When A 90 G Sample Of An Alloy At 100.0 Oc Is Dropped Into 90.0 G Of Water At 24.9 Oc, The Final Temperature

When A 90 G Sample Of An Alloy At 100.0 Oc Is Dropped Into 90.0 G Of Water At 24.9 Oc, The Final Temperature is a classic problem in thermodynamics, specifically involving heat transfer and the principle of conservation of energy. This scenario provides an excellent opportunity to understand how heat exchange occurs between different materials and how to calculate the resulting equilibrium temperature. In this article, we will explore the detailed steps to determine the final temperature of the system when an alloy is dropped into water, considering the specific heat capacities, initial temperatures, and masses involved.

Understanding the Problem

Before jumping into calculations, it’s essential to understand the components involved and the assumptions typically made in such problems.

Components and Data

- Sample of alloy:
- Mass: 90 grams
- Initial temperature: 100.0°C
- Specific heat capacity: Typically varies depending on alloy composition, but for simplicity, we assume a value or consider it known.

- Water:
- Mass: 90 grams
- Initial temperature: 24.9°C
- Specific heat capacity: approximately 4.18 J/g°C

Assumptions

- No heat is lost to the surroundings or the container (isolated system).
- The alloy and water reach thermal equilibrium at a common final temperature, \(T_f \).
- The specific heat capacity of the alloy remains constant over the temperature range.
- The process occurs instantaneously, with no phase changes or chemical reactions.

Key Concepts in Heat Transfer

Understanding the fundamental principles involved helps in setting up the problem correctly.

Conservation of Energy

The total heat lost by the hotter object (the alloy) equals the heat gained by the cooler object (the water):

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

Mathematically, this becomes:

$$
m_{alloy} \times c_{alloy} \times (T_{initial, alloy} - T_f) = m_{water} \times c_{water} \times (T_f - T_{initial, water})
$$

where:
- m is mass
- c is specific heat capacity
- $T_{initial}$ is initial temperature
- T_f is the final temperature

Heat Transfer Equation

Using the known quantities, the equation becomes:

$$
90 \times c_{alloy} \times (100.0 - T_f) = 90 \times 4.18 \times (T_f - 24.9)
$$

The main challenge is that c_{alloy} is not specified, so either it must be known or estimated for the specific alloy.

Calculating the Final Temperature

Let’s assume the specific heat capacity of the alloy is known or approximated. For many alloys, a typical value might be around 0.385 J/g°C (similar to some metals like copper), but the exact value should be used if provided.

Suppose:
\[

$$
c_{alloy} = 0.385 \text{ J/g°C}
$$

Now, set up the heat transfer equation:

$$
90 \times 0.385 \times (100.0 - T_f) = 90 \times 4.18 \times (T_f - 24.9)
$$

Simplify both sides:

$$
34.65 \times (100.0 - T_f) = 376.2 \times (T_f - 24.9)
$$

Expand both sides:

$$
34.65 \times 100.0 - 34.65 T_f = 376.2 T_f - 376.2 \times 24.9
$$

Calculate the constants:

$$
3465 - 34.65 T_f = 376.2 T_f - 9361.38
$$

Bring all terms involving T_f to one side and constants to the other:

$$
3465 + 9361.38 = 376.2 T_f + 34.65 T_f
$$

$$
12826.38 = 410.85 T_f
$$

Solve for T_f:

$$
T_f = \frac{12826.38}{410.85} \approx 31.24^\circ C
$$

Final Answer:

$$
\boxed{
T_f \approx 31.2^\circ C
}
$$

This is the temperature at which the alloy and water reach thermal equilibrium.

Factors Affecting the Final Temperature

While the above calculation assumes ideal conditions, real-world scenarios may involve additional factors:

1. Heat Loss to the Environment

In practical situations, some heat escapes to the surroundings, causing the final temperature to be slightly lower than predicted.

2. Variability in Specific Heat Capacities

The specific heat capacity of alloys can vary depending on their composition. Using precise data yields more accurate results.

3. Phase Changes or Chemical Reactions

If the alloy undergoes phase changes or reactions at certain temperatures, it could absorb or release additional heat, altering the final temperature.

Applications of Heat Transfer Calculations

Understanding how to determine the final temperature when different substances are mixed has several practical applications:

- Designing cooling or heating systems in engineering.
- Predicting temperature changes in chemical processes.
- Estimating energy efficiency in thermal management.
- Assessing safety limits in manufacturing processes involving hot metals and liquids.

Conclusion

The problem of determining the final temperature when an alloy at 100.0°C is dropped into water at 24.9°C involves fundamental principles of thermodynamics and heat transfer.

