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Understanding the thermal response of materials to heat transfer is a fundamental concept in thermodynamics and materials science. When a specific amount of heat is supplied to a substance, its temperature changes depending on properties such as specific heat capacity, mass, and initial temperature. In this article, we will explore in detail how to determine the final temperature of a small brass sample after it absorbs a given quantity of heat, elucidate the underlying principles, and provide a comprehensive step-by-step calculation.

Fundamentals of Heat Transfer and Specific Heat Capacity

What Is Heat and How Is It Transferred?

Heat is a form of energy transfer between systems or objects due to temperature differences. It can be transferred through conduction, convection, or radiation. When heat is added to a substance, it increases the internal energy, leading to a rise in temperature assuming no phase change occurs.

Specific Heat Capacity: Definition and Significance

The specific heat capacity (c) of a material is the amount of heat required to raise the temperature of 1 gram of the substance by 1°C (or 1 K). It is expressed in units of J/(g·°C) or J/(g·K). Different materials have varying specific heat capacities; for example, metals typically have lower specific heat capacities than water.

Heat Equation for Temperature Change

The fundamental relation connecting heat transfer and temperature change is:

$$Q = mc\Delta T$$

where:
- Q = heat added or removed (J)
- m = mass of the substance (g)
- c = specific heat capacity (J/(g·°C))
- ΔT = change in temperature (°C)

This equation assumes no phase change and constant specific heat capacity over the temperature range.

Properties of Brass Relevant to this Problem

What Is Brass?

Brass is an alloy primarily composed of copper and zinc, and it exhibits specific thermodynamic properties that are well documented. The specific heat capacity of brass typically varies around 0.380 J/(g·°C). For precise calculations, consulting a reliable data source or material property chart is recommended.

Typical Specific Heat Capacity of Brass

- Approximate value: $c_{brass} \approx 0.380$ J/(g·°C)

Mass and Initial Temperature

- Mass, m: 5.0 g
- Initial temperature, $T_{initial}$: 25°C

Calculating the Final Temperature

Step 1: Write Down Known Quantities

- Heat absorbed, Q: 75 J
- Mass, m: 5.0 g
- Specific heat capacity, c: 0.380 J/(g·°C)
- Initial temperature, $T_{initial}$: 25°C

Step 2: Rearrange the Heat Equation to Find ΔT

$$
\Delta T = \frac{Q}{mc}
$$

This formula calculates the temperature change resulting from the absorbed heat.

Step 3: Compute ΔT

$$
\Delta T = \frac{75\, \text{J}}{5.0\, \text{g} \times 0.380\, \text{J/(g·°C)}} = \frac{75}{1.9} \approx 39.47^\circ C
$$

The temperature increase is approximately 39.47°C.

Step 4: Determine the Final Temperature

$$
T_{final} = T_{initial} + \Delta T = 25^\circ C + 39.47^\circ C \approx 64.47^\circ C
$$

Thus, after absorbing 75 J of heat, the brass sample's temperature will rise to approximately 64.5°C.

Discussion and Considerations

Assumption of Constant Specific Heat Capacity

The calculation assumes that the specific heat capacity remains constant over the temperature range. In reality, c can vary slightly with temperature, but for small temperature changes like this, the approximation is typically valid.

Neglecting Heat Losses

The calculation presumes no heat loss to surroundings during the process, which is idealized. In practical scenarios, some heat may dissipate, leading to a slightly lower final temperature.

Phase Changes and Material Integrity

Since the temperature increase is well below brass's melting point (around 900°C), phase changes are not considered. The material remains in the solid state.

Additional Factors Influencing Final Temperature

- **Environmental Conditions:** Insulation or heat exchange with surroundings affects actual temperature change.
- **Heat Capacity Variability:** For precise calculations, temperature-dependent specific heat capacities can be used instead of a constant value.
- **Measurement Precision:** Error margins in mass, heat input, and specific heat data can influence results.

Summary

To summarize, the final temperature of a 5.0 g brass sample initially at 25°C, after absorbing 75 J of heat, is approximately 64.5°C. This calculation hinges on fundamental principles of thermodynamics, assuming constant specific heat capacity and no heat losses. Such calculations are essential in designing thermal systems, understanding material behavior under heating, and in various engineering applications.

