A Sample Of Gas At 4.0 Atm And 25.0 Ml Is Heated From 25 C To 40 C. If The Pressure Remains Constant,

A Sample Of Gas At 4.0 Atm And 25.0 Ml Is Heated From 25 C To 40 C. If The Pressure Remains Constant, understanding how gases behave under changing conditions is fundamental in chemistry and physics. The principles governing gas behavior are primarily described by the ideal gas law, which relates pressure, volume, temperature, and the amount of gas. When a gas sample is heated at constant pressure, its volume changes in response to temperature variations, following a predictable pattern. This article explores the thermodynamic principles involved in heating a gas sample, the calculations needed to determine the changes in volume, and the practical applications of these concepts in various scientific and industrial contexts.

Understanding the Ideal Gas Law

Fundamental Equation

The ideal gas law is expressed as:

$$PV = nRT$$

Where:

- P = pressure (atm, Pa, etc.)
- V = volume (L, mL, etc.)
- n = number of moles of gas
- R = ideal gas constant (8.314 J/mol·K or 0.0821 L·atm/mol·K)
- T = temperature in Kelvin (K)

This law states that for a fixed amount of gas at constant pressure, the volume is directly proportional to the temperature in Kelvin. When the pressure remains constant, any change in temperature results in a proportional change in volume.

Scenario Overview: Heating a Gas Sample at Constant Pressure

Given data:

- Initial pressure, $P_1 = 4.0 \, \text{atm}$
- Initial volume, $V_1 = 25.0 \, \text{mL}$
- Initial temperature, $T_1 = 25^\circ \text{C}$
- Final temperature, $T_2 = 40^\circ \text{C}$
- Pressure remains constant throughout the process.

The goal is to determine the final volume V_2 after heating the gas from 25°C to 40°C at constant pressure, and to understand the implications of this change.

Converting Temperatures to Kelvin

Since the ideal gas law requires temperature in Kelvin:

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

Calculations:

- Initial temperature:

$$T_1 = 25 + 273.15 = 298.15 \, \text{K}$$

- Final temperature:

$$T_2 = 40 + 273.15 = 313.15 \, \text{K}$$

Calculating the Change in Volume

Using Charles's Law

Charles's Law states that, at constant pressure and amount of gas:

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

Rearranged to find V_2:

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

Plugging in the known values:

$$ V_2 = 25.0 \, \text{mL} \times \frac{313.15 \, \text{K}}{298.15 \, \text{K}} $$

$$ V_2 \approx 25.0 \times 1.050 $$

$$ V_2 \approx 26.25 \, \text{mL} $$

Therefore, the volume of the gas increases from 25.0 mL to approximately 26.25 mL when heated from 25°C to 40°C at constant pressure.

Implications of the Volume Change

The increase in volume, although seemingly small, reflects the fundamental behavior of gases: they expand when heated at constant pressure due to increased kinetic energy of the molecules. This expansion is predictable and follows the proportional relationship described by Charles's Law, a component of the ideal gas law.

Key points:

- The volume increases proportionally with temperature in Kelvin.
- The change in volume is approximately 1.25 mL, which, for many practical purposes, can be significant in precise measurements or industrial processes.
- Understanding this behavior is critical in applications such as gas storage, chemical reactions involving gases, and the design of engines and refrigeration systems.

Additional Calculations and Considerations

Calculating the Number of Moles of Gas

If needed, the number of moles n can be calculated using the ideal gas law:

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

Using the initial conditions and R = 0.0821 L·atm/mol·K:

- Convert volume to liters:

$$ V_1 = 25.0 \, \text{mL} = 0.025 \, \text{L} $$

- Apply the formula:

\[n = \frac{4.0 \, \text{atm} \times 0.025 \, \text{L}}{0.0821 \, \text{L·atm/mol·K} \times 298.15 \,

\text{K}} \]

\[n \approx \frac{0.1}{24.45} \]

\[n \approx 0.00409 \, \text{mol} \]

The amount of gas remains constant during heating, so this value can be used to confirm the calculations or for further analysis.

Practical Applications of Gas Behavior Under Constant Pressure

Understanding how gases expand upon heating is essential in numerous scientific and industrial sectors:

- Chemical Manufacturing: Precise control of gas volumes during reactions ensures safety and efficiency.
- Aerospace Engineering: Designing pressurized cabins and fuel systems relies on understanding gas expansion.
- Environmental Science: Modeling atmospheric gas behavior under temperature variations.
- Medical Devices: Gas flow regulation in respiratory devices depends on predictable gas volume changes.

