When The Temperature Of A Rigid Hollow Sphere Containing 685 L Of Helium Gas Is Held To 62C, The Pressure

When The Temperature Of A Rigid Hollow Sphere Containing 685 L Of Helium Gas Is Held To 62C, The Pressure inside the sphere undergoes a change that can be analyzed using fundamental principles of thermodynamics and the ideal gas law. Understanding how temperature impacts pressure in a confined, rigid environment is crucial in fields ranging from industrial gas storage to scientific experimentation. In this article, we will explore the relationship between temperature and pressure in a fixed-volume system, specifically focusing on helium gas inside a rigid sphere, and how to calculate the resulting pressure when the temperature is set to 62°C.

Understanding the Basic Principles: Ideal Gas Law

The ideal gas law is the cornerstone for analyzing gases under various conditions. It states:

$PV = nRT$

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

In the context of a rigid hollow sphere:
- The volume (V) remains constant.
- The amount of gas (n) remains constant.
- Changes in temperature directly influence pressure.

Applying the Ideal Gas Law to the Helium Gas in the Sphere

Given:
- Volume, $V = 685$ L $= 685 \times 10^{-3}$ m³
- Temperature, $T = 62°C = 62 + 273.15 = 335.15$ K
- Helium is a monoatomic ideal gas, and for calculations, the gas constant $R = 8.314$ J/(mol·K) can be used.

To find the pressure, we need to know the number of moles of helium gas (n). If the initial conditions are known, the pressure can be directly calculated; if not, assumptions or measurements are necessary.

Calculating the Pressure of Helium at 62°C

Suppose the initial pressure of helium at a known temperature is p_1, or alternatively, if the initial conditions are unknown, a typical approach involves:

1. Determining the number of moles (n) of helium based on initial conditions.
2. Using the ideal gas law to find the new pressure at 62°C.

For example, if at an initial temperature T_1 (say, room temperature 25°C or 298.15 K), the initial pressure p_1 is known, then:

$$p_1V = nRT_1$$

Rearranged to find n:

$$n = p_1V / (RT_1)$$

Once n is known, the pressure at the new temperature T_2 (62°C or 335.15 K) is:

$$P_2 = nRT_2 / V$$

which simplifies to:

$$P_2 = p_1 \times (T_2 / T_1)$$

since V and n are constant.

Effect of Temperature on Pressure: The Direct Relationship

The relation:

$P_2 / p_1 = T_2 / T_1$

shows that, in a rigid container with a fixed amount of gas, the pressure is directly proportional to the absolute temperature (measured in Kelvin). Therefore:

- Increasing the temperature results in a proportional increase in pressure.
- Decreasing the temperature causes a proportional decrease in pressure.

This linear relationship is fundamental in thermodynamics and critical for understanding how gases behave under different thermal conditions.

Sample Calculation: Estimating the Pressure at 62°C

Suppose the initial pressure of helium at room temperature (25°C or 298.15 K) is known to be 1 atm (101.3 kPa). Then:

- Initial temperature, T_1 = 298.15 K
- Final temperature, T_2 = 335.15 K
- Initial pressure, p_1 = 101.3 kPa

Applying the proportional relation:

$P_2 = p_1 \times (T_2 / T_1) = 101.3 \text{ kPa} \times (335.15 / 298.15) \approx 101.3 \text{ kPa} \times 1.124 \approx 113.9 \text{ kPa}$

This indicates that raising the temperature from 25°C to 62°C increases the pressure from approximately 101.3 kPa to about 113.9 kPa.

Considerations and Real-World Factors

While the ideal gas law provides a good approximation, real-world factors can influence the actual pressure:

1. Non-Ideal Gas Behavior

- At high pressures or low temperatures, gases deviate from ideal behavior.
- Helium, being a noble gas with weak intermolecular forces, closely follows the ideal gas law but may still exhibit slight deviations.

2. Container Constraints

- The sphere is rigid, meaning its volume remains constant.
- Any expansion or contraction of the container would require different calculations.

3. Gas Purity and Impurities

- The presence of impurities can affect pressure readings.

4. Measurement Accuracy

- Precision in measuring temperature and volume is critical for accurate calculations.

