A Copper Container Of Mass 500 G Contains 1 Liter Of Water At 293 K. Calculate The Quantity Of Heat Required

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Understanding the heat transfer involved in heating water within a copper container is fundamental in thermodynamics, especially for applications in engineering, cooking, and scientific experiments. This comprehensive guide will walk you through the detailed calculation of the heat energy required to raise the temperature of both the water and the copper container from an initial temperature of 293 K, considering their respective thermophysical properties. Whether you're a student preparing for exams or an enthusiast interested in thermal physics, this article provides clarity on the process with step-by-step explanations and relevant formulas.

Introduction to Heat Transfer and Specific Heat Capacity

Heat transfer is the process of energy movement between systems or within parts of a system due to temperature difference. The amount of heat energy (Q) required to change the temperature of a substance depends on its mass (m), the material’s specific heat capacity (c), and the temperature change (ΔT).

The fundamental relation governing this is:

$$
Q = mc\Delta T
$$

where:
- Q = heat energy (in joules, J),
- m = mass of the substance (kg),
- c = specific heat capacity (J/kg·K),
- ΔT = change in temperature (K).

In this problem, we need to calculate the total heat required to:
- Raise the temperature of water from 293 K to a desired temperature.
- Raise the temperature of the copper container from 293 K to the same

temperature.

Given Data and Assumptions

Before proceeding with calculations, let's organize the given data:

1. **Mass of copper container (m_{Cu}):** 500 grams = 0.5 kg
2. **Volume of water (V_{water}):** 1 liter = 1 kg (since the density of water is approximately 1 kg/L)
3. **Initial temperature ($T_{initial}$):** 293 K (which is approximately 20°C)
4. **Final temperature (T_{final}):** To be determined or assumed based on context. For this calculation, let's assume the water is heated to 373 K (100°C), typical boiling point at atmospheric pressure, but the problem can be adjusted accordingly.
5. **Specific heat capacity of water (c_{water}):** 4186 J/kg·K
6. **Specific heat capacity of copper (c_{Cu}):** 385 J/kg·K

Note: If the problem specifies a different final temperature, adjust calculations accordingly.

Step-by-Step Calculation of Heat Required

The total heat energy required is the sum of the heat needed to warm the water and the copper container:

$$
Q_{total} = Q_{water} + Q_{copper}
$$

1. Calculating Heat Needed for Water

Using the formula:

$$

$$
Q_{water} = m_{water} \times c_{water} \times \Delta T
$$

where:

- $m_{water} = 1\, \text{kg}$,
- $c_{water} = 4186\, \text{J/kg·K}$,
- $\Delta T = T_{final} - T_{initial} = 373\, \text{K} - 293\, \text{K} = 80\, \text{K}$.

Substituting values:

$$
Q_{water} = 1 \times 4186 \times 80 = 334,880\, \text{J}
$$

2. Calculating Heat Needed for Copper Container

Similarly,

$$
Q_{copper} = m_{Cu} \times c_{Cu} \times \Delta T
$$

where:

- $m_{Cu} = 0.5\, \text{kg}$,
- $c_{Cu} = 385\, \text{J/kg·K}$,
- $\Delta T = 80\, \text{K}$.

Calculating:

$$
Q_{copper} = 0.5 \times 385 \times 80 = 15,400\, \text{J}
$$

3. Total Heat Energy Required

Adding both:

$$
Q_{total} = 334,880 + 15,400 = 350,280\, \text{J}
$$

Therefore, approximately 350,280 joules of heat energy are required to raise the temperature of 1 liter of water from 293 K to 373 K in a 500 g copper container initially at 293 K.

Additional Considerations and Real-World Factors

While the calculated value provides a theoretical estimate, real-world scenarios involve additional factors that may influence the actual heat required or time taken:

1. Heat Losses

- Heat may be lost to the surroundings via conduction, convection, or radiation.
- Insulation minimizes these losses but cannot eliminate them entirely.

2. Efficiency of Heating Source

- The heating device's efficiency impacts the actual energy consumption.
- No heating system is 100% efficient; some energy is inevitably lost.

