In A Thermodynamically Sealed Container, 20.0 G Of 17.0C Water Is Mixed With 40.0 G Of 61.0C Water. Calculate

In A Thermodynamically Sealed Container, 20.0 G Of 17.0C Water Is Mixed With 40.0 G Of 61.0C Water. Calculate the final temperature of the water mixture, considering the principles of thermodynamics and heat transfer. This problem involves understanding how heat flows from the warmer water to the cooler water until thermal equilibrium is reached within a closed system. It serves as an excellent example of energy conservation and thermal physics, which are foundational concepts in thermodynamics.

Understanding the Problem Context

Before delving into calculations, it is essential to grasp the fundamental concepts involved in the problem. The system involves two quantities of water at different temperatures, combined in a sealed environment where no heat is lost to the surroundings. The primary goal is to determine the equilibrium temperature after the two quantities of water are mixed.

Key Assumptions

To solve this problem effectively, several assumptions are typically made:

- The container is perfectly insulated, meaning no heat escapes to the environment.
- The specific heat capacity of water remains constant over the temperature range considered.
- No phase change or evaporation occurs during the mixing process.
- The water is well-mixed, ensuring uniform temperature throughout the system at equilibrium.

Fundamental Concepts in Heat Transfer and Thermodynamics

Understanding the basic principles helps in setting up the calculation correctly.

Specific Heat Capacity of Water

The specific heat capacity (c) of water is approximately 4.18 J/g°C. This value indicates the amount of heat energy required to raise the temperature of 1 gram of water by 1°C.

Principle of Conservation of Energy

In an isolated system, energy cannot be created or destroyed. When two quantities of water at different temperatures are mixed, heat flows from the warmer to the cooler until equilibrium is established. The heat lost by the hot water equals the heat gained by the cold water:

$$ Q_{hot} = Q_{cold} $$

Step-by-Step Calculation of Final Temperature

Let's now proceed with the detailed calculation.

Variables and Data

- Mass of cold water, $m_{cold} = 20.0\,g$
- Initial temperature of cold water, $T_{cold,i} = 17.0^\circ C$
- Mass of hot water, $m_{hot} = 40.0\,g$
- Initial temperature of hot water, $T_{hot,i} = 61.0^\circ C$
- Specific heat capacity of water, $c = 4.18\, J/g^\circ C$
- Final temperature, T_f (unknown)

Formulating the Heat Transfer Equation

Applying the conservation of energy:

$$ m_{hot} \times c \times (T_{hot,i} - T_f) = m_{cold} \times c \times (T_f - T_{cold,i}) $$

Since c appears on both sides, it cancels out:

$$ m_{hot} \times (T_{hot,i} - T_f) = m_{cold} \times (T_f - T_{cold,i}) $$

Substituting the known values:

$$ 40.0 \times (61.0 - T_f) = 20.0 \times (T_f - 17.0) $$

Solving for T_f

Expand both sides:

$$ 40.0 \times 61.0 - 40.0 \times T_f = 20.0 \times T_f - 20.0 \times 17.0 $$

Calculate the constants:

$$ 2440.0 - 40.0 T_f = 20.0 T_f - 340.0 $$

Bring all terms to one side:

$$ 2440.0 + 340.0 = 20.0 T_f + 40.0 T_f $$

$$ 2780.0 = 60.0 T_f $$

Solve for T_f:

$$ T_f = \frac{2780.0}{60.0} $$

$$ T_f \approx 46.33^\circ C $$

Therefore, the final temperature of the water mixture is approximately 46.33°C.

Additional Considerations and Real-World Implications

While the calculation provides an idealized solution, real-world scenarios may introduce factors such as heat loss to surroundings, imperfect mixing, or temperature-dependent specific heats.

Heat Loss and Environmental Factors

In practical applications, the container may not be perfectly insulated, leading to some heat exchange with the environment. This can slightly alter the equilibrium temperature, making it lower than the theoretical estimate.

Variations in Specific Heat Capacity

The specific heat capacity of water can vary slightly with temperature, especially over broader ranges. However, for typical laboratory calculations, assuming a constant value suffices.

