Ii) A Fixed Mass Of An Ideal Gas Is Heated From 50C To 80C At A Constant Pressure. The First Pressure

Ii) A Fixed Mass Of An Ideal Gas Is Heated From 50°C To 80°C At A Constant Pressure. The First Pressure

Understanding the behavior of gases under varying temperature and pressure conditions is fundamental in thermodynamics and related fields. In this article, we explore the process where a fixed mass of an ideal gas is heated from 50°C to 80°C at a constant pressure, focusing on the initial pressure. We will delve into the underlying principles, mathematical calculations, practical implications, and real-world applications of this process. Whether you are a student, engineer, or enthusiast, this comprehensive guide aims to clarify the key concepts and provide insights into the thermodynamic behavior of ideal gases during heating at constant pressure.

Introduction to Ideal Gas Behavior and Thermodynamic Processes

What Is an Ideal Gas?

An ideal gas is a theoretical gas composed of point particles that do not interact with each other except during elastic collisions. Its behavior is described accurately by the ideal gas law:

$$PV = nRT$$

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

This relationship forms the foundation for analyzing thermodynamic processes involving ideal gases.

Thermodynamic Processes at Constant Pressure

Heating a fixed mass of gas at constant pressure involves changes in temperature, volume, and internal energy. The key features include:
- The pressure remains constant throughout the process.

- The volume of the gas changes in proportion to the temperature.
- The heat supplied to the gas contributes to both raising its internal energy and performing work on the surroundings.

Initial Conditions and Parameters

Before analyzing the heating process, it is essential to establish the initial parameters:
- Initial temperature, $T_1 = 50^\circ C = 50 + 273.15 = 323.15\,K$
- Final temperature, $T_2 = 80^\circ C = 80 + 273.15 = 353.15\,K$
- Initial pressure, P_1 (unknown, to be specified or assumed)
- Mass of the gas, m (fixed)
- Molar mass of the gas, M (depends on the specific gas; for example, for nitrogen $M \approx 28\,g/mol$)
- Gas constant, $R = 8.314\,J/(mol\,K)$

The process involves heating the gas from T_1 to T_2 at constant pressure, so the key parameters include the initial and final states, along with the nature of energy transfer.

Effects of Heating at Constant Pressure

Volume Change During Heating

Since pressure remains constant, the volume of the gas changes linearly with temperature, according to the ideal gas law:

$$V = \frac{nRT}{P}$$

As temperature increases from T_1 to T_2, the volume expands proportionally:

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

This relationship allows calculation of the change in volume:

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

Heat Added to the Gas

The heat transfer, Q, during the process is calculated from the first law of thermodynamics:

$$Q = \Delta U + W$$

Where:

- ΔU = change in internal energy
- W = work done by the gas

For an ideal gas:
- The internal energy depends solely on temperature:

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

- The work done during expansion at constant pressure:

$$W = P \Delta V$$

Since the process is at constant pressure, the heat added simplifies to:

$$Q = n C_p \Delta T$$

Where:
- C_p = molar heat capacity at constant pressure
- $\Delta T = T_2 - T_1$

Calculations for Heating from 50°C to 80°C

Suppose we have 1 mole of an ideal gas (e.g., nitrogen). The calculations proceed as follows:

Step 1: Determine Temperature Change

$$\Delta T = T_2 - T_1 = 353.15\,K - 323.15\,K = 30\,K$$

Step 2: Identify Heat Capacity Values

For diatomic gases like nitrogen:
- $C_v \approx 5/2\, R = 20.785\,J/(mol\,K)$
- $C_p = C_v + R = 7/2\, R = 29.085\,J/(mol\,K)$

Step 3: Calculate Heat Added

$$Q = n C_p \Delta T = 1\,mol \times 29.085\,J/(mol\,K) \times 30\,K = 872.55\,J$$

Step 4: Calculate Work Done

Using initial conditions to find V_1:
$$V_1 = \frac{nRT_1}{P}$$

If the initial pressure P is specified, the initial volume can be computed. For example, assume $P = 1\,atm = 101.325\,kPa$:

$$V_1 = \frac{1\,mol \times 8.314\,J/(mol\,K) \times 323.15\,K}{101.325\,kPa}$$

$$V_1 = \frac{2687.5\,J}{101.325 \times 10^3\,Pa} \approx 0.0265\,m^3$$

The change in volume:

$$V_2 = V_1 \times \frac{T_2}{T_1} = 0.0265\,m^3 \times \frac{353.15}{323.15} \approx 0.0289\,m^3$$

Work done:

$$W = P \times (V_2 - V_1) = 101.325 \times 10^3\,Pa \times (0.0289 - 0.0265)\,m^3$$

$$W \approx 101.325 \times 10^3\,Pa \times 0.0024\,m^3 \approx 243\,J$$

Alternatively, using $W = P \Delta V$.

