.A. A Gas Absorbs 500J Of Heat, While Having 200J Of Work Done On It. What Is The Change In Internal

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Understanding the principles of thermodynamics is fundamental in physics and engineering, especially when analyzing energy exchanges in gases and other systems. One common scenario involves calculating the change in a gas's internal energy when it absorbs heat and work is performed on it. This article explores the detailed process of determining the change in internal energy, using a specific example where a gas absorbs 500 joules of heat and 200 joules of work is done on it. We'll break down the concepts, equations, and calculations involved to ensure a comprehensive understanding.

Introduction to Thermodynamics and Internal Energy

Thermodynamics is the branch of physics that deals with heat, work, and energy transfer. It provides the framework to analyze how energy is conserved and transformed within physical systems.

Internal energy (U):
The internal energy of a system refers to the total energy contained within the system due to the microscopic motions and interactions of particles. It encompasses kinetic energy, potential energy, and other forms of microscopic energies.

First Law of Thermodynamics:
The first law states that the change in internal energy of a system is equal to the heat added to the system minus the work done by the system:

$$
\Delta U = Q - W
$$

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

However, it is important to note the sign conventions:
- If heat is added to the system, Q is positive.
- If work is done by the system, W is positive.
- Conversely, work done on the system is considered negative in this convention.

Note: In many physics problems, it is common to define work done on the system as positive, which might invert the sign conventions. Always check the specific convention used.

Scenario Breakdown: Absorbing Heat and Work Done on the Gas

In our specific example:
- The gas absorbs 500 J of heat ($Q = +500\,J$)
- The work done on the gas is 200 J ($W_{on} = +200\,J$), which indicates work is being applied to the gas.

Given this, the change in internal energy can be calculated using the first law:

$$
\Delta U = Q - W
$$

But since work done on the system is positive, we need to clarify the sign convention to correctly apply the formula.

Applying the First Law of Thermodynamics

Step 1: Clarify the Sign Convention

- If work done on the system is positive, then the first law becomes:

$$
\Delta U = Q + W_{on}
$$

- If work done by the system is positive, then:

$$
\Delta U = Q - W_{by}
$$

In our problem, since the work is done on the gas, we take:

$$
\Delta U = Q + W_{on}
$$

Step 2: Plug in the Known Values

Given:
- $Q = +500\,J$
- $W_{on} = +200\,J$

Therefore:

$$
\Delta U = 500\,J + 200\,J = 700\,J
$$

Result:

$$
\boxed{
\text{Change in internal energy} = \Delta U = +700\,J
}
$$

This positive change indicates that the internal energy of the gas has increased by 700 Joules.

Understanding the Significance of the Result

The increase in internal energy signifies that the gas's microscopic particles have gained energy. This energy increase occurs because:

- The gas absorbs heat energy, which directly raises its internal energy.
- Work done on the gas adds additional energy to its internal state.

Implications:

- The system's temperature will tend to rise if the process occurs at constant volume.
- If the process occurs at constant pressure, the gas may expand, doing work on the surroundings, but since work is done on the gas here, expansion is not necessarily implied unless specified.

Additional Concepts Related to Internal Energy Changes

Understanding the change in internal energy in practical scenarios often involves additional concepts:

1. Specific Heat and Temperature Change

For processes where the temperature change is of interest, the relation:

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

can be used, where:
- n = number of moles,
- C_v = molar heat capacity at constant volume,
- ΔT = change in temperature.

However, in our scenario, the total change in internal energy is directly calculated from the heat and work.

2. Work Done in Thermodynamic Processes

Work done by or on the gas can take various forms:

- P-V Work: Expansion or compression work, expressed as $W = P \Delta V$.
- Electrical Work: In processes involving electrical energy transfer.
- Other forms: Shaft work, surface work, etc.

In most ideal gas problems, the focus is on pressure-volume work.

3. Types of Thermodynamic Processes

- Isobaric: constant pressure
- Isochoric: constant volume
- Isothermal: constant temperature
- Adiabatic: no heat exchange

The change in internal energy depends on the process type, especially in relation to temperature change.

