What Is The Change In Entropy When 94.7 G Of Neon Gas Undergoes Isothermal Contraction

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Understanding the change in entropy during the isothermal contraction of neon gas provides valuable insights into thermodynamic processes, especially in the context of ideal gases. This article explores the concept of entropy, the principles governing isothermal processes, and the detailed calculation of entropy change for neon gas undergoing such a process. Whether you're a student, educator, or enthusiast in thermodynamics, this comprehensive guide will clarify the key concepts and calculations involved.

Introduction to Entropy and Thermodynamic Processes

What Is Entropy?

Entropy, often denoted by the symbol S, is a fundamental thermodynamic property that measures the degree of disorder or randomness in a system. It also quantifies the number of microscopic configurations that correspond to a thermodynamic state. In simple terms, higher entropy indicates a more disordered system, while lower entropy suggests a more ordered state.

The concept of entropy is central to the second law of thermodynamics, which states that in an isolated system, entropy tends to increase or remain constant over time. This law underpins the irreversibility of natural processes and helps predict the spontaneity of reactions.

Thermodynamic Processes and Isothermal Contraction

Thermodynamic processes describe how a system's state variables—such as pressure, volume, temperature, and entropy—change over time. Common processes include isothermal, adiabatic, isobaric, and isochoric changes.

Isothermal process: A process occurring at constant temperature (T). For an ideal gas, this implies that the internal energy remains unchanged, as internal energy depends only on temperature.

Isothermal contraction: When a gas contracts at constant temperature, its volume decreases, leading to an increase in pressure if the amount of gas remains constant. This process is vital in understanding real-world phenomena like gas compression, refrigeration cycles, and the behavior of gases in various thermodynamic systems.

Properties of Neon Gas Relevant to the Calculation

Before diving into calculations, it's essential to understand the properties of neon gas pertinent to the process:

- Neon is a noble gas, chemically inert, with a monatomic structure.
- It behaves approximately as an ideal gas under standard conditions.
- Molar mass of neon (M): approximately 20.18 g/mol.
- Ideal gas constant (R): 8.314 J/(mol·K).

Given mass of neon gas: 94.7 grams.

Calculating the Number of Moles of Neon

Since entropy change calculations involving ideal gases are typically expressed per mole or in terms of molar quantities, the first step is to find the number of moles (n):

$$
n = \frac{\text{mass}}{\text{molar mass}} = \frac{94.7\, \text{g}}{20.18\, \text{g/mol}} \approx 4.695\, \text{mol}
$$

This value will be used in subsequent calculations.

Understanding the Isothermal Process for Neon Gas

In an isothermal process, the temperature remains constant. For an ideal gas, the internal energy (U) depends solely on temperature, so:

$$
\Delta U = 0
$$

because temperature does not change.

The work done (W) during an isothermal contraction or expansion is given by:

$$
W = nRT \ln \left(\frac{V_f}{V_i} \right)
$$

where:

- V_i: initial volume,
- V_f: final volume,
- T: absolute temperature in Kelvin,
- n: number of moles,
- R: ideal gas constant.

The change in entropy (ΔS) for an ideal gas during an isothermal process can be derived from the fundamental thermodynamic relation:

$$
\Delta S = \int \frac{\delta Q_{rev}}{T}
$$

For an ideal gas, this simplifies to:

$$
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right)
$$

\]

since the heat exchanged in an isothermal process for an ideal gas is:

\[
Q_{rev} = W = n R T \ln \left(\frac{V_f}{V_i} \right)
\]

Calculating the Change in Entropy for Neon Gas

To determine the change in entropy, we need the ratio of the final to initial volume (\(V_f / V_i\)). This ratio depends on the specifics of the process—namely, how much the gas has contracted.

Assumption: Let's assume the initial and final states are characterized by known pressures or volumes, or that the process involves a specific pressure change at constant temperature.

For demonstration purposes, suppose:

- Initial pressure \(P_i\),
- Final pressure \(P_f\),
- Both at temperature T.

From the ideal gas law:

\[
PV = nRT
\]

which implies:

\[
\frac{V_f}{V_i} = \frac{P_i}{P_f}
\]

because \(T\) and \(n\) are constant.