Applications of Such Calculations

Understanding how to compute the final temperature in mixing scenarios has numerous real-world applications:

- Designing heating and cooling systems
- Mixing fluids in industrial processes

- Thermal management in electronic devices
- Environmental modeling of water bodies

Summary and Key Takeaways

- The problem involves the conservation of energy principle in an isolated system.
- By setting the heat lost by hot water equal to the heat gained by cold water, we derive an equation to find the equilibrium temperature.
- The specific heat capacity of water simplifies the calculations, allowing us to focus on mass and temperature differences.
- The calculated final temperature (~46.33°C) illustrates how heat transfer results in thermal equilibrium.

Conclusion

In thermodynamics, analyzing temperature changes in mixed fluids within a sealed environment demonstrates core principles of energy conservation, heat transfer, and material properties. This problem exemplifies the importance of understanding these concepts for engineers, physicists, and environmental scientists alike. Whether designing efficient thermal systems or studying natural water bodies, grasping how to calculate equilibrium temperatures is a fundamental skill that underpins many technological and scientific advancements.

Remember: Always consider the assumptions made during ideal calculations and be aware of real-world factors that could influence the outcome. This understanding ensures more accurate modeling and better system design in practical applications.

Frequently Asked Questions

What is the final temperature of the water mixture in a thermally sealed container when 20.0 g of water at 17.0°C is mixed with 40.0 g of water at 61.0°C?

The final temperature can be calculated using the principle of conservation of energy, assuming no heat loss: T_final = [(m1 c T1) + (m2 c T2)] / (m1 + m2). Substituting values: T_final = [(20.0 g 4.18 J/g°C 17.0°C) + (40.0 g 4.18 J/g°C 61.0°C)] / (20.0 g + 40.0 g) ≈ 49.7°C.

Why does the temperature of the water mixture in a sealed container equilibrate between the initial temperatures of the two water samples?

Because heat flows from the hotter water at 61.0°C to the cooler water at 17.0°C until thermal equilibrium is reached, resulting in a common final temperature. In a sealed container, no heat is lost to the surroundings, so energy conservation leads to temperature equilibration.

How does the mass of water affect the final temperature in this mixing process?

The final temperature depends on the masses of the water samples because heat transfer is proportional to mass. A larger mass of hot water will raise the final temperature more, while a larger mass of cold water will lower it, following the weighted average based on their masses.

What assumptions are made when calculating the final temperature of mixed water in a sealed container?

The calculation assumes no heat loss to the environment, uniform temperature distribution within the container, and that the specific heat capacity of water remains constant over the temperature range involved.

If heat losses were considered, how would the final temperature of the water mixture change?

Including heat losses to the surroundings would result in a final temperature lower than the ideal calculation, as some heat would escape, preventing the water from reaching the equilibrium temperature predicted by the simple conservation of energy.

What is the significance of using specific heat capacity in calculating the temperature change during mixing?

Specific heat capacity quantifies the amount of heat required to change the temperature of a unit mass of a substance by 1°C. It is essential for accurately calculating how much heat is transferred during mixing and thus determining the final temperature.

Additional Resources

In a thermodynamically sealed container, 20.0 g of 17.0°C water is mixed with 40.0 g of 61.0°C water. Calculate the final temperature of the mixture and analyze the underlying thermodynamic principles involved. This problem exemplifies fundamental concepts such as heat transfer, specific heat capacity, and conservation of energy within an isolated system, making it an ideal case study for understanding thermal equilibrium in a sealed environment.

Introduction

When two quantities of water at different temperatures are combined within a thermodynamically sealed container, the resulting temperature reaches an equilibrium point where no net heat transfer occurs. Since the container is sealed, it prevents heat exchange with the external environment, ensuring all heat transfer occurs solely between the water samples. Understanding this process involves applying basic principles of thermodynamics, specifically the conservation of energy and the specific heat capacity of water.

This scenario offers a practical illustration of how energy redistributes within a closed system, providing insights into thermal equilibrium and energy conservation laws.

Key Concepts and Principles

Before diving into the calculations, it's essential to clarify some fundamental concepts:

1. Specific Heat Capacity (c)

- The amount of heat required to raise the temperature of 1 gram of a substance by 1°C.
- For water, $c \approx 4.18$ J/g°C.