3. Heat Capacity Variations

- The specific heat capacities are temperature-dependent, especially over large temperature ranges.
- The calculations assume constant specific heat capacities over the temperature change.

4. Phase Changes

- If the temperature reaches boiling point, phase change occurs.
- Additional heat (latent heat) is required for vaporization, which is not included here.

Applications of the Calculation

Understanding how to calculate heat requirements has broad applications across various fields:

1. **Cooking and Food Preparation:** Estimating energy needs for boiling or heating liquids.

2. **Engineering:** Designing heating systems for industrial processes.

3. **Scientific Experiments:** Planning thermal experiments requiring precise energy inputs.

4. **Environmental Studies:** Assessing energy consumption and efficiency in thermal systems.

Summary of Key Points

- The total heat energy to raise water and copper container from 293 K to 373 K is approximately 350,280 J.
- The calculation relies on the fundamental relation $Q = mc\Delta T$.
- Real-world factors may cause deviations from the theoretical value.
- Proper insulation and efficient heating methods can reduce energy consumption.

Conclusion

Calculating the heat required to warm a copper container with water involves understanding the properties of the materials involved and applying basic thermodynamic principles. The process underscores the importance of specific heat capacities and temperature differences in thermal calculations. Such calculations are vital for designing heating systems, optimizing energy usage, and understanding thermal phenomena in various practical scenarios.

By mastering these concepts, students and professionals can better analyze thermal systems and improve energy efficiency in real-world applications.

End of Article

Frequently Asked Questions

What is the specific heat capacity of water used in calculating the heat required to warm 1 liter of

water?

The specific heat capacity of water is typically taken as 4.18 J/g°C.

How do you convert the mass of water from liters to grams for heat calculation?

Since 1 liter of water has a mass of approximately 1000 grams, the mass is 1000 g.

What is the initial temperature of water in the problem, and what is the typical temperature increase required?

The initial temperature is 293 K (20°C). To find the heat required, the temperature increase (ΔT) must be specified or assumed based on the context.

Does the heat capacity of the copper container affect the total heat required to warm the water?

Yes, if considering the container's heat capacity, you need to include the heat needed to raise the container's temperature, calculated using its specific heat capacity and mass.

How is the total heat required calculated when heating both water and the copper container?

Total heat (Q) = (mass of water × specific heat of water × ΔT) + (mass of copper × specific heat of copper × ΔT).

What is the formula used to calculate the heat required to change the temperature of water and a copper container?

$Q = m_{water} \times c_{water} \times \Delta T + m_{copper} \times c_{copper} \times \Delta T$, where m is mass, c is specific heat capacity, and ΔT is temperature change.

Additional Resources

A Copper Container Of Mass 500 G Contains 1 Liter Of Water At 293 K. Calculate The Quantity Of Heat Required

In the realm of thermodynamics and heat transfer, understanding how to calculate the heat required to change the temperature of substances is fundamental. Imagine a scenario where a copper container, weighing 500 grams, is filled with one liter of water at room temperature, 293 Kelvin (approximately 20°C). The question arises: how much heat must be supplied to this system to raise its temperature by a certain amount? This seemingly simple problem involves concepts like specific heat capacity, the properties of materials involved, and the principles of heat transfer.

This article explores the detailed methodology to determine the quantity of heat needed to raise the temperature of both the copper container and the water it holds. We will delve into the physical properties of copper and water, the calculations involved, and the practical implications of such thermal processes.

Understanding the Physical Properties Involved

Before diving into calculations, it’s essential to understand the key physical properties that influence heat transfer:

1. Specific Heat Capacity

- Water: Specific heat capacity (c_{water}) of water is approximately 4.18 J/g·K. This means that to raise 1 gram of water by 1 Kelvin, 4.18 Joules of heat are needed.
- Copper: Specific heat capacity (c_{copper}) of copper is about 0.385 J/g·K. Copper heats up and cools down faster than water due to its lower specific heat capacity.

