A Tank (not Rigid) Contains 2.3L Of Helium Gas At 25C. What Will Be The Volume Of The Tank After Heating

A Tank (not Rigid) Contains 2.3L Of Helium Gas At 25°C. What Will Be The Volume Of The Tank After Heating

Understanding how gases behave under different conditions is fundamental in fields like physics, engineering, and chemistry. When dealing with a non-rigid tank containing helium gas, a key question often arises: if the temperature of the gas increases, what will be the new volume of the tank? This article explores this question by applying the principles of the ideal gas law, considering the characteristics of a non-rigid (flexible) tank, and providing a step-by-step approach to calculating the new volume after heating. Whether you're a student, engineer, or science enthusiast, understanding these concepts is essential for practical applications involving gases and flexible containers.

Understanding the Problem: Helium in a Flexible Tank

Before diving into calculations, it's important to understand the scenario:

- The initial volume of helium gas is 2.3 liters at 25°C.
- The tank is flexible (not rigid), meaning it can expand or contract in response to changes in gas pressure and temperature.
- The temperature will be increased, and we want to find out what the new volume will be after heating.

This setup involves the principles of thermodynamics and gas laws, particularly the ideal gas law, which relates pressure, volume, temperature, and the amount of gas.

Fundamentals of Gas Laws Relevant to the Problem

The Ideal Gas Law

The ideal gas law is expressed as:

$$PV = nRT$$

Where:

- P = pressure of the gas (in atm)
- V = volume of the gas (in liters)

- n = number of moles of gas
- R = ideal gas constant (0.0821 L·atm/(mol·K))
- T = temperature in Kelvin (K)

In this problem:

- The amount of helium (n) remains constant.
- The initial conditions are known.
- The tank is flexible, so volume (V) can change.
- The pressure is assumed to remain constant unless specified otherwise.

Assumptions for the Calculation

To simplify the problem, we make the following assumptions:

- The pressure remains constant during heating (e.g., the tank is open to the atmosphere or designed to maintain constant pressure).
- Helium behaves as an ideal gas.
- No gas leaks occur during heating.
- The amount of gas (n) stays constant.

These assumptions are typical in ideal gas law applications and help focus on the primary variables of temperature and volume.

Calculating the New Volume After Heating

Given the assumptions, we can apply the combined gas law, which relates initial and final states when pressure and amount of gas are constant:

$V_1 / T_1 = V_2 / T_2$

Where:

- V_1 = initial volume = 2.3 L
- T_1 = initial temperature in Kelvin
- V_2 = final volume (unknown)
- T_2 = final temperature in Kelvin

Step 1: Convert Temperatures to Kelvin

To use the gas law correctly, temperatures must be in Kelvin:

- T_1 = 25°C + 273.15 = 298.15 K

Suppose the gas is heated to a new temperature T_2. For demonstration, assume the temperature is increased to 100°C:

- T_2 = 100°C + 273.15 = 373.15 K

If the problem specifies a different temperature, simply substitute that value.

Step 2: Apply the Gas Law to Find V_2

Using the relation:

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

Plugging in the values:

$V_2 = 2.3\text{ L} \times (373.15\text{ K} / 298.15\text{ K})$

Calculating:

- $V_2 \approx 2.3\text{ L} \times 1.253 \approx 2.88\text{ L}$

Therefore, after heating from 25°C to 100°C, the volume of helium in the tank will increase to approximately 2.88 liters.

Implications of a Non-Rigid Tank

Since the tank is not rigid, it can expand in response to the increase in gas volume caused by heating. This is an important factor because:

- The volume of the tank will adjust to maintain pressure (assuming constant pressure).
- The final volume will be proportional to the temperature increase, as per the ideal gas law.

This behavior contrasts with rigid tanks, where the volume remains constant regardless of temperature changes, often leading to increased pressure.

Practical Applications and Considerations

Understanding how the volume of helium changes with temperature is critical in various practical scenarios:

- Balloon and Blimp Design: Engineers must account for volume expansion when helium balloons are heated by sunlight.
- Gas Storage Safety: Storage tanks designed to hold gases like helium must accommodate volume changes to prevent ruptures.
- Industrial Processes: Accurate calculations ensure proper handling and control of gases in

manufacturing environments.

However, real-world applications often involve factors like non-ideal gas behavior, pressure variations, and tank material limits, which should be considered for precise analysis.

