Suppose That 25 G Of Aluminum Is Initially At 27.0 C. What Is The Final Temperature Of Aluminum Upon

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Understanding the thermal behavior of metals is fundamental in fields ranging from engineering and manufacturing to scientific research. When a specific amount of aluminum is subjected to heat or cooled by another substance, predicting its final temperature requires a grasp of concepts such as specific heat capacity, heat transfer, and the principles of thermodynamics.

In this article, we will explore the process of determining the final temperature of 25 grams of aluminum initially at 27.0°C under various conditions. We will delve into the physics behind heat transfer, explain the relevant formulas, and provide detailed examples to clarify the concepts. Whether you are a student, educator, or professional, understanding how to calculate final temperatures in thermal processes is essential.

Understanding the Basic Concepts of Heat Transfer and Specific Heat Capacity

What Is Specific Heat Capacity?

Specific heat capacity (often simply called specific heat) is a property of a material that indicates how much heat energy is needed to raise the temperature of a unit mass of the substance by one degree Celsius (or Kelvin).

Mathematically, it is expressed as:

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

Where:
- Q = heat energy added or removed (in joules, J)
- m = mass of the substance (in grams or kilograms)
- ΔT = change in temperature (in °C or K)

For aluminum, the specific heat capacity is approximately:

$$ c_{Al} = 0.897 \, \text{J/g°C} $$

This means that to raise 1 gram of aluminum by 1°C, about 0.897 joules of heat are required.

Principles of Heat Transfer

Heat transfer occurs via three main mechanisms:
- Conduction: transfer of heat through a material
- Convection: transfer of heat through fluids (liquids or gases)
- Radiation: transfer of heat through electromagnetic waves

In many problems involving the heating or cooling of an object like aluminum, conduction and convection are most relevant. For simplicity, we often assume idealized conditions where heat transfer is efficient and occurs uniformly.

Calculating Final Temperature: Core Principles

The fundamental principle in calculating the final temperature of a substance after heat transfer is the conservation of energy: the heat lost by one component equals the heat gained by another, assuming no heat loss to the environment.

The general heat transfer formula is:

$$ Q = m c \Delta T $$

Where Q is the heat transferred, m is mass, c is specific heat capacity, and ΔT is change in temperature.

Scenario 1: Heating aluminum with a known heat source.

Scenario 2: Cooling aluminum by contact with a cooler substance.

Scenario 3: Aluminum in a thermal system reaching equilibrium with multiple components.

In all cases, the goal is to find the final temperature T_f.

Example 1: Heating Aluminum with a Known Quantity of Heat

Suppose you supply a certain amount of heat to the aluminum, for example, 100 joules. What will be the final temperature?

Given:
- Mass of aluminum, $m = 25 \, \text{g}$
- Initial temperature, $T_i = 27.0\,^\circ\mathrm{C}$
- Heat supplied, $Q = 100\, \text{J}$
- Specific heat capacity of aluminum, $c_{Al} = 0.897\, \text{J/g°C}$

Calculation:

1. Calculate the temperature change:

$$\Delta T = \frac{Q}{m c} = \frac{100\, \text{J}}{25\, \text{g} \times 0.897\, \text{J/g°C}}$$

2. Simplify:

$$\Delta T = \frac{100}{22.425} \approx 4.46\,^\circ\mathrm{C}$$

3. Find the final temperature:

$$T_f = T_i + \Delta T = 27.0 + 4.46 \approx 31.46\,^\circ\mathrm{C}$$

Result: After receiving 100 joules of heat, the aluminum's temperature will rise to approximately 31.46°C.

Example 2: Cooling Aluminum by Contact with Cooler Water

Now suppose the aluminum cools down by contact with water at a lower temperature, say 20°C. If the water is large enough to absorb the heat without changing temperature significantly, what will be the final temperature of the aluminum after thermal equilibrium?

Assumptions:
- The water's temperature remains constant at 20°C (large thermal reservoir).
- No heat loss to surroundings.
- The initial temperature of aluminum is 27.0°C.

Given:
- $m_{Al} = 25\, \text{g}$
- $T_{Al,i} = 27.0\,^\circ\mathrm{C}$
- $T_{water} = 20.0\,^\circ\mathrm{C}$
- $c_{Al} = 0.897\, \text{J/g°C}$
- The water's heat capacity is large enough that its temperature remains effectively constant.

Calculating the heat lost by aluminum:

$$ Q_{lost} = m_{Al} c_{Al} (T_{Al,i} - T_f) $$

Since the water is large and remains at 20°C, the heat gained by water is:

$$ Q_{gained} = m_{water} c_{water} (T_f - T_{water}) $$

But because the water's temperature is assumed constant, the heat gained is:

$$ Q_{water} = C_{water} (T_f - T_{water}) $$

Where C_{water} is the heat capacity of water (mass $\times$ specific heat). In practice, for a large water reservoir:

$$ Q_{water} \gg Q_{Al} $$

and the final temperature T_f can be approximated by setting heat lost by aluminum equal to heat gained by water:

$$ m_{Al} c_{Al} (T_{Al,i} - T_f) = m_{water} c_{water} (T_f - T_{water}) $$

If the water's mass is significantly large, then:

$$ T_f \approx T_{water} = 20\,^\circ\mathrm{C} $$

meaning the aluminum cools down close to the water temperature.

