

If 40.5 J Of Heat Is Added To A 15.4 G Sample Of Silver, How Much Will The Temperature Increase By? The

If 40.5 J Of Heat Is Added To A 15.4 G Sample Of Silver, How Much Will The Temperature Increase The – this question touches upon fundamental concepts in thermodynamics, specifically heat transfer, specific heat capacity, and temperature change calculation. Understanding how heat energy affects materials, especially metals like silver, is essential for students, engineers, and scientists working in fields such as materials science, physics, chemistry, and engineering. This article aims to provide a comprehensive explanation of how to determine the temperature increase of a silver sample when a specific amount of heat is added, including the relevant formulas, step-by-step calculations, and practical implications.

Understanding the Basic Concepts

What Is Heat Energy?

Heat energy 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 changes in temperature, phase, or both. The amount of heat energy transferred is measured in joules (J).

Specific Heat Capacity

The specific heat capacity (often just called specific heat) of a substance is the amount of heat required to raise the temperature of one gram of the substance by one degree Celsius (or Kelvin). It is a property that indicates how resistant a material is to temperature change when heat is added or removed.

Mathematically, specific heat capacity (c) is expressed as:

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

where:

- Q = heat energy transferred (J)
- m = mass of the substance (g)
- ΔT = change in temperature ($^{\circ}\text{C}$ or K)

Rearranged to find the temperature change:

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

Why Silver?

Silver is a highly conductive metal with unique thermal properties. Its high thermal conductivity makes it excellent for heat transfer applications, but it also has a specific heat capacity that influences how much its temperature will change when subjected to heat.

The specific heat capacity of silver at room temperature is approximately:

$$c_{\text{Ag}} = 0.235 \text{ J/g}\cdot\text{K}$$

This value implies that 0.235 Joules of heat are needed to raise 1 gram of silver by 1°C.

Step-by-Step Calculation of Temperature Increase

To determine how much the temperature of the silver sample increases when 40.5 J of heat is added, follow these steps:

Step 1: Gather Known Values

- Heat energy added, $Q = 40.5 \text{ J}$
- Mass of silver sample, $m = 15.4 \text{ g}$
- Specific heat capacity of silver, $c_{\text{Ag}} = 0.235 \text{ J/g}\cdot\text{K}$

Step 2: Apply the Formula for Temperature Change

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

$$\Delta T = \frac{40.5}{15.4 \times 0.235}$$

Step 3: Perform the Calculation

First, compute the denominator:

$$15.4 \times 0.235 = 3.619$$

Then, divide the heat energy by this value:

$$\Delta T = \frac{40.5}{3.619} \approx 11.19^\circ\text{C}$$

Result:

The temperature of the silver sample will increase by approximately 11.19°C when 40.5 Joules of heat are added.

Additional Considerations and Practical Implications

Factors Affecting the Accuracy of Calculations

While the calculation above provides a straightforward estimate, real-world factors may influence the actual temperature change:

- Heat Loss: In practical scenarios, heat may be lost to surroundings via conduction, convection, or radiation.
- Temperature-Dependent Properties: The specific heat capacity of silver can vary slightly with temperature, especially over large temperature ranges.
- Sample Purity and Structure: Impurities or structural defects can affect thermal properties.

Applications of Heat Transfer in Silver

Understanding how silver responds to heat is vital in several applications:

- Electronics: Silver's high thermal conductivity makes it ideal for heat sinks and thermal management.
- Jewelry and Art: Precise temperature control during melting or shaping processes.
- Scientific Experiments: Accurate thermal measurements are essential in research involving silver.

Real-World Examples

- Cooling Systems: Silver-coated components in spacecraft and satellites.
- Thermal Imaging: Silver's reflective properties are used in thermal cameras.
- Manufacturing: Silver's thermal properties influence melting and casting techniques.

Additional Resources and Learning Tips

- Understand Units and Conversions: Always ensure that units are consistent, especially when working with grams, joules, and Celsius/Kelvin.
- Practice with Different Materials: Calculate temperature changes for materials with different specific heat capacities to deepen understanding.
- Use Simulation Tools: Software like thermodynamic calculators or physics simulation apps can help visualize heat transfer processes.
- Explore Advanced Topics: Investigate concepts such as latent heat, phase changes, and heat capacity variations with temperature for a more comprehensive grasp.

