

A System Gains 1500J Of Heat And 2200J Of Work Is Done By The System On Its Surroundings. Determine The

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Understanding the principles of thermodynamics is essential in analyzing energy transfer processes within physical systems. When a system gains heat and performs work on its surroundings, it's crucial to determine the change in the system's internal energy, as this provides insight into the system's energetic behavior. In this detailed guide, we will explore how to analyze such a scenario step-by-step, covering fundamental concepts, relevant formulas, and practical calculations to help you understand and solve similar problems efficiently.

Fundamental Concepts in Thermodynamics

Before diving into calculations, it's important to familiarize yourself with key thermodynamic principles that underpin the problem.

1. The First Law of Thermodynamics

- The first law states that energy cannot be created or destroyed; it can only be transferred or converted.
- Mathematically, it is expressed as:

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$$\Delta U = Q - W$$

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where:

- ΔU = change in internal energy of the system
- Q = heat added to the system
- W = work done by the system on its surroundings

2. Sign Conventions

- Heat (Q): Positive when heat is added to the system; negative when heat is removed.
- Work (W): Positive when work is done by the system; negative when work is done on the system.
- Internal Energy (ΔU): Change in the system's internal energy, positive if energy increases.

Analyzing the Given Data

The problem provides specific values:

- Heat gained by the system, $Q = +1500\text{ J}$
- Work done by the system, $W = +2200\text{ J}$

Our goal is to determine the change in internal energy, ΔU , of the system based on these values.

Step 1: Identify the Sign Conventions

- Since the system gains heat, $Q = +1500\text{ J}$.
- The system performs work on surroundings, so $W = +2200\text{ J}$.

Step 2: Apply the First Law of Thermodynamics

Using the formula:

$$\Delta U = Q - W$$

Plugging in the known values:

$$\Delta U = 1500\text{ J} - 2200\text{ J}$$

Calculating the Change in Internal Energy

Perform the subtraction:

$$\Delta U = -700\text{ J}$$

This indicates that the internal energy of the system decreases by 700 Joules during the process.

Interpreting the Results

The negative value of (ΔU) signifies that despite gaining heat, the system has performed more work on its surroundings, leading to an overall decrease in its internal energy.

Implications of the Result

- Energy Loss: The system expended more energy in doing work than it gained in heat, resulting in a net loss.
- System Behavior: This scenario is typical in processes like expansion where the system does work and cools or loses internal energy.

Additional Considerations

While the primary goal was to find the change in internal energy, understanding related concepts can provide a more comprehensive view.

1. Efficiency of Energy Transfer

- Assess how effectively the system converts heat into work.
- The efficiency (η) can be approximated as:

$$\eta = \frac{W}{Q}$$

Plugging in the values:

$$\eta = \frac{2200\text{ J}}{1500\text{ J}} \approx 1.47$$

- Since efficiency cannot exceed 1 (or 100%), this suggests the process involves additional energy inputs or that the values are part of a larger cycle.

2. Real-World Applications

- Such calculations are vital in designing engines, refrigerators, and other thermodynamic systems.
- Understanding energy transfer helps optimize performance and efficiency.

Summary and Key Takeaways

- The change in internal energy (ΔU) for the system is calculated using the first law:

$$\boxed{\Delta U = Q - W}$$

- Given $(Q = +1500\text{ J})$ and $(W = +2200\text{ J})$:

$$\Delta U = -700\text{ J}$$

- The negative sign indicates a net decrease in the system's internal energy.
- Proper sign conventions are crucial for accurate calculations.
- Understanding these principles is essential in thermodynamics applications, including engine efficiency, refrigeration cycles, and energy management.

Practical Tips for Solving Similar Problems

- Always clearly identify the sign conventions for heat and work based on the problem statement.
- Use the first law of thermodynamics as the fundamental relation.
- Convert all quantities to consistent units before calculations.
- Consider the physical implications of the sign of (ΔU) to interpret the process correctly.
- Cross-verify results with physical intuition to avoid common mistakes.