Real-World Applications and Importance

Understanding how heat and work affect internal energy is crucial in numerous practical contexts:

- Engine cycles: Internal combustion, jet engines
- Refrigeration systems: Absorbing and releasing heat
- Chemical reactions: Energy changes during reactions
- Material science: Thermal treatments

In designing these systems, engineers need to precisely calculate energy exchanges to optimize efficiency.

Summary and Key Takeaways

- The first law of thermodynamics provides a straightforward way to calculate the change in internal energy: $\Delta U = Q + W_{on}$ when work is done on the system.
- In the given example, the gas absorbs 500 J of heat and has 200 J of work done on it, leading to a total internal energy increase of 700 J.
- Sign conventions are critical in thermodynamics; always clarify whether work is done by or on the system.
- The increase in internal energy results in microscopic energy gains within the particles making up the gas, which could lead to temperature increases or phase changes depending on the process.

Conclusion

Calculating the change in internal energy of a gas when heat is absorbed and work is performed on it involves a clear understanding of the first law of thermodynamics and the sign conventions used. In this scenario, the internal energy increases by 700 Joules, reflecting the combined effect of heat absorption and work done on the gas. Mastery of these concepts is essential for analyzing thermodynamic systems, optimizing processes, and designing energy-efficient technologies across various engineering and scientific disciplines.

Additional Resources:

- Thermodynamics Textbooks (e.g., "Fundamentals of Engineering Thermodynamics" by Moran & Shapiro)
- Online simulations of thermodynamic cycles
- Educational videos explaining the first law of thermodynamics
- Practice problems on heat, work, and internal energy calculations

Keywords for SEO:

- Internal energy change calculation
- First law of thermodynamics example
- Heat transfer in gases
- Work done on a gas
- Thermodynamic processes
- Energy transfer in thermodynamics
- Heat absorbed by gases
- Work done on thermodynamic systems

Frequently Asked Questions

What is the change in internal energy of the gas if it absorbs 500J of heat and has 200J of work done on it?

The change in internal energy (ΔU) is given by $\Delta U = Q - W$. Here, $Q = 500J$ and $W = 200J$, so $\Delta U = 500J - 200J = 300J$.

How do heat absorption and work done relate to the internal energy change in a gas?

According to the first law of thermodynamics, the change in internal energy equals heat added to the system minus work done by the system. If heat is absorbed and work is done on the system, the internal energy increases.

If a gas absorbs heat but has work done on it, does its internal energy increase or decrease?

The internal energy increases if the heat absorbed exceeds the work done. In this case, since the gas absorbs 500J and has 200J of work done on it, the internal energy increases by 300J.

What is the significance of the work done on the gas in calculating internal energy change?

Work done on the gas contributes positively to the internal energy change. When work is done on the system, it adds energy, so it must be subtracted from the heat absorbed to find the net change in internal energy.

Can you determine the change in internal energy if only the heat and work values are given?

Yes, using the first law of thermodynamics: $\Delta U = Q - W$. With heat and work values provided, you can directly calculate the change in internal energy.

What are the units used in calculating the change in internal energy for this problem?

The units are joules (J), with heat absorbed (Q) and work done (W) both measured in joules, making the change in internal energy also expressed in joules.

Why is understanding the change in internal energy important in thermodynamics?

It helps in analyzing energy transfer processes within systems, predicting system behavior, and designing engines and other thermodynamic devices by understanding how heat and work influence internal energy.

Additional Resources

Understanding the Change in Internal Energy: A Deep Dive into Thermodynamics

When exploring the fascinating world of thermodynamics, one fundamental concept that often comes into focus is the change in a system's internal energy. A gas absorbs 500J of heat, while having 200J of work done on it—these are classic parameters in thermodynamic analysis, illustrating how energy transfer processes influence the internal energy of a system. Grasping how to analyze such a scenario not only deepens our understanding of energy conservation but also enhances our ability to interpret real-world processes, from engines to atmospheric phenomena.

In this article, we'll thoroughly examine this problem step-by-step, breaking down the principles involved, the relevant equations, and the reasoning to determine the change in the internal energy of the gas. Whether you're a student, a professional, or an enthusiast, this comprehensive guide aims to clarify the concepts and provide a solid framework for approaching similar thermodynamic problems.

Fundamental Concepts in Thermodynamics

Before diving into the specific problem, it's essential to revisit some core principles and definitions in thermodynamics that form the foundation of our analysis.