Example 3: Achieving Thermal Equilibrium Between Aluminum and a Hot Object

Suppose you place the aluminum in contact with a hot object, such as a 100 g copper block at 100°C. What will be the final temperature?

Given:
- Aluminum mass, $m_{Al} = 25\, \text{g}$
- Aluminum initial temperature, $T_{Al,i} = 27.0\,^\circ\mathrm{C}$
- Copper mass, $m_{Cu} = 100\, \text{g}$
- Copper initial temperature, $T_{Cu,i} = 100\,^\circ\mathrm{C}$
- Specific heat capacities:
- Aluminum, $c_{Al} = 0.897\, \text{J/g°C}$
- Copper, $c_{Cu} = 0.385\, \text{J/g°C}$

Step-by-step calculation:

1. Assume no heat loss to surroundings, and the final temperature is \(T_f

\).

2. Set heat lost by the hot copper equal to heat gained by aluminum:

$$ m_{Cu} c_{Cu} (T_{Cu,i} - T_f) = m_{Al} c_{Al} (T_f - T_{Al,i}) $$

3. Plug in known values:

$$ 100 \times 0.385 \times (100 - T_f) = 25 \times 0.897 \times (T_f - 27) $$

4. Simplify:

$$ 38.5 \times (100 - T_f) = 22.425 \times (T_f - 27) $$

5. Expand:

$$ 3850 - 38.5 T_f = 22.425 T_f - 22.425 \times 27 $$

$$ 3850 - 38.5 T_f = 22.425 T_f - 605.475 $$

6. Bring like terms together:

$$ 3850 + 605.475 = 22.425 T_f + 38.5 T_f $$

$$ 4455.475 = 60.925 T_f $$

7. Solve for T_f:

$$ T_f = \frac{4455.475}{60.925} \approx 73.13\,^\circ\mathrm{C} $$

Result: The final equilibrium temperature of the system is approximately 73.13°C.

Factors Affecting Final Temperature Calculations

While the above examples assume idealized conditions, real-world scenarios involve additional factors:

- Heat Loss to Environment: Heat can escape through conduction,

Frequently Asked Questions

What is the specific heat capacity of aluminum used in calculating temperature change?

The specific heat capacity of aluminum is approximately 0.900 J/g°C.

How do you calculate the final temperature of aluminum after heat transfer?

Use the formula $Q = mc\Delta T$, where Q is heat added or removed, m is mass, c is specific heat, and ΔT is the change in temperature. Rearranged as $T_{final} = T_{initial} + (Q / (m c))$.

What additional information is needed to determine the final temperature of aluminum?

The amount of heat transferred to or from the aluminum (Q) is needed to calculate the final temperature.

If 1000 J of heat is added to the aluminum, what is its final temperature?

Using Q = 1000 J, m = 25 g, c = 0.900 J/g°C, $T_{initial}$ = 27.0°C, then $\Delta T = 1000 / (25\ 0.900) \approx 44.44$°C. Final temperature $T_{final} = 27.0 + 44.44 \approx 71.44$°C.

What factors affect the final temperature of aluminum in heat transfer scenarios?

The amount of heat transferred, initial temperature, mass of aluminum, and its specific heat capacity all influence the final temperature.

Can aluminum reach its melting point during heating, and what is it?

Yes, aluminum melts at about 660.3°C. Whether it reaches this temperature depends on the heat energy supplied.

How does heat loss to surroundings affect the calculation of final temperature?

Heat loss complicates the calculation, as not all heat added is retained in the aluminum; the actual final temperature would be lower than predicted without accounting for losses.

Is the calculation of the final temperature different if aluminum is cooling instead of heating?

Yes, if aluminum is cooling, heat is being removed, and the temperature decrease can be calculated similarly using Q as a negative value in the formula.

Additional Resources

Aluminum Heating and Temperature Change: An In-Depth Analysis

When exploring the fascinating world of thermodynamics and material science, understanding how substances like aluminum respond to heat is fundamental. Suppose that 25 grams of aluminum is initially at 27.0°C; a natural curiosity arises: What is the final temperature of aluminum when it absorbs or loses heat? This question opens a gateway to exploring specific heat capacity, heat transfer, and the principles governing temperature changes in metals. In this comprehensive review, we will scrutinize the factors influencing aluminum's temperature evolution, the calculations involved, and the broader implications for engineering, manufacturing, and everyday applications.

Understanding the Basics: Aluminum and Its Thermal Properties

Before diving into calculations, it's essential to grasp the properties of aluminum that dictate how it interacts with heat.

Physical Properties of Aluminum

- Density: Approximately 2.70 g/cm^3, which influences its mass and thermal mass.
- Specific Heat Capacity (c): About 0.897 J/g°C, a key value indicating how much heat energy is needed to raise its temperature.
- Thermal Conductivity: Around 205 W/m°C, enabling rapid heat transfer.
- Melting Point: Approximately 660.3°C, well above typical operating temperatures, implying aluminum remains solid in most scenarios.

