Specific Heat Capacity Practice Problems

Specific Heat

DIRECTIONS: Use q = (m)(ΔT)(Cp) to solve the following problems. Show all work and units.

1. A 15.75-g piece of iron absorbs 1086.75 joules of heat energy, and its temperature changes from 25°C to 175°C. Calculate the specific heat capacity of iron.

2. How many joules of heat are needed to raise the temperature of 10.0 g of aluminum from 22°C to 55°C, if the specific heat of aluminum is 0.90 J/g°C?

3. To what temperature will a 50.0 g piece of glass raise if it absorbs 5275 joules of heat and its specific heat capacity is 0.50 J/g°C? The initial temperature of the glass is 20.0°C.

4. Calculate the heat capacity of a piece of wood if 1500.0 g of the wood absorbs 6.75×10^4 joules of heat, and its temperature changes from 32°C to 57°C.

5. 100.0 mL of 4.0°C water is heated until its temperature is 37°C. If the specific heat of water is 4.18 J/g°C, calculate the amount of heat energy needed to cause this rise in temperature.

6. 25.0 g of mercury is heated from 25°C to 155°C, and absorbs 455 joules of heat in the process. Calculate the specific heat capacity of mercury.

7. What is the specific heat capacity of silver metal if 55.00 g of the metal absorbs 47.3 **calories** of heat and the temperature rises 15.0°C?

8. If a sample of chloroform is initially at 25°C, what is its final temperature if 150.0 g of chloroform absorbs 1.0 **kilojoules** of heat, and the specific heat of chloroform is 0.96 J/g°C?

9. How much energy must be absorbed by 20.0 g of water to increase its temperature from 283.0 °C to 303.0 °C? (Cp of H_2O = 4.184 J/g °C)

10. When 15.0 g of steam drops in temperature from 275.0 °C to 250.0 °C, how much heat energy is released? (Cp of H_2O = 4.184 J/g °C)

11. How much energy is required to heat 120.0 g of water from 2.0 °C to 24.0 °C? (Cp of H_2O = 4.184 J/g °C)

12. How much heat (in J) is given out when 85.0 g of lead cools from 200.0 °C to 10.0 °C? (Cp of Pb = 0.129 J/g °C)

13. If it takes 41.72 joules to heat a piece of gold weighing 18.69 g from 10.0 °C to 27.0 °C, what is the specific heat of the gold?

14. A certain mass of water was heated with 41,840 Joules, raising its temperature from 22.0 °C to 28.5 °C. Find the mass of the water, in grams. (Cp of H_2O = 4.184 J/g °C)

15. How many joules of heat are needed to change 50.0 grams of ice at -15.0 °C to steam at 120.0 °C? (Cp of H_2O = 4.184 J/g °C)

16. Calculate the number of joules given off when 32.0 grams of steam cools from 110.0 °C to ice at -40.0 °C. (Cp of H_2O = 4.184 J/g °C)

17. The specific heat of ethanol is 2.46 J/g °C. Find the heat required to raise the temperature of 193 g of ethanol from 19°C to 35°C.

18. When a 120 g sample of aluminum (Al) absorbs 9612 J of energy, its temperature increases from 25°C to 115°C. Find the specific heat of aluminum.

Specific heat capacity practice problems are essential for students and professionals alike, as they provide a practical understanding of how different materials absorb and transfer heat. The concept of specific heat capacity (C) is fundamental in thermodynamics and material science, as it helps explain how substances react to heating and cooling. This article will explore specific heat capacity, its formula, and several practice problems that will enhance your comprehension and application of this important concept.

Understanding Specific Heat Capacity

Specific heat capacity is defined as the amount of heat energy (Q) required to raise the temperature of one unit mass of a substance by one degree Celsius (or one Kelvin). It is an intrinsic property of materials and varies from one substance to another. The formula for specific heat capacity can be expressed as:

$$C = \frac{Q}{m \Delta T}$$

Where:
- C = specific heat capacity (J/kg·°C)
- Q = heat energy absorbed or released (Joules)
- m = mass of the substance (kg)
- ΔT = change in temperature (°C or K)

Units of Specific Heat Capacity

Specific heat capacity is typically measured in the following units:
- Joules per kilogram per degree Celsius (J/kg·°C)
- Joules per kilogram per Kelvin (J/kg·K)

Interestingly, since a change of one degree Celsius is equivalent to a change of one Kelvin, these units can often be used interchangeably.

Importance of Specific Heat Capacity

Understanding specific heat capacity is crucial for several reasons, including:

1. Thermal Management: In engineering and design, knowing how materials respond to heat can inform the choice of materials for thermal insulation or conduction.

2. Chemical Reactions: In chemistry, specific heat capacity can help predict the energy changes during reactions, especially in calorimetry experiments.

3. Environmental Science: It plays a role in understanding climate change, as different materials and fluids on Earth respond differently to temperature changes.

4. Everyday Applications: Cooking, heating, and cooling processes in our daily lives depend on the specific heat capacities of various substances.

Practice Problems

To solidify your understanding of specific heat capacity, let’s work through some practice problems. For each problem, we will provide a detailed explanation of how to approach and solve it.

Problem 1: Heating Water

Problem Statement: A 2 kg pot of water is heated from 25°C to 75°C. If the specific heat capacity of water is 4,186 J/kg·°C, how much heat energy is required?

