41) If 50 G Of Lead (of Specific Heat 0.11 Kcal/kg C) At 100C Is Put Into 75 G Of Water (of Specific

41) If 50 G Of Lead (of Specific Heat 0.11 Kcal/kg C) At 100C Is Put Into 75 G Of Water (of Specific, it presents a classic thermodynamics problem involving heat transfer between two substances with different specific heats and initial temperatures. Understanding how heat exchange occurs in such a system not only enhances our grasp of basic physics principles but also has practical applications in engineering, environmental science, and everyday phenomena. This article explores the detailed process of heat transfer, the calculations involved, and the implications of such interactions, providing insights into the fundamental concepts of specific heat capacity, thermal equilibrium, and energy conservation.

Introduction to Heat Transfer and Specific Heat

What is Specific Heat Capacity?

Specific heat capacity is a physical property of a substance that indicates the amount of heat required to raise the temperature of 1 kilogram of the substance by 1 degree Celsius (or Kelvin). It is expressed in units such as kcal/kg°C or J/kg°C. The higher the specific heat, the more heat is needed to change the temperature of the material.

Significance of Specific Heat in Heat Transfer

Understanding specific heat is essential in predicting how different materials respond to heat exchange. For instance:
- Water has a high specific heat (~1 kcal/kg°C), making it resistant to temperature changes.
- Lead has a relatively low specific heat (~0.11 kcal/kg°C), meaning it heats up and cools down quickly.

This disparity influences how substances reach thermal equilibrium when in contact.

Details of the Problem: Heat Exchange Between Lead and Water

Given Data:

- Mass of lead, m_{lead} = 50 g = 0.05 kg

- Initial temperature of lead, $T_{lead\_initial}$ = 100°C
- Specific heat capacity of lead, c_{lead} = 0.11 kcal/kg°C
- Mass of water, m_{water} = 75 g = 0.075 kg
- Initial temperature of water, $T_{water\_initial}$ = 25°C (assuming room temperature)
- Specific heat capacity of water, c_{water} = 1 kcal/kg°C

Note: The initial temperature of water is assumed at room temperature (25°C) if not specified. Adjustments can be made based on actual data.

Objective:

Determine the final equilibrium temperature (Tfinal) of the system after the lead and water are brought into contact, assuming no heat loss to surroundings.

Fundamental Principles Behind the Calculation

Law of Conservation of Energy

The total heat lost by the hotter substance (lead) equals the total heat gained by the cooler substance (water), assuming an isolated system:

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

Heat Transfer Equation

The heat transferred to or from a substance is given by:

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

where:
- Q = heat energy,
- m = mass,
- c = specific heat capacity,
- ΔT = change in temperature.

In this scenario:
- Lead cools down from 100°C to Tfinal.
- Water heats up from 25°C to Tfinal.

Therefore:

$$ m_{lead} \times c_{lead} \times (100 - T_{final}) = m_{water} \times c_{water} \times (T_{final} - 25) $$

Step-by-Step Calculation of Final Temperature

1. Write the Heat Balance Equation

$$
0.05 \times 0.11 \times (100 - T_{final}) = 0.075 \times 1 \times (T_{final} - 25)
$$

2. Simplify Both Sides

$$
0.0055 \times (100 - T_{final}) = 0.075 \times (T_{final} - 25)
$$

3. Expand Both Sides

$$
0.0055 \times 100 - 0.0055 \times T_{final} = 0.075 \times T_{final} - 0.075 \times 25
$$

$$
0.55 - 0.0055 T_{final} = 0.075 T_{final} - 1.875
$$

4. Rearrange to Solve for T_{final}

Bring all T_{final} terms to one side:

$$
0.55 + 1.875 = 0.075 T_{final} + 0.0055 T_{final}
$$

$$
2.425 = 0.0805 T_{final}
$$

$$
T_{final} = \frac{2.425}{0.0805} \approx 30.1°C
$$

Result: The final temperature of the system is approximately 30.1°C.

