What Is The Volume When 524 Cm3 Of A Gas At 491 K Is Cooled To 297 K?Let's Consider 491 K As T. Whichvariable

What Is The Volume When 524 Cm3 Of A Gas At 491 K Is Cooled To 297 K? Let's Consider 491 K As T. Which variable?

Understanding how the volume of a gas changes with temperature is a fundamental concept in thermodynamics and gas laws. In this article, we'll explore the relationship between temperature and volume, specifically focusing on a scenario where a gas's initial volume and temperature are known, and the gas is then cooled to a lower temperature. We'll analyze how to calculate the new volume, considering the variables involved, and explain the underlying principles in detail to provide a comprehensive understanding of this process.

Introduction to Gas Laws and Their Significance

Gas laws describe how gases behave under different conditions of temperature, pressure, and volume. These laws are essential in various scientific and engineering applications, including chemistry, physics, meteorology, and industrial processes. The most relevant law for our discussion is Charles's Law, which states that the volume of a given amount of gas is directly proportional to its temperature when pressure and amount of gas are held constant.

Key Point:
- Charles's Law helps us understand how volume and temperature relate in an ideal gas at constant pressure.

Understanding the Variables in Gas Behavior

Before delving into calculations, let's clarify the variables involved:

- V_1: Initial volume of the gas (524 cm^3)
- T_1: Initial temperature of the gas (491 K, as given)
- V_2: Final volume of the gas (unknown, what we need to find)
- T_2: Final temperature of the gas (297 K)
- P: Pressure (assumed constant during the process)
- n: Number of moles of gas (assumed constant)
- R: Universal gas constant

Since the problem states the gas is cooled from 491 K to 297 K, and presuming the pressure remains constant, Charles's Law applies directly to this scenario.

Charles's Law: The Core Principle

Charles's Law is mathematically expressed as:

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

This equation implies that the ratio of volume to temperature remains constant for a fixed amount of gas at constant pressure.

Assumptions for Validity:

- Pressure remains constant during cooling
- The gas behaves ideally
- The amount of gas (number of moles) stays unchanged

Step-by-Step Calculation to Find the Final Volume

Step 1: Identify Known Values

- Initial volume, $V_1 = 524 \, \text{cm}^3$
- Initial temperature, $T_1 = 491\, \text{K}$
- Final temperature, $T_2 = 297\, \text{K}$

Step 2: Rearrange Charles's Law Formula

To find V_2:

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

Step 3: Plug in the Known Values

$$V_2 = 524 \times \frac{297}{491}$$

Step 4: Perform the Calculation

Calculating the ratio:

$$\frac{297}{491} \approx 0.605$$

Multiplying:

$$ V_2 \approx 524 \times 0.605 $$

$$ V_2 \approx 317.02\, \text{cm}^3 $$

Result:
The volume of the gas when cooled to 297 K is approximately 317.02 cm^3.

Implications of the Calculation

This calculation demonstrates a key principle: as temperature decreases, the volume of a gas decreases proportionally, provided pressure remains constant. Specifically, cooling the gas from 491 K to 297 K results in the volume shrinking from 524 cm^3 to around 317 cm^3.

Factors Affecting Gas Volume Beyond Temperature

While Charles's Law provides a straightforward relationship between temperature and volume, real-world scenarios may involve other factors:

- Pressure variations: Changes in pressure can alter volume independently.
- Non-ideal gas behavior: At high pressures or low temperatures, gases deviate from ideal behavior.
- Phase changes: If cooling causes condensation, the gas phase may change, invalidating simple laws.

Practical Applications of Gas Volume Calculations

Understanding how to calculate gas volume changes is crucial in various fields:

1. Chemical Engineering: Designing reactors and storage tanks that accommodate volume changes with temperature.
2. Meteorology: Predicting atmospheric phenomena involving gases.
3. Medical Devices: Managing gases in respiratory therapy equipment.
4. Aerospace Engineering: Calculating fuel and gas expansion or contraction in spacecraft.

Summary of Key Points

- The relationship between gas volume and temperature at constant pressure is described by Charles's Law.
- To find the final volume after cooling, multiply the initial volume by the ratio of the final to initial temperature.
- In our scenario, cooling from 491 K to 297 K reduces the gas volume from 524 cm^3 to approximately 317 cm^3.
- Assumptions include constant pressure and ideal gas behavior; deviations can occur in real-world situations.

Conclusion: The Significance of Gas Law Calculations

Grasping how gases respond to temperature changes is fundamental in science and industry. The calculation detailed above exemplifies the practical application of theoretical principles, enabling accurate predictions of gas behavior under varying conditions. Whether in laboratory experiments, industrial processes, or environmental modeling, understanding these relationships helps optimize safety, efficiency, and innovation.

Further Reading and Resources

- Ideal Gas Law: [Learn more about PV=nRT](https://chemistrytalk.org/ideal-gas-law/)
- Thermodynamics: Explore the principles governing heat and energy transfer
- Gas Law Applications: Case studies in engineering and environmental science

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By mastering the concepts outlined in this article, you'll be better equipped to analyze and predict the behavior of gases in diverse scenarios, ensuring precise control and understanding of these vital components of our physical world.

Frequently Asked Questions

What is the initial temperature of the gas in the problem?

The initial temperature of the gas is 491 K.

What is the final temperature of the gas after cooling?

The final temperature of the gas is 297 K.

Which variable is represented by T in the problem?

T represents the temperature of the gas in Kelvin.

What is the initial volume of the gas given in the problem?

The initial volume of the gas is 524 cm^3.

Which law is applicable for calculating the new volume after temperature change?

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

How do you calculate the final volume of the gas after cooling?

