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13) A Gas Has An Initial State Of 500 K, 6.5 Atm, And Occupies 8.0 L. What Will The Final Volume Be If

Understanding the behavior of gases under changing conditions is fundamental in the field of thermodynamics and chemical engineering. When dealing with gases, the relationship between pressure, volume, temperature, and amount of gas is described by the ideal gas law. This law provides a powerful tool for predicting how a gas will respond to various changes in its environment. In this article, we will explore the problem of determining the final volume of a gas given its initial conditions and certain changes, focusing specifically on the use of the ideal gas law, understanding the variables involved, and applying the appropriate calculations step-by-step.

Understanding the Initial Conditions of the Gas

Before we dive into the calculations, it’s essential to understand the initial state of the gas, which is characterized by three key parameters:

Initial Temperature (T_1)

- 500 K (Kelvin)

Initial Pressure (P_1)

- 6.5 atm (atmospheres)

Initial Volume (V_1)

- 8.0 L (liters)

These initial conditions serve as the starting point for applying the ideal gas law, which relates these variables to the amount of gas present (n) and the ideal gas constant (R).

The Ideal Gas Law: A Fundamental Tool

The ideal gas law is expressed as:

$$PV = nRT$$

Where:
- P = pressure
- V = volume
- n = number of moles of gas
- R = ideal gas constant
- T = temperature in Kelvin

This relationship indicates that, for a fixed amount of gas, the product of pressure and volume is proportional to temperature.

Key Assumptions in the Problem

To determine the final volume, certain assumptions are typically made:
- The amount of gas (n) remains constant during the process.
- The gas behaves ideally, meaning interactions between molecules are negligible.
- The process occurs at constant pressure or temperature, depending on the scenario.

In this case, since the problem statement is incomplete regarding what changes occur, but asks for the final volume, we will analyze common scenarios where either temperature, pressure, or both change, assuming the amount of gas remains constant.

Step-by-Step Calculation Approach

To find the final volume, we will:

1. Identify the process type: Is it isothermal (constant temperature), isobaric (constant pressure), or isochoric (constant volume)?
2. Apply the appropriate form of the ideal gas law: For example, when temperature changes at constant pressure, the relation:

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

applies, assuming pressure and moles are constant.
3. Use known variables to solve for unknowns.

Scenario 1: Final Volume with Known Final Temperature

Suppose the process involves heating or cooling the gas, resulting in a change in temperature. The ideal gas law relates initial and final states as:

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

If pressure remains constant ($P_1 = P_2$), then:

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

Rearranged to find V_2:

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

Example Calculation:

- Initial volume, $V_1 = 8.0\, \text{L}$
- Initial temperature, $T_1 = 500\, \text{K}$
- Final temperature, $T_2 = ?$

If, for instance, the temperature is increased to 600 K:

$$ V_2 = 8.0\, \text{L} \times \frac{600\, \text{K}}{500\, \text{K}} = 8.0 \times 1.2 = 9.6\, \text{L} $$

Thus, the final volume would be 9.6 L under these conditions.

Scenario 2: Final Volume with Known Final Pressure

Suppose the pressure changes while temperature remains constant (isothermal process). The relation becomes:

$$ P_1 V_1 = P_2 V_2 $$

Rearranged:

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

Example Calculation:

- Initial pressure, $P_1 = 6.5\, \text{atm}$
- Final pressure, $P_2 = ?$

If the pressure drops to 4 atm:

$$V_2 = 8.0\, \text{L} \times \frac{6.5}{4} = 8.0 \times 1.625 = 13.0\, \text{L}$$

The final volume would be 13.0 L when pressure decreases to 4 atm at constant temperature.

Scenario 3: Final Volume with Changes in Both Temperature and Pressure

In more complex cases where both temperature and pressure change, the combined gas law applies:

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

Rearranged:

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

By inputting known initial and final values, you can determine the resulting volume.

