What Will Be The Equilibrium Temperature When A 215 G Block Of Copper At 255 C Is Placed In A 155 G Aluminum

What Will Be The Equilibrium Temperature When A 215 G Block Of Copper At 255°C Is Placed In A 155 G Aluminum

Understanding the final temperature when two objects at different temperatures are brought into contact is a fundamental concept in thermodynamics. In this article, we will explore how to determine the equilibrium temperature when a 215 g block of copper, initially at 255°C, is placed in contact with a 155 g aluminum object. The process involves applying principles of heat transfer, specific heat capacities, and energy conservation to arrive at an accurate solution.

Introduction to Heat Transfer and Equilibrium Temperature

Heat transfer is the movement of thermal energy from a region of higher temperature to a region of lower temperature. When two objects are placed in contact, heat flows until thermal equilibrium is reached, meaning both objects attain the same final temperature. The key points to understand include:

- Specific Heat Capacity: The amount of heat required to raise the temperature of a unit mass of a substance by one degree Celsius.
- Conservation of Energy: The heat lost by the hotter object equals the heat gained by the cooler object, assuming no heat loss to the surroundings.
- Final Equilibrium Temperature: The temperature at which heat transfer ceases, and both objects are at the same temperature.

Key Data and Assumptions

Before calculating, it's essential to identify the known data and assumptions:

Known Data:

Property	Copper	Aluminum
Mass (m)	215 g	155 g
Initial Temperature (Tinitial)	255°C	Assumed ambient or initial
Specific Heat Capacity (c)	approximately 0.385 J/g°C	approximately

0.897 J/g°C |

Assumptions:

- The system is perfectly insulated; no heat is lost to the environment.
- Heat transfer occurs only between the copper and aluminum.
- Both objects reach thermal equilibrium at the same final temperature (Tfinal).
- The specific heat capacities are constant over the temperature range.

Calculating the Equilibrium Temperature

The core principle applied here is the conservation of energy:

Heat lost by the hot object = Heat gained by the cold object

Since copper is initially hotter, it will lose heat, and aluminum will gain heat until they reach equilibrium.

Step 1: Write the heat transfer equation:

$$ m_{Cu} \times c_{Cu} \times (T_{initial,Cu} - T_{final}) = m_{Al} \times c_{Al} \times (T_{final} - T_{initial,Al}) $$

Note: If the initial temperature of aluminum is not given, it is often assumed to be at room temperature (e.g., 25°C). If the problem states otherwise, adjust accordingly.

Step 2: Insert known values:

- $m_{Cu} = 215\,g$
- $c_{Cu} = 0.385\,J/g°C$
- $T_{initial,Cu} = 255°C$

- $m_{Al} = 155\,g$
- $c_{Al} = 0.897\,J/g°C$
- $T_{initial,Al}$ = 25°C (assumed)

Step 3: Set up the equation:

$$ 215 \times 0.385 \times (255 - T_{final}) = 155 \times 0.897 \times (T_{final} - 25) $$

Step 4: Simplify the equation:

Calculate the coefficients:

- $215 \times 0.385 = 82.775$
- $155 \times 0.897 = 139.035$

So, the equation becomes:

$$ 82.775 \times (255 - T_{final}) = 139.035 \times (T_{final} - 25) $$

Step 5: Expand both sides:

$$ 82.775 \times 255 - 82.775 \times T_{final} = 139.035 \times T_{final} - 139.035 \times 25 $$

Calculate:

- $82.775 \times 255 = 21,096.125$
- $139.035 \times 25 = 3,475.875$

Now, the equation:

$$ 21,096.125 - 82.775 T_{final} = 139.035 T_{final} - 3,475.875 $$

Step 6: Rearrange to solve for T_{final}:

Bring all T_{final} terms to one side:

$$ 21,096.125 + 3,475.875 = 139.035 T_{final} + 82.775 T_{final} $$

Sum:

$$ 24,572 = 221.81 T_{final} $$

Divide both sides:

$$ T_{final} = \frac{24,572}{221.81} \approx 110.66°C $$

Final Equilibrium Temperature and Interpretation

Based on the calculations, the equilibrium temperature when a 215 g copper block initially at 255°C is placed in contact with a 155 g aluminum object (initially at 25°C) is approximately 110.7°C.

This temperature is reasonable considering the heat capacities and masses involved. Copper, with a lower specific heat, cools down more significantly, transferring heat to the aluminum, which warms up from 25°C to this intermediate temperature.

Factors Affecting the Equilibrium Temperature

While the calculations above are based on ideal assumptions, real-world factors can influence the actual temperature:

- Initial temperature of aluminum: If the aluminum starts at a different temperature, the equilibrium will shift accordingly.
- Heat loss to surroundings: In practical scenarios, heat may dissipate to the environment, resulting in a lower equilibrium temperature.
- Material properties: Variations in specific heat capacities with temperature could slightly alter the results.
- Contact quality: Imperfect contact or surface area can influence heat

transfer efficiency.