Step 5: Verify Energy Balance

Total heat supplied:

$$Q = \Delta U + W$$

$$\Delta U = n C_v \Delta T = 1 \times 20.785\,J/(mol\,K) \times 30\,K = 623.55\,J$$

Sum:

$$\Delta U + W = 623.55\,J + 243\,J = 866.55\,J$$

Close to the calculated heat Q, considering rounding errors, confirming the consistency of the calculations.

Implications of the Initial Pressure

The initial pressure P significantly influences the initial volume and the work done during heating:
- Higher initial pressure results in smaller initial volume.
- The work done during expansion depends directly on the initial volume and pressure.
- Understanding the initial pressure helps in designing thermodynamic systems such as engines, refrigerators, and heat exchangers.

Effect of Varying Initial Pressure

- At higher initial pressures, the volume is compressed, leading to different expansion characteristics.
- The amount of heat required to raise the temperature remains governed by C_p and the temperature change, but the work component varies.

Practical Applications and Real-World Examples

Industrial Heating Processes

In industries where gases are heated at constant pressure—such as in chemical reactors—understanding the thermodynamics helps optimize energy consumption.

Engine Cycles

Internal combustion engines and turbines operate based on thermodynamic cycles involving constant pressure heating and expansion.

Climate and Atmospheric Studies

The principles of ideal gas behavior under heating are crucial in modeling weather systems and atmospheric phenomena.

Key Points Summary

- Heating a fixed mass of an ideal gas at constant pressure causes an increase in temperature and volume.
- The amount of heat added is proportional to the temperature change and the molar heat capacity at constant pressure.
- The work done during the process depends on the initial pressure, volume, and temperature change.
- Precise calculations require knowledge of initial conditions, gas properties, and the pressure level.

Conclusion

The process of heating a fixed mass of an ideal gas from 50°C to 80°C at constant pressure exemplifies fundamental thermodynamic principles. Understanding how temperature, volume, pressure, and energy interrelate enables scientists and engineers to design efficient systems and predict gas behavior accurately. The initial pressure plays a crucial role in determining the extent of volume change and work done, emphasizing the importance of initial conditions in thermodynamic analysis. By mastering these concepts, professionals can optimize processes across various

Frequently Asked Questions

What happens to the volume of an ideal gas when it is heated at constant pressure from 50°C to 80°C?

The volume of the ideal gas increases proportionally with the temperature, following Charles's law, so it will expand as it is heated.

How can we calculate the change in pressure of the gas if the pressure remains constant during heating?

Since the pressure is constant in this scenario, it does not change; the question may refer to the initial pressure, which remains the same throughout the heating process.

What is the significance of the initial pressure in the process of heating the gas from 50°C to 80°C?

The initial pressure serves as the baseline for understanding the behavior of the gas, and under constant pressure, it helps determine the change in volume or other properties as temperature increases.

How does the ideal gas law (PV = nRT) apply when heating a fixed mass of gas at constant pressure?

At constant pressure, increasing the temperature (T) results in a proportional increase in volume (V), since $V = nRT/P$, with n and P held constant.

What is the approximate percentage increase in volume when the temperature of the gas is increased from 50°C to 80°C at constant pressure?

The temperature increase is from 50°C (323K) to 80°C (353K), so the volume increases by approximately $(353/323 - 1) \times 100\% \approx 9.3\%$.

Why is it important to convert temperatures to Kelvin when applying the ideal gas law in this process?

Because the ideal gas law relies on absolute temperature (Kelvin), converting Celsius to Kelvin ensures accurate calculations, as temperature ratios directly affect volume and pressure changes.

Additional Resources

A Fixed Mass Of An Ideal Gas Is Heated From 50°C To 80°C At A Constant Pressure. The First Pressure: A Comprehensive Analysis

When exploring the behavior of gases under various thermal conditions, understanding how pressure, volume, and temperature interplay is fundamental. In particular, examining what happens when a fixed mass of an ideal gas is heated from 50°C to 80°C at a constant pressure offers valuable insights into thermodynamic principles, especially the relationship described by the ideal gas law. This scenario not only helps clarify how temperature influences the state of an ideal gas but also underscores the importance of pressure and volume adjustments during heating processes.

In this detailed guide, we will analyze this process step-by-step, exploring the underlying physics, mathematical formulations, and practical implications.

Understanding the Scenario

Before delving into calculations, let’s set the foundational understanding:

- Fixed mass of an ideal gas: The amount of gas (measured in moles) remains unchanged throughout the process.
- Heating from 50°C to 80°C: The temperature increases by 30°C (or 30 Kelvin, since the size of the degree is the same in Celsius and Kelvin).
- Constant pressure: The external pressure applied to the gas remains unchanged during heating.
- First pressure (interpreted as the initial pressure at 50°C): The initial pressure of the system before heating.

