Calculate The New Volume If 12.78 L Of A Gas At -50*C Is Heated To A Temperature Of 28*C

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Understanding how gases behave when subjected to temperature changes is fundamental in chemistry and physics. When a gas is heated or cooled, its volume typically changes, provided the pressure remains constant. This relationship is described by Charles's Law, a key principle in understanding gas laws. In this article, we will explore how to calculate the new volume of a gas when its temperature changes from -50°C to 28°C, starting with an initial volume of 12.78 liters.

Understanding Gas Behavior and Charles's Law

Before delving into the calculation, it's important to understand the core concept behind the problem—Charles's Law.

What Is Charles's Law?

Charles's Law states that, at constant pressure, the volume of a fixed amount of gas is directly proportional to its temperature in Kelvin. Mathematically, it is expressed as:

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

Where:
- V_1 = initial volume
- T_1 = initial temperature in Kelvin
- V_2 = final volume
- T_2 = final temperature in Kelvin

This law implies that if you increase the temperature of a gas, its volume increases proportionally, assuming the pressure remains constant.

Converting Temperatures to Kelvin

Since Charles's Law requires temperatures in Kelvin, the first step is converting the given Celsius temperatures:

- Initial temperature, T_1: -50°C
- Final temperature, T_2: 28°C

The conversion formula:

$$ T(K) = T(°C) + 273.15 $$

Applying this:

- $T_1 = -50 + 273.15 = 223.15\,K$
- $T_2 = 28 + 273.15 = 301.15\,K$

Calculating the New Volume

Using the formula derived from Charles's Law:

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

Plugging in the known values:

$$ V_2 = 12.78\,L \times \frac{301.15\,K}{223.15\,K} $$

Calculating the ratio:

$$ \frac{301.15}{223.15} \approx 1.349 $$

Now, multiply to find the new volume:

$$ V_2 = 12.78\,L \times 1.349 \approx 17.23\,L $$

Therefore, the gas's volume increases to approximately 17.23 liters when heated from -50°C to 28°C.

Step-by-Step Summary of the Calculation

To clarify the process, here is a step-by-step outline:

1. Identify known values:
- Initial volume (V_1): 12.78 L
- Initial temperature (T_1): -50°C

- Final temperature (T_2): 28°C

2. Convert temperatures to Kelvin:
- $T_1 = -50 + 273.15 = 223.15\,K$
- $T_2 = 28 + 273.15 = 301.15\,K$

3. Apply Charles's Law:
- $V_2 = V_1 \times \frac{T_2}{T_1}$

4. Calculate the ratio:
- $\frac{301.15}{223.15} \approx 1.349$

5. Compute the new volume:
- $V_2 = 12.78 \times 1.349 \approx 17.23\,L$

Additional Considerations in Gas Volume Calculations

While the calculation above provides a straightforward method, there are additional factors and scenarios to consider:

Pressure Conditions

- The calculation assumes constant pressure. If pressure varies, Boyle’s Law or combined gas laws must be used.
- Real-world applications often involve pressure changes, requiring more complex calculations.

Ideal Gas Behavior

- The calculations assume gases behave ideally.
- Deviations can occur at high pressures or low temperatures, affecting accuracy.

Practical Applications

- This calculation is useful in engineering, meteorology, and laboratory settings.
- Understanding gas volume changes is vital for designing chemical reactors, breathing apparatus, and weather predictions.

Common Mistakes to Avoid

When performing such calculations, be cautious of:

- Forgetting to convert Celsius to Kelvin.
- Using the wrong ratio or misapplying the law.
- Assuming pressure changes when the problem specifies constant pressure.
- Rounding errors—use sufficient decimal places for accuracy.

Summary and Key Takeaways

- Gas volume changes proportionally with temperature when pressure remains constant.
- Convert all temperatures to Kelvin before calculation.
- Use the formula $V_2 = V_1 \times \frac{T_2}{T_1}$ to find the new volume.
- For the given problem, the volume increases from 12.78 L at -50°C to approximately 17.23 L at 28°C.

Conclusion

Understanding how to calculate the change in gas volume with temperature is a foundational skill in chemistry and physics. By applying Charles's Law and carefully converting temperatures, you can accurately determine how gases expand or contract under different thermal conditions. This knowledge is essential for various scientific and industrial applications, ensuring safe and efficient designs and processes.

Remember: Always verify that pressure remains constant or adjust calculations accordingly, and consider real-world deviations from ideal behavior for precise measurements.

Frequently Asked Questions

What is the initial volume and temperature of the gas?

The initial volume is 12.78 L and the initial temperature is -50°C.

What is the final temperature of the gas in Celsius?

The final temperature of the gas is 28°C.

Which gas law do we use to calculate the change in volume with temperature?

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

What is the formula to calculate the new volume after heating?

The formula is $V2 = V1 (T2 / T1)$, where temperatures are in Kelvin.

How do you convert Celsius temperatures to Kelvin?

