A Mass Of 0.5kg Of Water At 10c Is Converted Into Ice At 0c The Specific Latent Heat Of Water Is 4.2jkg/c

A Mass Of 0.5kg Of Water At 10°C Is Converted Into Ice At 0°C The Specific Latent Heat Of Water Is 4.2 J/kg/°C

Understanding the process of water changing from a liquid to a solid is fundamental in thermodynamics and physical science. When a mass of 0.5 kg of water at 10°C is converted into ice at 0°C, it involves a series of energy exchanges, particularly involving the concepts of specific heat capacity and latent heat. The specific latent heat of water, given as 4.2 J/kg/°C, plays a crucial role in this transformation. This article explores the detailed physics behind this process, including calculations, principles, and real-world applications.

Introduction to Water's Phase Change and Latent Heat

What is Latent Heat?

Latent heat refers to the heat energy absorbed or released by a substance during a phase change without changing its temperature. For water, the phase change from liquid to solid (freezing) involves releasing latent heat, which must be removed from the water for it to freeze at 0°C.

Specific Latent Heat of Water

The specific latent heat of water (commonly denoted as L) is the amount of heat required to convert 1 kg of water at its melting point into ice (or vice versa) without changing temperature. The value given as 4.2 J/kg/°C in this context appears to be a typo or misinterpretation because the standard latent heat of fusion of water is approximately 334,000 J/kg. The figure 4.2 J/kg/°C more accurately relates to the specific heat capacity of water, which is about 4.2 J/g/°C or 4200 J/kg/°C. For the purpose of this article, we assume the standard latent heat of fusion, 334,000 J/kg, as the correct value to analyze the phase change.

Calculating the Energy Required to Freeze Water

Step 1: Cooling Water from 10°C to 0°C

Before water can freeze, it must be cooled from its initial temperature (10°C) down to the freezing point (0°C). The energy removed during this cooling process can be calculated using the specific heat capacity.

The formula:
$$ Q = mc\Delta T $$
Where:
- Q is the heat energy (J)
- m is the mass of water (kg)
- c is the specific heat capacity of water (J/kg/°C)
- ΔT is the temperature change (°C)

Given:
- $m = 0.5\,kg$
- $c = 4200\,J/kg/°C$
- $\Delta T = 10\,°C - 0\,°C = 10\,°C$

Calculating:
$$ Q_{cooling} = 0.5 \times 4200 \times 10 = 21,000\,J $$

This is the amount of heat energy that must be removed to bring the water from 10°C to 0°C.

Step 2: Freezing the Water at 0°C

Once the water reaches 0°C, it must lose additional energy to undergo the phase change into ice. This involves removing the latent heat of fusion.

The formula:
$$ Q_{fusion} = m \times L $$
Where:
- L is the latent heat of fusion for water, approximately 334,000 J/kg.

Calculating:
$$ Q_{fusion} = 0.5 \times 334,000 = 167,000\,J $$

This is the energy that must be removed to convert 0.5 kg of water at 0°C into ice at 0°C.

Total Energy Removal and Practical Implications

Overall Energy to Convert Water at 10°C to Ice at 0°C

Adding the two components:
$$ Q_{total} = Q_{cooling} + Q_{fusion} $$
$$ Q_{total} = 21,000 + 167,000 = 188,000\,J $$

Therefore, approximately 188,000 Joules of heat energy must be removed from 0.5 kg of water initially at 10°C to convert it into ice at 0°C.

Implications in Real-World Scenarios

Understanding this energy transfer is vital in many practical applications, including:
- Designing refrigeration and freezing systems
- Weather phenomena like frost formation
- Cryopreservation processes
- Climate studies involving ice melting and formation

Thermodynamics Principles Involved

Conservation of Energy

The process illustrates the conservation of energy principle: the heat removed from the water equals the energy needed for phase change and temperature reduction.

Heat Transfer Mechanisms

- Conduction: Heat transfer through direct contact in cooling systems.
- Convection: Movement of water or air facilitating heat exchange.
- Radiation: Emission or absorption of electromagnetic waves, especially in large-scale cooling.

Additional Factors Affecting the Phase Change Process

Environmental Conditions

Ambient temperature, pressure, and insulation impact how efficiently water cools and freezes.

Impurities and Water Quality

Impurities can alter the melting point, affecting the energy calculations and phase change dynamics.

Container Material and Geometry

The material and shape influence heat transfer rates and freezing patterns.

Conclusion

Transforming 0.5 kg of water at 10°C into ice at 0°C involves a calculated removal of approximately 188,000 Joules of energy. This process underscores the importance of understanding specific heat capacity and latent heat in thermodynamics. Whether in industrial applications, natural phenomena, or scientific research, these principles govern how water transitions between states, with energy considerations being central to controlling and predicting these changes.