Sample Calculation with Hypothetical Pressures

Suppose:

- Initial pressure \(P_i = 1\, \text{atm}\),
- Final pressure \(P_f = 2\, \text{atm}\),
- Temperature \(T = 300\, \text{K}\).

Then:

\[
\frac{V_f}{V_i} = \frac{P_i}{P_f} = \frac{1}{2} = 0.5
\]

The change in entropy:

$$
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right) = 4.695\, \text{mol} \times 8.314\, \text{J/(mol·K)} \times \ln(0.5)
$$

Calculating:

$$
\ln(0.5) = -0.6931
$$

$$
\Delta S = 4.695 \times 8.314 \times (-0.6931) \approx -4.695 \times 8.314 \times 0.6931
$$

$$
\approx -4.695 \times 5.759 \approx -27.02\, \text{J/K}
$$

This negative value indicates a decrease in entropy during contraction at constant temperature, consistent with the intuitive understanding that reducing volume (and thus increasing pressure) decreases the system's entropy.

General Formula for Entropy Change in Isothermal Processes

The general expression for entropy change in an ideal gas during an isothermal process is:

$$
\boxed{
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right)
}
$$

or equivalently, in terms of pressures:

$$
\Delta S = n R \ln \left(\frac{P_i}{P_f} \right)
$$

This relation emphasizes that the entropy change depends on the initial and final states, which can be characterized by pressure, volume, or temperature.

Implications and Real-World Applications

Understanding entropy change during isothermal contraction is fundamental in many practical and theoretical contexts:

- Refrigeration cycles: Many refrigeration systems operate through isothermal compression or expansion, where entropy change analysis helps optimize efficiency.
- Gas storage: Compressed gas cylinders involve isothermal processes during filling and dispensing.

- Thermodynamic efficiency: Calculating entropy changes informs the second law analysis of engines and other energy systems.
- Cryogenics: Neon is used in cryogenic applications, and understanding entropy changes during phase changes or contractions aids in designing efficient cooling systems.

Conclusion

The change in entropy when 94.7 grams of neon gas undergoes an isothermal contraction depends primarily on the ratio of the initial and final volumes or pressures. For an ideal gas, the fundamental relation:

$$
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right)
$$

provides a straightforward way to compute entropy change based on known initial and final states.

In the case of neon, with approximately 4.695 mols, the specific entropy change can be calculated once the process specifics—such as pressure or volume ratios—are known. Typically, a contraction at constant temperature results in a negative entropy change, reflecting increased order in the system.

Understanding these thermodynamic principles is essential for designing and analyzing systems involving gases, whether in industrial applications, scientific research, or theoretical studies. Mastery of entropy calculations enhances our ability to predict system behavior, optimize processes, and develop more efficient energy systems.

Additional Resources

- Textbooks on Thermodynamics: "Fundamentals of Engineering Thermodynamics" by Moran and Shapiro.
- Online calculators for ideal gas properties.
- Scientific articles on entropy and thermodynamic cycles involving noble gases.
- Educational videos explaining entropy and isothermal processes.

By mastering the calculation of entropy changes in gases like neon, engineers and scientists can better understand energy transformations and improve technological applications across multiple industries.

Frequently Asked Questions

What is the formula to calculate the change in entropy for isothermal contraction of neon gas?

The change in entropy (ΔS) for an ideal gas during an isothermal process is given by $\Delta S = nR \ln(V_f/V_i)$, where n is the number of moles, R is the gas constant, and V_f and V_i are the final and initial volumes respectively.

How do you determine the number of moles of 94.7 g of neon gas?

Number of moles n = mass / molar mass. Neon has a molar mass of approximately 20.18 g/mol, so n = 94.7 g / 20.18 g/mol ≈ 4.69 mol.

What assumptions are made when calculating entropy change for neon gas in this process?

Assumptions include that neon behaves as an ideal gas, the process is perfectly isothermal, and there are no additional heat exchanges or work interactions beyond the volume change.

How does the temperature affect the change in entropy during the isothermal process?

In an ideal gas, the change in entropy during an isothermal process depends on volume change and is independent of temperature, assuming temperature remains constant throughout.

What additional information is needed to compute the actual change in entropy for neon gas during contraction?

The initial and final volumes (or pressures), or the ratio of these volumes, are needed to compute the entropy change using $\Delta S = nR \ln(V_f/V_i)$.

Can you estimate the change in entropy if the volume of neon gas halves during contraction?

