

What Is The Mass Of A Sample Of Water That Takes 2000 KJ Of Energy To Boil Into Steam At 373 K. The Latent

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Understanding the relationship between energy transfer and phase change in water is fundamental in thermodynamics and various practical applications like heating, cooking, and industrial processes. When water transitions from its liquid state to vapor at its boiling point, it requires a specific amount of energy known as the latent heat of vaporization. This article explores how to determine the mass of a water sample that absorbs 2000 kilojoules (kJ) of energy during boiling at 373 Kelvin (100°C). We will delve into the concepts of specific heat capacity, latent heat, and the calculations involved to provide a comprehensive understanding of this process.

Fundamental Concepts in Water Heating and Phase Change

To accurately calculate the mass of water that absorbs a certain amount of energy during boiling, it is essential to understand several key thermodynamic principles.

Specific Heat Capacity of Water

The specific heat capacity (c) is the amount of heat energy required to raise the temperature of one kilogram of a substance by one Kelvin (or degree Celsius). For water, this value is approximately:

$$c = 4.186 \text{ kJ/kg}\cdot\text{K}$$

This means that to increase the temperature of 1 kg of water by 1 K, 4.186 kJ of energy is needed.

Latent Heat of Vaporization

The latent heat of vaporization (L) is the heat energy required to convert a unit mass of a liquid into vapor without changing its temperature. For water

at 100°C, the latent heat of vaporization is approximately:

- $L = 2260 \text{ kJ/kg}$

This value indicates that to turn 1 kg of water at boiling point into steam, 2260 kJ of energy must be absorbed.

Phase Change Process of Water

The process of boiling involves two main stages:

1. Heating the water from initial temperature to the boiling point (if necessary).
2. The phase change from liquid to vapor, which requires latent heat.

In our case, since the water is already at the boiling point (373 K), only the latent heat is relevant.

Calculating the Mass of Water Using Energy Input

Given the problem statement, the total energy supplied to the water is 2000 kJ, and the goal is to find out how much water this energy can vaporize at 373 K.

Step 1: Confirm the Process Conditions

- Initial temperature of water: 373 K (100°C)
- Final state: Water vapor at 373 K
- Energy supplied: 2000 kJ

Since the water is already at boiling temperature, we do not need to consider heating from a lower temperature; only the latent heat of vaporization is involved.

Step 2: Use the Latent Heat of Vaporization to Find Mass

The formula to determine the mass (m) of water vaporized with a given energy (Q) is:

$$Q = m \times L$$

Rearranged to solve for mass:

$$m = \frac{Q}{L}$$

Substituting the known values:

$$m = \frac{2000 \text{ kJ}}{2260 \text{ kJ/kg}}$$

Calculating:

$$m \approx 0.885 \text{ kg}$$

Answer: Approximately 0.885 kilograms of water are vaporized when 2000 kJ of energy is supplied at boiling point.

Additional Considerations in Energy Calculations

While the above calculation directly uses the latent heat of vaporization, real-world scenarios often involve additional factors.

Heating Water from a Lower Temperature to Boiling Point

If the water did not start at 100°C, you would need to account for the energy required to heat it from its initial temperature (T_{initial}) to the boiling point (373 K). The total energy would then be:

$$Q_{\text{total}} = m \times c \times (T_{\text{boiling}} - T_{\text{initial}}) + m \times L$$

Where:

- c = specific heat capacity
- T_{initial} = initial temperature

In such cases, the calculation involves solving for m considering both heating and phase change energies.

Impact of Pressure and Temperature Variations

The values of latent heat and boiling point are dependent on pressure conditions. For instance:

- At higher pressures, water boils at temperatures above 100°C.
- The latent heat of vaporization decreases slightly with increasing temperature.

These factors are critical in industrial applications like pressurized boilers and steam turbines.

Practical Applications of the Calculation

Understanding how to calculate the mass of water vaporized with a given energy input has several practical implications.

1. Designing Heating Systems

Engineers use these calculations to design efficient heating systems, ensuring they provide adequate energy to convert water into steam for power generation or industrial processes.

2. Estimating Energy Consumption

Accurate estimations of energy requirements help in budgeting and optimizing energy usage, especially in large-scale operations like thermal power plants.

3. Cooking and Food Processing

Cooks and food processing industries rely on precise heat calculations to control moisture content and ensure safety.

Summary and Key Takeaways

- The mass of water that can be vaporized with 2000 kJ at 373 K is approximately 0.885 kg.
- The calculation is based on the latent heat of vaporization, which is 2260 kJ/kg for water at boiling point.
- No additional heating energy is needed if the water is already at boiling temperature.
- Real-world scenarios may involve additional factors like initial temperature, pressure, and heat losses.

Conclusion

Determining the mass of water that absorbs a specific amount of energy during boiling is a fundamental thermodynamic calculation with broad applications in science and industry. By understanding the concepts of specific heat capacity and latent heat of vaporization, and applying straightforward formulas, one can accurately predict the amount of water vaporized under given energy inputs. In this case, supplying 2000 kJ of energy to water at 373 K results in approximately 0.885 kg of water being converted into steam, illustrating the direct relationship between energy transfer and phase change. Mastery of these calculations enhances efficiency in energy management, process design, and scientific analysis.

Keywords: water boiling, latent heat of vaporization, thermodynamics, energy calculation, phase change, specific heat capacity, steam production, energy transfer, industrial processes

Frequently Asked Questions

How do you calculate the mass of water that requires 2000 kJ to boil at 373 K?

You can calculate the mass by dividing the heat energy (Q) by the latent heat of vaporization (L). Using the formula $m = Q / L$, where L is approximately 2260 kJ/kg for water.

