If 22.5 L Of Nitrogen At 748 Mm Hg And 273 K Are Compressed To 725 Mm Hg And 50.0 Degree C At Constant

If 22.5 L Of Nitrogen At 748 Mm Hg And 273 K Are Compressed To 725 Mm Hg And 50.0 Degree C At Constant pressure, it involves understanding the fundamental principles of gas laws, particularly Boyle's Law and Charles's Law, and how they apply to the behavior of gases during compression and temperature changes. This scenario provides an excellent opportunity to explore the relationships between pressure, volume, temperature, and amount of gas, as well as to perform calculations based on the combined gas law. Whether you're a student studying chemistry or a professional working in gas-related industries, understanding these principles is key to predicting and controlling gas behavior in various applications.

Understanding the Fundamentals of Gas Laws

Before delving into the specific problem, it's essential to grasp the core concepts of the gas laws that govern the behavior of gases under different conditions.

Boyle's Law

- States that the pressure of a fixed amount of gas is inversely proportional to its volume at constant temperature.
- Mathematically: $P_1 V_1 = P_2 V_2$ (at constant temperature and amount of gas).

Charles's Law

- Describes the direct relationship between temperature and volume at constant pressure.
- Expressed as: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (at constant pressure).

Gay-Lussac's Law

- Indicates that pressure is directly proportional to temperature when volume is held constant.
- Expressed as: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$.

The Combined Gas Law

- Integrates Boyle's, Charles's, and Gay-Lussac's laws to relate pressure, volume, and temperature simultaneously.
- Mathematically: $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$.

Analyzing the Given Scenario

The problem provides the initial conditions of nitrogen gas and asks to understand how the gas's volume and temperature change when compressed under differing pressure conditions.

Initial Conditions

- Volume (V_1): 22.5 liters
- Pressure (P_1): 748 mm Hg
- Temperature (T_1): 273 K

Final Conditions

- Pressure (P_2): 725 mm Hg
- Temperature (T_2): 50.0°C (which is 323 K when converted to Kelvin)
- Volume (V_2): To be determined

Understanding these parameters allows us to determine the final volume or any other variable of interest by applying the combined gas law.

Step-by-Step Solution Using the Combined Gas Law

The core of solving this problem involves applying the combined gas law:

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

Rearranged to solve for the unknown final volume:

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

\]

Let's proceed with detailed steps:

Step 1: Convert all temperatures to Kelvin

- $T_1 = 273\, \text{K}$
- $T_2 = 50.0^\circ C + 273 = 323\, \text{K}$

Step 2: Substitute known values into the equation

$$
V_2 = 22.5\, \text{L} \times \frac{748\, \text{mm Hg}}{725\, \text{mm Hg}} \times \frac{323\, \text{K}}{273\, \text{K}}
$$

Step 3: Calculate the ratios

- Pressure ratio: $\frac{748}{725} \approx 1.031$
- Temperature ratio: $\frac{323}{273} \approx 1.183$

Step 4: Final calculation

$$
V_2 \approx 22.5\, \text{L} \times 1.031 \times 1.183
$$
$$
V_2 \approx 22.5\, \text{L} \times 1.219 \approx 27.44\, \text{L}
$$

Result: The final volume of nitrogen after compression and heating is approximately 27.44 liters.

Implications and Practical Applications

Understanding how gases behave during compression and temperature changes is vital in many real-world applications.

Industrial Gas Storage and Transportation

- Accurate calculations ensure safe and efficient storage of gases.
- Compressed gases like nitrogen are used in food preservation, electronics

manufacturing, and medical applications.

Refrigeration and Air Conditioning

- Knowledge of gas laws helps design systems that efficiently manage pressure and temperature changes.

Chemical Reaction Engineering

- Precise control over gas conditions improves reaction outcomes and yields.

Environmental Monitoring

- Predicting gas behavior aids in modeling atmospheric phenomena and pollution dispersion.

Additional Considerations in Gas Law Calculations

While the calculations above provide a straightforward application of the combined gas law, several factors can influence the outcome:

Real Gas Behavior

- Under high pressures or low temperatures, gases deviate from ideal behavior.
- Van der Waals Equation accounts for molecular size and intermolecular forces for more accurate predictions.

Measurement Accuracy

- Precise measurement of pressure, temperature, and volume is crucial.
- Calibration of instruments ensures reliable data.

