Suppose You Mix 100.0 G Of Water At 23.1 Oc With 75.0 G Of Water At 73.1 Oc. What Will Be The Final Temperature

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Introduction

Mixing two quantities of water at different temperatures is a common problem in thermodynamics, chemistry, and physics. It involves understanding how heat transfers between substances until thermal equilibrium is reached. In this case, we are given two masses of water at different temperatures, and we are asked to determine the final temperature after they are mixed. This scenario is prevalent in laboratory experiments, industrial processes, and even everyday life—such as mixing hot and cold water to reach a desired temperature.

Understanding the principles behind this problem is essential for students and professionals working in fields like chemical engineering, environmental science, and physics. It involves concepts like specific heat capacity, heat transfer, and conservation of energy. Moreover, solving such problems enhances comprehension of how energy exchanges occur in real-world systems.

Background Concepts

Specific Heat Capacity of Water

The specific heat capacity (c) of water is a fundamental property that indicates how much heat energy is needed to raise the temperature of 1 gram of water by 1°C. For water, this value is approximately:

- c = 4.18 J/g°C

This means that to increase the temperature of 1 gram of water by 1°C, 4.18 joules of energy are required.

Principle of Conservation of Energy

When two quantities of water at different temperatures are mixed, heat flows from the hotter water to the colder water until thermal equilibrium is reached. The key assumption here is that no heat is lost to the surroundings, meaning the system is insulated.

The heat lost by the hot water equals the heat gained by the cold water:

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

Expressed mathematically:

$$ m_{hot} \times c \times (T_{hot,initial} - T_{final}) = m_{cold} \times c \times (T_{final} - T_{cold,initial}) $$

where:

- m_{hot} and m_{cold} are masses of hot and cold water,
- $T_{hot,initial}$ and $T_{cold,initial}$ are their initial temperatures,
- T_{final} is the final temperature after mixing.

Since the specific heat capacity cancels out on both sides (assuming same substance: water), the equation simplifies to:

$$ m_{hot} \times (T_{hot,initial} - T_{final}) = m_{cold} \times (T_{final} - T_{cold,initial}) $$

Step-by-Step Solution

Given Data

- Cold water:
- Mass, $m_{cold} = 100.0\, \text{g}$
- Initial temperature, $T_{cold,initial} = 23.1\,^\circ C$

- Hot water:
- Mass, $m_{hot} = 75.0\, \text{g}$
- Initial temperature, $T_{hot,initial} = 73.1\,^\circ C$

Objective

Calculate the final equilibrium temperature, T_{final}.

Applying the Heat Balance Equation

Using the simplified energy balance:

$$ m_{hot} \times (T_{hot,initial} - T_{final}) = m_{cold} \times (T_{final} - T_{cold,initial}) $$

Substitute the known values:

$$ 75.0\, \text{g} \times (73.1 - T_{final}) = 100.0\, \text{g} \times (T_{final} - 23.1) $$

Solving for T_{final}

1. Expand both sides:

$$ 75.0 \times 73.1 - 75.0 \times T_{final} = 100.0 \times T_{final} - 100.0 \times 23.1 $$

2. Calculate constants:

$$ 75.0 \times 73.1 = 5482.5 $$
$$ 100.0 \times 23.1 = 2310 $$

3. Rewrite the equation:

$$ 5482.5 - 75.0 T_{final} = 100.0 T_{final} - 2310 $$

4. Bring like terms together:

$$ 5482.5 + 2310 = 100.0 T_{final} + 75.0 T_{final} $$

$$ 7792.5 = 175.0 T_{final} $$

5. Solve for T_{final}:

$$ T_{final} = \frac{7792.5}{175.0} $$

$$ T_{final} \approx 44.52\,^\circ C $$

Final Answer and Interpretation

The final temperature resulting from mixing 100.0 g of water at 23.1°C with 75.0 g of water at 73.1°C is approximately 44.5°C.

This value makes sense intuitively, as it lies between the initial temperatures of the two water samples. The hot water cools down, transferring heat to the colder water, which warms up until a uniform temperature is reached.

Additional Factors and Real-World Considerations

While the above calculation assumes ideal conditions (no heat loss, perfect insulation), real-world scenarios may vary slightly due to factors such as:

- Heat loss to surroundings (air, container walls)
- Impurities in water affecting heat capacity
- Measurement inaccuracies

In practical applications, these factors can be minimized with proper insulation and precise measurements.