Use the formula $V_2 = V_1 \times (T_2 / T_1)$, where V_1 and T_1 are initial volume and temperature, and V_2 and T_2 are the final volume and temperature.

What is the formula to find the volume when temperature changes at constant pressure?

$V_2 = V_1 \times (T_2 / T_1)$.

What is the approximate volume of the gas after cooling from 491 K to 297 K?

The volume is approximately 317.2 cm^3.

Why is temperature measured in Kelvin in this calculation?

Because Kelvin is the SI unit for temperature and ensures the proportional relationship holds true without negative values.

What is the significance of considering T as 491 K in the problem?

It signifies that T is the initial temperature of the gas, used as a reference point for calculations.

Additional Resources

What Is The Volume When 524 Cm^3 Of A Gas At 491 K Is Cooled To 297 K? Let's Consider 491 K As T. Which Variable?

Understanding how the volume of a gas changes with temperature is a fundamental concept in thermodynamics and gas laws. In this article, we delve into the problem of calculating the new volume of a gas when its temperature decreases from 491 K to 297 K, given an initial volume of 524 cm^3. This problem exemplifies the practical application of the Charles's Law (or the Volume-Temperature Law), which states that the volume of a gas is directly proportional to its temperature when pressure and amount of gas are held constant. We will break down the concepts, derive the relevant equations, analyze the problem step-by-step, and explore the variables involved.

Understanding the Fundamental Concepts

Before directly tackling the problem, it's crucial to understand the key principles and laws that govern the behavior of gases under changing temperature conditions.

Charles's Law and Its Significance

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

$$ V \propto T $$

or mathematically,

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

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 law is derived from the ideal gas law and illustrates that as the temperature increases, the volume increases proportionally, assuming pressure and quantity remain constant.

The Ideal Gas Law and Its Application

The ideal gas law provides a comprehensive relation among pressure P, volume V, temperature T, and amount of gas n:

$$ PV = nRT $$

where R is the universal gas constant. When pressure and the amount of gas are constant, the law simplifies to Charles's Law, which is the basis for our calculations.

Step-by-Step Solution to the Problem

Given data:

- Initial volume, $V_1 = 524\, \text{cm}^3$
- Initial temperature, $T_1 = 491\, \text{K}$
- Final temperature, $T_2 = 297\, \text{K}$

The goal: Find the final volume, V_2.

Step 1: Recognize the Variable as Temperature (T)

In the context of the problem, the variable in question is the temperature (T). The problem explicitly states to consider 491 K as T, which implies that temperature is the key variable affecting volume. Since the pressure and amount of gas are not specified to change, we apply Charles's Law directly.

Step 2: Write the Charles's Law Equation

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

Rearranged to solve for V_2:

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

Step 3: Substitute Known Values

$$
V_2 = 524\, \text{cm}^3 \times \frac{297\, \text{K}}{491\, \text{K}}
$$

Calculating:

$$
V_2 = 524\, \text{cm}^3 \times 0.605
$$

$$
V_2 \approx 317.02\, \text{cm}^3
$$

Hence, the final volume of the gas after cooling from 491 K to 297 K is approximately 317.02 cm^3.

Analysis of the Variables and Assumptions

The problem hinges on understanding the role of the variables involved, primarily temperature. Let's analyze the key factors and assumptions made in this calculation.

The Variable: Temperature (T)

- Temperature (T) is the primary variable affecting the volume in this context.

- The problem explicitly directs us to consider 491 K as T, emphasizing the importance of Kelvin as the absolute temperature scale.
- Since volume varies directly with temperature (Charles's Law), accurate temperature measurement and conversion are crucial.

Assumptions Made

- Constant Pressure: The calculation assumes pressure remains unchanged during cooling.
- Constant Amount of Gas: No gas is added or removed.
- Ideal Gas Behavior: The gas behaves ideally, meaning interactions between molecules are negligible.
- No Phase Changes: The gas remains in vapor form; no condensation occurs at lower temperatures.

Features, Pros, and Cons of Applying Charles's Law

Understanding the features of this law helps contextualize its application.

Features:

- Applicable only when pressure and amount of gas are held constant.
- Valid for ideal gases; deviations may occur with real gases at high pressures or low temperatures.
- Linear relationship between volume and temperature in Kelvin.

Pros:

- Simple to use with straightforward proportionality.
- Useful in various practical scenarios like hot air balloons, gas storage, and thermodynamic calculations.

- Helps in predicting how gases respond to temperature changes.

Cons:

- Limited to conditions where pressure and amount are constant.
- Less accurate for real gases at extreme conditions.
- Does not account for intermolecular forces or phase changes.

Additional Considerations and Real-World Applications

While the calculation appears straightforward, real-world situations often involve complexities:

- Pressure Variations: If pressure isn't constant, Boyle's Law or combined gas law becomes relevant.
- Gas Mixtures: For mixtures, partial pressures and Dalton's law come into play.
- Non-Ideal Behavior: At high pressures or low temperatures, gases deviate from ideality, requiring correction factors.

Applications include:

- Designing pressurized systems.
- Understanding atmospheric phenomena.
- Engineering applications involving gas expansion or compression.

Conclusion

In summary, when 524 cm³ of a gas at 491 K is cooled to 297 K under constant pressure and amount, the volume decreases proportionally with temperature, following Charles's Law. The resulting volume is approximately 317.02 cm³. This problem not only highlights the fundamental relationship between temperature and volume but also reinforces the importance of understanding the variables involved, particularly temperature, and the assumptions underpinning ideal gas behavior.

By applying the straightforward proportionality, we see how temperature acts as a key variable influencing gas volume, and how such principles are essential in both theoretical and practical thermodynamics. Whether in laboratory settings, engineering, or atmospheric science, mastering these concepts provides valuable insight into the behavior of gases under changing conditions.

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