Yes. If the volume halves ($V_f = V_i/2$), then $\Delta S = nR \ln(1/2) = -nR \ln(2)$. Substituting $n \approx 4.69$ mol and $R \approx 8.314$ J/mol·K, $\Delta S \approx -4.69 \times 8.314 \times 0.693 \approx -26.9$ J/K.

What is the significance of the negative sign in the entropy change calculation during contraction?

A negative ΔS indicates a decrease in entropy, meaning the system becomes more ordered as the gas contracts at constant temperature.

How does the concept of entropy relate to the second law of thermodynamics in this context?

The second law states that the total entropy of an isolated system never decreases. During isothermal contraction, the system's entropy decreases, but the surroundings gain entropy, ensuring total entropy increases or remains constant in ideal conditions.

Is it possible for the entropy of neon gas to increase during contraction, and under what circumstances?

In an ideal, purely isothermal contraction, entropy decreases. However, if heat is added or other processes occur, the entropy could increase elsewhere in the system or surroundings, but for the process itself, entropy decreases within the gas during contraction.

Additional Resources

Entropy

Understanding the thermodynamic behavior of gases, especially during processes like contraction or expansion, is fundamental in fields ranging from chemical engineering to atmospheric science. Today, we delve into a specific scenario: the change in entropy when 94.7 grams of neon gas undergoes an isothermal contraction. This

analysis not only helps clarify core principles of thermodynamics but also offers practical insights applicable in various scientific and industrial contexts.

Introduction to the Scenario

Imagine a sealed container filled with neon gas—an inert noble gas known for its stability and distinctive glow in neon signs. We consider a process where this neon gas, initially at a certain pressure and temperature, undergoes an isothermal contraction—meaning the temperature remains constant throughout the process.

The key question: What is the change in entropy of the neon gas during this isothermal contraction? To answer this, we must understand the nature of the process, the properties of neon, and the thermodynamic principles involved.

Fundamental Concepts and Definitions

What is Entropy?

Entropy, often denoted as S, is a thermodynamic property representing the degree of disorder or randomness in a system. In simple terms, it measures how much energy disperses or spreads out during a process. An increase in entropy signifies a move towards greater disorder, while a decrease indicates a more ordered state.

Mathematically, for reversible processes, the change in entropy is given by:

$$
\Delta S = \int \frac{\delta Q_{\text{rev}}}{T}
$$

where:
- δQ_{rev} is the heat exchange during a reversible process,
- T is the absolute temperature (in Kelvin).

In an isothermal process, because the temperature remains constant, the calculation simplifies, especially for ideal gases.

Properties of Neon Gas

Neon is a noble gas with the following key properties:
- Atomic mass: approximately 20.18 g/mol
- Critical temperature: approximately 44.4 K
- Ideal gas behavior at standard conditions
- Monatomic, simplifying thermodynamic calculations

Given its monatomic nature, neon's thermodynamic properties can be approximated using ideal gas laws and specific heat capacities.

The Isothermal Contraction Process

Understanding Isothermal Process

An isothermal process occurs at a constant temperature. For gases, this implies that any change in volume is compensated by heat exchange with the surroundings to maintain the temperature.

In a typical contraction:
- The gas volume decreases.
- The pressure increases (since $PV = nRT$).
- No change in internal energy ($\Delta U = 0$ for ideal gases, as internal energy depends only on temperature).

Relevance of Isothermal Conditions

Maintaining an isothermal process in practical scenarios often involves:
- Conducting the process slowly to allow heat exchange.
- Using a thermal reservoir to absorb or supply heat.
- Ensuring the process is quasi-static for reversibility.

The reversible nature of the process is essential in calculating the maximum possible change in entropy.

Calculating the Change in Entropy of Neon During Isothermal Contraction

Step 1: Determine the Number of Moles of Neon

Given:
- Mass of neon, $m = 94.7\, \text{g}$
- Molar mass of neon, $M = 20.18\, \text{g/mol}$

Number of moles, n:

$$
n = \frac{m}{M} = \frac{94.7}{20.18} \approx 4.695\, \text{mol}
$$

Step 2: Recall the Formula for Entropy Change in an Isothermal Process

For an ideal gas undergoing an isothermal process from initial volume V_i to final volume V_f:

$$
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right)
$$

where:
- $R = 8.314\, \text{J mol}^{-1}\text{K}^{-1}$ is the universal gas constant.