Conclusion

Adding 40.5 joules of heat to a 15.4-gram silver sample results in an approximate temperature increase of 11.19°C. This calculation highlights the importance of specific heat capacity in thermodynamics and provides insight into how metals like silver respond to thermal energy. Whether in industrial applications, scientific research, or everyday scenarios, understanding heat transfer principles is essential for controlling and predicting temperature changes in materials.

Key Takeaways:

- The formula to calculate temperature change is straightforward: $\Delta T = \frac{Q}{m \times c}$

c}\).

- Silver's high thermal conductivity makes it a critical material in heat transfer applications.
- Real-world factors can influence theoretical calculations, so always consider potential heat losses and material variations.

By mastering these concepts, students and professionals can better analyze thermal systems, optimize processes, and innovate in fields that rely on precise thermal management.

Meta Description:

Learn how to calculate the temperature increase of a silver sample when 40.5 J of heat is added. This detailed guide explains the concepts of heat transfer, specific heat capacity, and step-by-step calculations to help you understand thermal properties of metals.

Frequently Asked Questions

How do you calculate the temperature increase of silver when heat is added?

You use the formula $\Delta T = Q / (m c)$, where Q is the heat added, m is the mass of silver, and c is the specific heat capacity of silver.

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

The specific heat capacity of silver is approximately 0.235 J/g°C.

Given 40.5 J of heat added to 15.4 g of silver, what is the temperature increase?

The temperature increase is approximately 11.1°C, calculated as $\Delta T = 40.5 \text{ J} / (15.4 \text{ g } 0.235 \text{ J/g°C})$.

Why is it important to know the specific heat capacity when calculating temperature change?

Because the specific heat capacity indicates how much heat is needed to raise the temperature of a unit mass of material by one degree Celsius, which is essential for accurate calculations.

Can the formula $\Delta T = Q / (m c)$ be used for other materials besides silver?

Yes, the formula applies to any material, but you must use the specific heat capacity value relevant to that specific material for accurate results.

Additional Resources

Understanding the Temperature Increase of Silver When Heated with 40.5 Joules

When exploring the fascinating world of thermodynamics and material science, one common question involves determining how a substance's temperature changes when a specific amount of heat is added. In this case, we are examining how much the temperature of a silver sample will rise when 40.5 joules of heat are supplied. Diving deep into this problem not only enhances our grasp of heat transfer principles but also illustrates the practical application of specific heat capacity concepts.

Fundamental Concepts: Heat, Temperature, and Specific Heat Capacity

Before delving into the calculations, it's essential to understand the foundational concepts involved.

What Is Heat?

- Heat is a form of energy transfer between systems due to a temperature difference.
- It flows from the hotter object to the cooler one until thermal equilibrium is established.
- Measured in joules (J) in the SI system.

What Is Temperature?

- Temperature quantifies the average kinetic energy of particles in a substance.
- It is a measure of how hot or cold an object is, usually expressed in degrees Celsius ($^{\circ}\text{C}$), Kelvin (K), or Fahrenheit ($^{\circ}\text{F}$).
- For thermodynamic calculations, Kelvin is often preferred because of its absolute nature.

Specific Heat Capacity (c)

- The amount of heat needed to raise the temperature of 1 gram of a substance by 1°C (or 1 K).
- Units: $\text{J}/(\text{g}\cdot^{\circ}\text{C})$ or $\text{J}/(\text{g}\cdot\text{K})$.
- For silver, the specific heat capacity is approximately $0.235 \text{ J}/(\text{g}\cdot^{\circ}\text{C})$.

The Problem Breakdown

Given data:

- Heat added, $(Q = 40.5 \text{ J})$

- Mass of silver sample, $(m = 15.4, \text{g})$
- Specific heat capacity of silver, $(c = 0.235, \text{J/(g}\cdot\text{°C)})$

Question:

- How much will the temperature of the silver increase, (ΔT) ?

Step-by-Step Calculation Method

To find (ΔT) , we use the fundamental heat transfer equation:

$$Q = mc\Delta T$$

Rearranged to solve for (ΔT) :

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

This formula indicates that the temperature change is directly proportional to the heat added and inversely proportional to the mass and specific heat capacity of the substance.