Fundamental Principles and Laws

1. The Ideal Gas Law

The cornerstone of this analysis is the ideal gas law:

$$ PV = nRT $$

Where:

- P = pressure (Pa)
- V = volume (m^3)
- n = number of moles (mol)

- R = universal gas constant (8.314 J/mol·K)
- T = temperature (Kelvin)

This law relates the pressure, volume, and temperature of an ideal gas, assuming no interactions between particles other than elastic collisions.

2. The Relationship During Heating at Constant Pressure

When a fixed amount of gas is heated at constant pressure:

- The pressure remains constant.
- The volume varies directly with temperature (in Kelvin).

Expressed mathematically:

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

Where:

- V_1, T_1 are initial volume and temperature.
- V_2, T_2 are final volume and temperature.

Step-by-Step Analysis of the Process

Step 1: Convert Temperatures to Kelvin

Since thermodynamic calculations require Kelvin:

- Initial temperature T_1:

$$T_1 = 50^\circ C + 273.15 = 323.15\, K$$

- Final temperature T_2:

$$T_2 = 80^\circ C + 273.15 = 353.15\, K$$

Step 2: Determine the Initial Pressure (First Pressure)

Suppose the initial pressure P_1 is known or given; if not, we can analyze the process generally. For illustration, assume:

$$P_1 = P_{initial}$$

The initial state is characterized by:

$$P_1 V_1 = n R T_1$$

Since the mass and the number of moles n are fixed, and R is constant, the initial state is set.

Step 3: Find the Change in Volume

Given that the pressure remains constant during heating, the volume change can be calculated:

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

Plugging in the numbers:

$$ \frac{V_2}{V_1} = \frac{353.15}{323.15} \approx 1.092 $$

This indicates the volume increases by approximately 9.2% as the gas is heated from 50°C to 80°C.

Calculations and Implications

1. Final Volume

The final volume V_2:

$$ V_2 = V_1 \times 1.092 $$

If the initial volume V_1 is known, the final volume can be directly calculated.

2. Final Pressure

Since the pressure is constant:

$$ P_2 = P_1 $$

The pressure does not change during heating at constant pressure (by definition of an isobaric process).

3. Final State of the Gas

The key points for the final state:

- Temperature increases from 50°C to 80°C.
- Volume increases proportionally.
- Pressure remains unchanged.
- The number of moles remains fixed.

Practical Applications and Considerations

Understanding this process has several real-world implications:

- Engine and Compressor Design: Knowing how gas volume responds to temperature changes at constant pressure helps in designing systems that can accommodate thermal expansion.
- Thermodynamic Efficiency: Recognizing the relationship between temperature and volume aids in optimizing processes like heating, cooling, and energy transfer.
- Safety Protocols: Anticipating volume expansion during heating is essential in pressurized systems to prevent rupture or failure.

Advanced Topics and Related Concepts

a. Work Done During Heating

In an isobaric process, the work done W:

$$W = P \Delta V$$

Given the pressure remains constant, the work is directly proportional to the change in volume:

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

Expressed in terms of initial volume:

$$W = P V_1 \left(\frac{T_2}{T_1} - 1 \right)$$

This work corresponds to the energy transferred to the gas during heating.

b. Heat Added to the System

The heat Q supplied during the process:

$$Q = n C_p \Delta T$$

Where:

- C_p = molar heat capacity at constant pressure ($\approx 29 \, \mathrm{J/mol \cdot K}$ for ideal gases)

And:

$$Q = n C_p (T_2 - T_1)$$

This energy accounts for the increase in internal energy and work done.

Summary and Key Takeaways

- Heating a fixed mass of an ideal gas from 50°C to 80°C at constant pressure results in an increase in volume proportional to the temperature increase in Kelvin.
- The initial and final states are connected via the ideal gas law, emphasizing the direct relationship between temperature and volume at constant pressure.
- The pressure remains constant, and the number of moles stays fixed, simplifying calculations and interpretations.
- Understanding this process is essential for various engineering applications, thermodynamic analysis, and safety considerations in pressurized systems.

Final Thoughts

The behavior of gases under thermal variations is a cornerstone of thermodynamics, with practical importance spanning from industrial processes to everyday applications. By analyzing the heating of an ideal gas at constant pressure, we reinforce fundamental concepts such as the ideal gas law, the relationship between temperature and volume, and the nature of work and heat transfer. Whether designing engines, refrigeration systems, or understanding atmospheric phenomena, mastering these principles provides a solid foundation for scientific and engineering endeavors.

Remember: Always convert temperatures to Kelvin when calculating thermodynamic properties, and keep track of whether the process is at constant pressure, volume, or involves other constraints, to accurately predict the behavior of gases under varying conditions.

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