Question TwoOne-quarter Kmol Of Nitrogen Gas (N2) Undergoes A Process From P = 138 KPa, T = 278 K To

Question TwoOne-quarter Kmol Of Nitrogen Gas (N2) Undergoes A Process From P = 138 KPa, T = 278 K To

Introduction to the Thermodynamic Process of Nitrogen Gas

Understanding the behavior of nitrogen gas (N_2) during various thermodynamic processes is fundamental in fields such as chemical engineering, thermodynamics, and environmental science. When a specified amount of nitrogen gas undergoes a process starting from an initial state characterized by a pressure of 138 KPa and a temperature of 278 K, it can experience numerous possible transformations depending on the nature of the process—be it isothermal, adiabatic, isobaric, or isochoric.

This article explores the detailed analysis of such a process, focusing on the thermodynamic principles, calculations involved, and potential implications in real-world applications. We will analyze the initial conditions, the types of processes nitrogen might undergo, and how to determine the final state variables, work done, heat transfer, and other relevant parameters.

Initial Conditions and Basic Properties of Nitrogen Gas

Understanding the State Variables

Before delving into the process specifics, it's essential to understand the initial state of nitrogen gas:

- Moles (n): 0.25 kmol (or 0.25 Kmol)
- Initial Pressure (P_1): 138 KPa
- Initial Temperature (T_1): 278 K

Using these parameters, we can determine the initial volume, internal energy, and other thermodynamic properties.

Ideal Gas Assumption

For most practical purposes and within typical temperature and pressure ranges, nitrogen gas can be approximated as an ideal gas. This simplifies calculations significantly. The ideal gas law:

$$ PV = nRT $$

Where:

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

Calculating the initial volume:

$$ V_1 = \frac{nRT_1}{P_1} $$

Substituting the known values:

$$ V_1 = \frac{0.25 \times 8.314 \times 278}{138,000} \approx 0.0418 \, \text{m}^3 $$

This initial volume provides a reference point for analyzing the process.

Types of Thermodynamic Processes for Nitrogen Gas

Understanding the nature of the process—whether it is isothermal, adiabatic, isobaric, or isochoric—is crucial for analyzing the final state and work interactions.

Isothermal Process (Constant Temperature)

- The temperature remains constant ($T = T_1 = T_2$)
- The pressure and volume change such that $PV = \text{constant}$
- Heat transfer occurs to compensate for work done during expansion or compression

Adiabatic Process (No Heat Transfer)

- No heat exchange with surroundings ($Q = 0$)
- Pressure, volume, and temperature change according to adiabatic relations
- For ideal gases, the relation:

$$ TV^{\gamma - 1} = \text{constant} $$

where γ (gamma) = C_p / C_v (ratio of specific heats)

- For nitrogen gas, $\gamma \approx 1.4$

Isobaric Process (Constant Pressure)

- Pressure remains constant ($P = P_1$)
- Temperature and volume change accordingly
- Heat transfer occurs to change internal energy and work

Isochoric Process (Constant Volume)

- Volume remains constant ($V = V_1$)
- Pressure and temperature change
- Heat transfer alters the internal energy but no work is done

Analyzing the Process: Step-by-Step Approach

Depending on the type of process, the calculations differ. Let's consider the general approach and then specific cases.

Determining the Final State Variables

The goal is to find the final pressure (P_2), temperature (T_2), volume (V_2), and other parameters after the process.

Assuming the process specifics are known (e.g., isothermal, adiabatic), we proceed accordingly.

Case 1: Isothermal Expansion or Compression

- Since $T_2 = T_1 = 278\, \text{K}$, the volume changes:

$$V_2 = \frac{nRT_2}{P_2}$$

- If final pressure P_2 is given, volume can be directly calculated.

Case 2: Adiabatic Process

- Use the relation:

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

- And the temperature-volume relation:

$$ T_2 V_2^{\gamma - 1} = T_1 V_1^{\gamma - 1} $$

- To find the final pressure or temperature, additional information such as the final volume or work done is required.