Summary of Key Points

- Cooling water from 10°C to 0°C requires removing 21,000 Joules.
- Freezing the water at 0°C requires removing 167,000 Joules of latent heat.
- Total energy to be removed: approximately 188,000 Joules.
- The process exemplifies fundamental thermodynamics concepts such as latent heat, specific heat capacity, and energy conservation.
- Practical applications include refrigeration, climate science, and industrial freezing processes.

Understanding these concepts not only enhances our grasp of physics but also informs technological innovations and environmental strategies related to water and ice management.

Frequently Asked Questions

What is the amount of heat required to convert 0.5 kg of water at 10°C into ice at 0°C?

First, cool the water from 10°C to 0°C: Q1 = mass × specific heat capacity × temperature change = 0.5 kg × 4.2 J/kg°C × 10°C = 21 J. Then, convert water at 0°C to ice at 0°C: Q2 = mass × latent heat = 0.5 kg × 4.2 J/kg = 2.1 J. Total heat required = Q1 + Q2 = 21 J + 2.1 J = 23.1 J.

How much energy is released when 0.5 kg of water freezes at 0°C?

The energy released during freezing is equal to the latent heat: Q = 0.5 kg × 4.2 J/kg = 2.1 Joules.

What is the significance of the specific latent heat of water in this process?

The specific latent heat of water (4.2 J/kg) indicates the amount of energy required to convert 1 kg of water at 0°C into ice without changing temperature, which is essential for calculating energy exchanges during freezing.

If the initial water temperature was higher than 10°C, how

would that affect the heat needed to freeze the water?

The higher the initial temperature, the more heat must be removed to reach 0°C, increasing the total energy required for freezing.

Can the heat required to freeze 0.5 kg of water be supplied all at once, or does it need to be gradual?

While theoretically it can be supplied all at once, in practice, freezing is typically done gradually to control the process and prevent damage from rapid temperature changes.

What role does the specific heat capacity of water play in the cooling process before freezing?

The specific heat capacity determines how much heat needs to be removed to lower the water's temperature from 10°C to 0°C, which in this case is 21 Joules.

If water is already at 0°C, how much energy is needed to convert 0.5 kg into ice?

Only the latent heat is needed, which is 2.1 Joules, since there is no temperature change.

What assumptions are made in calculating the heat required to freeze water in this scenario?

Assumptions include that the water's specific heat capacity and latent heat are constant, the process occurs at constant pressure, and no heat is lost to the surroundings.

How does the mass of water affect the total energy required for freezing?

The total energy required is directly proportional to the mass; doubling the mass would double the heat needed for both cooling and freezing.

Why is it important to consider both specific heat capacity and latent heat in this process?

Because cooling from 10°C to 0°C involves heat removal related to specific heat capacity, and the phase change from water to ice involves latent heat; both contribute to the total energy exchange.

Additional Resources

A mass of 0.5kg of water at 10°C is converted into ice at 0°C. The specific latent heat of water is 4.2 kJ/kg. Understanding this process requires delving into the principles of heat transfer, phase change, and the specific properties of water. This article offers a comprehensive guide to the science behind this transformation, exploring the concepts step-by-step, and providing practical insights into the energy involved in converting water to ice.

Introduction

The process of changing water from a liquid at a certain temperature to solid ice at a lower temperature involves more than just cooling. It encompasses a fascinating interplay of thermodynamics, phase change principles, and energy calculations. When a mass of water cools from 10°C down to 0°C and then freezes, it undergoes temperature change and a phase change, each associated with distinct energy exchanges. The key parameters include the mass of water, initial and final temperatures, and the specific latent heat of fusion.

In this guide, we will analyze the scenario of 0.5kg of water at 10°C being converted into ice at 0°C, considering the relevant physics and calculations. The specific latent heat of water (4.2 kJ/kg) plays a vital role in determining the energy required for the phase change.

Understanding the Key Concepts

1. Specific Heat Capacity

- Definition: The amount of heat required to raise the temperature of 1 kg of a substance by 1°C.
- For water: The specific heat capacity is approximately 4.2 J/g/°C or 4200 J/kg/°C.

This property determines how much energy needs to be added or removed to change the water's temperature without changing its phase.

2. Latent Heat of Fusion

- Definition: The heat required to convert 1 kg of a substance from liquid to solid (or vice versa) at constant temperature.
- For water: The specific latent heat of fusion is approximately 4.2 kJ/kg.

This is the energy involved when water freezes at 0°C, without a change in temperature.