Conclusion

Understanding how heat affects materials is crucial across scientific and engineering disciplines. By applying the heat equation and knowledge of material properties, we can predict temperature changes with reasonable accuracy. In this specific case involving brass, the process demonstrates how relatively small quantities of heat can significantly raise the temperature of a small metal sample, highlighting the importance of specific heat capacity and mass in thermal calculations. This knowledge is not only academically interesting but also practically valuable in manufacturing, metallurgy, and thermal management systems.

Frequently Asked Questions

What is the final temperature of a 5.0 g brass sample initially at 25°C after absorbing 75 J of heat?

To find the final temperature, use the formula $Q = mc\Delta T$. The specific heat capacity of brass is approximately 0.380 J/g°C. First, calculate ΔT: $\Delta T = Q / (mc) = 75 \text{ J} / (5.0 \text{ g} \times 0.380 \text{ J/g°C}) \approx 39.47°C$. Since heat is absorbed, the temperature increases, so the final temperature is 25°C + 39.47°C ≈ 64.47°C.

How do you calculate the temperature change when a substance absorbs heat?

The temperature change (ΔT) is calculated using the formula $\Delta T = Q / (mc)$, where Q is the heat absorbed or released, m is the mass of the substance, and c is its specific heat capacity.

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

The specific heat capacity of brass used here is approximately 0.380 J/g°C.

Why is it important to know the specific heat capacity of brass in this problem?

Knowing the specific heat capacity of brass allows us to accurately calculate the temperature change when heat is absorbed or released, as it relates the heat energy to temperature change for a given mass.

What assumptions are made in calculating the final temperature of the brass sample?

The calculations assume that all the heat energy is used solely to raise the temperature of the brass without any heat loss to the surroundings, and that the specific heat capacity remains constant over the temperature range.

If the brass sample had a different mass, how would that affect the final temperature after absorbing 75 J of heat?

A larger mass would result in a smaller temperature increase, while a smaller mass would lead to a larger temperature increase, since $\Delta T = Q / (mc)$.

What other factors could influence the accuracy of this temperature calculation?

Factors such as heat loss to the environment, changes in specific heat capacity with temperature, and measurement errors could influence the accuracy of the calculation.

Can this method be used to determine the final temperature of other materials?

Yes, by knowing the material's specific heat capacity and mass, and the amount of heat absorbed or released, this method can be used to determine the final temperature of other substances as well.

Additional Resources

What Is The Final Temperature When A 5.0 G Sample Of Brass Initially At 25°C Absorbs 75 J Of Heat? The Answer Lies in Understanding Heat Transfer and Material Properties

In the realm of thermodynamics, the process of heat transfer within solids like metals is a fundamental concept that finds applications across engineering, manufacturing, and everyday phenomena. Among these materials, brass—a copper-zinc alloy—serves as a common example used to illustrate how heat affects temperature changes in solids. But what exactly happens when a small sample of brass absorbs heat? Specifically, if 5.0 grams of brass initially at 25°C absorbs 75 joules of heat, what will be its final temperature? Exploring this question requires a blend of physics principles, material properties, and calculations rooted in thermodynamics.

This article aims to demystify this process, guiding readers through the fundamental concepts, the step-by-step calculations involved, and the broader implications of understanding heat absorption in metals like brass. Whether you're a student, an educator, or an enthusiast curious about how heat influences materials, this comprehensive exploration offers clarity and insight.

Understanding the Basics: Heat, Temperature, and Specific Heat Capacity

Before diving into calculations, it's essential to grasp the key concepts involved: heat, temperature, and specific heat capacity.

What Is Heat?

Heat is a form of energy transfer between systems or objects due to a temperature difference. When heat is added to a substance, it can cause an increase in the internal energy, which often manifests as a rise in temperature.

What Is Temperature?

Temperature measures the average kinetic energy of particles within a substance. It is a scalar quantity expressed in units such as Celsius (°C), Kelvin (K), or Fahrenheit (°F). In thermodynamics, temperature indicates how hot or cold a body is relative to a standard.

Specific Heat Capacity (c)

The specific heat capacity of a substance is a property that indicates how much heat energy is required to raise the temperature of one gram of the substance by one degree Celsius (or Kelvin). It is expressed in units of J/(g·°C).