2. Mass and Volume

- Mass of Copper Container: 500 grams (g)
- Volume of Water: 1 liter

Since 1 liter of water has a mass of approximately 1000 grams (assuming the density of water as 1 g/mL), the water's mass is:

$$ m_{water} = 1000\,g $$

Assumptions and Conditions

For the purpose of calculation, we assume:

- The system is thermally isolated, meaning no heat is lost to the surroundings.
- The initial temperature of both the copper container and water is 293 K.
- We want to find the heat required to raise the temperature of the entire system by a certain temperature difference, ΔT. For illustration, let’s assume $\Delta T = 10$ K (from 293 K to 303 K).

These assumptions simplify calculations and provide a clear understanding of the core concepts.

Step-by-Step Calculation of Heat Required

The total heat required (Q_{total}) to increase the temperature of both the copper container and water can be expressed as:

$$ Q_{total} = Q_{copper} + Q_{water} $$

where:

- $Q_{copper} = m_{copper} \times c_{copper} \times \Delta T$
- $Q_{water} = m_{water} \times c_{water} \times \Delta T$

Let's compute each component.

Calculating Heat for the Copper Container

Given:

- $m_{copper} = 500\,g$
- $c_{copper} = 0.385\,J/g·K$
- $\Delta T = 10\,K$

The heat required to warm the copper container:

$$
Q_{copper} = 500\,g \times 0.385\,J/g·K \times 10\,K = 500 \times 0.385 \times 10
$$

$$
Q_{copper} = 500 \times 3.85 = 1925\,J
$$

Calculating Heat for the Water

Given:

- $m_{water} = 1000\,g$
- $c_{water} = 4.18\,J/g·K$
- $\Delta T = 10\,K$

The heat required to warm the water:

$$
Q_{water} = 1000\,g \times 4.18\,J/g\cdot K \times 10\,K = 1000 \times 41.8 = 41800\,J
$$

Total Heat Required

Adding both components:

$$
Q_{total} = Q_{copper} + Q_{water} = 1925\,J + 41800\,J = 43725\,J
$$

Therefore, approximately 43,725 Joules of heat are needed to raise the temperature of the entire system by 10 Kelvin under ideal, no-loss conditions.

Insights and Practical Considerations

While the calculation provides a clear theoretical value, real-world scenarios involve additional factors:

1. Heat Losses

In practice, some heat is lost to the environment through convection, conduction, and radiation. The actual heat supplied must be higher to compensate for these losses.

2. Rate of Heating

The rate at which heat is supplied influences temperature uniformity and potential thermal stresses, especially in metals like copper which conduct heat rapidly.

3. Material Conductivity

Copper’s high thermal conductivity ensures uniform temperature distribution within the container, but it also means that heat can quickly be transferred to surroundings unless insulation is used.

4. Application Scenarios

Understanding these calculations is vital in engineering applications such as designing heating systems, thermal management in reactors, or even in culinary processes where precise temperature control is crucial.

Extending the Calculation: Variable Temperature Increase

If the temperature increase (ΔT) differs, the calculation scales proportionally. For example, to raise the temperature by 20 K (from 293 K to 313 K):

$$
Q_{total} = (Q_{copper} + Q_{water}) \text{ at } \Delta T = 20\,K
$$

$$
Q_{copper} = 500 \times 0.385 \times 20 = 3850\,J
$$
$$
Q_{water} = 1000 \times 4.18 \times 20 = 83600\,J
$$
$$
Q_{total} = 3850 + 83600 = 87450\,J
$$

This demonstrates the linear relationship between heat energy and temperature change, assuming constant specific heats.

Concluding Remarks

Calculating the heat required to raise the temperature of a system comprising different materials involves understanding material properties, system parameters, and thermodynamic principles. In our example, the dominant factor is water's specific heat capacity, which underscores water's high thermal inertia compared to metals like copper.

Such calculations are foundational in fields ranging from mechanical engineering to environmental science, where precise thermal management is critical. Whether designing a heating system, optimizing industrial processes, or conducting scientific experiments, understanding how to quantify heat transfer is an essential skill.

While idealized calculations serve as a baseline, real-world applications must account for heat losses, material imperfections, and dynamic conditions. Nonetheless, mastering these principles provides a valuable foundation for further exploration into the fascinating domain of thermodynamics.

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