A Gas Is Placed In A Container At 25 C At 1 Atm When The Temperature Is Doubled To 50 C While The Pressure

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Understanding how gases respond to changes in temperature and pressure is fundamental in the study of thermodynamics and physical chemistry. When a gas is contained within a rigid or flexible vessel, alterations in temperature can significantly influence its pressure, volume, or both, depending on the constraints of the system. In this article, we explore the scenario where a gas initially at 25°C and 1 atm pressure undergoes a temperature increase to 50°C, analyzing how the pressure changes under different conditions, rooted in the principles of gas laws.

Fundamental Gas Laws Relevant to the Scenario

The behavior of gases under varying temperature and pressure conditions is primarily described by the ideal gas law, along with the combined and Dalton's laws. Here are the key principles:

Ideal Gas Law

The ideal gas law relates pressure (P), volume (V), temperature (T), and amount of gas (n):

$$
PV = nRT
$$

Where:
- P = pressure
- V = volume
- n = number of moles
- R = universal gas constant (8.314 J/(mol·K))
- T = temperature in Kelvin

Implication: For a fixed amount of gas in a rigid, sealed container, the volume remains constant, and the law simplifies to $P \propto T$.

Charles's Law

States that, at constant pressure and amount of gas, the volume of a gas is directly proportional to its temperature:

$$
\frac{V}{T} = \text{constant}
$$

Gay-Lussac's Law

States that, at constant volume and amount of gas, the pressure is directly proportional to temperature:

$$
\frac{P}{T} = \text{constant}
$$

Scenario Analysis: From 25°C to 50°C

Let’s examine the case where a gas initially at 25°C and 1 atm experiences a temperature increase to 50°C. The key question is: How does the pressure change?

Initial Conditions

- Temperature $T_1 = 25^\circ C = 25 + 273.15 = 298.15\,K$
- Pressure $P_1 = 1\,atm$
- Volume V (assumed constant unless specified)
- Number of moles n (assumed constant)

Final Conditions

- Temperature $T_2 = 50^\circ C = 50 + 273.15 = 323.15\,K$
- Pressure P_2 (to be determined)

Impact of Temperature on Pressure in a Rigid Container

If the gas is contained within a rigid, sealed container, the volume remains fixed. Under these conditions, the ideal gas law simplifies to:

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

Rearranged to find P_2:

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

Plugging in the known values:

$$
P_2 = 1\,atm \times \frac{323.15\,K}{298.15\,K} \approx 1\,atm \times 1.084
$$

$$
P_2 \approx 1.084\,atm
$$

Conclusion: When the temperature doubles from 25°C to 50°C in a rigid container, the pressure increases by approximately 8.4%.

Impact of Temperature on Volume in a Flexible Container

If the container is flexible or open to the atmosphere, the volume can change. In such circumstances, Charles's and Gay-Lussac's laws come into play.

- At constant pressure: Volume increases proportionally with temperature.
- At constant volume: Pressure increases proportionally with temperature.

Assuming the pressure remains constant (e.g., gas in an open container), then:

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

\]

Similarly, if volume is held constant, pressure changes as:

\[
P_2 = P_1 \times \frac{T_2}{T_1}
\]

which matches the earlier calculation for a rigid container.

Real-World Applications and Implications

Understanding the relationship between temperature and pressure of gases is crucial across various fields:

- **Engineering:** Designing pressure vessels and reactors that withstand temperature fluctuations.
- **Chemistry:** Reacting systems where temperature control influences reaction rates and gas pressures.
- **Environmental Science:** Predicting how atmospheric gases behave with temperature changes.
- **Medical Devices:** Ensuring safety of inhalers and ventilators operating under varying temperatures.

Additional Factors Influencing Gas Behavior

While ideal gas law provides a good approximation, real gases can deviate under certain conditions. Here are some considerations:

Non-Ideal Gas Behavior

- At high pressures or low temperatures, gas particles experience intermolecular forces.
- Deviations from ideality are described by the Van der Waals equation:

\[

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

where a and b are constants specific to each gas.

