A Gas At A Pressure Of 2.00 Atm Undergoes A Quasistatic Isobaric Expansion From 3.00 To 5.00 L. How Much

Understanding the Scenario: Gas Expansion at Constant Pressure

Introduction to Quasistatic Isobaric Processes

A gas undergoing a quasistatic process means that the transformation occurs slowly enough for the system to remain nearly in equilibrium at all times. When this process is isobaric, the pressure remains constant throughout the transformation. In the scenario described, a gas at a pressure of 2.00 atm expands quasistatically from a volume of 3.00 L to 5.00 L. The question posed is: "How much" — which, based on the context of thermodynamics, typically refers to the amount of heat exchanged, work done, or change in internal energy during this process.

Understanding the thermodynamic quantities involved in such a process is essential for analyzing and calculating the desired parameters. This article will explore the fundamental principles, relevant equations, and detailed calculations necessary for understanding this specific gas expansion.

Fundamental Concepts in Thermodynamics of Gas Expansion

Key Definitions and Principles

Before delving into calculations, it is important to clarify the key thermodynamic concepts involved:

- **Work done (W):** The energy transferred by the gas when it expands or compresses against a constant external pressure.
- **Heat exchanged (Q):** The amount of thermal energy transferred into or out of the system during the process.
- **Change in internal energy (ΔU):** The net energy change within the gas, depending on the type of gas and the process specifics.

The first law of thermodynamics relates these quantities:
\[
\Delta U = Q - W

\]

In an isobaric process, the work done by the gas is given by:

$$
W = P \Delta V
$$

where P is the constant pressure, and ΔV is the change in volume.

Ideal Gas Law and Its Relevance

For most practical purposes involving gases under moderate conditions, the ideal gas law applies:

$$
PV = nRT
$$

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

This law allows us to connect changes in volume and temperature, assuming the amount of gas remains constant, to calculate the heat exchanged and other parameters.

Calculating Work Done During the Quasistatic Isobaric Expansion

Work Calculation

Since the process occurs at constant pressure:

$$
W = P \Delta V
$$

Given:
- $P = 2.00\, \text{atm}$,
- $V_i = 3.00\, \text{L}$,
- $V_f = 5.00\, \text{L}$.

First, convert pressure to SI units:

$$
1\, \text{atm} = 101.325\, \text{kPa}
$$

Therefore:

$$
P = 2.00\, \text{atm} = 2.00 \times 101.325\, \text{kPa} = 202.65\, \text{kPa}
$$

Calculate the change in volume:

$$
\Delta V = V_f - V_i = 5.00\, \text{L} - 3.00\, \text{L} = 2.00\, \text{L}
$$

Convert volume to cubic meters:

$$
1\, \text{L} = 10^{-3}\, \text{m}^3
$$

Thus:

$$
\Delta V = 2.00 \times 10^{-3}\, \text{m}^3
$$

Now, compute the work done:

$$
W = P \Delta V = 202.65\, \text{kPa} \times 2.00 \times 10^{-3}\, \text{m}^3
$$

$$
W = 202.65 \times 10^{3}\, \text{Pa} \times 2.00 \times 10^{-3}\, \text{m}^3
$$

$$
W = 405.3\, \text{J}
$$

Result: The work done by the gas during this process is approximately 405.3 Joules.

Determining the Temperature Change During Expansion

Using the Ideal Gas Law

Since the process is quasistatic and involves a change in volume at constant pressure, the temperature of the gas changes accordingly.

The ideal gas law states:

$$
PV = nRT
$$

At constant pressure:

$$
V \propto T
$$

Thus:

$$
\frac{V_i}{T_i} = \frac{V_f}{T_f}
$$

or,

$$
T_f = T_i \times \frac{V_f}{V_i}
$$

To find the temperature change, initial temperature T_i must be known or assumed.