Case 3: Isobaric Process

- The final temperature:

$$ T_2 = T_1 + \frac{Q}{n C_p} $$

- And the final volume:

$$ V_2 = \frac{nRT_2}{P_1} $$

Case 4: Isochoric Process

- The pressure:

$$ P_2 = \frac{nRT_2}{V_1} $$

- The temperature:

$$ T_2 = \frac{P_2 V_1}{n R} $$

Calculations of Work, Heat Transfer, and Internal Energy

For each process type, the work done (W), heat transfer (Q), and change in internal energy (ΔU) can be calculated as follows:

Work Done (W)

- Isothermal:

$$ W = nRT \ln \frac{V_2}{V_1} $$

- Adiabatic:

$$ W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1} $$

- Isobaric:

$$W = P (V_2 - V_1)$$

- Isochoric:

$$W = 0$$

Change in Internal Energy (ΔU)

- For ideal gases:

$$\Delta U = n C_v \Delta T$$

where $C_v = \frac{R}{\gamma - 1}$

Heat Transfer (Q)

- Using the first law of thermodynamics:

$$Q = \Delta U + W$$

Practical Applications and Significance

Understanding the thermodynamic behavior of nitrogen gas during various processes has numerous real-world applications:

- Industrial Gas Handling: Designing compressors, turbines, and storage tanks involves understanding nitrogen's behavior under different conditions.
- Cryogenics and Liquefaction: Nitrogen is often liquefied for cooling applications; understanding its thermodynamic properties is crucial.
- Environmental Science: Nitrogen cycles and atmospheric processes depend on understanding nitrogen transformations at different pressures and temperatures.
- Refrigeration Cycles: Nitrogen is used as a refrigerant in some systems, requiring knowledge of adiabatic and isothermal processes.

Conclusion and Summary

Analyzing the process undergone by 0.25 kmol of nitrogen gas starting from an initial state of 138 KPa and 278 K, involves understanding the initial conditions, the nature of the process, and applying thermodynamic principles accordingly. Whether the process is isothermal, adiabatic, isobaric, or isochoric, applying ideal gas laws, thermodynamic relations, and energy balance equations allows for accurate determination of the final state and the work, heat transfer, and internal energy changes involved.

This comprehensive understanding is essential for engineers and scientists working in designing efficient systems involving nitrogen gas, optimizing processes, and predicting system behavior under varying conditions. Mastery of these principles also assists in advancing research in thermodynamics and related fields.

Further Reading and Resources

- Thermodynamics: An Engineering Approach by Yunus Çengel and Michael Boles
- Introduction to Thermodynamics by Richard E. Sonntag and Claus Borgnakke
- Online calculators for ideal gas properties
- Software tools like REFPROP for real gas property calculations

By understanding and applying these principles, professionals can effectively analyze and design systems involving nitrogen gas, ensuring safety, efficiency, and sustainability in various applications.

Frequently Asked Questions

What is the significance of calculating the process for one-quarter kmol of nitrogen gas transitioning from P = 138 KPa and T = 278 K to a new state?

Calculating this process helps in understanding the thermodynamic behavior of nitrogen gas during specific transformations, which is essential for designing industrial processes, refrigeration cycles, and understanding energy exchanges in engineering applications.

How can we determine the final state of nitrogen gas after the process starting from P = 138 KPa and T = 278 K?

By applying the ideal gas law or real gas equations, along with thermodynamic principles such as the first law of thermodynamics, we can calculate the final pressure, temperature, or volume of nitrogen after the process, depending on the process details.

What types of processes could nitrogen undergo from the initial state of P = 138 KPa and T = 278 K, and how do they affect the gas properties?

Nitrogen can undergo isothermal, isobaric, isochoric, or adiabatic processes. Each affects the gas's temperature, pressure, and volume differently, allowing engineers to select the appropriate process for desired outcomes in applications like liquefaction or compression.

Why is it important to consider the molar quantity,

specifically one-quarter kmol, when analyzing the thermodynamic process of nitrogen gas?

The molar quantity determines the amount of substance involved, which directly influences the calculation of work, heat transfer, and changes in internal energy during the process, ensuring precise and scalable thermodynamic analysis.

What additional information is needed to fully describe the process of nitrogen gas from the initial state P = 138 KPa, T = 278 K?