Practical Applications of Heat Transfer Calculations

Understanding how to calculate equilibrium temperatures has numerous practical applications:

- Thermal management in electronics: Ensuring components do not overheat.
- Material processing: Controlling heating and cooling in manufacturing.
- Engineering design: Designing systems that involve heat exchange, such as heat sinks and thermal insulators.
- Food industry: Calculating cooling times for hot items placed in different environments.

Summary and Conclusion

In conclusion, when a 215 g copper block at 255°C is placed in contact with a 155 g aluminum object initially at 25°C, the system reaches an equilibrium temperature of approximately 110.7°C under ideal, insulated conditions. This calculation demonstrates the importance of specific heat capacities and mass in thermodynamic heat transfer processes.

Understanding these principles enables engineers and scientists to predict temperature changes accurately in various systems, optimize thermal processes, and improve safety and efficiency in real-world applications.

FAQs

Q1: What if the initial temperature of aluminum is different?
Answer: The calculation can be adjusted by replacing the initial temperature of aluminum in the equation and solving again.

Q2: Does the specific heat capacity vary with temperature?
Answer: Yes, in some cases, specific heat capacities change with temperature, which can slightly affect the calculations.

Q3: How can heat loss to the environment be accounted for?
Answer: Incorporating heat transfer coefficients and environmental conditions into the model allows for more realistic predictions.

Q4: Can this method be used for other materials?
Answer: Absolutely. The method applies broadly, provided you know the specific heat capacities and initial temperatures.

Q5: Why is understanding equilibrium temperature important?
Answer: It helps in designing systems where temperature regulation is critical, ensuring safety, material integrity, and efficiency.

In summary, calculating the equilibrium temperature involves applying the conservation of energy principle, understanding material properties, and solving the resulting algebraic equations. Mastery of these concepts is essential for anyone working in thermodynamics, material science, or engineering fields.

Frequently Asked Questions

What is the equilibrium temperature when a 215 g copper block at 255°C is placed in 155 g aluminum?

The equilibrium temperature can be found by setting the heat lost by copper equal to the heat gained by aluminum, resulting in approximately 226.4°C.

How do you calculate the final temperature when two different metal objects are in thermal contact?

Use the principle of conservation of energy: the heat lost by the hotter object equals the heat gained by the cooler object, involving their masses, specific heats, and initial temperatures.

What is the specific heat capacity of copper and aluminum used in these calculations?

The specific heat capacity of copper is approximately 0.385 J/g°C, and for aluminum, it is about 0.897 J/g°C.

Why does the copper block cool down while the aluminum heats up when they are placed together?

Because heat flows from the higher temperature copper to the lower temperature aluminum until thermal equilibrium is reached.

What assumptions are made when calculating the equilibrium temperature in this scenario?

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

Can the final temperature be higher than the initial temperature of either metal?

No, the equilibrium temperature will be between the initial temperatures of the two objects, closer to the temperature of the object with the larger heat capacity.

What is the significance of the masses of the copper and aluminum in determining the equilibrium temperature?

The masses determine the amount of heat each metal can absorb or release, influencing the final equilibrium temperature.

How does the difference in initial temperatures of the two metals affect the equilibrium temperature?

The larger the initial temperature difference, the greater the heat transfer until equilibrium is reached; the final temperature depends on both initial temperatures and their heat capacities.

If the initial temperature of aluminum was higher than copper, how would that affect the equilibrium temperature?

The equilibrium temperature would be closer to the initial temperature of aluminum, as heat would flow from aluminum to copper until reaching a common temperature.

What practical applications involve calculating the equilibrium temperature of two metals in contact?

Applications include thermal management in electronics, material processing, designing heat exchangers, and understanding heat transfer in engineering systems.

Additional Resources

Equilibrium Temperature When A 215 G Block Of Copper At 255°C Is Placed In A 155 G Aluminum

Understanding the thermal interactions between different materials is fundamental in numerous scientific and engineering applications. When a copper block at a high temperature is introduced into an aluminum environment, heat transfer occurs until thermal equilibrium is achieved. The question of what the final equilibrium temperature will be in such a case involves principles from thermodynamics, specifically the conservation of energy and heat transfer mechanisms. This scenario provides an excellent opportunity to explore the concepts of specific heat capacity, heat exchange, and equilibrium in mixed materials.

Introduction to the Problem

Imagine taking a 215-gram block of copper heated to 255°C and placing it into a 155-gram block of aluminum, initially at a lower temperature. Over time, heat will flow from the hotter copper to the cooler aluminum until both materials reach a common temperature, known as the equilibrium temperature. The primary goal is to determine this temperature using fundamental principles of heat transfer and material properties.

This problem is a classic example used in thermodynamics to illustrate how heat exchange occurs between two objects with different initial temperatures and different heat capacities. It highlights the importance of parameters such as mass, specific heat capacity, and initial temperature in predicting the final thermal state.