Solution:

1. Identify the variables:
- Mass $m = 2$ kg
- Specific heat capacity $C = 4,186$ J/kg·°C
- Initial temperature $T_i = 25$°C
- Final temperature $T_f = 75$°C

2. Calculate the change in temperature ΔT:

$$
\Delta T = T_f - T_i = 75°C - 25°C = 50°C
$$

3. Use the formula for heat energy:

$$
Q = m \cdot C \cdot \Delta T
$$

Substituting in the values:

$$
Q = 2 \, \text{kg} \cdot 4,186 \, \text{J/kg·°C} \cdot 50 \, \text{°C}
$$

$$
Q = 418,600 \, \text{J}
$$

Answer: 418,600 Joules of heat energy is required to heat the water.

Problem 2: Cooling Down a Metal Block

Problem Statement: A 500 g block of aluminum (specific heat capacity = 900 J/kg·°C) is cooled from 150°C to 50°C. How much heat is lost by the aluminum block?

Solution:

1. Convert mass from grams to kilograms:
- $m = 500 \, \text{g} = 0.5 \, \text{kg}$

2. Identify the specific heat capacity:
- $C = 900 \, \text{J/kg·°C}$

3. Calculate the change in temperature ΔT:

$$
\Delta T = T_f - T_i = 50°C - 150°C = -100°C
$$

(The negative sign indicates a loss of heat.)

4. Calculate the heat lost:

$$
Q = m \cdot C \cdot \Delta T
$$

$$
Q = 0.5 \, \text{kg} \cdot 900 \, \text{J/kg·°C} \cdot (-100°C)
$$

$$
Q = -45,000 \, \text{J}
$$

Answer: The aluminum block loses 45,000 Joules of heat.

Problem 3: Mixture of Substances

Problem Statement: You have 300 g of water at 80°C mixed with 200 g of oil at 20°C. The specific heat capacities are 4,186 J/kg·°C for water and 2,000 J/kg·°C for oil. Assuming no heat is lost to the environment, what is the final equilibrium temperature of the mixture?

Solution:

1. Convert masses to kilograms:
- Water: $m_w = 0.3 \, \text{kg}$
- Oil: $m_o = 0.2 \, \text{kg}$

2. Identify specific heat capacities:
- $C_w = 4,186 \, \text{J/kg·°C}$
- $C_o = 2,000 \, \text{J/kg·°C}$

3. Set up the heat exchange equation:
$$
Q_{\text{lost by water}} + Q_{\text{gain by oil}} = 0
$$
$$
m_w C_w (T_f - T_w) + m_o C_o (T_f - T_o) = 0
$$
Where $T_w = 80°C$ and $T_o = 20°C$.

4. Substitute the known values:
$$
0.3 \cdot 4,186 \cdot (T_f - 80) + 0.2 \cdot 2,000 \cdot (T_f - 20) = 0
$$

5. Simplify and solve for T_f:
$$
1,255.8(T_f - 80) + 400(T_f - 20) = 0
$$
$$
1,255.8 T_f - 100464 + 400 T_f - 8000 = 0
$$
$$
1,655.8 T_f = 108464
$$
$$
T_f \approx 65.4°C
$$

Answer: The final equilibrium temperature of the mixture is approximately 65.4°C.

Conclusion

Specific heat capacity practice problems are invaluable for mastering the principles of heat transfer and energy conservation. By working through problems involving heating, cooling, and mixing different substances, you can develop a deeper understanding of how materials behave under temperature changes. The problems presented in this article illustrate different scenarios that can be encountered in both academic and practical applications. Regular practice with such problems will enhance your problem-solving skills and prepare you for more complex thermodynamic challenges.

Frequently Asked Questions

What is specific heat capacity and why is it important in practice problems?

Specific heat capacity is the amount of heat required to raise the temperature of one kilogram of a substance by one degree Celsius. It is important in practice problems because it helps determine how much energy is needed to change the temperature of a material.

How do you calculate the heat energy absorbed or released in a substance?

The heat energy (Q) can be calculated using the formula $Q = mc\Delta T$, where m is the mass of the substance, c is the specific heat capacity, and ΔT is the change in temperature.

If 200 grams of water is heated from 20°C to 80°C, how much energy is absorbed?

Using the specific heat capacity of water (c = 4.18 J/g°C), the energy absorbed is $Q = mc\Delta T = 200$ g 4.18 J/g°C (80°C - 20°C) = 50,160 J.

What happens to the temperature of a substance when it absorbs heat without changing its state?

When a substance absorbs heat without changing its state, its temperature increases. This is described by its specific heat capacity, which quantifies how much the temperature will rise for a given amount of heat.

How does the specific heat capacity of metals compare to that of water?

Metals generally have a lower specific heat capacity than water, meaning they heat up and cool down more quickly than water does when absorbing or releasing the same amount of heat.

In a calorimetry problem, how can you determine the specific heat capacity of an unknown metal?

To determine the specific heat capacity of an unknown metal, you can measure the heat lost by the metal as it cools down and the heat gained by a known mass of water, applying the principle of conservation of energy.

Why is it necessary to know the specific heat

capacities of different materials in engineering applications?

Knowing the specific heat capacities of materials is crucial in engineering applications for designing systems that involve heat transfer, such as HVAC systems, engines, and thermal insulations, to ensure efficiency and safety.

Can the specific heat capacity change with temperature, and how does this affect calculations?

Yes, the specific heat capacity can change with temperature. This variation must be accounted for in calculations, particularly in processes where large temperature changes occur, requiring the use of average specific heat values over the temperature range.

How do phase changes affect the calculation of heat energy in practice problems?

During phase changes, the temperature of a substance remains constant while heat is added or removed. This heat is calculated using latent heat rather than specific heat capacity, which must be considered separately in practice problems involving phase transitions.

Specific Heat Capacity Practice Problems

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