Conclusion

Analyzing energy transfer in thermodynamic systems involves understanding the interplay between heat, work, and internal energy. In this scenario, the system's internal energy decreases by 700 Joules due to the combination of heat gain and work performed on the surroundings. Mastery of these concepts aids in solving complex problems in physics, engineering, and related fields, enabling professionals and students to design and evaluate real-world thermal systems efficiently.

Frequently Asked Questions

What is the change in internal energy of the system when it gains 1500J of heat and does 2200J of work on its surroundings?

The change in internal energy (ΔU) is given by the first law of thermodynamics: $\Delta U = Q - W$. Substituting $Q = 1500\text{J}$ and $W = 2200\text{J}$, $\Delta U = 1500\text{J} - 2200\text{J} = -700\text{J}$. So, the internal energy decreases by 700J.

If a system absorbs 1500J of heat and performs 2200J of work, is the process endothermic or exothermic?

Since the system gains heat and does work on the surroundings, and the internal energy decreases, the process can be considered exothermic overall, as energy leaves the system in the form of work.

How do you calculate the work done by the system based on heat transfer and internal energy change?

Using the first law of thermodynamics: $W = Q - \Delta U$. If you know the heat added and the change in internal energy, you can find the work done. In this case, $W = 1500\text{J} - (-700\text{J}) = 2200\text{J}$, confirming the work done is 2200J.

What is the significance of the negative change in internal energy in this scenario?

A negative change in internal energy indicates that the system has lost energy, which aligns with the fact that it performed work (2200J) and gained heat (1500J), resulting in an overall energy decrease.

Can you determine the net energy transfer to or from the system in this process?

Yes. The net energy transfer to the system is the heat gained (1500J), but since the system performs work (2200J), the total energy change is negative, indicating a net loss of internal energy.

What thermodynamic principle is used to analyze this problem?

The first law of thermodynamics is used, which states that the change in internal energy equals heat added to the system minus work done by the system: $\Delta U = Q - W$.

If the work done by the system exceeds the heat gained, what does this imply about the system's energy?

It implies that the system's internal energy decreases because it expends more energy performing work than it gains from heat, leading to an overall energy loss.

What is the numerical value of the change in internal energy for this system?

The change in internal energy is -700J, calculated as $\Delta U = Q - W = 1500\text{J} - 2200\text{J} = -700\text{J}$.

Additional Resources

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Introduction

In the realm of thermodynamics, understanding energy exchanges within systems is fundamental to grasping how various physical processes occur. When a system interacts with its surroundings, it can absorb or release heat, perform work, or undergo a combination of both. The scenario where a system gains a specific amount of heat and simultaneously performs work on its surroundings provides an excellent case study for analyzing energy transfer, the first law of thermodynamics, and related concepts. This article aims to explore this scenario comprehensively, dissecting the principles involved, deriving the necessary quantities, and illustrating the implications of these energy exchanges.

Understanding the Fundamental Concepts

Before delving into calculations, it's essential to clarify the core principles underpinning this analysis: the first law of thermodynamics, heat, work, and internal energy.

The First Law of Thermodynamics

The first law of thermodynamics is a statement of conservation of energy tailored for thermodynamic systems. It states:

The change in internal energy (ΔU) of a system is equal to the heat added to the system (Q) minus the work done by the system (W).

Mathematically:

$$\Delta U = Q - W$$

Where:

- ΔU is the change in internal energy of the system.
- Q is the heat added to the system (positive when heat enters).
- W is the work done by the system (positive when work is done by the system).

This relation emphasizes that any change in the system's internal energy results from heat transfer and work interactions.

Heat (Q)

Heat refers to the transfer of energy due to temperature difference. It flows from higher to lower temperature regions, and in the context of a thermodynamic process, it can be absorbed or released by the system.

In the given scenario, the system gains 1500J of heat, indicating an energy influx from the surroundings.

Work (W)

Work in thermodynamics can take various forms, such as boundary work (expansion or compression of gases), electrical work, or other forms. Here, the system performs 2200J of work on its surroundings, implying the system expends energy to do so.

Internal Energy (U)

Internal energy is the total energy contained within the system due to microscopic motions and interactions. Changes in internal energy are central to understanding the process dynamics.

