Consider A Thermal System Consisting Of 50 G Of Ice At 25 C And 0.2 Kg Of Water At 15 C. A) What Is The

Consider A Thermal System Consisting Of 50 G Of Ice At 25°C And 0.2 Kg Of Water At 15°C. A) What Is The

Understanding the thermal behavior of mixtures involving ice and water is fundamental in thermodynamics, especially when analyzing phase changes, heat transfer, and energy balance. This article provides a comprehensive exploration of such a system, focusing on calculating the final temperature after thermal equilibrium is reached and related parameters. We will delve into the specific heat capacities, latent heat of fusion, and the step-by-step process to solve for the unknowns in this scenario.

Introduction to the System Components

Before analyzing the thermal interactions, it's essential to understand the properties of the individual components in the system:

Ice

- Mass: 50 grams (0.05 kg)
- Initial Temperature: 25°C
- Properties:
  - Specific heat capacity: approximately 2.1 kJ/(kg·°C)
  - Latent heat of fusion: approximately 334 kJ/kg

Water

- Mass: 0.2 kg
- Initial Temperature: 15°C

- Properties:
    - Specific heat capacity: approximately 4.18 kJ/(kg·°C)

Understanding the Thermodynamic Processes Involved

The system involves several potential processes:

1. Heating or cooling of ice to its melting point

- If the initial temperature of ice is below its melting point (0°C), it will need to be heated to 0°C before melting.
- In our case, the ice is at 25°C, which is above 0°C, implying the ice is initially in a superheated state. However, in practical scenarios, ice can't be at 25°C unless it's in a melted or mixed state. Usually, ice at 25°C would be in a melted state or the problem intends to analyze the melting process assuming initial states. For this analysis, assume the initial temperature of ice is 25°C, meaning the ice is actually water at 25°C or the problem intends the initial state to be at 0°C, and the temperature is misrepresented.
- For clarity, we assume the initial ice temperature is below melting point, say 0°C, to proceed logically.

2. Melting of ice into water

- Requires the absorption of latent heat at 0°C.
- The phase change is critical in energy calculations.

3. Heating of the melted ice to the final temperature

- Once melted, the water heats up from 0°C to the final equilibrium temperature.

4. Cooling or heating of water to final temperature

- The initial water at 15°C exchanges heat with the ice/melted ice until thermal equilibrium is reached.

Step-by-Step Calculation Approach

The solution involves energy balance: the heat lost by the warmer components equals the heat gained by the colder components until equilibrium.

Step 1: Clarify initial states

- For this problem, assume the ice is initially at 0°C (standard for melting calculations) and the water at 15°C.
- The ice is at its melting point, so no heating to 0°C is necessary.
- The initial water is at 15°C, which will cool down or heat up depending on the final temperature.

Step 2: Determine if the ice melts completely

- Calculate the heat required to melt all the ice.
- Calculate the heat transfer from water cooling from 15°C to the final temperature.

Step 3: Set up energy balance equation

- Total heat lost by water = total heat gained by ice and melted water.

Step 4: Solve for the final temperature

- Use the specific heat capacities and latent heat to formulate the equations.
- Determine whether the ice melts completely or only partially.

Detailed Calculations

1. Heat required to melt the ice

- Mass of ice: 0.05 kg
- Latent heat of fusion: 334 kJ/kg

$$
Q_{melt} = m_{ice} \times L_f = 0.05 \, \text{kg} \times 334 \, \text{kJ/kg} = 16.7 \, \text{kJ}
$$

2. Heat transfer from water cooling from 15°C to final

temperature T

- Mass of water: 0.2 kg
- Specific heat capacity of water: 4.18 kJ/(kg·°C)

$$
Q_{water} = m_{water} \times c_{water} \times (T_{initial} - T_{final}) = 0.2 \times 4.18 \times (15 - T)
$$

3. Heat required to raise melted ice from 0°C to T

- If the final temperature T > 0°C, the melted ice (which is water at 0°C) will absorb heat:

$$
Q_{ice\_warming} = m_{ice} \times c_{water} \times (T - 0) = 0.05 \times 4.18 \times T
$$

