and amount of gas are constant.
3. Use Boyle's Law or the ideal gas law as needed.

Example:
If the volume remains the same, but the temperature changes, then the pressure can be found using the combined gas law:

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

Or, if only pressure and volume are relevant, Boyle's Law suffices.

How to solve for pressure directly when the amount of gas and temperature are constant:

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

If the volume increases, pressure decreases proportionally, and vice versa.

Real-World Applications of Gas Law Calculations

Understanding how to manipulate and interpret these equations is vital in various fields such as:

- Chemical manufacturing (e.g., controlling gas pressures in reactors)
- Environmental science (e.g., modeling atmospheric gases)
- Medical applications (e.g., respiration and anesthetic gases)
- Engineering (e.g., designing pressurized containers)

The ability to determine the pressure of a gas under different conditions ensures safety, efficiency, and accuracy in these fields.

Pros and Cons of Using the Ideal Gas Law

Pros:
- Simplifies complex gas behaviors into a manageable mathematical model.
- Widely applicable for gases at low pressure and high temperature.
- Facilitates quick calculations and estimations.
- Useful for educational purposes to understand fundamental principles.

Cons:
- Assumes gases are ideal, neglecting interactions between particles and volume occupied by molecules.
- Less accurate at high pressures and low temperatures where deviations occur.
- Does not account for real gas behaviors such as liquefaction or condensation.

Special Considerations in Nitrogen Gas Calculations

Nitrogen (N_2) is a diatomic gas with relatively inert properties, making ideal gas assumptions often valid under standard conditions. However, at high pressures or low temperatures, nitrogen can deviate from ideality, and real gas corrections (such as Van der Waals equation) may be necessary for precise calculations.

Additional Factors:
- Temperature: Ensures the calculations are valid under the assumption of a constant temperature unless specified.
- Mass of nitrogen: If known, allows direct calculation of moles.
- Pressure units: Consistency in units (atm, Pa, Torr) is essential for accurate calculations.

Conclusion

The problem of determining the pressure of a certain mass of nitrogen gas occupying a specified volume exemplifies fundamental principles of chemistry and physics. By leveraging the ideal gas law and understanding the relationships between pressure, volume, temperature, and moles, one can accurately solve for unknown parameters. This skill is indispensable in scientific research, industrial applications, and everyday problem-solving involving gases. Always remember to check the assumptions, units, and conditions of your problem to select the appropriate law and approach. Mastery of these concepts not only enhances problem-solving skills but also deepens your understanding of the behavior of gases in the natural world.

If you have a specific change in conditions or additional parameters for this problem, please provide them, and I can assist further with detailed calculations.

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