A Gas Held Within A Fixed Container Has A Pressure Of 9.5 Atm At A Temperature Of 133 K. What Would Be

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Understanding the behavior of gases under various conditions is fundamental in fields such as chemistry, physics, engineering, and environmental sciences. When a gas is confined within a fixed container, its pressure, temperature, and volume are interrelated through the ideal gas law. In this article, we will explore the implications of the given conditions—pressure of 9.5 atm and temperature of 133 K—and analyze what would happen if certain variables change or if we seek to determine specific properties. We will delve into the principles governing gas laws, perform calculations, and discuss real-world applications to provide a comprehensive understanding.

Understanding Gas Laws and Their Significance

What Are Gas Laws?

Gas laws describe the relationships between pressure (P), volume (V), temperature (T), and amount of gas (n). They are foundational in predicting how gases behave under different conditions. The three main laws are:

- Boyle’s Law: For a fixed amount of gas at constant temperature, pressure and volume are inversely proportional ($P \propto 1/V$).
- Charles’s Law: For a fixed amount of gas at constant pressure, volume is directly proportional to temperature ($V \propto T$).
- Gay-Lussac’s Law: For a fixed amount of gas at constant volume, pressure is directly proportional to temperature ($P \propto T$).

Combined, these form the Ideal Gas Law:

$$PV = nRT$$

where:
- P = pressure in atm,
- V = volume in liters,
- n = number of moles,
- R = universal gas constant (0.0821 L·atm/(mol·K)),
- T = temperature in Kelvin.

Analyzing the Given Conditions

Initial Parameters

The problem states:
- Pressure, $P_1 = 9.5\, \text{atm}$
- Temperature, $T_1 = 133\, \text{K}$
- Volume, V (fixed container, so V remains constant)

Since the container is fixed, the volume does not change, and the amount of gas (number of moles, n) remains constant unless specified otherwise.

Implications of the Given Data

Using the ideal gas law, we can determine the number of moles of gas initially:

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

Because V and n are constant unless specified, any change in temperature or pressure will affect the other variables accordingly.

Calculating and Understanding Gas Behavior Under Different Conditions

Scenario 1: What Happens If Temperature Changes?

Suppose the temperature of the gas changes from 133 K to another temperature T_2. To find the new pressure P_2, assuming volume and moles stay constant, we use Gay-Lussac’s Law:

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

Rearranged to solve for P_2:

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

Example Calculation: If the temperature increases to 200 K,

$$
P_2 = 9.5\, \text{atm} \times \frac{200\, \text{K}}{133\, \text{K}} \approx 9.5 \times 1.5038 \approx 14.28\, \text{atm}
$$

Interpretation: As temperature increases, pressure increases proportionally when volume and moles are constant.

Scenario 2: What If The Temperature Decreases?

If the temperature drops to 100 K,

$$
P_2 = 9.5\, \text{atm} \times \frac{100\, \text{K}}{133\, \text{K}} \approx 9.5 \times 0.75 \approx 7.13\, \text{atm}
$$

Implication: Lower temperatures result in lower pressure within the fixed container.

Scenario 3: Changes in Moles of Gas

If gas is added or removed, the number of moles n changes, affecting the pressure and other properties. Using the ideal gas law:

$$
P = \frac{nRT}{V}
$$

Adding more gas increases n, thus increasing P, assuming temperature and volume are constant.

Theoretical and Practical Applications

Real-World Examples of Gas Behavior

Understanding how pressure and temperature relate in a fixed container has numerous applications:

- Aerospace Engineering: Designing pressurized cabins that must withstand temperature fluctuations.
- Chemical Reactors: Managing reactions where gases are confined under specific conditions.
- Environmental Science: Modeling atmospheric gas behaviors under temperature variations.

Safety Considerations

Changes in temperature can lead to significant pressure variations, which may pose safety risks:

- Over-pressurization can cause container failure.
- Rapid temperature drops or rises should be carefully controlled.

Key Calculations and Formulas

To facilitate understanding, here are essential formulas:

- Ideal Gas Law: $PV = nRT$
- Gay-Lussac’s Law: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- Boyle’s Law: $P_1 V_1 = P_2 V_2$ (for constant T and n)
- Charles’s Law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (for constant P and n)

Conclusion: What Would Be The Final Pressure?