Implications of the Result

Understanding the Thermal Equilibrium

The system stabilizes at around 30.1°C, which is closer to the initial temperature of water

(25°C) than to the initial temperature of lead (100°C). This reflects the fact that water, with its higher specific heat, absorbs heat more gradually, and the lead cools down significantly when in contact.

Practical Significance:

- Heating and Cooling Systems: Knowledge of such heat exchange helps design efficient thermal management systems.
- Material Selection: Understanding specific heats influences choices in applications where temperature regulation is critical.
- Environmental Science: Similar principles explain natural phenomena such as oceanic thermal buffering and climate moderation.

Additional Factors and Real-World Considerations

Heat Loss to Surroundings

In real-world scenarios, some heat may be lost to the environment due to conduction, convection, or radiation. This would result in a final temperature slightly lower than the calculated value.

Effect of Container and Material Conductivity

The container holding the water and lead can influence heat transfer rates, especially if it conducts heat away rapidly.

Phase Changes and Latent Heat

If the lead or water reaches their respective phase change temperatures, latent heat would need to be considered, complicating the calculations.

Extensions and Related Problems

1. Varying Initial Temperatures

Changing initial temperature assumptions alters the final equilibrium temperature.

2. Different Masses and Materials

Adjusting masses or using different materials with known specific heats can be analyzed similarly.

3. Multiple Substances in Contact

Extending this to systems with more than two substances involves solving a set of simultaneous heat transfer equations.

Conclusion

Analyzing the heat transfer between lead and water demonstrates fundamental thermodynamic principles in action. The precise calculation of the final temperature, considering specific heats and initial conditions, exemplifies the application of energy conservation in physical systems. Such understanding is essential in various scientific and engineering contexts, from designing cooling systems to understanding natural thermal processes. By mastering these concepts, one gains valuable insights into the behavior of materials under thermal interactions, enabling better practical applications and scientific comprehension.

Summary of Key Points

1. Specific heat capacity determines how much heat a material can store per unit temperature change.

2. Heat transfer between substances involves energy flow from hotter to cooler objects until thermal equilibrium is reached.

3. The final temperature depends on masses, specific heats, and initial temperatures.

4. Mathematical calculations involve setting heat lost equal to heat gained and solving for the unknown final temperature.

5. Real-world factors like heat loss and phase changes can influence theoretical outcomes.

Understanding these principles allows scientists and engineers to manipulate thermal systems effectively, optimize energy efficiency, and predict temperature behaviors in complex systems.

Frequently Asked Questions

What is the temperature change of water when 50 g of lead at 100°C is placed into 75 g of water?

The temperature change can be calculated using the principle of heat transfer: heat lost by lead = heat gained by water. Using $Q = mc\Delta T$, the water's temperature increase is approximately 3.33°C.

How do you determine the final temperature when lead is added to water?

Set the heat lost by lead equal to the heat gained by water: m_lead c_lead (T_initial_lead - T_final) = m_water c_water (T_final - T_initial_water). Solve for T_final.

What is the specific heat capacity of lead used in this calculation?

The specific heat capacity of lead given is 0.11 kcal/kg°C.

Why does the temperature of water increase when lead is added at 100°C?

Because the lead cools down from 100°C, transferring heat to the water, which increases its temperature until thermal equilibrium is reached.

What assumptions are made in calculating the final temperature of water and lead?

Assumptions include no heat loss to surroundings, perfect thermal contact, and that the specific heats remain constant over the temperature range.

How does the mass of lead and water affect the final temperature?

A larger mass of water relative to lead results in a smaller temperature rise of the water, and vice versa, due to the proportionality in heat transfer calculations.

If the specific heat of water is 1 kcal/kg°C, what is the approximate final temperature after mixing?

The final temperature is approximately 103.33°C; however, since water cannot exceed 100°C without boiling, the actual temperature would be close to 100°C, indicating heat loss or other factors may need consideration.

Can this calculation be used to determine the temperature at thermal equilibrium accurately?

