When The Volume Of A Gas Ischanged From 3.6 L To 15.5 L, Thetemperature Will Change FromC To 87C.Assume

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Understanding how gases behave under different conditions is fundamental in chemistry and physics. The relationship between a gas's volume, temperature, and pressure is described by the ideal gas law, which provides essential insights into various scientific and industrial processes. When the volume of a gas changes significantly, it often results in a corresponding change in temperature, especially when pressure is held constant. This article explores the underlying principles, calculations, and real-world applications related to such volume and temperature changes in gases.

Introduction to Gas Laws and Their Importance

Gases are unique states of matter characterized by their ability to expand to fill any container, compress easily, and have particles that move randomly at high speeds. Understanding how gases respond to changes in volume, temperature, and pressure is crucial across numerous fields, including chemistry, engineering, meteorology, and medicine.

The fundamental laws governing these behaviors include:

- Boyle’s Law: Describes the inverse relationship between pressure and volume at constant temperature.
- Charles’s Law: Explains the direct relationship between volume and temperature at constant pressure.
- Gay-Lussac’s Law: Details how pressure varies with temperature when volume is constant.
- The Combined Gas Law: Integrates Boyle’s, Charles’s, and Gay-Lussac’s laws, relating pressure, volume, and temperature when the amount of gas remains constant.
- Ideal Gas Law: \(PV = nRT \), combining the above principles into a single equation accounting for moles and universal constants.

In this context, since the problem involves a change in volume and temperature with an unspecified pressure, it’s most appropriate to analyze the scenario using Charles’s Law or the combined gas law, assuming other variables are held constant.

Understanding the Relationship Between Volume and Temperature

Charles's Law Explained

Charles's Law states that, at constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (measured in Kelvin). Mathematically, it's expressed as:

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

Where:
- V_1 and V_2 are the initial and final volumes, respectively.
- T_1 and T_2 are the initial and final temperatures in Kelvin.

This relationship indicates that increasing the temperature causes the gas to expand, while decreasing the temperature causes it to compress, provided the pressure remains unchanged.

Applying the Law to the Given Scenario

Given:
- Initial volume, $V_1 = 3.6\, \text{L}$
- Final volume, $V_2 = 15.5\, \text{L}$
- Initial temperature, $T_1 = ?$ (in Celsius)
- Final temperature, $T_2 = 87^\circ C$

The goal is to find the initial temperature T_1. Since the temperatures are in Celsius, they need to be converted to Kelvin:

$$
T(K) = T(^\circ C) + 273.15
$$

Calculating the Initial Temperature

Step 1: Convert Final Temperature to Kelvin

$$
T_2 = 87^\circ C + 273.15 = 360.15\, \text{K}
$$

Step 2: Set Up the Charles’s Law Equation

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

Rearranged to solve for T_1:

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

Step 3: Plug in known values

$$
T_1 = \frac{3.6\, \text{L} \times 360.15\, \text{K}}{15.5\, \text{L}}
$$

Calculating numerator and denominator:

$$
T_1 = \frac{1296.534}{15.5} \approx 83.66\, \text{K}
$$

Step 4: Convert T_1 back to Celsius

$$
T(^\circ C) = T(K) - 273.15 \approx 83.66 - 273.15 = -189.49^\circ C
$$

Result:
The initial temperature of the gas was approximately -189.5°C.

Interpretation and Significance of the Results

The calculation reveals that the gas initially existed at a very low temperature—around -189.5°C—before expanding from 3.6 L to 15.5 L and reaching 87°C. This drastic change in volume and temperature illustrates key principles of gas behavior:

- High sensitivity to temperature changes: Small increases in temperature can lead to significant volume expansion.
- Importance of temperature control: In industrial applications like gas storage, chemical reactions, or refrigeration, maintaining precise temperature conditions is vital.
- Practical applications in science: Understanding these relationships aids in designing engines, air conditioning systems, and even predicting weather patterns.

Real-World Applications of Gas Law Principles

1. Industrial Gas Storage and Transportation

Gases are often stored in compressed forms or in large tanks where temperature fluctuations can cause volume changes. Knowledge of gas laws ensures safety and efficiency.

2. Chemical Reaction Engineering

Reactions involving gases depend heavily on temperature and volume. Accurate calculations ensure optimal yield and safety.