Given the initial conditions — pressure of 9.5 atm at 133 K — and assuming the temperature is increased to 200 K, the new pressure can be calculated using Gay-Lussac’s Law:

$$
P_2 = 14.28\, \text{atm}
$$

Conversely, if the temperature decreases to 100 K, the pressure drops to approximately 7.13 atm.

In essence: The pressure of a gas in a fixed container directly correlates with its temperature, provided the amount of gas remains constant. This fundamental principle underpins many scientific and engineering applications, emphasizing the importance of understanding gas laws for safety, design, and analysis.

Additional Considerations

- Deviation from Ideal Behavior: Real gases deviate from ideal behavior at high pressures and low temperatures. Corrections such as Van der Waals equation can be used for more accurate modeling.
- Temperature Limits: Approaching absolute zero (0 K) causes gas behavior to become non-ideal; thus, practical calculations are valid within certain temperature ranges.
- Material Constraints: The physical strength of the container limits the maximum pressure it can withstand, which is vital in practical scenarios.

This comprehensive overview provides a detailed understanding of the relationships between pressure, temperature, and other variables for gases in fixed containers, equipping readers with the knowledge to analyze similar problems confidently.

Frequently Asked Questions

What is the initial pressure of the gas in the container?

The initial pressure of the gas is 9.5 atm.

What is the initial temperature of the gas?

The initial temperature of the gas is 133 K.

If the volume of the container remains fixed, how does the pressure change when the temperature increases?

According to Gay-Lussac's law, if the volume is constant, the pressure is directly proportional to the temperature, so increasing temperature increases pressure.

What is the approximate pressure of the gas if the temperature is increased to 200 K?

Using P1/T1 = P2/T2, P2 = (P1 T2) / T1 = (9.5 atm 200 K) / 133 K □ 14.3 atm.

How does decreasing the temperature to 100 K affect the pressure?

Using the same law, P2 = (9.5 atm 100 K) / 133 K □ 7.15 atm.

What assumptions are made when applying the ideal gas law in this scenario?

It is assumed that the gas behaves ideally, meaning negligible interactions between particles and that the gas particles occupy negligible volume compared to the container.

If the gas is compressed at constant temperature, how does the pressure change?

Under isothermal conditions, pressure is inversely proportional to volume (Boyle's law). Since volume is fixed here, pressure remains unchanged with temperature changes.

What is the significance of the gas being held in a fixed container for the calculations?

It means the volume remains constant, allowing the use of laws like Gay-Lussac's law to relate pressure and temperature directly.

What safety considerations should be taken into account when handling gases at high pressure like 9.5 atm?

Proper pressure-rated containers should be used, and safety protocols should be followed to prevent explosions or leaks due to high pressure.

Additional Resources

Pressure

Understanding the Behavior of Gases in Fixed Containers: An Expert Analysis

In the realm of thermodynamics and physical chemistry, understanding the behavior of gases confined within fixed containers is fundamental. The scenario presented—a gas held within a rigid, non-expanding container at a pressure of 9.5 atm and a temperature of 133 K—serves as an excellent case study to explore the underlying principles governing gas behavior, particularly the application of the ideal gas law and real gas considerations.

This article aims to dissect this situation comprehensively, providing insights into what these parameters imply, how they relate through fundamental equations, and what potential implications or next steps are relevant for scientists, engineers, or enthusiasts examining such a system.

The Core Question: What Would Be?

The phrase "What would be" in the context of this scenario invites an exploration of several possible directions:

- What is the volume of the gas?
- What is the number of moles of the gas?
- How does changing temperature or pressure affect the system?
- What are the real-world applications or implications of such a state?

Given the parameters provided—pressure and temperature, within a fixed container—the most logical starting point is to determine the number of moles of gas present, or the volume of the container, assuming one of these parameters is known or can be estimated.

The Fundamental Principles: Applying the Ideal Gas Law

At the heart of gas behavior analysis lies the ideal gas law:

$$PV = nRT$$

Where:

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

This equation assumes the gas behaves ideally—meaning molecules do not interact and occupy negligible volume—an approximation generally valid at high temperatures and low pressures.