Effect of Gas Purity

- Impurities can alter the gas's behavior, especially in sensitive applications.

Conclusion

In summary, the process of compressing nitrogen from 22.5 liters at 748 mm Hg and 273 K to a new state at 725 mm Hg and 50.0°C involves understanding and applying the combined gas law. By converting temperatures to Kelvin, calculating the relevant ratios, and substituting into the formula, we find that the final volume of nitrogen is approximately 27.44 liters. This example illustrates the practical application of fundamental gas laws in scientific and industrial contexts, emphasizing the importance of precise calculations and understanding the underlying principles governing gas behavior. Whether for designing industrial processes, ensuring safety standards, or conducting scientific research, mastering these concepts is essential for predicting and controlling the behavior of gases under varying conditions.

Frequently Asked Questions

What is the initial pressure of nitrogen in atmospheres?

The initial pressure is 748 mm Hg. Converting to atmospheres: 748 mm Hg ÷ 760 mm Hg/atm ≈ 0.983 atm.

What is the initial volume of nitrogen in liters?

The initial volume of nitrogen is 22.5 liters.

What is the initial temperature in Kelvin?

The initial temperature is 273 K.

What is the final pressure of nitrogen in mm Hg?

The final pressure is 725 mm Hg.

What is the final temperature in Celsius?

The final temperature is 50.0°C.

How do you convert the final temperature to Kelvin?

Add 273 to the Celsius temperature: 50.0°C + 273 = 323 K.

Which gas law relates pressure, volume, and

temperature in this problem?

The combined gas law relates pressure, volume, and temperature when amount of gas is constant.

What is the purpose of using the combined gas law in this problem?

To find the unknown volume or other variables after the change in pressure and temperature at constant amount of gas.

How do you set up the combined gas law for this problem?

Use $P_1V_1/T_1 = P_2V_2/T_2$, with all values in consistent units.

What is the final volume of nitrogen after compression at the new conditions?

Applying the combined gas law: $V_2 = (P_1V_1T_2) / (P_2T_1)$. Plugging in the values gives $V_2 \approx 22.5$ L (748 mm Hg / 725 mm Hg) (323 K / 273 K) ≈ 28.1 liters.

Additional Resources

If 22.5 L Of Nitrogen At 748 mm Hg And 273 K Are Compressed To 725 mm Hg And 50.0°C At Constant Pressure, it presents a compelling example of fundamental gas laws in action. Understanding the behavior of gases under varying conditions is essential not only for academic pursuits but also for practical applications across industries such as manufacturing, environmental science, and engineering. This scenario invites an exploration of the principles governing gas behavior, primarily focusing on the combined gas law, which relates pressure, volume, and temperature when the amount of gas remains constant.

Understanding the Scenario: Basic Parameters and Assumptions

At the outset, let's analyze the given data:

- Initial Volume (V_1): 22.5 liters
- Initial Pressure (P_1): 748 mm Hg
- Initial Temperature (T_1): 273 K (which corresponds to 0°C)
- Final Pressure (P_2): 725 mm Hg

- Final Temperature (T_2): 50.0°C, which converts to 323 K (since T(K) = T(°C) + 273)

The problem mentions a process involving compression of nitrogen gas, with the key point that the process occurs at constant pressure. However, the given data suggests a change in pressure, which indicates a potential inconsistency or perhaps a need to clarify whether the pressure is held constant or not. Since the title states "at constant" but provides different pressures, the most logical interpretation is that the process involves constant pressure—possibly a typo or an oversight in the initial data.

In typical gas law problems, when analyzing the effect of compression or expansion, the focus is on how volume and temperature change at constant pressure, or vice versa. But here, the initial and final pressures differ, which suggests the process does not occur at constant pressure but rather involves a change in both pressure and volume, possibly at constant temperature or other conditions.

Given the data, the most consistent approach is to analyze the process considering the combined gas law, which relates pressure, volume, and temperature during a process where the amount of gas is constant.

The Combined Gas Law: The Theoretical Framework

The combined gas law provides a relationship between initial and final states of a gas when the amount of gas remains unchanged:

$$
\frac{P_{1} V_{1}}{T_{1}} = \frac{P_{2} V_{2}}{T_{2}}
$$

Where:

- P_{1}, V_{1}, T_{1}: initial pressure, volume, and temperature
- P_{2}, V_{2}, T_{2}: final pressure, volume, and temperature

This law combines Boyle’s law ($PV = \text{constant}$), Charles’s law ($V/T = \text{constant}$), and Gay-Lussac’s law ($P/T = \text{constant}$) into a single expression, allowing for the calculation of unknowns when multiple variables change.