Internal Energy (U)

- Definition: The internal energy of a system (U) is the total energy contained within the system due to the microscopic motions and interactions of its particles.
- Significance: Changes in internal energy reflect the energy transferred as heat or work, according to the first law of thermodynamics.

First Law of Thermodynamics

- Statement: The change in the internal energy of a system is equal to the heat added to the system minus the work done by the system.
- Mathematical Expression:

$$
\Delta U = Q - W
$$

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

Important Note: The sign convention can vary. Here, we consider work done on the system as positive (since energy is being added to it), and heat absorbed as positive.

Analyzing the Given Scenario

Let's restate the problem with clarity:

> A gas absorbs 500J of heat, while having 200J of work done on it. What is the change in internal energy?

Key points:
- Heat absorbed, $Q = +500\, \text{J}$
- Work done on the system, $W_{on} = +200\, \text{J}$

Since the work is done on the gas, according to our sign convention, this work adds energy to the system, which is equivalent to considering $W = +200\, \text{J}$ in the first law.

Applying the First Law of Thermodynamics

The first law provides a straightforward approach:

$$
\Delta U = Q - W
$$

But note that the sign of W is crucial. Given the problem states "work done on it," the correct interpretation is:

- $Q = +500\, \text{J}$ (since heat is absorbed)
- $W = +200\, \text{J}$ (work done on the gas)

Plugging into the equation:

$$
\Delta U = 500\, \text{J} - 200\, \text{J} = 300\, \text{J}
$$

Result: The internal energy of the gas increases by 300 Joules.

Understanding the Significance of the Result

The positive change indicates an increase in the internal energy of the gas. This makes intuitive sense because:

- The gas absorbs heat energy (adding to its internal energy).
- Work done on the gas further supplies energy to it.
- The net effect is an overall increase in internal energy.

Key Takeaway: When a system absorbs heat and has work done on it, the change in internal energy is simply the net energy transfer, considering both heat and work contributions.

Broader Context and Additional Considerations

While the above calculation is straightforward, real-world thermodynamic systems can involve more complex factors. Here's a look into some additional considerations that often arise in such analyses:

Work Types and Their Significance

- Expansion Work: Work done when the gas expands against external pressure, typically $W = P \Delta V$.
- Boundary Work: General work done when the system's boundary moves.
- Electrical Work: Work done when electrical energy is transferred.

In our problem, the work done on the gas can be assumed to be boundary work, but the specific type doesn't alter the basic calculation.

Sign Conventions and Variations

- Different textbooks and contexts adopt different sign conventions.
- Be clear about whether work done by or on the system is considered positive.
- Always verify the conventions used before calculations.

Implications in Real-World Systems

- Engine Cycles: Understanding energy transfer helps optimize performance.
- Climate Science: Changes in internal energy relate to temperature and weather phenomena.
- Engineering Design: Thermodynamic efficiency hinges on accurately assessing energy changes.

Summary of the Calculation Process

Here's a step-by-step guide to approach similar problems:

1. Identify the quantities given:
- Heat added or removed (Q)
- Work done on or by the system (W)
2. Determine the sign conventions:
- Is heat absorbed or released?
- Is work done on or by the system?
3. Apply the first law of thermodynamics:

$$
\Delta U = Q - W
$$

4. Insert the known values with correct signs:

$$
\Delta U = 500\, \text{J} - 200\, \text{J} = 300\, \text{J}
$$

5. Interpret the result:
- Positive ΔU: internal energy increases
- Negative ΔU: internal energy decreases

Final Thoughts: The Power of Thermodynamics

This scenario exemplifies the elegance and utility of the first law of thermodynamics. By simply accounting for heat transfer and work done, we can precisely determine the change in a system's internal energy. Such analysis forms the backbone of thermal sciences, informing everything from designing efficient engines to understanding natural processes.

Remember: Always pay attention to sign conventions, clarify the type of work involved, and relate the mathematical results back to physical intuition. Mastery of these principles provides a powerful toolkit for tackling complex thermodynamic problems with confidence.

In conclusion, for the problem where a gas absorbs 500J of heat and has 200J of work done on it, the change in internal energy is 300 Joules. This simple yet profound calculation underscores the core principle that energy conservation governs all thermodynamic systems and processes.

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