Theoretical Background

Heat Transfer Principles

In the absence of heat loss to the environment (assuming an ideal isolated system), the heat lost by the hotter object equals the heat gained by the cooler object:

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

Mathematically, this translates to:

$$ m_{Cu} c_{Cu} (T_{initial,Cu} - T_{final}) = m_{Al} c_{Al} (T_{final} - T_{initial,Al}) $$

where:

- m_{Cu} and m_{Al} are the masses of copper and aluminum, respectively.
- c_{Cu} and c_{Al} are their specific heat capacities.
- $T_{initial,Cu}$ and $T_{initial,Al}$ are their initial temperatures.
- T_{final} is the equilibrium temperature, which we aim to find.

This approach assumes no heat loss to surroundings, which is idealized but provides a good approximation.

Material Properties

The key to solving this problem lies in the specific heat capacities:

- Copper: $c_{Cu} \approx 0.385\, \text{J/g°C}$
- Aluminum: $c_{Al} \approx 0.900\, \text{J/g°C}$

These values reflect how much energy is needed to raise the temperature of 1 gram of each material by 1°C.

Calculating the Equilibrium Temperature

Using the heat exchange principle, the equation becomes:

$$ m_{Cu} c_{Cu} (T_{initial,Cu} - T_{final}) = m_{Al} c_{Al} (T_{final} - T_{initial,Al}) $$

Given data:

- $ m_{Cu} = 215\, \text{g} $
- $ T_{initial,Cu} = 255^\circ C $
- $ m_{Al} = 155\, \text{g} $
- $ T_{initial,Al} = \text{unknown} $ (we need to assume or specify an initial temperature for aluminum; for simplicity, often it is taken as room temperature, say 25°C, unless specified otherwise).

Assuming the aluminum block is initially at room temperature:

- $ T_{initial,Al} = 25^\circ C $

Now, substituting the known values:

$$ 215 \times 0.385 \times (255 - T_{final}) = 155 \times 0.900 \times (T_{final} - 25) $$

Calculating the products:

$$ 82.775 \times (255 - T_{final}) = 139.5 \times (T_{final} - 25) $$

Expanding both sides:

$$ 82.775 \times 255 - 82.775 \times T_{final} = 139.5 \times T_{final} - 139.5 \times 25 $$

Calculating constants:

$$ 82.775 \times 255 \approx 21,096.625 $$
$$ 139.5 \times 25 = 3,487.5 $$

Rearranged equation:

$$ 21,096.625 - 82.775 T_{final} = 139.5 T_{final} - 3,487.5 $$

Bring all $ T_{final} $ terms to one side:

$$ 21,096.625 + 3,487.5 = 139.5 T_{final} + 82.775 T_{final} $$

$$ 24,584.125 = 222.275 T_{final} $$

Solve for $ T_{final} $:

$$ T_{final} = \frac{24,584.125}{222.275} \approx 110.4^\circ C $$

Result: The equilibrium temperature is approximately 110.4°C.

Analysis and Implications

Features of the Result

- The equilibrium temperature lies between the initial temperatures of copper (255°C) and room temperature (25°C), reflecting the heat transfer from hot copper to cooler aluminum.
- The higher specific heat capacity of aluminum means it can absorb more heat per unit temperature increase, influencing the final temperature.
- The mass of each material is significant; a larger mass of copper at a higher temperature tends to pull the equilibrium temperature closer to its initial temperature.

Variations and Assumptions

If the initial temperature of aluminum differs, the equilibrium temperature will shift accordingly. For example, if aluminum starts at a higher temperature, the equilibrium will be higher; if lower, the equilibrium drops.

It is also important to recognize the idealized assumptions:

- No heat loss to surroundings or environment.
- Perfect thermal contact between the blocks.
- No phase changes or other energy exchanges.

Including environmental factors would require more complex models involving heat transfer coefficients and conduction or convection considerations.

Pros and Cons of the Method

Pros:

- Simple and straightforward calculation based on fundamental laws.
- Uses readily available material properties.
- Provides a good approximation for idealized systems.

Cons:

- Assumes no heat loss to environment, which is rarely true in practical situations.
- Ignores heat conduction through contact resistance.
- Assumes uniform temperature within each block, which might not be accurate for larger objects.
- Does not account for phase changes or other energy exchanges.

Practical Applications and Relevance

Understanding equilibrium temperatures is critical in designing thermal systems, such as heat exchangers, electronic component cooling, and materials processing. Accurate predictions of final temperatures help prevent material damage, optimize energy efficiency, and ensure safety.

In real-world applications, engineers often include factors like heat losses, insulation, and transient heat transfer effects to refine their models, but the fundamental principles remain the same.

Conclusion

Predicting the equilibrium temperature when a hot copper block is placed in cooler aluminum involves applying the principles of conservation of energy and heat transfer. Based on the calculations and assumptions, the final temperature of approximately 110.4°C illustrates how the materials exchange heat until reaching thermal equilibrium. While this simplified model offers valuable insights, real-world scenarios require considering additional complexities such as environmental heat loss, conduction resistance, and non-uniform temperature distribution. Nonetheless, understanding these fundamental concepts forms the backbone of thermal analysis in engineering and scientific research.

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