Details such as the type of process (e.g., isothermal, adiabatic), the final state parameters (pressure, temperature, volume), and whether any work or heat interactions occur are necessary to fully characterize and analyze the process.

Additional Resources

Question TwoOne-quarter Kmol Of Nitrogen Gas (N_2) Undergoes A Process From P = 138 KPa, T = 278 K To

---

Introduction

The thermodynamic behavior of gases under various processes is a cornerstone of chemical and mechanical engineering. When dealing with nitrogen gas (N_2), which constitutes approximately 78% of Earth's atmosphere, understanding its response to different thermodynamic paths is crucial in applications ranging from industrial gas processing to environmental modeling. This article examines a specific problem: Question TwoOne-quarter Kmol Of Nitrogen Gas (N_2) Undergoes A Process From P = 138 KPa, T = 278 K To, exploring the detailed thermodynamic principles involved, the nature of the process, and the implications of such a transformation.

Background and Significance

Nitrogen gas, a diatomic molecule with a molar mass of approximately 28 g/mol, exhibits behavior that can often be approximated as an ideal gas under common conditions. Its thermodynamic properties are well-characterized, making it an ideal candidate for studying various process types—be they isobaric, isothermal, adiabatic, or polytropic.

Understanding the thermodynamic process involving 0.25 kmol (or one-quarter kilomole) of N_2 provides insights into energy transfer, work done by or on the system, and changes in internal energy and entropy. Such analyses are fundamental for designing efficient compression, expansion, heating, or cooling systems.

Initial Conditions and Process Parameters

The initial state of the nitrogen gas is given as:

- Pressure (P_1): 138 KPa
- Temperature (T_1): 278 K
- Amount of substance (n): 0.25 kmol

The process description indicates a change to an unknown final state, which might involve a different pressure, temperature, or both. The process could be characterized based on additional information or assumptions about the process path.

Assumptions and Approximations

In analyzing the process, certain assumptions are typically employed to simplify calculations:

- Ideal Gas Behavior: N_2 behaves as an ideal gas under the given conditions.
- Constant Specific Heats: For simplicity, specific heats (Cp and Cv) are assumed constant over the temperature range.
- No Phase Change: N_2 remains in the gaseous phase throughout.
- Process Path: Without explicit details, common process types (isothermal, adiabatic, polytropic, etc.) are considered.

These assumptions are justified given the moderate temperature and pressure range, where deviations from ideality are minimal.

Thermodynamic Analysis Framework

Fundamental Relationships

The analysis relies on the ideal gas law:

$$PV = nRT$$

where:

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

The initial state parameters provide a basis for calculating initial volume:

$$V_1 = \frac{nRT_1}{P_1}$$

Substituting known values:

$$ V_1 = \frac{0.25 \times 8.314 \times 278}{138,000} $$

$$ V_1 \approx \frac{0.25 \times 8.314 \times 278}{138,000} \approx \frac{0.25 \times 2312.172}{138,000} $$

$$ V_1 \approx \frac{578.043}{138,000} \approx 0.00419 \, \text{m}^3 $$

This initial volume serves as a reference for subsequent calculations.

Exploring the Possible Process Types

1. Isothermal Process (Constant T)

- Definition: Temperature remains constant during the process.
- Implication: Using ideal gas law, the volume change is directly proportional to the pressure change.

$$ P_1 V_1 = P_2 V_2 $$

- Work done (W):

$$ W = nRT \ln \frac{V_2}{V_1} = nRT \ln \frac{P_1}{P_2} $$

- Change in internal energy (ΔU):

$$ \Delta U = 0 $$

since internal energy for an ideal gas depends only on temperature.

- Heat transfer (Q):

$$ Q = W $$

2. Adiabatic Process (No heat exchange)

- Definition: No heat transfer ($Q=0$)
- Relation between P and V:

$$ PV^\gamma = \text{constant} $$

where:

$$ \gamma = \frac{C_p}{C_v} $$

for N_2, $\gamma \approx 1.4$.

- Final pressure or temperature can be calculated if one is known, using adiabatic relations.

3. Polytropic Process

- Definition: General case where

$$ PV^n = \text{constant} $$

with n as the polytropic index.