4. Energy balance equations

- If the ice melts completely, the total heat gained by the ice (melting + warming) plus the heat required to reach T equals the heat lost by water cooling from 15°C to T:

$$
Q_{water\_loss} = Q_{melt} + Q_{ice\_warming}
$$

$$
0.2 \times 4.18 \times (15 - T) = 16.7 + 0.05 \times 4.18 \times T
$$

- Rearranged:

$$
0.836 \times (15 - T) = 16.7 + 0.209 \times T
$$

$$
12.54 - 0.836 T = 16.7 + 0.209 T
$$

$$
-0.836 T - 0.209 T = 16.7 - 12.54
$$

$$
-1.045 T = 4.16
$$

$$
T = -\frac{4.16}{1.045} \approx -3.98^\circ C
$$

Since a negative temperature is physically impossible in this context (assuming the actual system), it indicates that the water cannot cool down to that temperature while melting all ice and reaching equilibrium. Therefore, the assumption that all ice melts is invalid; instead, only partial melting or no melting may occur.

Interpreting Results and Final State

Given the calculations, the system's actual behavior is:

1. No complete melting of ice

- Since the water temperature is only 15°C initially and the ice is at 0°C, the water can cool down to a temperature just above 0°C without melting all the ice if the energy transfer isn’t sufficient.

2. Final temperature estimation

- To find the final temperature, assume that the ice remains partially unmelted and calculate the temperature at which the heat exchange balances.

3. Energy balance for no melting scenario

- The water cools from 15°C to T, and the ice warms from 0°C to T:

$$
Q_{water} = 0.2 \times 4.18 \times (15 - T)
$$

$$
Q_{ice} = 0.05 \times 4.18 \times (T - 0)
$$

- The heat lost by water equals the heat gained by ice:

$$
0.2 \times 4.18 \times (15 - T) = 0.05 \times 4.18 \times T
$$

$$
0.836 \times (15 - T) = 0.209 \times T
$$

$$
12.54 - 0.836 T = 0.209 T
$$

$$
12.54 = 0.836 T + 0.209 T = 1.045 T
$$

$$
T = \frac{12.54}{1.045} \approx 12.0^\circ C
$$

This indicates that the system will reach a final temperature of approximately 12°C, with some ice remaining unmelted.

Conclusion: Final State of the System

Based on the detailed calculations and thermodynamic principles, the final temperature of the system where 50 grams of ice at 0°C and 0.2 kg of water at 15°C reach thermal equilibrium is approximately 12°C. At this temperature:

- Not all the ice melts; some remains in solid state.
- The system stabilizes with a mixture of ice and water at equilibrium.
- The energy exchange

Frequently Asked Questions

Consider a thermal system consisting of 50 g of ice at 25°C and 0.2 kg of water at 15°C. What is the final equilibrium temperature of the system after thermal interaction?

The final temperature can be found by equating heat lost by the warmer water and heat gained by the ice, considering phase change if necessary. Since the ice is initially at 25°C, which is above its melting point, the problem may involve melting the ice first, then reaching thermal equilibrium. Calculations would involve specific heat capacities and latent heat of fusion.

In a thermal system with 50 g of ice at 25°C and 0.2 kg of water at 15°C, how much energy is required to bring all components to a uniform temperature of 0°C?

To bring all components to 0°C, heat must be supplied to cool the water from 15°C to 0°C and to melt the ice at 25°C down to 0°C. The energy includes the sensible heat for cooling the water and the ice, and the latent heat of fusion to melt the ice.

What is the total heat transfer involved when 50 g of ice at 25°C is cooled to 0°C and melted, given the initial water at 15°C?

The total heat transfer includes cooling the ice from 25°C to 0°C and melting it, calculated using specific heat capacity of ice and latent heat of fusion. The initial water at 15°C may gain or lose heat depending on the final state, but if the goal is to reach 0°C, the heat involved is the sum of cooling and melting energies for the ice.

If the ice at 25°C and water at 15°C are allowed to reach thermal equilibrium, what phase changes occur, and how do they affect the final temperature?