Performing the Calculation

Plugging in the known values:

$$\Delta T = \frac{40.5, \text{J}}{15.4, \text{g} \times 0.235, \text{J/(g}\cdot\text{°C)}}$$

First, compute the denominator:

$$15.4, \text{g} \times 0.235, \text{J/(g}\cdot\text{°C)} = 3.619, \text{J/°C}$$

Next, divide the heat energy by this value:

$$\Delta T = \frac{40.5, \text{J}}{3.619, \text{J/°C}}$$

$$\Delta T = \frac{40.5 \text{ J}}{3.619 \text{ J/}^\circ\text{C}} \approx 11.2^\circ\text{C}$$

Result: The temperature of the silver sample will increase by approximately 11.2°C.

Implications and Real-World Applications

Understanding how a material's temperature responds to heat input is critical across various fields:

- Material Manufacturing: Precise control of temperature during metal processing ensures desired properties.
- Thermal Management: Designing cooling systems for electronics relies on understanding heat transfer.
- Scientific Experiments: Accurate temperature control is vital for reproducible results.

In the context of silver, a highly conductive metal, this calculation demonstrates that even a relatively modest amount of heat can significantly raise its temperature, especially considering its small mass.

Factors Affecting Temperature Change Beyond the Basic Calculation

While the basic formula provides a good estimate, real-world scenarios often involve additional factors:

- Heat Losses: During heating, some energy may dissipate to surroundings via radiation, convection, or conduction, reducing the actual temperature increase.
- Material Purity: Impurities can alter the specific heat capacity slightly.
- Phase Changes: If the temperature reaches melting point (961.8°C for silver), additional heat will go into phase change rather than temperature increase.
- Temperature-Dependent Specific Heat: For large temperature ranges, specific heat capacity may vary slightly with temperature.

Deeper Dive: Specific Heat Capacity of Silver

Understanding the specific heat capacity of silver offers insights into why it responds as it does:

- Silver's specific heat capacity (0.235 J/(g·°C)) is relatively low compared to many other metals,

indicating it heats up and cools down quickly.

- This property makes silver an excellent conductor for heat, which is why it is used in electronics and thermal applications.
- The low specific heat capacity means that less energy is required to raise its temperature compared to materials with higher specific heats, making it efficient for heat transfer applications.

Additional Calculations and Considerations

Suppose you want to extend this understanding:

1. Calculating the energy needed for a different temperature change:

$$Q = mc\Delta T$$

2. Determining the maximum temperature before phase change:

$$Q_{\text{max}} = m \times c \times (T_{\text{melt}} - T_{\text{initial}})$$

3. Considering heat capacity at different temperatures:

- For more precise calculations over a wide temperature range, account for temperature-dependent $c(T)$.

Practical Example: Heating Silver in the Laboratory

Imagine heating a 15.4 g silver specimen with 40.5 J of energy:

- The initial temperature is room temperature, say 25°C.
- The temperature after heating will be approximately:

$$T_{\text{final}} = T_{\text{initial}} + \Delta T = 25^{\circ}\text{C} + 11.2^{\circ}\text{C} \approx 36.2^{\circ}\text{C}$$

- This is a manageable and predictable temperature increase, useful for controlled experiments.

Limitations of the Calculation and Assumptions

While the calculation provides a clear estimate, it rests on certain assumptions:

- No Heat Losses: Perfect insulation is assumed, which is rarely the case.
- Constant Specific Heat: The specific heat capacity is assumed constant over the temperature range.
- Uniform Heating: Heat distributes evenly throughout the sample.
- No Phase Changes: The temperature increase is below melting point.

Understanding these limitations helps in designing experiments and industrial processes with realistic expectations.

Summary and Final Thoughts

Adding 40.5 joules of heat to a 15.4 g sample of silver results in approximately an 11.2°C increase in temperature. This calculation highlights the importance of the specific heat capacity in thermodynamics and offers a practical example of how energy transfer affects material temperature.

This insight is fundamental across disciplines, from designing thermal systems to understanding heat treatment processes in metallurgy. Recognizing the assumptions involved and considering real-world factors ensures more accurate and reliable application of these principles.

By mastering such calculations, scientists and engineers can better predict material behavior, optimize thermal processes, and innovate in fields where heat transfer plays a crucial role.

In conclusion, the relationship between heat energy, mass, and specific heat capacity is straightforward yet profound. It underscores how a small amount of energy can lead to measurable changes in temperature, especially in materials like silver with low specific heat. Whether in laboratory experiments or industrial applications, understanding this relationship is vital for effective thermal management and material processing.

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