2. Heat Transfer (Q)

- The heat exchanged between two bodies is given by:

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

where:
- m = mass
- c = specific heat capacity
- ΔT = change in temperature ($T_{final} - T_{initial}$)

3. Conservation of Energy

- In a thermodynamically sealed container, no heat is lost or gained from the surroundings.
- The heat lost by the warmer water equals the heat gained by the cooler water:

$$Q_{lost} = Q_{gained}$$

4. Thermal Equilibrium

- The system reaches a temperature where the net heat transfer is zero, i.e., both water samples share the same final temperature, T_{final}.

Step-by-Step Calculation

Step 1: Define Known Quantities

Quantity	Value	Description
m_1	20.0 g	Mass of cooler water
T_1	17.0°C	Initial temperature of cooler water
m_2	40.0 g	Mass of warmer water
T_2	61.0°C	Initial temperature of warmer water
c	4.18 J/g°C	Specific heat capacity of water

Step 2: Set Up the Heat Balance Equation

Since the container is sealed and insulated:

- Heat lost by hot water (water 2):

$Q_2 = m_2 \times c \times (T_2 - T\_final)$

- Heat gained by cold water (water 1):

$Q_1 = m_1 \times c \times (T\_final - T_1)$

Because no heat is lost to surroundings:

$Q_2 = Q_1$

which leads to:

$m_2 \times c \times (T_2 - T\_final) = m_1 \times c \times (T\_final - T_1)$

Step 3: Simplify the Equation

Cancel c from both sides:

$m_2 \times (T_2 - T\_final) = m_1 \times (T\_final - T_1)$

Plugging in the known values:

40.0 g × (61.0°C - T_final) = 20.0 g × (T_final - 17.0°C)

Step 4: Solve for T_final

Expand both sides:

40.0 × 61.0 - 40.0 × T_final = 20.0 × T_final - 20.0 × 17.0

Calculate constants:

- 40.0 × 61.0 = 2440.0
- 20.0 × 17.0 = 340.0

Rewrite:

$$2440.0 - 40.0\ T_{final} = 20.0\ T_{final} - 340.0$$

Bring like terms together:

$$2440.0 + 340.0 = 20.0\ T_{final} + 40.0\ T_{final}$$

Calculate sums:

$$2780.0 = 60.0\ T_{final}$$

Finally, solve for T_final:

$$T_{final} = 2780.0 / 60.0 = 46.33°C$$

Final Result

The final equilibrium temperature of the mixture in the thermodynamically sealed container is approximately 46.33°C.

Analysis and Implications

This calculation demonstrates a straightforward application of the conservation of energy in a closed system. The initial temperature difference between the two water samples results in heat transfer until thermal equilibrium is achieved at approximately 46.33°C.

Real-World Considerations

- No heat loss to surroundings: In reality, perfect insulation is rare, but for theoretical calculations, assuming an ideal sealed system simplifies analysis.
- Heat capacity assumptions: Water's specific heat capacity is nearly constant over typical temperature ranges, but minor variations can occur at extreme temperatures.
- Mass accuracy: Small errors in mass measurement can slightly alter the final temperature, emphasizing the importance of precision in experimental setups.

Broader Applications

Understanding such thermodynamic processes is crucial in various fields:

- Engineering: Designing insulated containers, such as thermos flasks.
- Environmental science: Analyzing heat exchange in natural water bodies.
- Food industry: Controlling temperature during heating or cooling processes.
- Physics education: Demonstrating conservation of energy principles.

Conclusion

In summary, mixing 20.0 g of 17.0°C water with 40.0 g of 61.0°C water within a thermodynamically sealed container results in a final temperature of approximately 46.33°C. This outcome underscores the principles of heat transfer, specific heat capacity, and energy conservation in an isolated system. Such calculations are foundational in thermodynamics and serve as a gateway to understanding more complex thermal processes in both natural and engineered environments.

Remember: Always verify assumptions and consider real-world factors—like heat loss or measurement uncertainties—when applying these principles to practical scenarios.

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