Applications of the Calculation

Understanding how to calculate final temperatures when mixing substances has numerous applications, including:

- Cooking: Ensuring food reaches a safe and desirable temperature.
- Chemical Processes: Controlling reaction conditions.
- Environmental Science: Predicting temperature changes in bodies of water.
- Engineering: Designing systems for heating, cooling, and thermal management.

Conclusion

In summary, when mixing two quantities of water at different temperatures, the final temperature can be accurately predicted using the principle of conservation of energy and the specific heat capacity of water. For the given problem, the final temperature is approximately 44.5°C, reflecting the thermal equilibrium point between the initial hot and cold water samples.

Mastering this concept enhances your understanding of thermal physics and prepares you for tackling more complex thermodynamic problems in scientific and engineering contexts. Whether you're a student, researcher, or professional, this fundamental principle is a cornerstone of heat transfer analysis.

Keywords for SEO Optimization

- Final temperature of water mixture
- Heat transfer in water
- Specific heat capacity of water
- Mixing hot and cold water calculation
- Thermodynamics problems
- Conservation of energy in water mixing
- How to calculate thermal equilibrium
- Water temperature calculation example
- Heat transfer equations
- Practical applications of thermal physics

Frequently Asked Questions

How do you determine the final temperature when mixing two quantities of water at different temperatures?

You use the principle of conservation of energy, equating the heat lost by the hot water to the heat gained by the cold water, and solve for the final temperature T_f using the formula: (mass1 × specific heat × (T1 - T_f)) = (mass2 × specific heat × (T_f - T2)). Since the specific heat of water is the same for both, it cancels out, simplifying the calculation.

What is the specific heat capacity of water used in calculating temperature changes?

The specific heat capacity of water is approximately 4.18 J/g°C, which is used to calculate the amount of heat gained or lost during temperature changes.

What is the final temperature when 100.0 g of water at 23.1°C is mixed with 75.0 g of water at 73.1°C?

The final temperature is approximately 42.8°C, calculated using the heat balance equation: (100.0 g × (23.1 - T_f)) = (75.0 g × (T_f - 73.1)).

Why does the mass of water matter in calculating the final temperature after mixing?

Because the heat transferred depends on both the mass and temperature change of each water sample, larger masses have a greater influence on the final temperature, so accurate mass measurements are essential for precise calculations.

Can the final temperature be estimated without considering the specific heat capacity of water?

No, because the heat transfer depends on the specific heat capacity. However, since water's specific heat is constant and identical in both samples, it cancels out in calculations, allowing the use of the simplified formula for temperature mixing.

Additional Resources

Suppose You Mix 100.0 G Of Water At 23.1°C With 75.0 G Of Water At 73.1°C: What Will Be The Final Temperature?

In the realm of thermodynamics and calorimetry, understanding how heat transfers between substances is fundamental. A common yet intriguing problem involves mixing two quantities of water at different temperatures and predicting the resulting equilibrium temperature. Such problems are not merely academic; they underpin practical applications ranging from environmental science to industrial processes and even culinary techniques. This article delves into the detailed methodology, underlying principles, and real-world implications of calculating the final temperature when mixing two masses of water at different initial temperatures.

Fundamentals of Heat Transfer in Water Mixtures

Before analyzing the specific scenario, it is essential to establish the core concepts underpinning heat transfer during mixing.

Specific Heat Capacity of Water

Water's high specific heat capacity (approximately 4.18 J/g°C) makes it a significant heat reservoir. This property indicates the amount of heat needed to raise the temperature of one gram of water by one degree Celsius. When two quantities of water are mixed, the heat lost by the warmer water is equal to the heat gained by the cooler water, assuming no heat loss to surroundings.

Principle of Conservation of Energy

The fundamental assumption in such problems is that the system is thermally isolated; thus, the total heat content remains constant. The heat lost by the hot water equals the heat gained by the cold water:

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

or, more explicitly,

$$ m_{hot} c \Delta T_{hot} = - m_{cold} c \Delta T_{cold} $$

where:

- m = mass of water
- c = specific heat capacity
- ΔT = change in temperature

Given that water has the same specific heat capacity throughout, the formula simplifies calculations.

Calculating the Final Temperature: Step-by-Step Approach

Given:

- Mass of cold water, $m_{cold} = 100.0\,g$
- Initial temperature of cold water, $T_{cold,i} = 23.1^\circ C$
- Mass of hot water, $m_{hot} = 75.0\,g$
- Initial temperature of hot water, $T_{hot,i} = 73.1^\circ C$

Objective:

- Find the final temperature T_{final}, assuming no heat loss to surroundings.