Additional Factors to Consider

While the ideal gas law provides a good approximation, real gases and practical systems may deviate from this ideal behavior due to:

- **Non-ideal Gas Behavior:** At high pressures or low temperatures, gases deviate from ideality.
- **Pressure Changes:** If the pressure isn't maintained constant, both pressure and volume will change in response to temperature.
- **Tank Material Limitations:** The tank's material may have maximum allowable expansion or pressure tolerances.
- **Leakage or Loss of Gas:** Over time, gases may escape, affecting the total amount of gas and volume calculations.

Careful consideration of these factors ensures safe and accurate applications in real-world scenarios.

Summary and Final Thoughts

In summary, when a non-rigid tank containing helium gas is heated, its volume expands proportionally to the temperature increase, provided pressure remains constant. Using the ideal gas law, the calculation involves converting temperatures to Kelvin and applying the relation $V_2 = V_1 \times (T_2 / T_1)$. For example, heating helium from 25°C to 100°C increases its volume from 2.3 liters to approximately 2.88 liters.

Understanding this behavior is essential for designing safe storage systems, predicting gas behavior in various environments, and ensuring the integrity of flexible containers. Always consider real-world factors that can influence these idealized calculations, and consult engineering standards when applying these principles practically.

Whether you're working on scientific experiments, industrial applications, or educational projects, mastering the relationship between temperature and volume in gases will enhance your ability to predict and control gas behavior effectively.

Frequently Asked Questions

How does heating affect the volume of a non-rigid helium tank at constant pressure?

Heating increases the temperature of the helium gas, causing its volume to expand proportionally, according to Charles's Law, assuming the tank is flexible and pressure remains constant.

What is the formula to calculate the new volume of helium after heating in a flexible tank?

The formula is V2 = V1 (T2 / T1), where V1 is the initial volume, T1 is the initial temperature in Kelvin, T2 is the final temperature in Kelvin, and V2 is the final volume.

Given initial conditions of 2.3L helium at 25°C, what will be the volume after heating to 50°C?

Convert temperatures to Kelvin: 25°C = 298K, 50°C = 323K. Using V2 = V1 (T2 / T1): V2 = 2.3L (323 / 298) ≈ 2.3L 1.085 ≈ 2.5L. So, the volume will be approximately 2.5 liters.

Why is it important that the tank is non-rigid when calculating the volume change due to heating?

Because a non-rigid (flexible) tank allows the volume to change with temperature, following gas laws. Rigid tanks do not change volume, so temperature changes would not affect volume in that case.

What assumptions are made when calculating the volume change of helium in a flexible tank upon heating?

The assumptions include that the pressure remains constant, the gas behaves ideally, and the tank's material can expand freely without any constraints.

Additional Resources

Helium Tank Volume Expansion Upon Heating: An In-Depth Analysis

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Introduction

When dealing with gases stored under pressure or within containers, understanding how temperature affects their volume is fundamental—be it in industrial applications, scientific research, or recreational uses such as balloons and airships. Today, we focus on a specific scenario: a non-rigid tank containing 2.3 liters of helium gas at 25°C. Our goal is to determine what the volume of the tank will be after heating the helium to a higher temperature.

This analysis combines principles from thermodynamics, gas laws, and practical engineering considerations, providing a comprehensive understanding of the phenomena involved.

The Scenario in Detail

Imagine a flexible, non-rigid tank—think of a balloon or a flexible container—that currently holds 2.3 liters of helium gas at a temperature of 25°C (which is 298.15 K in Kelvin). Now, suppose we heat this tank to a higher temperature. The question is: what will be the new volume of the tank?

Before diving into calculations, it's essential to clarify key points:

- Non-rigid tank: It can expand or contract depending on internal pressure and temperature changes.
- Helium gas: An ideal gas approximation is often valid at standard conditions, but real gas effects might be negligible for this analysis.
- Heating process: Assume the process is quasi-static (slow enough for equilibrium to be maintained) and occurs at constant pressure (or constant initial pressure, depending on context).

Fundamental Principles and Gas Laws

The core principle governing the behavior of gases under changing conditions is the Ideal Gas Law:

$$
PV = nRT
$$

Where:

- P = pressure (in atmospheres or Pascals)
- V = volume (in liters or cubic meters)
- n = number of moles of gas
- R = ideal gas constant ($8.314\, \mathrm{J\,mol^{-1}\,K^{-1}}$)
- T = temperature in Kelvin

For our problem, the key variables are V, T, and n. Since the amount of helium remains constant (no gas added or removed), n stays the same.

Modeling the Heating Process

The critical assumptions are:

- Closed system: The amount of helium remains unchanged.
- Constant pressure: The tank can expand freely, allowing pressure to remain constant during

heating.
- Ideal gas behavior: At the given conditions, helium behaves approximately as an ideal gas.