3. Phase Change Process

The transition from water at 10°C to ice at 0°C involves:
- Cooling the water from 10°C to 0°C.
- Freezing the water at 0°C into ice.

Step-by-Step Breakdown of the Process

Step 1: Cooling Water from 10°C to 0°C

The initial step is to remove heat to lower the temperature of water from 10°C down to 0°C.

Calculation:
- Heat removed, Q_1, is given by:

$$
Q_1 = m \times c \times \Delta T
$$

Where:
- $m = 0.5\, \text{kg}$
- $c = 4200\, \text{J/kg/°C}$
- $\Delta T = 10\,^\circ C - 0\,^\circ C = 10\,^\circ C$

$$
Q_1 = 0.5 \times 4200 \times 10 = 0.5 \times 42,000 = 21,000\, \text{J}
$$

Interpretation: Removing 21,000 Joules cools the water to 0°C.

Step 2: Freezing Water at 0°C

Once the water reaches 0°C, the next step is phase change—freezing the water into ice.

Calculation:
- Heat removed during freezing, Q_2, is:

$$
Q_2 = m \times L_f
$$

Where:
- $L_f = 4.2\, \text{kJ/kg} = 4200\, \text{J/kg}$

$$
Q_2 = 0.5 \times 4200 = 2100\, \text{J}
$$

Interpretation: An additional 2,100 Joules must be removed to convert water at 0°C into ice at 0°C.

Total Energy Removed

Adding both components:

$$
Q_{total} = Q_1 + Q_2 = 21,000\, \text{J} + 2,100\, \text{J} = 23,100\, \text{J}
$$

Thus, 23,100 Joules of energy must be extracted to convert 0.5 kg of water at 10°C into ice at 0°C.

Practical Implications and Applications

1. Cooling and Freezing Processes

Understanding heat transfer during phase changes is essential in designing refrigeration systems, ice-making equipment, and climate control technologies. For example, quantifying the energy removal helps in selecting appropriate cooling capacities and ensuring efficiency.

2. Energy Conservation and Efficiency

Knowledge of the energy involved in phase changes aids in optimizing energy consumption. For instance, in large-scale freezing operations, minimizing unnecessary energy expenditure during cooling and freezing can lead to significant cost savings.

3. Environmental Considerations

Efficient use of energy during freezing processes reduces environmental impact, especially when electricity is generated from fossil fuels. Calculations like those above inform sustainable practices in industry.

Additional Insights

A. Effect of Initial Temperature

The initial temperature of water influences the total energy required. If the water started at a higher temperature, more heat would need to be removed for cooling, increasing the total energy involved.

B. Heating and Cooling Cycles

In many practical scenarios, water may undergo multiple heating and cooling cycles. Understanding the energy involved at each stage helps in energy budgeting and system design.

C. Factors Affecting Latent Heat

While the latent heat of fusion is approximately 4.2 kJ/kg for pure water at 0°C, impurities or pressure variations can slightly alter this value, influencing energy calculations.

Summary: Key Calculations Recap

Step	Description	Energy (J)
1	Cooling water from 10°C to 0°C	21,000
2	Freezing water at 0°C into ice	2,100
Total	Energy removed to complete process	23,100

Final Remarks

Transforming water into ice at 0°C involves more than just reaching the freezing point; it requires careful consideration of both temperature reduction and phase change energy. The specific latent heat of water (4.2 kJ/kg) is a critical parameter, dictating how much energy must be extracted during the phase transition. Whether in industrial applications or scientific experiments, understanding these principles ensures precise control over thermal processes.

By mastering these calculations and concepts, engineers, scientists, and students can better predict energy requirements, optimize cooling systems, and deepen their understanding of thermodynamics in everyday phenomena.

In conclusion, the conversion of 0.5kg of water at 10°C into ice at 0°C involves removing approximately 23.1 kJ of energy—an elegant demonstration of the interplay between heat capacity and latent heat, fundamental to thermodynamics and practical engineering solutions.

A Mass Of 0 5kg Of Water At 10c Is Converted Into Ice At 0c The Specific Latent Heat Of Water Is 4 2jkg C

A Mass Of 0 5kg Of Water At 10c Is Converted Into Ice At 0c The Specific Latent Heat Of Water Is 4 2jkg C

Related Articles

- Detailed Instructions:1. Download The Spreadsheet, TED Talk Activity 3.xlsx (below Is Screenshot)2. Write
- Find The Equation For (a) The Tangent Plane And (b) The Normal Line At The Point P0(2,0,2) On The Surface
- A __________ Is A Large Grant To A State By The Federal Government With Only General Spending Guidelines.

Back to Home