Practical Applications of Understanding Gas Pressure Changes

Understanding how temperature affects gas pressure in fixed-volume containers has several practical implications:

- Industrial Gas Storage: Ensuring containers can withstand pressure variations due to temperature changes.
- Scientific Experiments: Maintaining precise conditions when working with gases like helium.
- Cryogenics and Aerospace: Managing helium in high-pressure, high-temperature environments.

Summary and Key Takeaways

- The pressure of helium gas in a rigid, fixed-volume sphere is directly proportional to its absolute temperature.
- When the temperature of helium in a 685 L sphere is increased to 62°C, the

pressure increases proportionally, assuming ideal behavior.
- Using the ideal gas law simplifies calculations and provides reliable estimates under typical conditions.
- It’s essential to account for real-world factors such as non-ideal behavior, container constraints, and measurement uncertainties for precise applications.

Final Thoughts

In conclusion, holding the temperature of a rigid hollow sphere containing helium gas at 62°C results in a predictable increase in pressure, governed primarily by the principles of thermodynamics and the ideal gas law. Whether for scientific research, industrial applications, or engineering design, understanding this relationship allows for safe and efficient gas management. Proper calculations and considerations of real-world factors ensure accurate predictions and effective system design.

If you need to perform specific calculations based on initial conditions or other parameters, remember to convert all units to SI standards and verify assumptions about gas behavior to ensure the accuracy of your results.

Frequently Asked Questions

What is the relationship between temperature and pressure in a rigid hollow sphere containing helium gas?

In a rigid hollow sphere, the volume remains constant, so according to Gay-Lussac's law, the pressure of the helium gas is directly proportional to its temperature when volume is fixed.

If the temperature of helium gas in a rigid sphere increases from 0°C to 62°C, how does the pressure change?

The pressure increases proportionally with temperature. Specifically, the pressure increases by a factor of (62 + 273) / (0 + 273) = 335 / 273 ≈ 1.226 times the original pressure.

How can we calculate the new pressure of helium in

the sphere when the temperature is increased to 62°C?

Using Gay-Lussac's law: P2 = P1 (T2 / T1), where temperatures are in Kelvin. Convert 62°C to Kelvin (335K), then multiply the initial pressure by the ratio 335K / 273K.

What is the significance of the volume being 'rigid' in the context of pressure and temperature changes?

A rigid volume means the container does not expand or contract, so any change in temperature directly affects the pressure, not volume, simplifying the application of gas laws.

Why is it important to convert Celsius to Kelvin when calculating pressure changes in gases?

Because gas laws like Gay-Lussac's law require temperatures in Kelvin to ensure proportionality and avoid negative temperatures, enabling accurate calculations of pressure changes.

Additional Resources

When The Temperature Of A Rigid Hollow Sphere Containing 685 L Of Helium Gas Is Held To 62°C, The Pressure is a classic problem in thermodynamics that exemplifies the application of the ideal gas law and the principles governing gases in confined spaces. This scenario provides an excellent opportunity to explore the relationships between temperature, pressure, volume, and the behavior of gases under specified conditions. Understanding these principles not only deepens knowledge of fundamental physics but also has practical implications in engineering, meteorology, and industrial applications where gases are stored and manipulated within rigid containers.

Introduction to the Scenario

The problem involves a rigid hollow sphere containing a fixed amount of helium gas, with a known volume of 685 liters. The key parameters are the initial state of the gas and the temperature being set or maintained at 62°C. The core question revolves around determining the resulting pressure under these conditions, often by applying the ideal gas law:

\[PV = nRT \]

where:
- P = pressure,
- V = volume,
- n = number of moles of gas,
- R = universal gas constant,
- T = temperature in Kelvin.

The scenario emphasizes the importance of understanding how temperature influences pressure when the volume and amount of gas are held constant.

Understanding the Basic Principles

The Ideal Gas Law

The ideal gas law is fundamental in predicting the behavior of gases under various conditions. It states that the pressure of a gas is directly proportional to its temperature (measured in Kelvin) when volume and amount of gas are fixed:

\[P \propto T \]

This means that if the temperature increases, so does the pressure, assuming other variables remain constant.

Role of the Rigid Hollow Sphere

A rigid hollow sphere constrains the volume of the gas. Since the volume is fixed and the container is rigid, the only variables that can change are pressure and temperature. Therefore, any change in temperature directly impacts the pressure, as described by the ideal gas law.