Assuming an Initial Temperature

Suppose the initial temperature of the gas is $T_i = 300\, \text{K}$. Then:

$$
T_f = 300\, \text{K} \times \frac{5.00\, \text{L}}{3.00\, \text{L}} = 300\, \text{K} \times \frac{5}{3} \approx 500\, \text{K}
$$

Result: The temperature increases from 300 K to approximately 500 K during the expansion.

Calculating the Heat Exchange (Q) During the Process

Using the First Law of Thermodynamics

Recall:

$$
\Delta U = Q - W
$$

For an ideal gas, the change in internal energy depends only on temperature:

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

Where:

- C_v = molar heat capacity at constant volume,
- $\Delta T = T_f - T_i$.

For a monatomic ideal gas:

$$
C_v = \frac{3}{2} R
$$

And for a diatomic gas (common in many real gases):

$$
C_v = \frac{5}{2} R
$$

Assuming a diatomic ideal gas, which is typical for many gases like nitrogen or oxygen:

$$
C_v = \frac{5}{2} R \approx 20.785\, \text{J/mol·K}
$$

Next, determine the number of moles n:

Using the ideal gas law at initial conditions:

$$
n = \frac{PV}{RT}
$$

Assuming $T_i = 300\, \text{K}$:

$$
n = \frac{202.65\, \text{kPa} \times 3.00\, \text{L}}{8.314\, \text{J/mol·K} \times 300\, \text{K}}
$$

Convert volume to m^3:

$$
3.00\, \text{L} = 3.00 \times 10^{-3}\, \text{m}^3
$$

Plugging in:

$$
n = \frac{202.650 \times 10^{3}\, \text{Pa} \times 3.00 \times 10^{-3}\, \text{m}^3}{8.314\, \text{J/mol·K} \times 300}
$$

$$
n = \frac{607.95\, \text{J}}{2494.2\, \text{J/mol}} \approx 0.244\, \text{mol}
$$

Calculate ΔT:

$$
\Delta T = T_f - T_i = 500\, \text{K} - 300\, \text{K} = 200\, \text{K}
$$

Now, compute ΔU:

$$
\Delta U = n C_v \Delta T = 0.244\, \text{mol} \times 20.785\, \text{J/mol·K} \times 200\, \text{K}
$$

$$
\Delta U \approx 0.244 \times 20.785 \times 200 \approx 1015\, \text{J}
$$

Finally, calculate the heat exchanged:

$$
Q = \Delta U + W = 1015\, \text{J} + 405.3\, \text{J} \approx 1420\, \text{J}
$$

Result: The gas absorbs approximately 1420 Joules of heat during the expansion.

Summary of Results and Physical Insights

- **Work done by the gas**: approximately 405.3 Joules.
- **Temperature change**: from assumed 300 K to about 500 K, reflecting the increase in temperature during expansion.
- **Heat absorbed by the gas**: approximately 1420 Joules.

These calculations demonstrate how therm

Frequently Asked Questions

What is the initial pressure of the gas in the given problem?

The initial pressure of the gas is 2.00 atm.

What is the volume change during the quasistatic isobaric expansion?

The volume increases from 3.00 L to 5.00 L.

What is the type of process described in the problem?

It is a quasistatic isobaric (constant pressure) expansion.

How do you calculate the work done by the gas during this expansion?

Work done (W) = P × ΔV, where P is pressure and ΔV is change in volume.

What is the value of the work done during the expansion?

Work done = 2.00 atm × (5.00 L − 3.00 L) = 2.00 atm × 2.00 L = 4.00 L·atm.

How can the work done be converted into joules?

1 L·atm ≈ 101.3 Joules, so work = 4.00 L·atm × 101.3 J/L·atm ≈ 405.2 Joules.

What additional information is needed to calculate the heat transferred during the process?

The initial and final temperatures of the gas are needed to determine the heat transferred.

How does the ideal gas law relate to this problem?

It can be used to find the initial or final temperature if the amount of gas and pressure are known, via PV = nRT.

What assumptions are made in solving this problem?

Assuming the gas behaves ideally, and the process is quasistatic and isobaric, ensuring pressure remains constant during expansion.