Applying the Combined Gas Law to the Scenario

Given the initial conditions and the change in pressure and temperature, the goal is to determine the final volume (V_2). This involves rearranging the combined gas law:

$$
V_{2} = V_{1} \times \frac{P_{1}}{P_{2}} \times \frac{T_{2}}{T_{1}}
$$

Note: Since the question states "compressed," it suggests a change in volume, which we aim to calculate.

Let's substitute the known values:

- $V_{1} = 22.5\, \text{L}$
- $P_{1} = 748\, \text{mm Hg}$
- $P_{2} = 725\, \text{mm Hg}$
- $T_{1} = 273\, \text{K}$
- $T_{2} = 50.0^\circ C = 323\, \text{K}$

Calculating V_{2}:

$$
V_{2} = 22.5\, \text{L} \times \frac{748}{725} \times \frac{323}{273}
$$

Breaking down the calculation:

1. Pressure ratio:

$$
\frac{748}{725} \approx 1.0310
$$

2. Temperature ratio:

$$
\frac{323}{273} \approx 1.184
$$

3. Final volume:

$$
V_{2} = 22.5 \times 1.0310 \times 1.184 \approx 22.5 \times 1.220 \approx 27.45\, \text{L}
$$

Result: The final volume of nitrogen after the process is approximately 27.45 liters.

Interpreting the Results: Physical Implications

Contrary to initial expectations, the volume increases during the process, despite the term "compression" being used. This suggests that the process involves a complex interplay of parameters, perhaps involving a change in temperature that outweighs pressure reduction, leading to an overall expansion in volume.

Key observations:

- Temperature Effect: Raising the temperature from 0°C to 50°C causes the gas to expand if pressure remains constant, as per Charles's law.
- Pressure Change: Slight decrease in pressure from 748 mm Hg to 725 mm Hg tends to increase volume (Boyle's law).
- Net Effect: The combined effect results in a net increase in volume, aligning with the calculations.

This emphasizes the importance of considering all variables simultaneously when dealing with gas behavior.

Real-World Applications and Significance

Understanding how gases respond to simultaneous changes in pressure, volume, and temperature has numerous practical implications:

- Industrial Gas Handling: Storage and transport of gases require precise calculations to ensure safety and efficiency.
- Chemical Manufacturing: Reactions often involve gases at varying conditions; predicting volume changes is vital for process optimization.
- Environmental Science: Modeling atmospheric phenomena depends on understanding gas behavior under different conditions.
- Engineering Design: Equipment such as compressors, turbines, and reactors are designed based on principles elucidated by the gas laws.

For example, in designing a nitrogen storage tank, engineers need to predict how volume might change with temperature fluctuations or pressure adjustments to prevent accidents or inefficiencies.

Limitations and Considerations

While the combined gas law is robust, several factors can influence its applicability:

- Ideal Gas Assumption: The law presumes gases behave ideally, which is an approximation. Real gases exhibit deviations at high pressures or low temperatures.
- Constant Amount of Gas: The calculation assumes no gas escapes or is added during the process.
- Uniform Conditions: It presumes the entire sample experiences the same pressure, temperature, and volume conditions.

In practical applications, corrections might be necessary to account for non-ideal behavior, especially under extreme conditions.

Conclusion: Integrating Gas Laws in Practical Scenarios

The analysis of nitrogen's compression from 22.5 liters at 748 mm Hg and 273 K to a new state at 725 mm Hg and 50.0°C underscores the elegance and utility of the combined gas law. It illustrates how multiple variables—pressure, volume, and temperature—interact in real-world processes. Whether in laboratories, manufacturing plants, or environmental systems, mastering these principles enables scientists and engineers to predict behavior accurately, optimize processes, and ensure safety.

In this particular case, the final volume of approximately 27.45 liters reflects the complex interplay of thermal expansion and pressure reduction, demonstrating that even with the word "compression," the net effect can sometimes be expansion depending on the circumstances. This nuanced understanding forms the backbone of applied gas physics, bridging theoretical principles with tangible applications across diverse fields.

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