Yes, by setting heat lost by lead equal to heat gained by water, assuming no heat loss elsewhere, the final equilibrium temperature can be accurately estimated.

Additional Resources

Thermal Equilibrium and Heat Transfer in Lead-Water System: An In-Depth Analysis

---

Introduction

Understanding the principles of heat transfer and thermal equilibrium is fundamental in thermodynamics, especially when analyzing interactions between different substances. The problem involving 50 grams of lead at 100°C placed into 75 grams of water offers a classic scenario to explore concepts such as specific heat capacity, heat exchange, and temperature equilibrium. This detailed review dissects the problem comprehensively, elucidating each step, underlying principles, and implications.

The Core Problem

Given Data:

- Mass of lead, $m_{Pb} = 50\, \text{g} = 0.05\, \text{kg}$
- Specific heat capacity of lead, $c_{Pb} = 0.11\, \text{kcal/kg°C}$
- Initial temperature of lead, $T_{Pb,i} = 100^\circ C$

- Mass of water, $m_{water} = 75\, \text{g} = 0.075\, \text{kg}$
- Specific heat capacity of water, $c_{water} \approx 1\, \text{kcal/kg°C}$ (standard value)
- Initial temperature of water, $T_{water,i} = ?$

Objective:

- Find the final equilibrium temperature T_f after lead is immersed in water and heat exchanges occur.
- Understand the heat transfer process, energy conservation, and the effect of specific heat capacities.

Conceptual Foundations

1. Heat Transfer and Conservation of Energy

When two substances at different temperatures are brought into contact, heat flows from the hotter to the cooler until they reach thermal equilibrium. The principle of conservation of energy states:

$$
\text{Heat lost} = \text{Heat gained}
$$

Assuming no heat losses to the surroundings:

$$
Q_{lost} + Q_{gained} = 0
$$

In this scenario, since lead starts at 100°C and water at a lower temperature, the lead will cool down, and water may warm up depending on initial conditions (though initial water temperature isn't specified, we often assume it to be at a lower temperature, such as room temperature or 25°C).

---

2. Specific Heat Capacity

The specific heat capacity (c) indicates how much heat is needed to raise 1 kg of a substance by 1°C:

$$
Q = mc\Delta T
$$

- For lead: $c_{Pb} = 0.11\, \text{kcal/kg°C}$
- For water: $c_{water} \approx 1\, \text{kcal/kg°C}$

This means water can absorb or release significantly more heat per unit temperature change than lead.

Step-by-Step Solution

Step 1: Assumptions and Initial Conditions

- Assumption: The water's initial temperature $T_{water,i}$ is not specified; for meaningful analysis, we assume standard room temperature, say 25°C.
- No heat loss: The system is thermally insulated.

Step 2: Equate Heat Transfer

Let the final equilibrium temperature be T_f. The heat lost by lead:

$$
Q_{Pb} = m_{Pb} \times c_{Pb} \times (T_{Pb,i} - T_f)
$$

The heat gained by water:

$$
Q_{water} = m_{water} \times c_{water} \times (T_f - T_{water,i})
$$

Since heat lost by lead is gained by water:

\[
Q_{Pb} = Q_{water}
\]

Expressed mathematically:

\[
m_{Pb} \times c_{Pb} \times (T_{Pb,i} - T_f) = m_{water} \times c_{water} \times (T_f - T_{water,i})
\]

Step 3: Plugging in Values

\[
0.05\, \text{kg} \times 0.11\, \text{kcal/kg°C} \times (100 - T_f) = 0.075\, \text{kg} \times 1\, \text{kcal/kg°C} \times (T_f - 25)
\]

Simplify:

\[
(0.0055)\times (100 - T_f) = 0.075 \times (T_f - 25)
\]

Step 4: Solving for \(T_f \)

Expand both sides:

\[
0.0055 \times 100 - 0.0055 \times T_f = 0.075 T_f - 0.075 \times 25
\]

Calculate constants:

\[
0.55 - 0.0055 T_f = 0.075 T_f - 1.875
\]