Additional Resources

A Gas At A Pressure Of 2.00 Atm Undergoes A Quasistatic Isobaric Expansion From 3.00 To 5.00 L. How Much?

Introduction: Understanding the Scenario

In the realm of thermodynamics, the study of gases undergoing various processes provides crucial insights into energy transfer, work, and heat interactions. The scenario presented involves a gas initially at a pressure of 2.00 atm, undergoing a quasistatic (or quasi-equilibrium) isobaric (constant pressure) expansion from a volume of 3.00 liters to 5.00 liters. The question posed—"How much?"—suggests an inquiry into the work done by the gas during this process, and possibly other thermodynamic parameters such as heat exchanged or changes in internal energy.

This analysis aims to dissect this problem comprehensively, employing foundational principles of thermodynamics, ideal gas law, and the mathematical relationships governing isobaric processes. We will explore the physical meaning of the process, derive the relevant equations, and interpret the results within the broader context of thermodynamic cycles and real-world applications.

Fundamental Concepts in Thermodynamics

Before delving into the specific calculations, it is essential to revisit key concepts that underpin the problem:

1. Quasistatic Processes

A quasistatic process is one that occurs infinitesimally slowly, allowing the system to remain in near-equilibrium states at all times. This ensures that thermodynamic properties such as pressure, temperature, and volume are well-defined at every stage, simplifying analysis and making the process idealized yet practically approximable in controlled experiments.

2. Isobaric Processes

An isobaric process occurs at constant pressure. During such a process, the volume and temperature of the gas change in a way that maintains the pressure unchanged. The work done by the gas in an isobaric process can be directly related to the change in volume, a property that makes it relatively straightforward to calculate.

3. The First Law of Thermodynamics

Expressed as:

$$
\Delta U = Q - W
$$

where:
- ΔU is the change in internal energy,
- Q is the heat added to the system,
- W is the work done by the system.

Understanding the interplay between these quantities is critical when analyzing thermodynamic processes.

Applying the Ideal Gas Law

The initial and final states of the gas are characterized by their volumes, pressure, and temperature. The ideal gas law provides a bridge connecting these variables:

$$
PV = nRT
$$

where:
- P is pressure,
- V is volume,
- n is the number of moles,
- R is the universal gas constant ($8.314\, J\, mol^{-1}\,K^{-1}$),
- T is temperature in Kelvin.

Given initial and final volumes, and constant pressure, the change in temperature during expansion can be calculated, which further informs energy and work calculations.

Step-by-Step Analysis of the Process

1. Initial State

- Pressure, $P_i = 2.00\, atm$
- Volume, $V_i = 3.00\, L$

2. Final State

- Volume, $V_f = 5.00\, L$

Since the process is isobaric, the pressure remains at 2.00 atm throughout.

3. Calculating the Change in Temperature

Using the ideal gas law:

$$
T = \frac{PV}{nR}
$$

Assuming the amount of gas n remains constant:

- Initial temperature:

$$
T_i = \frac{P_i V_i}{n R}
$$

- Final temperature:

$$
T_f = \frac{P_f V_f}{n R}
$$

Because $P_i = P_f = 2.00\, atm$, the ratio of temperatures simplifies to:

$$
\frac{T_f}{T_i} = \frac{V_f}{V_i} = \frac{5.00\, L}{3.00\, L} \approx 1.6667
$$

If we know the initial temperature, we can find the final temperature, or vice versa. For illustration, let’s assume the initial temperature T_i is known or given, or simply expressed in terms of n.