Analyzing the Scenario Step-by-Step

Given Data:

- Heat gained by the system, $(Q = +1500\text{ J})$

- Work done by the system on surroundings, $(W = 2200, \text{J})$

The goal:

- To determine the change in internal energy, (ΔU)
- To analyze the implications of these energy exchanges
- To interpret whether the process is feasible or what it signifies in real-world contexts

Applying the First Law of Thermodynamics

Using the fundamental relation:

$$\Delta U = Q - W$$

Substituting the known values:

$$\Delta U = 1500, \text{J} - 2200, \text{J} = -700, \text{J}$$

Interpretation:

- The negative sign indicates that the internal energy of the system decreases by 700J during the process.
- Despite gaining heat, the system performs more work than the heat it absorbs, leading to an overall reduction in internal energy.

Implications:

- The process involves energy transfer from the system to its surroundings, with the work output outweighing the heat input.
- This scenario is characteristic of processes such as expansion work, where the system expends energy to perform work, possibly in the form of gas expansion or mechanical movement.

Physical Interpretation and Real-World Examples

Understanding the physical significance of these energy exchanges helps contextualize the theoretical calculations.

Scenario in Practical Terms

Imagine a gas contained within a piston-cylinder assembly:

- The gas absorbs 1500J of heat from an external source, raising its internal energy.
- Simultaneously, the gas expands against external pressure, performing 2200J of work on the surroundings (e.g., moving the piston).
- The net energy change indicates that the internal energy decreases, meaning the gas cools down or loses energy through expansion work despite heat absorption.

Real-World Analogues

- Engine Cycles: Internal combustion engines and turbines often involve heat absorption and work

output, with internal energy fluctuating based on these interactions.

- Refrigeration and Heat Engines: These systems operate through energy transfer processes where heat and work are exchanged to achieve desired outcomes.
- Industrial Processes: Chemical reactions or phase changes that involve heat transfer and work do so in ways similar to this scenario, affecting the energy balance.

Broader Thermodynamic Implications

This analysis underscores several vital principles:

Energy Conservation and Efficiency

- The process exemplifies the conservation of energy, illustrating how heat input and work output relate to internal energy change.
- The efficiency of such a process can be considered, especially if it aligns with thermodynamic cycles like Carnot, Otto, or Rankine cycles.

Entropy Considerations

- Although not explicitly asked, entropy changes would be relevant for a complete thermodynamic analysis, especially if the process is reversible or irreversible.
- Gaining heat and performing work typically involve entropy transfer and production, with potential implications for system irreversibility.

Limitations and Assumptions

- The calculations assume a closed system with no mass transfer.
- Work is considered only as boundary work; other forms of work are not accounted for.
- The process occurs at constant pressure or volume unless specified otherwise, which can influence the interpretation.

Advanced Analytical Perspectives

Beyond the simple application of the first law, more sophisticated analyses can be employed:

Calculating the Change in Entropy

If the process involves heat transfer at a constant temperature or a known temperature profile, the change in entropy ΔS can be determined:

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

where Q_{rev} is the heat transfer in a reversible process, and T is the temperature.

However, since the process involves work performed and possibly irreversibility, the actual entropy change might differ, requiring more detailed data.

Work Done in Different Forms

The calculation assumes work as boundary work; in real systems, other forms such as shaft work, electrical work, or shaft work may contribute, adding complexity to the energy accounting.

Energy Balance in Cyclic Processes

In cyclic processes, the net change in internal energy over a cycle is zero, yet energy exchanges occur in the form of heat and work, which aligns with the principles demonstrated here.

Concluding Remarks

The scenario where a system gains 1500J of heat while performing 2200J of work on its surroundings offers rich insights into thermodynamic principles. The key outcome—the internal energy decreasing by 700J—highlights the dominance of work output over heat input in this process. Such analyses are foundational in designing engines, understanding energy efficiency, and optimizing industrial processes.

Understanding these energy exchanges not only deepens our grasp of thermodynamics but also informs practical applications across engineering, physics, and energy management sectors. As we continue to pursue sustainable and efficient energy utilization, mastering these fundamental concepts remains more relevant than ever.

References

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Note: This article provides a comprehensive analysis based on the provided data and fundamental thermodynamic principles. For specific real-world applications, additional factors such as process irreversibility, temperature variations, and system constraints should be considered.

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