3. Meteorology and Climate Science

Understanding how atmospheric gases expand and contract with temperature variations helps in weather prediction models.

4. Medical Applications

Gas laws are crucial in designing ventilators and anesthetic delivery systems that rely on precise gas volumes and temperatures.

Factors Affecting Gas Behavior Beyond Volume and Temperature

While the primary focus here is on volume and temperature, other factors can influence gas behavior:

- Pressure: Changes in pressure significantly affect volume and temperature, especially in closed systems.
- Amount of Gas (moles): The number of particles impacts the gas's behavior, as described by the ideal gas law.
- Real Gas Deviations: Under high pressure or low temperature, gases deviate from ideal behavior, requiring correction factors.

Conclusion

The relationship between volume and temperature in gases is a fundamental principle demonstrated by Charles’s Law. When a gas expands from 3.6 L to 15.5 L, and its temperature increases to 87°C, the initial temperature can be calculated as approximately -189.5°C, highlighting the significant temperature change required for such volume expansion at constant pressure.

Understanding these principles is crucial across scientific disciplines and industries. Accurate application of gas laws enables engineers, chemists, meteorologists, and medical professionals to design safe, efficient, and effective systems that depend on the predictable behavior of gases under varying conditions.

By mastering the concepts and calculations related to gas volume and temperature changes, professionals can better predict and control the behavior of gases in real-world scenarios, ensuring safety, efficiency, and innovation in their respective fields.

Frequently Asked Questions

What is the initial volume of the gas before the change?

The initial volume of the gas is 3.6 liters.

To what volume does the gas expand after the change?

The gas volume increases to 15.5 liters.

What is the initial temperature of the gas before the volume change?

The initial temperature is 0°C.

What is the final temperature of the gas after the volume change?

The final temperature is 87°C.

Which gas law can be used to relate the volume and temperature changes in this problem?

Charles's Law can be used, which states that volume is directly proportional to temperature at constant pressure.

Assuming pressure remains constant, how can you calculate the initial temperature in Kelvin?

Convert 0°C to Kelvin by adding 273.15, so the initial temperature is 273.15 K.

Additional Resources

When The Volume Of A Gas Is Changed From 3.6 L To 15.5 L, The Temperature Will Change From 0°C To 87°C: An Investigative Analysis

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Introduction

The behavior of gases under varying conditions of temperature, pressure, and volume has long been a cornerstone of chemical and physical sciences. Central to understanding this behavior are the ideal gas laws, which offer a simplified model to predict how gases respond to changes in these parameters. This article delves into a specific scenario: when the volume of a gas increases from 3.6 liters to 15.5 liters, the temperature shifts from 0°C to 87°C. By examining this transition, we explore the fundamental principles governing gases, their real-world implications, and the theoretical calculations that underpin such phenomena.

The Fundamental Principles: Ideal Gas Law and Its Relevance

The ideal gas law, expressed as PV = nRT, relates pressure (P), volume (V), temperature (T), and the amount of gas in moles (n), with R being the universal gas constant. This law assumes gases behave ideally—meaning particles have negligible volume and do not interact. Although real gases exhibit deviations, especially at high pressures or low temperatures, the ideal law provides a robust approximation for many practical scenarios.

In the context of volume and temperature changes, the law can be rearranged to examine their relationship:

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

assuming constant pressure and amount of gas.

Setting the Stage: The Scenario and Known Data

Let us consider a closed system containing a fixed amount of gas. Initially, the gas occupies a volume of 3.6 liters at 0°C (273.15 K). The volume is then increased to 15.5 liters, and the temperature is observed to reach 87°C (360.15 K). Our goal is to understand:

- How these quantities relate under the ideal gas assumptions.
- Whether the observed temperature change aligns with theoretical expectations.
- The implications of these changes in practical and experimental settings.

Initial Conditions:

- Initial volume, V_1 = 3.6 L
- Initial temperature, T_1 = 0°C = 273.15 K
- Final volume, V_2 = 15.5 L
- Final temperature, T_2 = 87°C = 360.15 K

Theoretical Analysis

Applying the Ideal Gas Law

Since the amount of gas (n) and pressure (P) are assumed constant, the relationship simplifies to:

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

Rearranged to find the expected final temperature:

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

Plugging in the known values:

$$T_2 = 273.15\, \text{K} \times \frac{15.5\, \text{L}}{3.6\, \text{L}} \approx 273.15 \times 4.3056 \approx 1176.4\, \text{K}$$

which corresponds to approximately 903.3°C.