What is the significance of the latent heat of

vaporization in this problem?

The latent heat of vaporization represents the energy needed to convert a unit mass of water from liquid to vapor at its boiling point without changing temperature. It is essential for calculating the mass based on the total energy supplied.

If the energy supplied is 2000 kJ, what is the approximate mass of water that can be vaporized at 373 K?

Using the latent heat of 2260 kJ/kg, the mass is approximately $2000 / 2260 \approx 0.885$ kg.

Does the initial temperature of water affect the calculation of the mass in this context?

No, because the temperature of the water is already at 373 K, the boiling point, so the energy supplied is solely used for vaporization, not heating the water further.

What assumptions are made when calculating the mass of water in this scenario?

The calculation assumes the latent heat of vaporization is constant at 2260 kJ/kg, the entire 2000 kJ is used solely for vaporization without heat losses, and the water is at its boiling point at atmospheric pressure.

Additional Resources

What Is The Mass Of A Sample Of Water That Takes 2000 KJ Of Energy To Boil Into Steam At 373 K. The Latent heat is a fundamental concept in thermodynamics, especially relevant when analyzing phase changes such as boiling. Understanding how much water corresponds to a specific amount of energy required for vaporization provides valuable insights into energy transfer, phase transition processes, and practical applications in engineering, meteorology, and everyday life. In this article, we will delve into the principles governing this problem, explore the relevant formulas, and walk through a step-by-step calculation to determine the mass of the water sample.

Introduction to the Problem

Suppose you have a sample of water at its boiling point, 373 K (which is equivalent to 100°C at standard atmospheric pressure). You are provided with

a total energy input of 2000 kJ (kilojoules) to convert this water entirely into steam. The question is: what is the mass of the water that requires this amount of energy for vaporization?

This problem involves understanding the concepts of latent heat, energy transfer during phase changes, and the relationship between heat energy and mass.

Key Concepts and Definitions

1. Latent Heat of Vaporization

The latent heat of vaporization (L_v) is the amount of energy required to convert a unit mass of a substance from the liquid phase into the vapor phase at constant temperature and pressure.

- For water at 100°C, L_v is approximately 2260 kJ/kg.
- It signifies that 2260 kJ of energy is needed to vaporize 1 kg of water at boiling point.

2. Energy for Phase Change

The total energy (Q) required to vaporize a certain mass (m) of water is:

$$Q = m \times L_v$$

Where:

- Q is the total heat energy supplied (in kJ),
- m is the mass of water (in kg),
- L_v is the latent heat of vaporization (in kJ/kg).

Step-by-Step Calculation

1. Identify the Known Values

Parameter	Value	Description
Q	2000 kJ	Total energy supplied
L_v	2260 kJ/kg	Latent heat of vaporization at 100°C

2. Write the Relevant Equation

Given the relation:

$$Q = m \times L_v$$

Rearranged to find the mass:

$$\left[m = \frac{Q}{L_v} \right]$$

3. Plug in Known Values

$$\left[m = \frac{2000 \text{ kJ}}{2260 \text{ kJ/kg}} \right]$$

4. Perform the Calculation

$$\left[m \approx 0.884 \text{ kg} \right]$$

So, approximately 0.884 kilograms of water require 2000 kJ of energy to vaporize at 373 K.

Additional Considerations

1. Specific Heat and Heating Before Vaporization

This calculation assumes the water is already at boiling point (373 K). If the water starts below boiling temperature, additional energy would be needed to heat it up to boiling point.

- Specific heat capacity of water: approximately 4.186 kJ/kg·K.
- Energy to heat water from initial temperature T_i to boiling point:

$$\left[Q_{\text{heat}} = m \times c \times (T_{\text{boiling}} - T_i) \right]$$

where:

- $c = 4.186 \text{ kJ/kg}\cdot\text{K}$,
- T_i = initial temperature.

If the initial temperature is known, this energy should be added to the vaporization energy to get the total energy required.

2. Effect of Pressure and Temperature

The latent heat of vaporization varies slightly with pressure and temperature. The value used here (2260 kJ/kg) is standard at 100°C and atmospheric pressure. For other conditions, consult thermodynamic tables.

3. Energy Losses and Practical Realities

In real systems, energy transfer isn't perfectly efficient. Heat losses to surroundings or equipment can mean more energy is needed in practice.

Practical Applications and Implications

Understanding the relationship between energy input and mass vaporized is

essential in various fields:

- Power plants: Estimating how much water is converted into steam to generate electricity.
- Meteorology: Modeling evaporation and condensation processes.
- Cooking and industry: Controlling boiling processes and energy usage.
- Chemical engineering: Designing distillation and separation processes.

Summary

To summarize:

- The mass of water that takes 2000 kJ of energy to boil into steam at 373 K (assuming ideal conditions and standard latent heat) is approximately 0.884 kg.
- The calculation relies on the fundamental relationship:

$$m = \frac{Q}{L_v}$$

- Recognizing the importance of the latent heat of vaporization simplifies the problem and provides a clear pathway for calculations involving phase changes.

Final Thoughts

Understanding phase change energetics is a cornerstone of thermodynamics and engineering. When analyzing real-world scenarios, always consider initial conditions, environmental factors, and system efficiencies. This problem illustrates how fundamental principles translate into practical calculations, empowering engineers, scientists, and students alike to make informed decisions about energy transfer and material properties.

In conclusion, the question about the mass of water requiring 2000 kJ to vaporize at boiling point elegantly demonstrates the application of latent heat concepts. Whether designing industrial processes or studying natural phenomena, grasping these principles enables accurate energy management and system optimization.

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