Effects of Container Material and Gas Composition

- Container elasticity: Flexibility influences how pressure and volume respond to temperature.
- Gas mixture composition: Different gases have different responses based on molecular weights and interactions.

Summary and Key Takeaways

- When a gas in a rigid, sealed container is heated from 25°C to 50°C, its pressure increases proportionally to the temperature ratio.
- The approximate increase in pressure is 8.4% under ideal conditions.
- If the container is flexible, the volume can increase with temperature, influencing pressure differently.
- Real-world applications require considering deviations from ideal behavior and material properties.

Conclusion

The relationship between temperature and pressure in gases is governed by fundamental principles encapsulated in the ideal gas law and related laws like Charles’s and Gay-Lussac’s laws. In the specific scenario where a gas is initially at 25°C and 1 atm, and the temperature is increased to 50°C, the pressure in a sealed, rigid container will increase by about 8.4%. Understanding these principles is essential for designing safe and efficient systems involving gases, from industrial processes to environmental management.

Note: Always consider the specific conditions and properties of the gas and container when analyzing such scenarios, especially when operating outside ideal conditions.

Frequently Asked Questions

What happens to the pressure of a gas when its temperature is doubled at constant volume?

The pressure of the gas doubles when the temperature is doubled at constant volume, according to Gay-Lussac's Law.

If a gas is initially at 25°C and 1 atm, what is its pressure when the temperature increases to 50°C at constant volume?

The pressure increases from 1 atm to 2 atm because pressure is directly proportional to temperature (in Kelvin).

How do you convert Celsius temperature to Kelvin in this context?

Add 273.15 to the Celsius temperature; so, 25°C becomes 298.15 K and 50°C becomes 323.15 K.

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

Pressure and temperature are directly proportional for a fixed volume and amount of gas, as described by Gay-Lussac's Law.

Does the amount of gas affect the change in pressure when temperature is doubled?

No, if the volume and amount of gas are constant, the change in pressure depends solely on the change in temperature.

What law governs the behavior of gas when temperature and pressure change at constant volume?

Gay-Lussac's Law governs this behavior, stating that pressure is directly proportional to temperature at constant volume.

If the initial pressure is 1 atm at 25°C, what is the final pressure at 50°C?

The final pressure will be approximately 2 atm because pressure doubles as temperature doubles in Kelvin.

What precautions should be taken when heating a gas in a closed container?

Ensure the container can withstand increased pressure, as heating can cause pressure to rise significantly, potentially leading to rupture.

Additional Resources

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Introduction

A gas is placed in a sealed container at a temperature of 25°C and an initial pressure of 1 atmosphere (atm). When the temperature of this gas is increased to 50°C—doubling the original temperature—the pressure within the container also changes. This scenario exemplifies fundamental principles in thermodynamics and gas laws, which describe how gases respond to variations in temperature, pressure, and volume. Understanding these relationships is crucial in fields ranging from chemical engineering to meteorology, and they form the backbone of classical thermodynamics.

In this article, we will delve into the underlying physics governing the behavior of gases under changing thermal conditions, explore the mathematical formulations that describe these phenomena, and analyze what happens to the pressure when the temperature doubles, assuming the volume remains constant. We will examine the ideal gas law, real-world considerations, and practical implications of such changes.

Understanding the Fundamentals: The Ideal Gas Law

The Core Equation

The behavior of gases under varying conditions is primarily described by the ideal gas law, which states:

\[PV = nRT \]

Where:

- P = Pressure of the gas

- V = Volume of the gas

- n = Number of moles of gas

- R = Universal gas constant (~8.314 J/(mol·K))

- T = Temperature in Kelvin (K)

This relationship assumes that the gas particles do not interact with each other and occupy negligible volume—assumptions that are valid under many conditions but not all.

Key Assumptions and Their Implications

- Ideal Behavior: The law presumes ideality, which is generally good at low pressures and high temperatures. Deviations occur at high pressures or low temperatures where intermolecular forces become significant.

- Constant Volume and Moles: The scenario assumes the volume and the number of moles of gas remain constant during the temperature change, aligning with a rigid, sealed container.