For brass, the specific heat capacity is approximately 0.380 J/(g·°C). This value can vary slightly depending on the alloy composition, but 0.380 J/(g·°C) is a typical approximation.

The Thermodynamic Equation for Heat Absorption

The core equation connecting heat transfer and temperature change is:

$$Q = mc \Delta T$$

Where:
- Q = heat energy absorbed or released (in joules)
- m = mass of the substance (in grams)
- c = specific heat capacity (J/(g·°C))
- ΔT = change in temperature (final temperature minus initial temperature)

This relation assumes the process occurs at constant pressure and that the material's specific heat capacity remains constant over the temperature range involved.

Applying the Concepts: Calculating the Final Temperature

Given:
- Mass of brass, $m = 5.0\,g$
- Initial temperature, $T_i = 25^\circ C$
- Heat absorbed, $Q = 75\,J$
- Specific heat capacity of brass, $c = 0.380\,J/(g·^\circ C)$

The goal is to find the final temperature T_f.

Rearranged equation:

$$\Delta T = \frac{Q}{mc}$$

And:

$$T_f = T_i + \Delta T$$

Plugging in the numbers:

$$\Delta T = \frac{75\,J}{5.0\,g \times 0.380\,J/(g·^\circ C)}$$

Calculating the denominator:

$$5.0\,g \times 0.380\,J/(g·^\circ C) = 1.9\,J/^\circ C$$

Therefore:

$$\Delta T = \frac{75\,J}{1.9\,J/^\circ C} \approx 39.47^\circ C$$

Finally, the final temperature:

$$T_f = 25^\circ C + 39.47^\circ C \approx 64.5^\circ C$$

Conclusion:
The brass sample's temperature increases from 25°C to approximately 64.5°C after absorbing 75 joules of heat.

Deeper Insights and Practical Considerations

While the calculation appears straightforward, several factors and assumptions are worth examining to contextualize this result.

Assumption of Constant Specific Heat Capacity

The calculation assumes that the specific heat capacity remains constant across the temperature range. In reality, c can vary slightly with temperature, especially over larger temperature changes. For small to moderate changes like this, the approximation is typically acceptable.

No Heat Losses or Gains from Surroundings

The calculation presumes an ideal scenario where all the heat added is used solely to increase the temperature of the brass sample. In practical settings, heat losses to the environment—through conduction, convection, or radiation—can occur, leading to a final temperature lower than the calculated value.

Material Homogeneity

It is assumed that the brass sample is homogeneous and that its properties are uniform throughout. Variations in alloy composition could slightly alter the specific heat capacity.

Implications and Broader Applications

Understanding how heat affects metals like brass isn't merely an academic exercise; it has tangible applications across industries and scientific research.

Engineering and Manufacturing

Engineers rely on precise calculations of temperature changes to design components that can withstand thermal stresses. For example, brass fittings or components in machinery are selected and tested based on their thermal properties to prevent failure.

Thermal Management

In electronics and instrumentation, managing heat is critical. Knowing how much a material's temperature will rise with a given heat input informs cooling strategies and safety protocols.

Material Science and Research

Scientists use heat transfer calculations to study material behaviors under different thermal conditions, aiding in the development of new alloys and materials with tailored properties.

Conclusion: The Power of Thermodynamics in Everyday Life

The question of what final temperature a brass sample reaches after absorbing a specific amount of heat encapsulates the elegance of thermodynamics—predicting how matter responds to energy inputs. Through fundamental principles, straightforward calculations, and an understanding of material properties, one can accurately determine temperature changes in solids like brass.

In this example, a small 5-gram sample of brass initially at 25°C absorbs 75 joules of heat, leading to a rise of approximately 39.5°C, culminating in a final temperature near 64.5°C. Such insights are invaluable across engineering, scientific research, and practical applications, demonstrating the profound relevance of basic physics principles in everyday phenomena. Whether designing thermal systems or conducting educational

DEMONSTRATIONS, UNDERSTANDING HEAT TRANSFER CONTINUES TO BE A CORNERSTONE OF SCIENTIFIC LITERACY AND TECHNOLOGICAL ADVANCEMENT.

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