Since the ice is initially at 25°C, which is above its melting point, it would first need to cool down to 0°C before melting. In this process, the ice would undergo cooling to 0°C, then melt into water. The final temperature depends on the heat exchange and the amount of energy transferred, likely stabilizing at or below 0°C after melting.

How do the specific heats of ice and water influence the final temperature in the system comprising 50 g of ice at 25°C and 0.2 kg of water at 15°C?

The specific heats determine how much energy is required to change the temperature of each substance. A higher specific heat means more energy is needed for a given temperature change. These values influence the amount of heat exchanged, thus affecting the final equilibrium temperature of the system.

Additional Resources

Consider a thermal system consisting of 50 g of ice at 25°C and 0.2 kg of water at 15°C—a classic problem in thermodynamics that illustrates the fundamental principles of heat transfer, phase change, and energy balance. Analyzing such a system provides valuable insights into how heat flows between different substances, how phase changes influence energy calculations, and how to approach real-world problems involving multiple thermal components. Whether you're a student, engineer, or enthusiast, understanding this scenario enhances your grasp of thermal system analysis and the application of thermodynamic laws.

Introduction to the System

Imagine a small container holding two distinct quantities of water and ice:

- Ice: 50 grams (0.05 kg) at 25°C

- Liquid Water: 200 grams (0.2 kg) at 15°C

This setup might be encountered in various practical contexts, such as cooling processes, refrigeration systems, or even in everyday scenarios like melting ice in a drink. The key question typically posed is: What is the final temperature of the system once thermal equilibrium is reached?

To analyze this, we need to understand the thermal properties of ice and water, the heat transfer processes involved, and the phase change phenomena.

Fundamental Concepts and Assumptions

Before diving into calculations, let's clarify some fundamental concepts and assumptions:

- Thermal Equilibrium: The system reaches a point where all components share a common temperature and no further net heat transfer occurs.
- Negligible Heat Loss: The system is perfectly insulated, meaning no heat escapes to the surroundings.
- Constant Properties: Specific heats and latent heats are constant over the temperature ranges considered.
- No External Work: The process involves only heat transfer; no work is done on or by the system.
- Phase Change Consideration: Ice may melt, and water may freeze, depending on energy exchanges.

Thermal Properties Required

To analyze the system, we need specific thermodynamic properties:

Property	Value	Units	Description
Specific heat of ice, c_{ice}	2.1	kJ/(kg·°C)	Heat capacity of ice
Specific heat of water, c_{water}	4.18	kJ/(kg·°C)	Heat capacity of water
Latent heat of fusion of ice, L_f	334	kJ/kg	Energy required to convert ice at 0°C to water at 0°C

Note: Values are typical and can vary slightly depending on temperature, but these are standard approximations.

Step-by-Step Analysis Approach

The goal is to determine the final temperature of the system after thermal interactions have ceased. The analysis involves:

1. Assessing whether the ice will melt completely or only partially.
2. Calculating the heat transfer required to bring the ice to melting point, melt it, and then warm the resulting water.
3. Determining if the warm water can transfer enough heat to melt the ice and reach equilibrium at

a certain temperature.
4. Applying energy balance equations to find the final temperature.

Step 1: Calculate the initial thermal energy content

The initial thermal energies stored in the ice and water:

- Ice at 25°C: Since ice is initially at 25°C but below the melting point (0°C), it must be cooled down to 0°C before melting.
- Water at 15°C: It can be heated up or cooled down depending on the final temperature.

Step 2: Energy needed to cool the ice to 0°C

The ice needs to be cooled from 25°C down to 0°C:

$$
Q_{ice\_cool} = m_{ice} \times c_{ice} \times (0 - T_{initial,ice}) = 0.05\,kg \times 2.1\,kJ/(kg\cdot°C) \times (0 - 25°C)
$$

$$
Q_{ice\_cool} = 0.05 \times 2.1 \times (-25) = -2.625\,kJ
$$

Negative sign indicates heat is released by the ice as it cools.

Step 3: Energy needed to warm the water from 15°C to the final temperature

Suppose the final temperature of the system is T_f (in °C). The water initially at 15°C:

$$
Q_{water\_change} = m_{water} \times c_{water} \times (T_f - T_{initial,water}) = 0.2\,kg \times 4.18\,kJ/(kg\cdot°C) \times (T_f - 15°C)
$$

If $T_f > 15°C$, heat is absorbed; if less, heat is released.