- Temperature in Kelvin: To accurately apply the law, temperatures must be converted from Celsius to Kelvin:

$$ T(K) = T(°C) + 273.15 $$

For 25°C: $25 + 273.15 = 298.15\,K$

For 50°C: $50 + 273.15 = 323.15\,K$

Analyzing the Pressure Change with Temperature

Applying the Ideal Gas Law for Constant Volume and Moles

Since the volume V and the amount n of gas are fixed, the relation simplifies to:

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

Where:

- P_1, T_1 are initial pressure and temperature
- P_2, T_2 are final pressure and temperature

Given that:

- $P_1 = 1\,atm$
- $T_1 = 298.15\,K$
- $T_2 = 323.15\,K$

The goal is to find P_2, the final pressure after the temperature doubles.

Rearranged formula:

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

Calculating:

$$P_2 = 1\,atm \times \frac{323.15\,K}{298.15\,K} \approx 1\,atm \times 1.084 \approx 1.084\,atm$$

Result: The pressure increases from 1 atm to approximately 1.084 atm when the temperature doubles from 25°C to 50°C, assuming ideal behavior and constant volume.

Practical Implications and Real-World Considerations

Expected Behavior in Real Gases

While the ideal gas law provides a robust approximation, real gases exhibit deviations at various conditions. Factors influencing the actual pressure change include:

- Intermolecular Forces: Attractive or repulsive forces can cause deviations, especially at higher pressures or lower temperatures.
- Finite Molecular Volume: Molecules occupy space, which affects the volume available and thus the pressure.

- Compressibility Factors: Engineers often use correction factors (compressibility factor Z) to account for real-gas deviations:

$$PV = ZnRT$$

where Z approaches 1 for ideal gases but can differ notably under real conditions.

Implications for Engineering and Industry

Understanding how pressure varies with temperature is vital for numerous practical applications:

- Pressurized Containers: Engineers must account for pressure increases when heating gases in sealed vessels to prevent rupture.

- Thermodynamic Cycles: In engines and refrigeration systems, temperature-induced pressure changes are harnessed for work extraction and cooling.

- Safety Protocols: Knowledge of pressure changes guides safety standards to prevent accidents due to over-pressurization.

Limitations and Safety Precautions

- Material Constraints: Containers must withstand the maximum expected pressure.

- Monitoring and Control: Sensors and control systems are used to regulate temperature and pressure.

- Understanding Non-Ideal Conditions: In extreme conditions, more complex models (van der Waals equation, Redlich-Kwong, etc.) are employed for accurate predictions.

Extended Scenarios and Additional Variables

While the primary focus has been on the effect of temperature at constant volume, other variables can influence the pressure:

Changing Volume

If the container's volume is allowed to change (e.g., a piston), then the pressure change due to temperature variation follows Boyle’s law combined with Charles’s law, leading to more complex relationships.

Adding or Removing Gas

Altering the amount of gas (adding more moles) also affects pressure, adding another layer of complexity.

Multiple Gas Mixtures

Different gases respond differently to temperature changes, especially if non-ideal behavior or interactions are significant.

Conclusion: Summarizing the Key Takeaways

The behavior of gases under changing thermal conditions is governed by well-established physical laws, with the ideal gas law serving as the foundational principle. When a gas is placed in a sealed container at 25°C and the temperature is increased to 50°C, assuming the volume remains constant and the gas behaves ideally, the pressure increases proportionally with temperature.

Specifically, doubling the temperature from 25°C to 50°C results in approximately an 8.4% increase in pressure, from 1 atm to roughly 1.084 atm. This relatively modest increase illustrates how sensitive gaseous systems are to temperature fluctuations, highlighting the importance of careful design and safety considerations in engineering applications.

Understanding these principles is crucial for scientists and engineers to predict system behavior accurately, optimize processes, and ensure safety. While ideal gas law provides a solid approximation, real-world systems often require correction factors and more complex models to account for deviations, especially under extreme conditions. Recognizing these nuances ensures that the theoretical predictions align with practical outcomes, enabling more robust and reliable applications across industries.

In essence, the interplay between temperature and pressure in gases exemplifies the elegant simplicity of classical physics, combined with the complexity of real-world behaviors, forming a cornerstone of modern science and engineering.

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