By applying the conservation of energy and knowing (or estimating) specific heat capacities, we can accurately predict the equilibrium temperature of the combined system. In our example, with the assumed specific heat capacity, the system reaches approximately 31.2°C. Always remember to consider real-world factors like heat loss and material variability for more precise calculations.

Understanding these concepts not only helps in solving academic problems but also plays a crucial role in various engineering and scientific applications, ensuring safe and efficient thermal management across industries.

Frequently Asked Questions

What is the main principle used to determine the final temperature when an alloy is dropped into water?

The main principle is the conservation of energy, where the heat lost by the alloy equals the heat gained by the water, assuming no heat loss to the surroundings.

How do you calculate the heat transfer between the alloy and the water?

The heat transfer is calculated using the formula $Q = mc\Delta T$, where m is mass, c is specific heat capacity, and ΔT is the temperature change for each substance.

What information do you need to find the final temperature of the system?

You need the masses and specific heat capacities of both the alloy and water, as well as their initial temperatures.

Why is it important to assume no heat loss to the surroundings in this problem?

Assuming no heat loss simplifies calculations and is a common approximation in calorimetry, ensuring that all heat exchange occurs only between the alloy and water.

If the specific heat capacity of the alloy is unknown, how can you determine the final temperature?

You need to know or estimate the alloy's specific heat capacity; otherwise, you cannot accurately calculate the final temperature without that information.

How does the temperature difference between the alloy

and water affect the final temperature?

The larger the temperature difference, the greater the heat transfer until both reach thermal equilibrium at the final temperature.

What role does the mass of the alloy and water play in calculating the final temperature?

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

Can this problem be solved using an algebraic equation? If so, what is the general form?

Yes, by setting heat lost by alloy equal to heat gained by water: m_alloy c_alloy (T_initial_alloy - T_final) = m_water c_water (T_final - T_initial_water).

Additional Resources

Understanding the Final Temperature When a 90 G Alloy Is Dropped Into Water at 24.9°C

Introduction

The process of mixing a hot alloy with water and predicting the final equilibrium temperature is a classic problem in thermodynamics and heat transfer. It involves understanding concepts such as heat capacity, specific heat, thermal equilibrium, and energy conservation. This analysis is not only fundamental in academic settings but also has practical implications in industrial processes involving temperature regulation and material safety.

In this detailed discussion, we'll explore the scenario where a 90 g sample of an alloy at 100.0°C is dropped into 90 g of water at 24.9°C, and we'll determine the final temperature of the system after thermal equilibrium is achieved. To do this, we'll delve into the principles of heat exchange, assumptions involved, and the calculations needed to arrive at the solution.

Setting Up the Problem

The Scenario

- Sample of Alloy:
- Mass, $m_{a} = 90\,g$
- Initial temperature, $T_{a,i} = 100.0^\circ C$

- Sample of Water:
- Mass, $m_{w} = 90\,g$
- Initial temperature, $T_{w,i} = 24.9^\circ C$

- Final Temperature:
- T_f (unknown, to be calculated)

Assumptions for Simplification

Before proceeding with calculations, certain assumptions are necessary to make the problem tractable:

1. No Heat Loss to Surroundings:
The system is perfectly insulated, meaning all heat lost by the alloy is gained by the water, and vice versa.

2. Thermal Equilibrium Achieved:
The alloy and water reach a common temperature T_f.

3. Constant Specific Heats:
The specific heat capacities remain constant over the temperature change. For the alloy, this may be an approximation unless the specific heat is known.

4. No Phase Changes or Chemical Reactions:
The process involves purely sensible heat exchange without phase changes.

5. Uniform Temperature Distribution:
The alloy and water are each at uniform temperature throughout their mass.

Fundamental Principles: Conservation of Energy

The core principle here is the conservation of energy, which states that the heat lost by the hotter substance equals the heat gained by the cooler substance:

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

Expressed mathematically:

$$
m_{a} c_{a} (T_{a,i} - T_f) = m_{w} c_{w} (T_f - T_{w,i})
$$

where:

- c_{a} = specific heat capacity of the alloy (J/g°C)
- c_{w} = specific heat capacity of water (~4.18 J/g°C)

Determining the Specific Heat of the Alloy

The specific heat capacity of alloys varies depending on their composition. Since the problem does not specify the alloy's composition, a typical approximation is to assume a specific heat similar to that of metals, often ranging from 0.38 to 0.45 J/g°C for common metals such as iron, aluminum, or copper.

For this analysis, we'll assume:

$$
c_{a} = 0.40\, \text{J/g°C}
$$

This value is a reasonable approximation for many metallic alloys. If the exact composition is known, this value should be adjusted accordingly.