Add 273.15 to the Celsius temperature to convert to Kelvin.

What is the calculated new volume of the gas after heating?

The new volume is approximately 19.77 L.

Why is it important to convert temperatures to Kelvin for this calculation?

Because Charles's Law requires absolute temperature in Kelvin to accurately relate temperature and volume changes.

Additional Resources

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Introduction

Understanding the behavior of gases under varying temperature conditions is fundamental in chemistry and physics, especially when applying the ideal gas law. The problem at hand involves calculating the new volume of a gas when its temperature changes from -50°C to 28°C, given its initial volume. This type of calculation is essential in various scientific and industrial applications, including chemical manufacturing, environmental science, and engineering. In this detailed analysis, we will explore the underlying principles, step through the calculations, and discuss the implications and real-world relevance of such a temperature-volume relationship.

Theoretical Foundations: The Ideal Gas Law

Understanding the Ideal Gas Law

The ideal gas law is expressed as:

$$ PV = nRT $$

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

When the amount of gas and pressure are held constant, the law simplifies to relate volume and temperature:

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

This is known as Charles's Law, which states that at constant pressure and amount of gas, the volume is directly proportional to the temperature in Kelvin.

Converting Temperatures to Kelvin

To accurately perform calculations, temperatures must be converted from Celsius to Kelvin:

$$ T(K) = T(°C) + 273.15 $$

- Initial temperature:

$$ T_1 = -50°C + 273.15 = 223.15\,K $$

- Final temperature:

$$ T_2 = 28°C + 273.15 = 301.15\,K $$

Assumptions and Conditions

Before proceeding, it's vital to specify the assumptions:

- Constant pressure: No change in external pressure during heating.
- Constant amount of gas: No gas is added or removed.
- Ideal behavior: The gas behaves ideally, with negligible interactions between particles and negligible volume of particles themselves.

These assumptions are typical in theoretical calculations and often approximate real-world conditions closely, especially at moderate pressures and temperatures.

Step-by-Step Calculation of the Final Volume

Using Charles's Law:

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

Rearranged to solve for V_2:

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

Given:
- $V_1 = 12.78\,L$
- $T_1 = 223.15\,K$
- $T_2 = 301.15\,K$

Calculating:

$$ V_2 = 12.78\,L \times \frac{301.15\,K}{223.15\,K} $$

$$ V_2 \approx 12.78\,L \times 1.349 $$

$$ V_2 \approx 17.23\,L $$

Thus, the new volume of the gas after heating to 28°C is approximately 17.23 liters.

Critical Analysis of the Calculation

Validity of Assumptions

While the calculation hinges on ideal conditions, real gases exhibit deviations, especially at high pressures or low temperatures. Nonetheless, for most laboratory and practical purposes, such an approximation is sufficiently accurate.

Sensitivity to Temperature Variations

The linear relationship between volume and temperature in Kelvin means even small temperature changes can significantly impact volume, emphasizing the importance of precise temperature control in gas-related processes.

Impact of External Conditions

- Pressure: If pressure varies, the relationship becomes more complex, involving Boyle's Law or combined gas law.
- Gas type: Some gases deviate from ideal behavior—especially gases near condensation points or under high pressures—necessitating correction factors.

Broader Implications and Applications

Industrial Processes

In industries such as chemical manufacturing or aerospace, understanding how gases expand with temperature is critical for designing containers, reactors, and safety protocols.

Environmental Science

Accurately modeling the behavior of atmospheric gases under temperature fluctuations aids in climate modeling and pollution control.

Laboratory Settings

Precise calculations of gas volumes under varying conditions are fundamental in experimental design, calibration, and data interpretation.

Potential Sources of Error and Limitations

While the ideal gas law provides a robust foundation, real-world scenarios may introduce errors:

- Non-ideal gas behavior at high pressures or low temperatures.

- Measurement inaccuracies in initial volume or temperature.
- Assumed constant pressure may not hold in dynamic systems.

In such cases, correction factors such as Van der Waals equations can improve accuracy.

Summary and Conclusions

The calculation of the new volume of a gas when heated from -50°C to 28°C demonstrates the practical application of fundamental thermodynamic principles. By converting temperatures to Kelvin and applying Charles's Law, the initial volume of 12.78 liters expands to approximately 17.23 liters upon heating.

This exercise underscores several key points:

- The direct proportionality between temperature and volume at constant pressure.
- The importance of accurate temperature conversions.
- The relevance of ideal gas assumptions in real-world applications.

Understanding these principles enables scientists and engineers to predict and manipulate gas behaviors effectively, ensuring safety, efficiency, and precision in various scientific endeavors.

Final Remarks

Calculations like these form the backbone of thermodynamic analysis, and mastery of the concepts ensures accurate modeling of physical systems. Whether designing a new chemical reactor or predicting atmospheric conditions, the fundamental relationship between temperature and volume remains a cornerstone of scientific investigation.

References

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Note: For exact applications, always consider real gas corrections and experimental conditions.

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