Bring all terms to one side:

\[
0.55 + 1.875 = 0.075 T_f + 0.0055 T_f
\]

\[

$$
2.425 = 0.0805 T_f
$$

Solve for T_f:

$$
T_f = \frac{2.425}{0.0805} \approx 30.1^\circ C
$$

Final Equilibrium Temperature

$$
\boxed{
T_f \approx 30.1^\circ C
}
$$

This indicates that after the heat exchange, the system stabilizes close to 30°C, with the lead cooling from 100°C to about 30.1°C and water warming from 25°C to roughly 30.1°C.

Deeper Insights and Implications

1. Effect of Specific Heat Capacities

- Lead's low specific heat capacity (0.11 kcal/kg°C) implies it requires less heat to change temperature, so it cools rapidly.
- Water's high specific heat capacity (1 kcal/kg°C) makes it capable of absorbing more heat with less temperature change, which is why the temperature of water increases significantly relative to lead's temperature decrease.

2. Energy Conservation and System Behavior

- The calculated T_f aligns with expectations: the lead cools down, transferring heat to water.
- The system reaches a thermal equilibrium dictated by the relative heat capacities and initial temperatures.

3. Role of Initial Water Temperature

- If the initial water temperature were higher (say, 40°C), the final temperature would be higher, and the lead might even warm slightly if the water is hotter.
- Conversely, if water were colder, the final temperature would be lower, as the water would absorb less heat.

Additional Considerations

1. Heat Losses and Real-World Applications

- In practical scenarios, some heat might be lost to surroundings, so actual final temperatures could be lower.
- The calculation assumes perfect insulation, which is rarely the case.

2. Phase Changes and Material Properties

- Lead melts at 327.5°C, so at 100°C, it remains solid.
- Water can vaporize if heated beyond 100°C, but in this scenario, the temperature remains below boiling point.

3. Implications in Engineering and Thermodynamics

- Such calculations are crucial in designing cooling systems, heat exchangers, and thermal management in various industries.
- Understanding specific heat capacities helps in estimating energy requirements for heating or cooling processes.

Extending the Analysis

1. Varying Initial Temperatures

- How would the final temperature change if water started at a different temperature?
- Setting $T_{water,i}$ to various values allows for plotting T_f versus initial water temperature, illustrating the thermal response.

2. Mass Ratios and Material Choices

- Increasing lead's mass would make the system's final temperature closer to lead's initial temperature.
- Choosing materials with different specific heats influences thermal exchange efficiency.

Summary

This comprehensive analysis demonstrates the principles of heat transfer, specific heat capacities, and energy conservation through a practical scenario involving lead and water. The key takeaways include:

- The importance of specific heat capacities in determining temperature changes.
- How to apply heat transfer equations to find equilibrium temperatures.
- The significance of initial conditions in thermal systems.
- Real-world considerations such as heat losses and phase changes.

Understanding these concepts equips engineers, physicists, and students with the tools to analyze thermal interactions effectively, laying the foundation for more complex thermodynamic systems.

Final Remarks

The calculation and reasoning presented here highlight the power and elegance of thermodynamic principles. While simplified, such models form the backbone of thermal analysis in science and engineering, enabling precise control and optimization of heat-related processes across diverse fields.

41 If 50 G Of Lead Of Specific Heat 0 11 Kcal Kg C At 100c Is Put Into 75 G Of Water Of Specific

41 If 50 G Of Lead Of Specific Heat 0 11 Kcal Kg C At 100c Is Put Into 75 G Of Water Of Specific

Related Articles

- A Child's Toy Consists Of A Block That Attaches To A Table With A Suction Cup, A Spring Connected To
- A Pre-image Has Coordinates N(3, -2), A(5, 0) And P(2, 4). The Image Has Coordinates N (2, 0), A'(4,
- (08.01)Two Lines, A And B, Are Represented By The Following Equations:Line A: 2x + 2y = 8Line B: X +

Back to Home