Calculating the Final State: Hypothetical Scenarios

Since the question does not specify the final conditions, common assumptions are considered:

Scenario 1: Isothermal Compression or Expansion

Suppose the process is isothermal, with the final pressure P_2 being specified or to be derived. For example, if the process ends at $P_2 = 69 \, \text{kPa}$:

$$ V_2 = \frac{nRT}{P_2} $$

$$ V_2 = \frac{0.25 \times 8.314 \times 278}{69,000} \approx 0.00837 \, \text{m}^3 $$

The volume doubles, indicating expansion or compression depending on initial and final states.

Scenario 2: Adiabatic Expansion to a Lower Pressure

Assuming an adiabatic process from initial conditions:

$$ \frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{(\gamma - 1)/\gamma} $$

Choosing a final pressure, say $P_2 = 69 \, \text{kPa}$:

$$ T_2 = 278 \times \left(\frac{69}{138} \right)^{(0.4/1.4)} \approx 278 \times (0.5)^{0.2857} $$

$$ T_2 \approx 278 \times 0.824 \approx 229 \, \text{K} $$

The temperature drops, consistent with adiabatic expansion.

Energy Transfers and Efficiency Considerations

Work Done

In any process, work can be calculated through:

$$ W = \int_{V_1}^{V_2} P \, dV $$

- For isothermal:

$$ W = nRT \ln \frac{V_2}{V_1} $$

- For adiabatic:

$$ W = \frac{P_2 V_2 - P_1 V_1}{1 - n} $$

Heat Transfer

- Zero in adiabatic processes.
- Equal to work in isothermal processes.

Internal Energy Change

For ideal gases:

$$ \Delta U = n C_v \Delta T $$

where C_v for N_2 is approximately 0.743 kJ/kg·K, or in molar basis, roughly 20.8 J/mol·K.

Practical Implications and Applications

Understanding such thermodynamic processes in nitrogen gas is essential for various industrial applications:

- Gas compression and storage: Designing compression systems involves knowledge of work and energy transfer during pressure increase.
- Cryogenic cooling: Expansion processes, especially adiabatic, are foundational in cryogenic systems.
- Environmental modeling: Nitrogen cycles and atmospheric processes rely on understanding gas transformations.
- Industrial gas production: Purification, liquefaction, and transportation of nitrogen require precise thermodynamic calculations.

Limitations and Further Research

While ideal gas assumptions simplify analysis, real gases exhibit deviations at high pressures or low temperatures. For enhanced accuracy:

- Incorporate real gas equations of state (e.g., Van der Waals, Peng-Robinson).
- Consider variable specific heats, especially over large temperature ranges.
- Analyze non-ideal effects for high-pressure processes.

Further research can extend to dynamic process modeling, including transient effects, irreversibilities, and entropy generation.

Conclusion

The thermodynamic transformation of 0.25 kmol of nitrogen gas from an initial state of 138 KPa and 278 K exhibits rich analysis avenues depending on the process nature. Whether it is an isothermal, adiabatic, or polytropic process, fundamental principles such as the ideal gas law, energy conservation, and entropy considerations provide a framework for understanding and predicting the behavior of N_2 under these conditions. Such insights are invaluable in the design, optimization, and analysis of industrial systems involving nitrogen gas, contributing to efficiency, safety, and environmental sustainability.

References

- Moran, M. J., & Shapiro, H. N. (2008). Fundamentals of Engineering Thermodynamics. 6th Edition. Wiley.
- Çengel, Y. A., & Boles, M. A. (2014). Thermodynamics: An Engineering Approach.

Question Twoone Quarter Kmol Of Nitrogen Gas N2 Undergoes A Process From P 138 Kpa T 278 K To

Question Twoone Quarter Kmol Of Nitrogen Gas N2 Undergoes A Process From P 138 Kpa T 278 K To

Related Articles

- PLZZ HELP I WILL GIVE 100 POINTS Read This Excerpt From The Passage. "...you Cannot Reproach Me With
- Specialization And Comparative Advantage Part 2 A. Lead To International Trade And Overall Gains For
- Review QuestionsChoose The Best Answer From The Following Alternatives.1. One Of The Following Is An

Back to Home