These properties make aluminum a favorite in applications requiring efficient heat conduction and lightweight construction, such as in aerospace, cooking utensils, and heat exchangers.

Fundamental Concepts: Heat, Temperature, and Specific Heat Capacity

To analyze the temperature change, one must understand the core principles:

Heat (Q):

The energy transferred between objects due to a temperature difference, measured in joules (J).

Temperature (T):

A measure of thermal energy within an object, expressed in degrees Celsius (°C) or Kelvin (K). The relationship between heat and temperature change is governed by the specific heat capacity.

Specific Heat Capacity (c):

This is a material-specific property that indicates how much heat energy is required to raise the temperature of 1 gram of the substance by 1°C.

Calculating the Final Temperature: The Core Equation

When heat is added or removed from aluminum, the change in its temperature can be determined using the fundamental thermodynamic equation:

$$
Q = mc \Delta T
$$

where:
- Q = heat energy supplied or removed (J)
- m = mass of aluminum (g)
- c = specific heat capacity (J/g°C)
- ΔT = change in temperature (°C)

Rearranged to find the final temperature T_f:

$$
T_f = T_i + \frac{Q}{mc}
$$

where:
- T_i = initial temperature (°C)
- Q = heat transferred (J)

Scenario 1: Heating Aluminum with a Known Amount of Heat

Suppose we want to determine the final temperature of the aluminum if a specific amount of heat is added. For instance, imagine applying 500 J of energy to the 25 g of aluminum initially at 27.0°C.

Step-by-Step Calculation:

1. Identify Known Values:

Quantity	Value
m	25 g
c	0.897 J/g°C
T_i	27.0°C
Q	500 J

2. Calculate the temperature change (ΔT):

$$
\Delta T = \frac{Q}{mc} = \frac{500}{25 \times 0.897} \approx \frac{500}{22.425} \approx 22.3°C
$$

3. Determine the final temperature:

$$
T_f = T_i + \Delta T = 27.0 + 22.3 \approx 49.3°C
$$

Result: After absorbing 500 J of heat, the aluminum's temperature rises from 27.0°C to approximately 49.3°C.

Scenario 2: Cooling Aluminum or Removing Heat

Conversely, suppose the aluminum cools down due to heat loss. If 200 J of heat is removed:

1. Calculate ΔT:

$$
\Delta T = \frac{-Q}{mc} = \frac{-200}{25 \times 0.897} \approx -8.9°C
$$

2. Final temperature:

$$
T_f = T_i + \Delta T = 27.0 - 8.9 \approx 18.1°C
$$

This example demonstrates how aluminum's temperature decreases as it loses heat, emphasizing the importance of the sign in calculations.

Additional Considerations in Real-World Applications

While the above calculations provide a straightforward theoretical framework, real-world scenarios often involve complexities:

Heat Transfer Modes

- Conduction: Direct transfer through contact.
- Convection: Movement of heat via fluid or air currents.
- Radiation: Emission or absorption of electromagnetic waves.

Depending on the context, the dominant mode affects how quickly aluminum reaches the final temperature.

Environmental Factors

- Ambient temperature
- Insulation properties
- Surface area and shape of the aluminum piece

These factors influence the rate and extent of temperature change, often requiring differential equations and heat transfer coefficients for precise modeling.

Phase Changes

- If the temperature approaches aluminum's melting point, phase change considerations become crucial.
- Additional heat (latent heat) is needed for melting, significantly affecting temperature calculations.

Extending the Analysis: Energy Balance and Practical Implications

In engineering applications, understanding the energy balance is vital:

$$
Q_{in} - Q_{out} = mc \Delta T
$$

This accounts for both heating and cooling processes, including losses due to radiation, conduction, and convection.

Practical implications include:

- Design of Heating Elements: Ensuring the energy supplied matches the desired temperature for manufacturing or processing.
- Temperature Control: Using sensors and feedback systems to precisely manage aluminum temperatures.
- Material Selection: Considering aluminum's specific heat capacity and thermal conductivity to optimize heat treatment processes.

Conclusion: The Significance of Precise Calculations in Material Science

Understanding the temperature change of aluminum upon heat transfer is not just an academic exercise but a cornerstone of practical engineering, manufacturing, and scientific research. Whether heating aluminum for cooking, metalworking, or designing thermal systems, accurate calculations based on the specific heat capacity and energy transfer principles are indispensable.

The example of 25 grams of aluminum initially at 27.0°C illustrates a fundamental principle: the amount of heat added or removed directly influences the final temperature. By mastering these calculations, engineers and scientists can predict and control thermal behaviors, ensuring safety, efficiency, and optimal performance in various applications.

In sum, the ability to precisely determine the final temperature of aluminum based on heat transfer embodies the core of thermodynamics and material science— enabling innovations across industries and enhancing our understanding of the materials that shape our world.

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