50.0 M3 At 55.1 KPa To 98.7 KPa: _________ M3 (No Temp. Change)

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Understanding the relationship between pressure and volume is fundamental in thermodynamics, especially when dealing with gases. When a gas undergoes a pressure change without any alteration in temperature, its volume adjusts accordingly, adhering to the principles of Boyle's Law. This article explores the calculation of the final volume of a gas initially occupying 50.0 cubic meters at 55.1 KPa when the pressure increases to 98.7 KPa, assuming temperature remains constant.

Introduction to Boyle's Law and Gas Behavior

Understanding Boyle's Law

Boyle's Law states that for a fixed amount of an ideal gas at constant temperature, the volume of the gas is inversely proportional to its pressure. Mathematically, it is expressed as:

\[P_1 V_1 = P_2 V_2 \]

where:
- \(P_1 \) and \(V_1 \) are the initial pressure and volume
- \(P_2 \) and \(V_2 \) are the final pressure and volume

This relationship implies that as pressure increases, the volume decreases, provided the temperature and amount of gas stay constant.

Significance in Practical Applications

Understanding how volume changes with pressure is essential in various fields such as engineering, chemistry, and atmospheric science. Whether designing pressurized containers, calculating gas storage capacities, or modeling atmospheric phenomena, Boyle's Law provides a foundational tool for these calculations.

Calculating Final Volume of Gas at New Pressure

Given Data

To find the final volume, consider the following initial and final conditions:

- Initial Volume, \(V_1 \) = 50.0 m^3

- Initial Pressure, P_1 = 55.1 KPa
- Final Pressure, P_2 = 98.7 KPa
- Temperature remains constant

Applying Boyle's Law

Since temperature is constant, Boyle's Law applies directly. Rearranged to find the final volume:

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

Plugging in the known values:

$$V_2 = \frac{55.1 \ \text{KPa} \times 50.0 \ \text{m}^3}{98.7 \ \text{KPa}}$$

Calculating the numerator:

$$55.1 \times 50.0 = 2755$$

Then dividing:

$$V_2 = \frac{2755}{98.7} \approx 27.89 \ \text{m}^3$$

Therefore, the final volume of the gas at 98.7 KPa is approximately 27.89 m3.

Understanding the Implications of the Calculation

Physical Interpretation

The volume decreases from 50.0 m3 to about 27.89 m3, nearly halving as the pressure nearly doubles from 55.1 KPa to 98.7 KPa. This inverse relationship underscores Boyle's Law: as pressure increases, volume decreases proportionally, assuming temperature remains constant.

Practical Significance

This calculation is crucial in scenarios such as:
- Designing gas storage systems where volume adjustments are needed to accommodate pressure changes
- Calculating the safe limits of pressurized containers
- Understanding how gases behave in natural and industrial processes

It demonstrates the importance of monitoring pressure and volume to ensure safety and efficiency.

Factors Influencing Gas Behavior Beyond Boyle's Law

Temperature Variations

While Boyle's Law assumes constant temperature, real-world situations often involve temperature changes, which would require using the combined gas law:

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

In this case, since temperature remains unchanged, the calculation simplifies, but always consider temperature effects in practical applications.

Gas Realities Versus Ideal Behavior

Boyle's Law applies best to ideal gases. Real gases may deviate slightly due to intermolecular forces and volume of gas particles, especially at high pressures or low temperatures. Using real gas equations, like the Van der Waals equation, can provide more accurate results in such cases.

Additional Considerations and Safety Measures

Pressure Limits and Safety

When compressing gases or increasing pressure, it is vital to know the maximum allowable pressure for the container to prevent rupture or leaks. Calculations like these help determine safe operating conditions.

Temperature Control and Monitoring

Despite the assumption of constant temperature, in practical scenarios, temperature must be monitored and controlled to prevent unintended pressure or volume changes that could compromise safety.

Summary and Key Takeaways

- Boyle's Law states $P_1 V_1 = P_2 V_2$ for gases at constant temperature.
- In this scenario, the initial volume of 50.0 m^3 at 55.1 KPa increases in pressure to 98.7 KPa, resulting in a decreased volume of approximately 27.89 m^3.
- This inverse proportionality underscores the importance of pressure-volume relationships in engineering, chemistry, and safety management.