Limitations of the Ideal Gas Law

While the ideal gas law provides a good approximation for many conditions, real gases exhibit deviations under high pressure or low temperature:

- Van der Waals Equation: Adjusts for interactions between molecules and finite molecular sizes.
- Non-ideal behavior: At extremes, gases may liquefy or condense, invalidating ideal assumptions.

In the context of this scenario, the gas behaves approximately ideally, given the moderate temperature and pressure.

Conclusion

Heating a gas sample at constant pressure results in a proportional increase in volume, directly related to the temperature change in Kelvin, as described by Charles's Law. In our specific case, increasing the temperature from 25°C to 40°C causes the volume to grow from 25.0 mL to approximately 26.25 mL. This understanding is crucial for scientists and engineers involved in processes where precise gas measurements are critical. Mastery of the ideal gas law and related principles enables accurate predictions of gas behavior under various thermodynamic conditions, facilitating safer and more efficient designs across multiple fields.

Keywords: gas law, ideal gas law, Charles's law, gas expansion, gas heating, constant pressure, thermodynamics, volume change, temperature conversion, molar calculations, practical applications of gases

Frequently Asked Questions

What is the relationship between the volume and temperature of a gas at constant pressure?

At constant pressure, the volume of a gas is directly proportional to its temperature in Kelvin, following Charles's Law ($V_1/T_1 = V_2/T_2$).

How do you convert Celsius temperatures to Kelvin for gas law calculations?

Add 273.15 to the Celsius temperature to convert it to Kelvin. For example, 25°C becomes 298.15 K, and 40°C becomes 313.15 K.

What is the initial volume of the gas in milliliters?

The initial volume of the gas is 25.0 mL.

If the gas is heated from 25°C to 40°C at constant pressure, what is the new volume?

Using Charles's Law, the volume increases proportionally with temperature: $V_2 = V_1 (T_2 / T_1)$. So, $V_2 = 25.0$ mL (313.15 K / 298.15 K) ≈ 26.3 mL.

Does the pressure of the gas change during heating in this scenario?

No, the pressure remains constant as specified in the problem statement.

What gas law is applicable in this problem and why?

Charles's Law is applicable because the pressure remains constant, and the problem involves changes in temperature and volume.

How does the pressure of the gas relate to the ideal gas law under these conditions?

Since the pressure remains constant, the ideal gas law (PV = nRT) indicates that any change in temperature will directly affect volume, assuming the amount of gas and pressure are unchanged.

Additional Resources

A Sample Of Gas At 4.0 Atm And 25.0 Ml Is Heated From 25°C To 40°C. If The Pressure Remains Constant,

Understanding the behavior of gases under different conditions is fundamental in chemistry and physics. The scenario involving a sample of gas initially at 4.0 atm pressure, occupying 25.0 mL at 25°C, and then heated to 40°C at constant pressure provides an excellent basis for exploring the principles of gas laws, particularly Charles's Law. This situation encapsulates the core concepts about how temperature influences the volume of a gas when pressure remains unchanged. In this article, we will analyze this specific case in detail, examining the underlying principles, calculations, practical implications, and broader applications.

Fundamental Concepts: Gas Laws and Their Relevance

Before delving into the specifics of the problem, it is essential to understand the foundational gas laws that govern such processes. Gases are highly compressible and their properties are described by various laws that relate pressure (P), volume (V), temperature (T), and amount of gas (n). The ideal gas law, expressed as PV = nRT, serves as a cornerstone in understanding these relationships.

Charles's Law, which is central to this problem, states that at constant pressure and amount of gas, the volume of a gas is directly proportional to its temperature in Kelvin:

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

This law indicates that if the temperature of a gas increases, its volume will also increase proportionally, provided the pressure remains unchanged. This principle underpins many practical applications, including hot air balloons, weather balloons, and various industrial processes.

Initial Conditions and Data Analysis

The initial state of the gas is characterized by the following parameters:

- Pressure (P_1): 4.0 atm
- Volume (V_1): 25.0 mL

- Temperature (T_1): 25°C

The final state involves heating the gas to:

- Temperature (T_2): 40°C

The main goal is to determine the final volume (V_2) of the gas under these conditions, assuming the pressure remains constant during the heating process.