Given these assumptions, the relation simplifies to:

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

Where:

- $V_1 = 2.3\, \mathrm{L}$, initial volume
- $T_1 = 25^\circ C = 298.15\, \mathrm{K}$
- $V_2 = ?$, volume after heating
- $T_2 =$ final temperature in Kelvin

Determining the Final Volume After Heating

Suppose the tank is heated to a new temperature T_2. For example, if the temperature is increased to 100°C (373.15 K), the volume change can be calculated as:

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

Plugging in numbers:

$$
V_2 = 2.3\, \mathrm{L} \times \frac{373.15\, \mathrm{K}}{298.15\, \mathrm{K}} \approx 2.3\, \mathrm{L} \times 1.253 \approx 2.88\, \mathrm{L}
$$

This means that if the tank were perfectly flexible and pressure remained constant, its volume would increase from 2.3 L to approximately 2.88 liters when heated from 25°C to 100°C.

Key takeaway: The volume of a non-rigid tank containing helium expands proportionally with temperature when pressure is held constant.

Exploring Different Heating Scenarios

The above calculation assumes the tank can freely expand to maintain constant pressure. However, in real-world applications, the final volume depends on the constraints and pressure conditions.

1. Constant Pressure Conditions

- The tank is flexible, and pressure is maintained at atmospheric pressure.
- Volume increases with temperature as shown.

2. Constant Volume Conditions

- The tank is rigid, and volume remains fixed.
- Heating increases internal pressure, which can be calculated via:

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

- The internal pressure would rise proportionally with temperature, possibly reaching safety limits.

3. Adiabatic or Other Conditions

- If the process occurs quickly or with heat exchange constraints, different models apply.

For our purposes, assuming the tank is non-rigid and pressure remains constant provides a straightforward, practical approach.

Practical Implications and Engineering Considerations

Understanding the volume change with temperature is critical for:

- Safety: Over-expansion can compromise tank integrity.
- Design: Ensuring the tank can accommodate volume changes without failure.
- Calibration: Knowing how volume varies with temperature aids in precise measurements.

Safety factors include:

- Material flexibility: The tank must withstand expansion without rupturing.
- Pressure relief mechanisms: To prevent overpressure situations.
- Material properties: Helium’s behavior at high temperatures, though generally ideal, can deviate at very high temperatures or pressures.

Real-World Applications

This fundamental understanding is essential in various fields:

Application	Relevance
Ballooning & Airships	Helium expands with temperature; knowing volume changes informs safety protocols.
Scientific Laboratories	Precise control of gas volumes in experiments requires understanding thermal expansion.
Industrial Gas Storage	Designing flexible tanks that accommodate temperature-induced volume changes ensures safety and efficiency.
Cryogenics & Space Missions	Managing helium in variable thermal environments demands detailed thermodynamic modeling.

Additional Factors to Consider

While the ideal gas law provides a solid approximation, real-world scenarios might involve:

- Non-ideal gas effects: At high pressures or low temperatures, deviations occur.
- Material constraints: Tank elasticity limits.
- Temperature gradients: Uneven heating can cause localized stresses.
- Gas purity and impurities: Can influence expansion behavior.

For high-precision applications, correction factors or real gas equations (like Van der Waals) might be employed.

Summary

In conclusion, for a non-rigid tank containing helium gas at 25°C with an initial volume of 2.3 liters, heating the gas to a higher temperature at constant pressure leads to a proportional increase in volume:

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

- Example: Heating from 25°C (298.15 K) to 100°C (373.15 K):

$$
V_2 \approx 2.88\, \text{L}
$$

- Implication: The tank's volume expands by approximately 25%, demonstrating the importance of designing flexible containers that can accommodate thermal expansion.

This analysis underscores the importance of understanding thermodynamic principles in designing safe, efficient storage systems for gases like helium, especially when temperature variations are involved. Whether in scientific research, industrial processes, or recreational applications, anticipating how gases behave under changing thermal conditions ensures safety, accuracy, and optimal performance.

Final Thoughts

Leveraging fundamental gas laws allows engineers and scientists to predict and manage the behavior of gases in dynamic environments. As we've seen, temperature plays a pivotal role in determining the volume of helium in a non-rigid container. Properly accounting for these changes is crucial for safety, efficiency, and precision in any application involving helium storage and use.

Note: Always consider real-world safety margins and consult relevant standards when designing or working with pressurized gases to prevent accidents and ensure compliance.

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