- Always consider real gas behavior and temperature effects in practical applications for more accurate calculations.

Conclusion

Understanding how a gas's volume responds to pressure changes at constant temperature is essential in numerous scientific and industrial contexts. The calculation of the new volume when the pressure increases from 55.1 KPa to 98.7 KPa, starting from an initial volume of 50.0 m3, exemplifies Boyle's Law in action. Recognizing and applying these principles ensures safety, efficiency, and precision in handling gases across various applications. Always remember to account for real-world variables and safety margins when performing such calculations to ensure reliable and safe operations.

Frequently Asked Questions

What is the significance of changing pressure from 55.1 KPa to 98.7 KPa in a 50.0 M3 container without temperature change?

Changing the pressure affects the volume of the gas, and since temperature remains constant, the volume will adjust according to Boyle's Law, which relates pressure and volume for a fixed amount of gas at constant temperature.

How do you calculate the new volume of a gas when pressure changes at constant temperature?

You can use Boyle's Law: $P1 \times V1 = P2 \times V2$. Rearranged, $V2 = (P1 \times V1) / P2$. Plugging in the known values allows calculation of the new volume.

What is the new volume of the gas when pressure increases from 55.1 KPa to 98.7 KPa, given an initial volume of 50.0 M3?

Using Boyle's Law: $V2 = (55.1 \text{ KPa} \times 50.0 \text{ M3}) / 98.7 \text{ KPa} \approx (2755) / 98.7 \approx 27.9$ M3. So, the new volume is approximately 27.9 M3.

Why does the volume decrease when the pressure increases at constant temperature?

According to Boyle's Law, pressure and volume are inversely proportional at constant temperature. Increasing pressure compresses the gas, reducing its volume.

Are there any assumptions or limitations when applying Boyle's Law in this scenario?

Yes, Boyle's Law assumes ideal gas behavior, constant temperature, and no chemical reactions. Real gases may deviate slightly, especially at high pressures or low temperatures, but for many practical purposes, it provides a good approximation.

Additional Resources

50.0 M3 At 55.1 KPa To 98.7 KPa: __________ M3 (No Temp. Change)

Understanding the behavior of gases under varying pressure conditions is fundamental in fields ranging from engineering and physics to chemistry and environmental science. The statement "50.0 M3 at 55.1 KPa to 98.7 KPa: __________ M3 (No Temp. Change)" encapsulates a classic problem in gas laws, particularly Boyle's Law, which describes how a gas's volume responds to changes in pressure at constant temperature. This article aims to explore this scenario comprehensively, breaking down the fundamental principles, calculations, implications, and practical applications associated with such a transformation.

Introduction to Gas Laws and the Context of the Problem

The problem presented involves a fixed amount of gas, initially occupying a volume of 50.0 cubic meters (M3), subjected to a pressure change from 55.1 KPa to 98.7 KPa, with no change in temperature. The goal is to determine the final volume after this pressure variation.

This scenario is a classic illustration of Boyle's Law, which states that, for a fixed amount of gas at constant temperature, the pressure and volume are inversely proportional:

$$P_1 V_1 = P_2 V_2$$

where:
- P_1 and V_1 are the initial pressure and volume,
- P_2 and V_2 are the final pressure and volume.

Understanding this relationship is crucial for applications such as gas storage, pneumatic systems, breathing apparatus, and industrial processes where controlling volume and pressure is necessary.

Fundamentals of Boyle's Law

Principles and Assumptions

Boyle's Law assumes:
- The amount of gas remains constant.
- Temperature remains constant throughout the process.
- The gas behaves ideally, meaning interactions between molecules are negligible, and the volume of molecules themselves is insignificant compared to the container.

These assumptions simplify real-world behavior but are generally valid under many conditions, especially for gases at moderate pressures and temperatures.

Mathematical Expression

The law can be mathematically expressed as:

$$ P_1 V_1 = P_2 V_2 $$

or

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

This formula allows direct calculation of the final volume once the initial parameters and final pressure are known.