Alternatively, since pressure and volume are inversely related at constant temperature, the same expression can be written in terms of pressures:

$$
\Delta S = n R \ln \left(\frac{P_i}{P_f} \right)
$$

but the volume-based form is more straightforward if volume data is known or can be estimated.

Step 3: Obtain or Assume Initial and Final Conditions

Since the problem statement does not specify initial and final volumes or pressures, we need to make reasonable assumptions or analyze the process in terms of volume change.

Suppose the neon gas undergoes a contraction from an initial volume V_i to a final volume V_f. The key is to find the ratio $\frac{V_f}{V_i}$.

Interpreting the Volume Change

Without explicit initial and final volumes, let's consider a typical scenario:

- The initial volume V_i is known or set as a reference.
- The contraction reduces the volume to a fraction α of the original:

$$
V_f = \alpha V_i, \quad 0 < \alpha < 1
$$

Suppose, for illustration, the final volume is half of the initial:

$$
V_f = \frac{1}{2} V_i
$$

This is a common assumption in contraction studies for illustrative purposes.

Calculating the Entropy Change for the Assumed Contraction

Using the volume ratio:

$$
\Delta S = n R \ln \left(\frac{V_f}{V_i} \right) = n R \ln (\alpha)
$$

For $\alpha = 1/2$:

$$
\Delta S = 4.695 \times 8.314 \times \ln \left(\frac{1}{2} \right)
$$

Calculating:

$$
\ln \left(\frac{1}{2} \right) = -0.6931
$$

$$
\Delta S = 4.695 \times 8.314 \times (-0.6931) \approx -4.695 \times 8.314 \times 0.6931
$$

$$
\Delta S \approx -4.695 \times 8.314 \times 0.6931 \approx -4.695 \times 5.759 \approx -27.03\, \text{J/K}
$$

Thus, the entropy decreases by approximately 27.03 J/K during the contraction.

Analyzing the Results and Their Significance

Implication of Entropy Decrease

A negative change in entropy indicates the system's molecules become more ordered as the volume decreases at constant temperature. This aligns with the intuitive understanding that compressing a gas reduces its positional disorder.

Role of Reversibility

The calculation assumes a reversible process, meaning heat exchange with a thermal reservoir is perfectly efficient, and the process proceeds slowly enough to maintain equilibrium at all steps.

In real-world applications, irreversible factors can cause the actual entropy change to differ, often increasing the total entropy of the universe due to entropy production.

Potential Variations with Different Volume Ratios

- If the contraction is more substantial (e.g., $V_f = \frac{1}{10} V_i$), the entropy change magnitude increases.
- Conversely, less contraction results in a smaller entropy change.

This highlights the logarithmic relationship between volume change and entropy variation.

Factors Affecting the Calculation and Practical Considerations

Assumption of Ideal Gas Behavior

Neon, at moderate pressures and temperatures above its liquefaction point, behaves closely as an ideal gas. Deviations become significant at high pressures or low temperatures, but for typical conditions, the ideal gas approximation remains valid.

Temperature Constraints

Since the process is isothermal:
- The temperature must be maintained constant.
- Heat exchange with surroundings is necessary to compensate for work done during contraction.

Real-World Applications

Understanding entropy changes during gas compression or expansion has implications in:
- Designing efficient compressors and expanders.
- Thermodynamic cycle analysis (e.g., in refrigeration or power cycles).
- Studying atmospheric processes involving gas compression.

Conclusion: Summarizing the Key Insights

In essence, the change in entropy for 94.7 grams of neon gas undergoing an isothermal contraction depends primarily on the extent of volume reduction. Assuming a halving of volume, the entropy decreases by roughly 27 J/K, reflecting increased order within the system.

This analysis underscores several core principles:
- The direct relationship between volume change and entropy in ideal gases.
- The importance of process reversibility for accurate thermodynamic calculations.
- The utility of simplified models for understanding complex phenomena.

By mastering these concepts, scientists and engineers can better predict and manipulate the behavior of gases in various applications, ensuring efficiency and safety in processes involving thermal and mechanical work.

Final note: For precise calculations in practical scenarios, exact initial and final conditions are essential. Nonetheless, the foundational understanding provided here

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