Calculating the Work Done During Expansion

Since the process is isobaric, the work W done by the gas can be directly calculated by:

$$
W = P \Delta V
$$

where:

- P is the constant pressure,
- $\Delta V = V_f - V_i$

Convert pressure from atm to SI units:

$$
1\, atm = 101.325\, kPa
$$

So,

$$
P = 2.00\, atm = 2.00 \times 101.325\, kPa = 202.65\, kPa
$$

Similarly, volume change:

$$
\Delta V = (5.00 - 3.00)\, L = 2.00\, L
$$

Convert liters to cubic meters:

$$
1\, L = 1 \times 10^{-3}\, m^3
$$

Thus,

$$
\Delta V = 2.00\, L = 2.00 \times 10^{-3}\, m^3
$$

Now, the work:

$$
W = P \times \Delta V = 202.65\, kPa \times 2.00 \times 10^{-3}\, m^3
$$

Remembering that $1\, kPa \times m^3 = 1\, kJ$:

$$
W = 202.65\, kPa \times 2.00 \times 10^{-3}\, m^3 = 0.4053\, kJ
$$

or approximately:

$$
W \approx 405.3\, J
$$

Interpretation: The gas does approximately 405.3 Joules of work on the surroundings during this expansion.

Thermodynamic Quantities: Heat and Internal Energy Changes

While the work calculation is straightforward, understanding the heat exchanged (Q) and the change in internal energy (ΔU) enriches the analysis.

1. Change in Internal Energy

For an ideal gas, the internal energy depends solely on temperature:

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

where:
- C_v is the molar heat capacity at constant volume,
- $\Delta T = T_f - T_i$.

Alternatively, expressing ΔU in terms of initial and final states:

$$
\Delta U = \frac{n C_v}{R} R \Delta T
$$

Given the temperature ratio:

$$
T_f = T_i \times 1.6667
$$

Thus,

$$
\Delta T = T_i (1.6667 - 1) = 0.6667\, T_i
$$

Without specific initial temperature or number of moles, the exact numerical value remains in terms of n and T_i.

2. Heat Exchange (Q)

From the first law:

$$
Q = \Delta U + W
$$

Since ΔU depends on the change in temperature, which in turn depends on n and T_i, the heat added can be expressed as:

$$
Q = n C_v \Delta T + W
$$

For an ideal gas:

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

where $\gamma = \frac{C_p}{C_v}$, the heat capacity ratio.

Implications and Broader Context

The quantitative insights into this isobaric expansion process reveal how energy transfer and work interplay in thermodynamic systems. The work done (about 405 Joules) indicates a significant energy transfer to the surroundings during the expansion, which could be harnessed in engines, turbines, or other energy conversion devices.

In real-world applications, understanding such processes is vital in designing efficient engines, refrigerators, and other thermodynamic machines. The idealized calculations provide baseline expectations, but real systems often involve irreversibilities, heat losses, and non-ideal behavior.

Furthermore, the temperature change during expansion influences the thermodynamic efficiency of processes. For example, in internal combustion engines, the expansion stroke involves similar principles, albeit with more complex cycles and additional factors.

Conclusion: Synthesis of Key Findings

In summary, a gas initially at 2.00 atm undergoing a quasistatic isobaric expansion from 3.00 liters to 5.00 liters performs approximately 405 Joules of work. This process involves an increase in temperature proportional to the volume change, leading to energy transfer in the form of work and heat. Understanding these fundamental principles illuminates the core mechanics behind many thermodynamic systems and underscores the importance of precise calculations when analyzing energy transformations.

This scenario exemplifies the elegance of thermodynamics: simple assumptions like ideal gas behavior and process idealizations yield powerful insights into energy flow, enabling engineers and scientists to optimize

A Gas At A Pressure Of 2 00 Atm Undergoes A Quasistatic Isobaric Expansion From 3 00 To 5 00 L How Much

A Gas At A Pressure Of 2 00 Atm Undergoes A Quasistatic Isobaric Expansion From 3 00 To 5 00 L How Much

Related Articles

- A Source Vibrating At Constant Frequency Generates A Sinusoidal Wave On A String Under Constant Tension.
- 8. By Using Appropriate Levels Of Eye Contact, Moving Purposefully, And Smiling While Talking, A Speaker
- When A Method Resides Entirely Within Another Method, And Can Only Be Called From Within The Containing

Back to Home