Applying Boyle's Law to the Given Scenario

Given:
- $V_1 = 50.0 \, \text{M}^3$
- $P_1 = 55.1 \, \text{KPa}$
- $P_2 = 98.7 \, \text{KPa}$

Find:
- V_2

Using the formula:

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

Plugging in the known values:

$$ V_2 = \frac{55.1 \times 50.0}{98.7} $$

Calculating numerator:

$$ 55.1 \times 50.0 = 2755 $$

Dividing:

$$ V_2 = \frac{2755}{98.7} \approx 27.88 \, \text{M}^3 $$

Final Volume: approximately 27.88 M3

This calculation indicates that when the pressure increases from 55.1 KPa to 98.7 KPa, the volume decreases from 50.0 M3 to approximately 27.88 M3, assuming temperature remains unchanged.

Implications and Real-World Significance

The straightforward application of Boyle’s Law in this scenario demonstrates the inverse relationship between pressure and volume in gases. This understanding is fundamental across various domains:

- Industrial Gas Storage: Engineers can predict how gas containers will behave under different pressure conditions, ensuring safety and efficiency.
- Pneumatic Systems: Compressed air tools and systems rely on precise calculations of volume and pressure to operate effectively.
- Environmental Science: Understanding how gases expand or compress contributes to modeling atmospheric phenomena and pollutant dispersion.
- Respiratory Physiology: Boyle's Law underpins the mechanics of breathing, where lung volume changes in response to pressure variations.

Practical Applications and Considerations

Designing Gas Containers

Knowledge of how volume changes with pressure helps in designing tanks and cylinders that can withstand specific pressure ranges without failure. Materials must be selected based on expected operational pressures.

Safety Measures

Accurate calculations prevent over-pressurization, which could lead to explosions or leaks. Safety protocols often involve understanding the maximum pressure a container can sustain and how volume adjustments affect internal pressures.

Limitations and Real-World Deviations

While Boyle’s Law provides a reliable approximation, real gases can deviate, especially at high pressures or low temperatures where gas molecules interact more significantly. Factors such as gas compressibility, non-ideal behavior, and container elasticity can influence actual outcomes.

Advantages and Disadvantages of Boyle's Law in Practice

Advantages:
- Simple and easy to use for quick calculations.
- Provides a clear relationship between pressure and volume.
- Fundamental in scientific education and practical engineering.

Disadvantages:
- Assumes ideal gas behavior; less accurate under extreme conditions.
- Ignores temperature variations, which can be significant in some applications.
- Does not account for gas molecule interactions at high pressures.

Extended Considerations: Beyond Boyle's Law

While Boyle's Law is instrumental in understanding basic gas behavior, real-world scenarios often involve multiple variables. For comprehensive analysis, combined gas laws such as Charles's Law and Gay-Lussac's Law come into play, considering temperature and pressure simultaneously.

In some cases, the ideal gas law, $PV = nRT$, provides a more complete picture, especially when the amount of gas changes or temperature varies.

Conclusion: The Significance of the Volume Change Calculation

The calculation of the final volume when a fixed amount of gas is subjected to a pressure change from 55.1 KPa to 98.7 KPa reveals a significant reduction in volume, from 50.0 M3 to approximately 27.88 M3. This exemplifies Boyle’s Law's core principle: pressure and volume are inversely proportional at constant temperature.

Understanding this relationship is essential for designing safe and efficient systems involving gases, from industrial storage tanks to physiological processes. While the law provides a straightforward mathematical framework, practitioners must be aware of its assumptions and limitations, especially when operating outside ideal conditions.

In summary, the scenario underscores the importance of fundamental gas laws in real-world applications and highlights the necessity of precise calculations in engineering, environmental science, and beyond. Whether managing gases in a laboratory, designing a pneumatic system, or understanding atmospheric phenomena, grasping how pressure influences volume without temperature change remains a cornerstone of scientific and engineering endeavors.

50 0 M3 At 55 1 Kpa To 98 7 Kpa M3 No Temp Change

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