This suggests that, under ideal conditions, expanding the gas from 3.6 L to 15.5 L at constant pressure and amount would result in a temperature increase to approximately 1176°C, vastly higher than the observed 87°C.

Implications of the Discrepancy

The actual temperature change from 0°C to 87°C during this volume expansion indicates that the process is not purely adiabatic or isothermal, and other factors influence the system, such as:

- Pressure variations during expansion
- Heat exchange with the surroundings
- Non-ideal gas behavior

To reconcile the observed temperature change, we must consider these factors and explore alternative scenarios, including isobaric (constant pressure) and adiabatic processes.

Deep Dive: Process Types and Their Impact

Isobaric Expansion (Constant Pressure)

In an isobaric process, the pressure remains constant while volume and temperature change. The ideal gas law simplifies to:

\[\frac{V}{T} = \text{constant} \]

Thus:

\[T_2 = T_1 \times \frac{V_2}{V_1} \]

which, as calculated earlier, yields a final temperature of approximately 1176°C if the process was purely isobaric and ideal, inconsistent with the observed 87°C.

Real-World Explanation:

In practical settings, the expansion may be controlled or occur alongside heat exchange, limiting the temperature increase. The final observed temperature of 87°C suggests that the process includes heat loss to surroundings or occurs at a constant temperature environment, such as in an isothermal process.

Isothermal Expansion (Constant Temperature)

If the process were perfectly isothermal, the temperature would remain at 0°C during expansion, which contradicts the observed change to 87°C.

Conclusion:

The actual process likely involves a combination of factors—partial heat exchange, pressure variation, and non-idealities—that cause the temperature to increase from 0°C to 87°C as the volume expands.

Practical Considerations and Real-World Applications

Gas Behavior in Engineering Systems

Understanding how gases respond to volume changes is critical in designing engines, chemical reactors, and HVAC systems. For example:

- Internal combustion engines rely on controlled compression and expansion, where temperature and volume changes are carefully managed.
- Chemical reactors depend on predictable gas behavior for safety and efficiency.
- Aerospace engineering considers gas expansion in high-altitude conditions.

Temperature Control and Safety

The increase from 0°C to 87°C during expansion highlights the importance of temperature regulation. Rapid or uncontrolled expansion can lead to:

- Overpressure scenarios
- Structural damage
- Safety hazards

Designing systems that account for these parameters prevents accidents.

Experimental Validation and Measurement Techniques

To verify the relationships and calculations, experimental setups involve:

- Gas cylinders with controlled expansion mechanisms
- Temperature sensors (thermocouples, infrared sensors)
- Pressure gauges
- Data acquisition systems for real-time monitoring

Precise measurements enable scientists to test theoretical models against real-world behavior, refining our understanding of thermodynamic processes.

Limitations of the Ideal Gas Model

While the ideal gas law offers valuable insights, real gases deviate, especially at high pressures or low temperatures. Deviations are accounted for by equations of state like Van der Waals:

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

where a and b are substance-specific constants.

In the context of this scenario:

- For gases like nitrogen or oxygen, deviations are minimal under moderate conditions.
- For gases with strong intermolecular forces or at extreme conditions, corrections are necessary.

Summary and Conclusions

The scenario of changing the volume of a gas from 3.6 L to 15.5 L, with a corresponding temperature rise from 0°C to 87°C, encapsulates core principles of thermodynamics and gas behavior.

Key takeaways include:

- Under ideal conditions and constant pressure, expanding a gas significantly increases its temperature, potentially to thousands of degrees Celsius.
- The observed temperature increase from 0°C to 87°C during such an expansion suggests the presence of heat exchange with surroundings, non-ideal behavior, or controlled process parameters.
- Real-world applications demand careful management of these variables to ensure safety and efficiency.

By integrating theoretical calculations with experimental insights, scientists and engineers can better predict and control gas behavior in complex systems, ensuring optimal performance and safety.

Final Remarks

Understanding the interplay between volume and temperature in gases is fundamental across scientific disciplines and industries. This investigation not only reinforces core thermodynamic principles but also underscores the importance of considering real-world complexities when applying theoretical models. Whether in laboratory research, industrial applications, or environmental systems, mastering these relationships is crucial for advancing technology and ensuring safety.

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