Step 1: Write the heat transfer equations

The heat gained or lost by each water sample:

$$ Q_{cold} = m_{cold} c (T_{final} - T_{cold,i}) $$
$$ Q_{hot} = m_{hot} c (T_{final} - T_{hot,i}) $$

Since heat lost by hot water equals heat gained by cold water:

$$ m_{hot} c (T_{final} - T_{hot,i}) + m_{cold} c (T_{final} - T_{cold,i}) = 0 $$

Dividing through by c:

$$ m_{hot} (T_{final} - T_{hot,i}) + m_{cold} (T_{final} - T_{cold,i}) = 0 $$

Step 2: Rearrange for T_{final}

Expanding:

$$m_{hot} T_{final} - m_{hot} T_{hot,i} + m_{cold} T_{final} - m_{cold} T_{cold,i} = 0$$

Grouping T_{final}:

$$(m_{hot} + m_{cold}) T_{final} = m_{hot} T_{hot,i} + m_{cold} T_{cold,i}$$

Solving for T_{final}:

$$T_{final} = \frac{m_{hot} T_{hot,i} + m_{cold} T_{cold,i}}{m_{hot} + m_{cold}}$$

Step 3: Plug in the known values

$$T_{final} = \frac{75.0\,g \times 73.1^\circ C + 100.0\,g \times 23.1^\circ C}{75.0\,g + 100.0\,g}$$

Calculating numerator:

$$(75.0 \times 73.1) + (100.0 \times 23.1) = 5482.5 + 2310.0 = 7792.5$$

Total mass:

$$75.0 + 100.0 = 175.0\,g$$

Final temperature:

$$T_{final} = \frac{7792.5}{175.0} \approx 44.52^\circ C$$

Thus, the mixture stabilizes at approximately 44.5°C.

Deeper Considerations and Assumptions

While the calculation appears straightforward, several nuanced factors influence the accuracy and applicability of the result.

Assumption of No Heat Loss

The calculation assumes perfect insulation, meaning no heat escapes to the environment. In practical scenarios, especially in open containers, some heat will dissipate, potentially resulting in a final temperature slightly lower than predicted.

Thermal Equilibrium and Mixing Dynamics

The system reaches thermal equilibrium rapidly at the molecular level. Nonetheless, mixing may involve minor delays, and temperature gradients might exist temporarily during the process.

Impact of Impurities and Container Material

Real-world water may contain impurities, and the container's material can influence heat transfer rates. For precise scientific measurements, these factors should be accounted for.

Heat Capacity of the Container

If the container has substantial heat capacity, it might absorb some heat, affecting the final temperature. In controlled calculations, this is often neglected for simplicity unless specified.

Applications and Broader Implications

Understanding how to accurately determine the final temperature of mixed water has broad applications:

- Environmental Science: Predicting temperature changes in natural water bodies after mixing cold and warm streams.
- Industrial Processes: Managing heat exchange in manufacturing, chemical reactions, or cooling systems.
- Culinary Arts: Achieving desired temperatures in cooking techniques involving water mixtures.
- Educational Demonstrations: Teaching principles of heat transfer and thermodynamics.

Limitations and Extensions of the Model

While the simple calorimetry approach provides a solid foundation, more complex systems may require advanced modeling:

- Heat Loss to Surroundings: Incorporating convective and radiative heat transfer coefficients.

- Phase Changes: If mixing involves water at or near boiling point, phase change considerations become necessary.
- Non-Uniform Temperature Distributions: Especially in larger volumes or rapid mixing scenarios.

Extensions of this model include computational simulations for dynamic systems or experimental measurements to validate theoretical predictions.

Conclusion: The Final Temperature in Context

The calculated final temperature of approximately 44.5°C exemplifies the predictable nature of heat transfer in water systems, grounded in fundamental thermodynamics. It underscores the importance of precise measurements, acknowledgment of assumptions, and awareness of real-world complexities. Whether in the laboratory, industry, or everyday life, understanding such heat exchange principles enhances our capacity to manipulate and control thermal processes effectively.

In summary, when mixing 100.0 g of water at 23.1°C with 75.0 g of water at 73.1°C, the system reaches an equilibrium temperature close to 44.5°C under ideal, insulated conditions. This insight not only clarifies a specific problem but also reinforces core concepts in thermal physics, emphasizing the elegance and utility of scientific reasoning in practical scenarios.

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