Converting Temperatures to Kelvin

Since gas laws require absolute temperature measurements, convert Celsius to Kelvin:

$$ T(K) = T(°C) + 273.15 $$

- Initial temperature: $T_1 = 25 + 273.15 = 298.15\,K$
- Final temperature: $T_2 = 40 + 273.15 = 313.15\,K$

Applying Charles's Law to Find Final Volume

Given that pressure remains constant, and the amount of gas does not change, Charles's Law provides a straightforward calculation:

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

Rearranged to solve for V_2:

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

Plugging in the known values:

$$ V_2 = 25.0\,mL \times \frac{313.15\,K}{298.15\,K} $$

Calculating the ratio:

$$ \frac{313.15}{298.15} \approx 1.050 $$

Therefore:

$$ V_2 \approx 25.0\,mL \times 1.050 = 26.25\,mL $$

Final volume: approximately 26.25 mL.

This result indicates that when the gas is heated from 25°C to 40°C at constant pressure, its volume increases from 25.0 mL to roughly 26.25 mL, reflecting the direct proportionality between temperature and volume.

Implications of the Calculation and Understanding Gas Behavior

The modest increase in volume illustrates how sensitive gases are to temperature changes, which is crucial in various applications. For example:

- In laboratory settings, precise control of temperature and volume is essential when preparing gases for experiments.
- In industry, understanding how gases expand with temperature helps design safety measures, such as pressure relief systems.
- In meteorology, the expansion of air with temperature influences weather patterns and the behavior of atmospheric gases.

Key Features and Practical Considerations

Features:

- The calculation assumes ideal gas behavior, which is generally valid at low pressures and high temperatures.
- The process is reversible and occurs under equilibrium conditions.
- The pressure remains constant, simplifying calculations and focusing solely on temperature and volume changes.

Practical considerations:

- Real gases deviate from ideal behavior at high pressures or low temperatures, where interactions between molecules become significant.
- The container must be flexible or capable of accommodating volume changes without rupture.
- Precise temperature control is necessary to accurately predict volume changes in sensitive applications.

Limitations and Assumptions in the Scenario

While the calculations presented are straightforward, they rest on several assumptions:

- Ideal Gas Assumption: Real gases do not perfectly follow PV = nRT, especially under high pressures or low temperatures. Deviations can affect the accuracy of predictions.
- Constant Pressure: Maintaining a perfectly constant pressure during heating can be challenging in practice, especially in rigid containers.
- No Chemical Reactions: The scenario assumes that heating does not cause any chemical reactions or phase changes, which might not always be valid.
- Uniform Temperature Distribution: It’s assumed that the entire gas sample reaches the final temperature uniformly; in reality, temperature gradients can occur.

These assumptions are generally reasonable for small-scale laboratory experiments but need careful consideration in industrial or more complex situations.

Broader Applications and Significance

Understanding how gases respond to temperature changes at constant pressure is vital across multiple fields:

- Engineering: Designing engines, turbines, and HVAC systems relies heavily on the principles of gas behavior.
- Environmental Science: Modeling atmospheric phenomena requires knowledge of how gases expand and contract with temperature fluctuations.
- Aerospace: The design of spacecraft and high-altitude equipment depends on precise predictions of gas behavior under varying conditions.
- Chemical Manufacturing: Reactor design often involves controlling temperature and pressure to optimize reactions involving gases.

The principles demonstrated in this problem form the foundation for more complex thermodynamic analyses involving real gases, phase changes, and energy transfer.

Conclusion

The scenario of heating a gas at constant pressure from 25°C to 40°C elegantly demonstrates the fundamental principles of Charles's Law. The calculated increase in volume from 25.0 mL to approximately 26.25 mL underscores the proportional relationship between temperature and volume in ideal gases. While the assumptions made simplify the analysis, they provide valuable insights into real-world applications where temperature fluctuations influence gas behavior. Mastery of these concepts is essential not only for academic understanding but also for practical applications across science and engineering disciplines. Recognizing the limitations and conditions under which these laws apply ensures that engineers, scientists, and technicians can make accurate predictions and design effective systems that account for the dynamic nature of gases.

A Sample Of Gas At 4 0 Atm And 25 0 Ml Is Heated From 25 C To 40 C If The Pressure Remains Constant

A Sample Of Gas At 4 0 Atm And 25 0 Ml Is Heated From 25 C To 40 C If The Pressure Remains Constant

Related Articles

- According To The Text, Effective, Cross-cultural Communication In Todays Global And "flattened" World
- Assume A Company's Sales Budget For April And May Is 33,000 Units And 35,000 Units, Respectively. Its
- A Rectangular Floor Of Area 360 M2 Is Going To Be Tiled. Each Tile Is Rectangular, And Has An Area Of

Back to Home