Importance of Accurate Data and Assumptions

When solving for the final volume of a gas, the accuracy of your answer depends on:
- Correct initial data measurement
- Clear understanding of the process (which variables change and which remain constant)
- Proper application of the ideal gas law or its variants
- Awareness of real gas deviations at high pressures or low temperatures

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Practical Applications of Gas Volume Calculations

Knowing how to calculate the final volume of a gas under different conditions is crucial in various fields:

- Chemical manufacturing: Designing reactors and storage tanks.
- Environmental science: Modeling gas emissions and atmospheric changes.
- Aerospace engineering: Calculating cabin pressurization and fuel gas expansion.
- Medical applications: Understanding respiratory gases and anesthetic delivery.

Summary of Key Points

- The ideal gas law is essential for predicting gas behavior during changes in pressure, volume, or temperature.
- For constant moles of gas, the relationships simplify to the combined gas law.
- Accurately determine the process type—whether isothermal, isobaric, or isochoric—to apply the correct formula.
- Always verify assumptions and data accuracy for reliable calculations.

Final Thoughts

The problem of determining the final volume of a gas with an initial state of 500 K, 6.5 atm, and 8.0 L involves understanding the interplay of pressure, volume, and temperature. Whether the temperature increases, decreases, or pressure varies, applying the ideal gas law allows for precise calculations. Mastery of these principles is vital for professionals and students working in fields related to thermodynamics, chemical engineering, and physical sciences. By carefully analyzing initial conditions and process specifics, you can confidently predict how gases will behave under various environmental changes.

Keywords: ideal gas law, final volume of gas, gas law calculations, pressure, temperature, volume, thermodynamics, chemical engineering, gas behavior, gas law formulas, physics of gases

Frequently Asked Questions

What is the final volume of the gas if the temperature and pressure change, assuming the amount of gas remains constant?

To determine the final volume, use the combined gas law: (P1 V1) / T1 = (P2 V2) / T2. If temperature change is unknown, more information is needed. Otherwise, specify T2 to solve.

How does an increase in pressure affect the volume of a gas at constant temperature?

At constant temperature, increasing pressure results in a decrease in volume, as described by Boyle's Law (P1 V1 = P2 V2).

If the temperature of the gas increases from 500 K to 600 K while pressure remains constant, what is the new volume?

Using Charles's Law: V2 = V1 (T2 / T1). Substituting values: V2 = 8.0 L (600 K / 500 K) = 9.6 L.

What assumptions are made when applying the ideal gas law to this problem?

Assumptions include that the gas behaves ideally with negligible interactions between molecules and that the gas particles occupy no volume themselves.

How would the final volume change if the initial pressure increased to 8.0 atm while keeping temperature constant?

Using Boyle's Law: V2 = V1 (P1 / P2). Substituting: V2 = 8.0 L (6.5 atm / 8.0 atm) = 6.5 L.

Additional Resources

13) A Gas Has An Initial State Of 500 K, 6.5 Atm, And Occupies 8.0 L. What Will The Final Volume Be If

Understanding the behavior of gases under varying conditions is fundamental in fields ranging from chemical engineering to environmental science. When a gas undergoes a change in its temperature, pressure, or volume, the relationships governing these properties come into play, allowing scientists and engineers to predict its behavior accurately. In this article, we will explore how to determine the final volume of a gas based on its initial conditions and a change in one or more parameters, using the principles of the ideal gas law.

Initial Conditions and the Problem Setup

Let's begin by considering the initial state of the gas:

- Temperature (T_1): 500 Kelvin
- Pressure (P_1): 6.5 atmospheres
- Volume (V_1): 8.0 liters

The question posed is: What will the final volume (V_2) be if the gas undergoes a process where certain conditions change?

To proceed, we first need to specify what parameters are changing. Is the pressure changing? Is the temperature changing? Or are both changing?

In most typical problems, unless otherwise specified, the process could be one of the following:

- Isothermal process: temperature remains constant
- Isobaric process: pressure remains constant
- Isochoric process: volume remains constant
- Adiabatic process: no heat exchange

For the purpose of this discussion, we will assume that the process involves a change in temperature or pressure, or both, and demonstrate how to calculate the final volume under such conditions.