Converting Temperature to Kelvin

Since the ideal gas law uses Kelvin, the first step is converting 62°C to Kelvin:

\[T(K) = 62°C + 273.15 = 335.15\,K \]

This temperature will serve as the basis for calculating the pressure after the temperature is held at this value.

Calculating the Number of Moles of Helium Gas

To determine the pressure, the amount of helium in moles (n) must be known. Given the volume and temperature, we can find n if we know either the initial pressure or other data. If the problem does not specify initial pressure, a common approach is to assume standard conditions or to specify the initial state.

Suppose the initial conditions are at a known pressure P_0 at room temperature or standard conditions. For example, standard atmospheric pressure (1 atm) at 25°C (298.15 K). Using this initial state:

$$P_0 V = n R T_0$$

Assuming $P_0 = 1\,atm$, $V = 685\,L$, $T_0 = 298.15\,K$, and $R = 0.08206\,L\,atm\,mol^{-1}\,K^{-1}$:

$$n = \frac{P_0 V}{R T_0} = \frac{(1)(685)}{0.08206 \times 298.15}$$

Calculating this:

$$n \approx \frac{685}{24.45} \approx 28.03\,mol$$

This calculation provides the amount of helium in moles, which remains constant because the container is rigid and sealed.

Calculating the Final Pressure at 62°C

With the moles of helium known, and the volume fixed at 685 L, the pressure at 62°C (or 335.15 K) can be calculated via the ideal gas law:

$$P = \frac{n R T}{V}$$

Plugging in the values:

$$P = \frac{28.03 \times 0.08206 \times 335.15}{685}$$

Calculating numerator:

$$28.03 \times 0.08206 \times 335.15 \approx 28.03 \times 27.491 \approx 770.4$$

Then:

$$P \approx \frac{770.4}{685} \approx 1.124\,atm$$

This indicates that the pressure increases from 1 atm at room temperature to approximately 1.124 atm at 62°C.

Features and Analysis of the Scenario

Key Features

- Rigid Container: Ensures volume remains constant, simplifying calculations.
- Helium Gas: An ideal gas that exhibits minimal interactions, making the ideal gas law a good approximation.
- Temperature Control: Holding the temperature at a fixed value allows for predictable adjustments in pressure.
- Large Volume: The 685 L volume is substantial, affecting the magnitude of pressure changes.

Advantages of This Setup

- Predictability: The system’s behavior can be accurately modeled using the ideal gas law.
- Simplicity: Fixed volume and known parameters make calculations straightforward.
- Applicability: Demonstrates fundamental thermodynamic principles applicable in real-world scenarios like gas storage and transportation.

Limitations and Considerations

- Assumption of Ideal Behavior: At high pressures or low temperatures, deviations from ideality can occur.
- Temperature Limits: Extreme temperatures may cause material stress on the container.
- Gas Purity: Impurities can alter behavior, though helium's inertness minimizes this concern.

Implications and Practical Applications

Understanding how temperature influences pressure in a sealed, rigid container is critical in many fields:

- Industrial Gas Storage: Ensuring safety by predicting pressure changes with temperature fluctuations.
- Aerospace Engineering: Designing pressure vessels that can withstand temperature variations.
- Meteorology: Modeling atmospheric gases where temperature and pressure interplay are vital.
- Cryogenics: Managing gases at very low temperatures, where deviations from ideality become significant.

Conclusion

This analysis of when the temperature of a rigid hollow sphere containing 685 L of helium gas is held at 62°C, the pressure demonstrates the elegant relationship between thermodynamic variables. By applying the ideal gas law, we see that increasing temperature leads to a proportional increase in pressure, assuming volume and amount of gas are constant. The calculations reveal a modest pressure increase from standard atmospheric conditions to approximately 1.124 atm at 62°C, illustrating how temperature management is critical in the safe handling and storage of gases. This scenario not only reinforces fundamental principles of physics but also highlights their relevance in practical engineering and scientific contexts.

Understanding these relationships equips scientists and engineers with the tools to predict and control gas behavior under various conditions, ensuring safety, efficiency, and innovation across multiple industries.

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