Mathematical Derivation of Final Temperature

Starting with the conservation of heat:

$$
m_{a} c_{a} (T_{a,i} - T_f) = m_{w} c_{w} (T_f - T_{w,i})
$$

Plugging in known values:

$$
(90\,g)(0.40\,J/g°C)(100.0°C - T_f) = (90\,g)(4.18\,J/g°C)(T_f - 24.9°C)
$$

Simplify the constants:

$$
(36\,J/°C)(100.0°C - T_f) = (376.2\,J/°C)(T_f - 24.9°C)
$$

Expanding both sides:

$$
36(100.0 - T_f) = 376.2(T_f - 24.9)
$$

$$
3600 - 36 T_f = 376.2 T_f - 9365.38
$$

Bring all terms to one side:

$$
3600 + 9365.38 = 376.2 T_f + 36 T_f
$$

$$
12965.38 = 412.2 T_f
$$

Solve for T_f:

$$
T_f = \frac{12965.38}{412.2} \approx 31.48^\circ C
$$

Interpretation of Results

The approximate equilibrium temperature of the system is around 31.5°C. This indicates that when the hot alloy is introduced into the cooler water, heat flows from the alloy to the water until both reach this common temperature.

Sensitivity to Alloy Specific Heat

It's instructive to analyze how different assumptions about c_{a} influence the final temperature:

Alloy Specific Heat c_{a} (J/g°C)	Final Temperature T_f (°C)
0.38	~31.9
0.40 (assumed)	~31.5
0.45	~30.9

The higher the specific heat of the alloy, the more heat it can store, resulting in a slightly higher final temperature since less of its heat is lost per degree of temperature change.

Additional Considerations

Heat Capacity of the Entire System

The total heat capacity C_{total} of the combined system is:

$$
C_{total} = m_{a} c_{a} + m_{w} c_{w}
$$

Using our values:

$$
C_{total} = (90\,g)(0.40\,J/g°C) + (90\,g)(4.18\,J/g°C) = 36\,J/°C + 376.2\,J/°C = 412.2\,J/°C
$$

This confirms the denominator in the temperature calculation and underscores that the water's heat capacity dominates due to its higher specific heat.

Effect of Mass Ratios

If the masses of alloy and water are not equal, the final temperature will shift accordingly. For example:

- Larger water mass relative to alloy results in a lower final temperature, as the water can absorb more heat without a large temperature rise.
- Larger alloy mass relative to water results in a higher final temperature.

Practical Implications and Safety Considerations

Understanding the temperature change when hot metals are introduced into water is crucial in industrial and safety contexts:

- Steam Generation and Explosive Risks:
Rapid boiling or steam formation can cause explosions if the alloy is extremely hot or if the water volume is small.

- Material Properties:
The alloy may undergo phase changes or structural modifications if the temperature exceeds certain thresholds.

- Thermal Shock:
Sudden temperature changes can cause cracking or deformation of materials.

Proper calculations like the one above help predict temperature changes and ensure safe handling procedures.

Limitations and Real-World Factors

While the above calculations provide a good estimate, real-world scenarios involve complexities:

1. Heat Loss to Surroundings:
In practice, some heat will be lost to the environment, slightly lowering or raising the final temperature.

2. Non-Constant Specific Heats:
Both water and alloys have temperature-dependent specific heats, especially over large

temperature ranges.

3. Initial Conditions:
The alloy's initial temperature might vary slightly, and the water might not be at a uniform temperature throughout.

4. Reaction or Phase Changes:
If the alloy contains reactive metals, chemical reactions could occur, affecting heat transfer.

Conclusion

In summary, when a 90 g alloy at 100.0°C is dropped into 90 g of water at 24.9°C, the system reaches a thermal equilibrium at approximately 31.5°C, assuming an alloy specific heat capacity of 0.40 J/g°C. This calculation demonstrates the fundamental principles of heat transfer, conservation of energy, and the importance of material properties in thermodynamic calculations.

This analysis is essential for designing processes where temperature control is crucial, highlighting the importance of understanding material-specific heats, mass ratios, and system insulation. Whether in laboratory experiments, industrial applications, or safety assessments, such detailed thermodynamic considerations form the backbone of effective and safe thermal management strategies.

When A 90 G Sample Of An Alloy At 100 0 Oc Is Dropped Into 90 0 G Of Water At 24 9 Oc The Final Temperature

When A 90 G Sample Of An Alloy At 100 0 Oc Is Dropped Into 90 0 G Of Water At 24 9 Oc The Final Temperature

Related Articles

- Lightning NOx Is A Very Efficient Source Of Tropospheric Ozone Because It Is Emitted In The Upper Troposphere
- Match The Microscopic Structure Of The Ovary With Its Description. Outer Portion Of Ovary: Contains Follicles
- Read The Excerpt From The An Understanding With The Indians (1621) Section From Of Plymouth Plantation.Select

Back to Home