The Ideal Gas Law as the Foundation

The key to solving this problem lies in the ideal gas law, which states:

$$ PV = nRT $$

Where:
- P = pressure
- V = volume
- n = number of moles of gas
- R = universal gas constant (8.314 J/mol·K or 0.0821 L·atm/mol·K)
- T = temperature in Kelvin

Since the amount of gas (n) and the gas constant (R) are constant, the law simplifies to the combined gas law:

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

This equation relates the initial and final states of the gas, assuming the amount of gas remains unchanged.

Applying the Combined Gas Law

Suppose the problem specifies that the pressure and temperature change, and we are asked to find the final volume. The combined gas law is expressed as:

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

Where:
- V_1, P_1, T_1: initial volume, pressure, temperature
- V_2, P_2, T_2: final volume, pressure, temperature

If the problem specifies the final pressure and temperature, plugging these values into the equation yields the answer.

Example: Calculating Final Volume with Given Data

Let’s assume a typical scenario: the gas is compressed, and the temperature increases. For example:

- Final pressure (P_2): 8.0 atm
- Final temperature (T_2): 600 K

Using the initial conditions:
- $P_1 = 6.5\,\text{atm}$
- $V_1 = 8.0\,\text{L}$
- $T_1 = 500\,\text{K}$

Applying the combined gas law:

$$
V_2 = 8.0\,\text{L} \times \frac{6.5\,\text{atm}}{8.0\,\text{atm}} \times \frac{600\,\text{K}}{500\,\text{K}}
$$

Calculating step-by-step:

1. Pressure ratio:

$$
\frac{6.5}{8.0} = 0.8125
$$

2. Temperature ratio:

$$
\frac{600}{500} = 1.2
$$

3. Final volume:

$$
V_2 = 8.0 \times 0.8125 \times 1.2 = 8.0 \times 0.975 = 7.8\,\text{L}
$$

So, the final volume would be approximately 7.8 liters under these conditions.

Sensitivity to Changes and Real-World Implications

This calculation highlights several important points:

- Pressure and volume are inversely related when temperature remains constant (Boyle’s Law). Increasing pressure tends to decrease volume.
- Temperature increases tend to expand the gas, increasing its volume if pressure remains constant (Charles’s Law).
- When multiple parameters change simultaneously, the combined gas law provides a straightforward way to predict outcomes.

In real-world applications, understanding these relationships is critical. For example, in designing pressurized containers, engines, or chemical reactors, engineers must anticipate how gases will behave under various temperature and pressure conditions to ensure safety and efficiency.

Limitations of the Ideal Gas Law

While the ideal gas law serves as an excellent approximation for many conditions, real gases deviate from ideality at high pressures and low temperatures. Under these conditions, intermolecular forces and the finite size of molecules become significant, and more complex models such as the Van der Waals equation are employed.

However, for most practical purposes involving moderate temperatures and pressures, the ideal gas law provides sufficiently accurate predictions.

Summary of Key Steps in Solving Gas Volume Problems

1. Identify known initial conditions: P_1, V_1, T_1.

2. Determine the final conditions: P_2, T_2, or both.
3. Use the combined gas law to relate initial and final states:

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

4. Calculate step-by-step to find the unknown V_2.

This approach ensures a systematic and accurate method for predicting how gases respond to changes in their environment.

Final Thoughts: Practical Significance

Understanding how to manipulate and predict the behavior of gases is foundational in many scientific and industrial processes. Whether it’s optimizing the combustion in engines, designing pressurized containers, or understanding atmospheric phenomena, the principles discussed here form the backbone of thermodynamics and fluid mechanics.

In conclusion, by applying the ideal gas law and the combined gas law, scientists and engineers can confidently forecast how a gas's volume will change in response to shifts in pressure and temperature, ensuring safety, efficiency, and innovation in various applications.

Note: The specific final volume in actual problems depends on the exact conditions given or desired. Always verify the parameters involved, and remember to convert units appropriately to maintain consistency throughout calculations.

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