Analyzing the Given Parameters

Pressure (P): 9.5 atm

Temperature (T): 133 K

These values suggest a gas under significant pressure but relatively low temperature, which can influence the ideality of the gas and the potential for deviations from ideal behavior.

Implications of the Given Parameters

- The pressure of 9.5 atm is nearly 10 times atmospheric pressure, indicating a tightly confined gas.
- The temperature of 133 K is well below room temperature (~298 K), approaching the condensation point for some gases.
- The combination of high pressure and low temperature suggests that real gas effects (intermolecular forces, volume occupied by molecules) could be significant, requiring correction factors like those provided by the Van der Waals equation.

Estimating the Container Volume or Moles

In many practical scenarios, either the volume of the container or the number of moles of gas is known, allowing calculations of the other. Let's explore how this can be approached:

Case 1: Known Volume, Find Moles

Suppose the container volume is known. For example, if the container volume is 10 liters, then:

$$
n = \frac{PV}{RT} = \frac{9.5 \times 10}{0.0821 \times 133} \approx \frac{95}{10.91} \approx 8.7 \text{ mol}
$$

This calculation indicates approximately 8.7 moles of gas are present in a 10-liter container under the specified conditions.

Case 2: Known Moles, Find Volume

If the system contains a known number of moles, say 5 mol, then:

$$
V = \frac{nRT}{P} = \frac{5 \times 0.0821 \times 133}{9.5} \approx \frac{54.6}{9.5} \approx 5.75 \text{ L}
$$

Thus, 5 mol of gas at the specified conditions would occupy approximately 5.75 liters.

The Role of Real Gas Corrections: Van der Waals Equation

While the ideal gas law provides a good approximation, the given conditions push us toward considering real gas behavior. The Van der Waals equation modifies the ideal gas law to account for molecular size and intermolecular forces:

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

Where:

- a = measure of the magnitude of intermolecular attractions
- b = volume occupied by gas molecules

Implications:

- For gases like CO_2, NH_3, or CH_4, the parameters a and b vary and are well-tabulated.
- At high pressures and low temperatures, the corrections become significant, and ignoring them can lead to inaccuracies.

Practical Example: Using Van der Waals Parameters

Suppose the gas is carbon dioxide (CO_2), with parameters:

- $a = 3.59 \, \text{L}^2 \text{atm} / \text{mol}^2$
- $b = 0.0427 \, \text{L} / \text{mol}$

If 8.7 mol are present (from earlier), the corrections can be computed to refine the volume or pressure estimates, especially if precise data is needed for engineering purposes.

Real-World Applications and Significance

Understanding the behavior of gases under such conditions is crucial across various fields:

- Chemical Engineering: Designing reactors or storage tanks where gases are stored at high pressures.
- Environmental Science: Modeling atmospheric gases or greenhouse gases under varying conditions.
- Cryogenics: Handling gases at low temperatures, especially near their liquefaction points.

- Aerospace: Managing cabin pressurization systems, where gases are confined in fixed volumes.

Safety Considerations

High-pressure gases, particularly at low temperatures, pose safety risks:

- Potential for rupture or explosion if pressure exceeds container limits.
- Condensation or liquefaction can occur, leading to phase changes and possible hazards.
- Proper materials and safety protocols are essential to prevent accidents.

Next Steps: Further Analysis and Experiments

For a comprehensive understanding, additional data may be required:

- Container volume or dimensions to precisely determine the amount of gas.
- Type of gas for accurate correction factors.
- Pressure and temperature change scenarios to assess system stability.

Laboratory experiments or simulations can help validate theoretical predictions, especially when real gas effects are significant.

Conclusion

The initial scenario—a gas confined within a fixed container at 9.5 atm and 133 K—serves as an illustrative case study for the principles of thermodynamics and gas behavior. By applying the ideal gas law, considering real gas corrections, and understanding the implications of the parameters, we gain valuable insights into the system's state and potential behaviors.

Whether for designing industrial processes, ensuring safety, or conducting scientific research, such detailed analysis underscores the importance of fundamental physics in practical applications. As technology advances and demands for precision grow, so does the need to understand and accurately model the complex behaviors of gases under various conditions.

In essence, grasping the nuances of gas behavior at fixed volumes and varying conditions enables scientists and engineers to predict, control, and optimize systems across a broad spectrum of applications.

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