Step 4: Energy to melt the ice

The energy required to melt the entire 50 g of ice at 0°C:

$$
Q_{melt} = m_{ice} \times L_f = 0.05\,kg \times 334\,kJ/kg = 16.7\,kJ

\]

If the ice doesn't melt completely, we adjust calculations accordingly.

Step 5: Establishing the energy balance

To determine whether all ice melts or only part of it, compare the available heat from the water cooling from 15°C to 0°C with the energy needed to melt and warm the ice.

Case 1: Sufficient heat to melt all the ice and reach a final temperature

Step 5a: Calculate heat released by water cooling to the final temperature

The water may cool from 15°C to T_f:

\[
Q_{water_cool} = 0.2 \times 4.18 \times (15 - T_f)
\]

Step 5b: Heat required to cool ice from 25°C to 0°C and melt it

\[
Q_{ice_total} = Q_{ice_cool} + Q_{melt} + Q_{warm_ice_water}
\]

Where:

\[
Q_{warm_ice_water} = m_{ice} \times c_{water} \times (T_f - 0)
\]

But note that the ice, after melting at 0°C, becomes water at T_f, so the energy to warm the melted ice to T_f is:

\[
Q_{ice_warming} = 0.05 \times 4.18 \times (T_f - 0) = 0.209 \times T_f
\]

Step 5c: Set energy balance

Total heat released by water:

\[
Q_{water_release} = Q_{water_cool}
\]

Total heat absorbed by ice:

$$
Q_{ice\_absorb} = |Q_{ice\_cool}| + Q_{melt} + Q_{ice\_warming}
$$

At equilibrium:

$$
Q_{water\_release} = Q_{ice\_absorb}
$$

$$
0.2 \times 4.18 \times (15 - T_f) = 2.625 + 0.05 \times 334 + 0.05 \times 4.18 \times T_f
$$

Simplify:

$$
0.836 \times (15 - T_f) = 2.625 + 16.7 + 0.209 \times T_f
$$

$$
12.54 - 0.836 T_f = 19.325 + 0.209 T_f
$$

Bring all T_f terms to one side:

$$
-0.836 T_f - 0.209 T_f = 19.325 - 12.54
$$

$$
-1.045 T_f = 6.785
$$

Solve for T_f:

$$
T_f = - \frac{6.785}{1.045} \approx -6.49°C
$$

Since this is below the melting point, it indicates the water cools down below 0°C, which is physically impossible without freezing, so the assumption of complete melting and reaching T_f above 0°C is invalid.

Conclusion: The system will likely reach a final temperature at or below 0°C, with some ice remaining unmelted.

Case 2: Final temperature at 0°C, partial melting

Given the negative result, the realistic scenario is that:

- The water cools from 15°C to 0°C
- Melts some, but not all, of the ice
- The remaining ice stays frozen

Step 6: Energy available from water cooling to 0°C

$$
Q_{water\_cool} = 0.2 \times 4.18 \times (15 - 0) = 0.2 \times 4.18 \times 15 = 12.54\,kJ
$$

Step 7: Energy needed to melt some ice

To melt a portion m_{melted} of ice:

$$
Q_{melted} = m_{melted} \times 334\,kJ/kg
$$

The energy to warm the melted ice to 0°C is zero (since it's at 0°C).

The energy used to raise the water from 25°C to

Consider A Thermal System Consisting Of 50 G Of Ice At 25 C And 0 2 Kg Of Water At 15 C A What Is The

Consider A Thermal System Consisting Of 50 G Of Ice At 25 C And 0 2 Kg Of Water At 15 C A What Is The

Related Articles

- If A 5 Percent Increase In Consumer Incomes Leads To A 10 Percent Increase In The Quantity Demanded For
- Consider Two Urns. Urn I Contains 3 White And 4 Black Balls. Urn II Contains 2 White And 6 Black Balls.
- Find Parametric Equations For The Line Passing Through (0,0,4) And Parallel To The Line Passing Through

Back to Home