2) How Much Heat Needs To Be Removed To Cause 112.0 G Of Barium Chloride To Experience A Change Of Temperature

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Understanding the amount of heat involved in temperature changes of chemical substances is fundamental in thermodynamics and industrial chemistry. Specifically, when dealing with barium chloride ($BaCl_2$), a common ionic compound used in various applications such as water treatment, laboratory experiments, and chemical synthesis, knowing how much heat must be removed to lower its temperature by a certain amount is crucial. This knowledge helps in designing cooling systems, understanding reaction energetics, and optimizing processes involving the compound. In this article, we explore how to calculate the heat removal required to cause a temperature change in 112.0 grams of barium chloride, emphasizing the core concepts, formulas, and step-by-step calculations to clarify this process.

Understanding the Basics of Heat Transfer and Specific Heat Capacity

Before delving into the calculation, it’s essential to understand the fundamental concepts involved:

What is Heat Transfer?

Heat transfer refers to the movement of thermal energy from one body or system to another due to a temperature difference. When cooling a substance, heat is removed from the material, leading to a decrease in temperature.

What is Specific Heat Capacity?

Specific heat capacity (often denoted as c) is the amount of heat required to raise or lower the temperature of one gram of a substance by one degree Celsius (or Kelvin). Conversely, it can be used to determine how much heat must be removed or added to change the temperature of a known mass of the substance.

Key Point:
- The amount of heat (Q) needed to change the temperature of a substance is

calculated by the formula:

$$
Q = mc\Delta T
$$

where:
- Q = heat energy (in joules, J)
- m = mass of the substance (in grams, g)
- c = specific heat capacity (J/g°C)
- ΔT = change in temperature (°C or K)

Determining the Specific Heat Capacity of Barium Chloride

A critical step in the calculation is knowing the specific heat capacity of barium chloride. Unlike water, which has a well-known specific heat capacity (~4.18 J/g°C), barium chloride's value depends on its physical state and whether it is hydrated or anhydrous.

Hydrated vs. Anhydrous Barium Chloride:
- Hydrated barium chloride (e.g., $BaCl_2 \cdot 2H_2O$) contains water molecules, affecting its heat capacity.
- Anhydrous barium chloride ($BaCl_2$) lacks water and typically has a different heat capacity.

Typical Values:
Since exact specific heat capacities can vary based on purity and form, approximate values are used in calculations:

- For anhydrous $BaCl_2$: approximately 0.55 J/g°C
- For hydrated $BaCl_2 \cdot 2H_2O$: approximately 0.65 J/g°C

For this discussion, we'll assume the substance is anhydrous barium chloride unless specified otherwise.

Calculating the Heat Removed from 112.0 g of Barium Chloride

Given Data:
- Mass of barium chloride, m = 112.0 g

- Temperature change, ΔT = (initial temperature - final temperature) (to be specified or assumed)
- Specific heat capacity, c ≈ 0.55 J/g°C

Note:
For the calculation, we need to know the intended temperature change. Since the user has asked generally “to cause a change of temperature,” we can assume a specific temperature change for illustrative purposes, say, a decrease of 10°C.

Step-by-Step Calculation Process

1. Define the Temperature Change (ΔT)

Suppose we want to lower the temperature of the barium chloride by 10°C:

\[
\Delta T = 10\,°C
\]

(Note: Since heat is being removed, the change is negative, but in the calculation, we take the absolute value to find the magnitude of heat removed.)

2. Apply the Heat Transfer Formula

Using:

\[
Q = mc\Delta T
\]

Substituting the known values:

\[
Q = 112.0\,g \times 0.55\,J/g°C \times 10\,°C
\]

\[
Q = 112.0 \times 0.55 \times 10
\]

\[
Q = 112.0 \times 5.5

\]

$$
Q = 616\,J
$$

Result:
Approximately 616 joules of heat must be removed to lower the temperature of 112.0 grams of anhydrous barium chloride by 10°C.

Adjusting for Different Temperature Changes

The calculation scales linearly with the temperature change:

- For a 5°C change:

$$
Q = 112.0 \times 0.55 \times 5 = 308\,J
$$

- For a 20°C change:

$$
Q = 112.0 \times 0.55 \times 20 = 1232\,J
$$

Implication:
Knowing the specific heat capacity allows easy computation of heat removal for any desired temperature change, assuming the substance remains in the same physical state.

Considering the Physical State and Its Impact on Heat Capacity

The specific heat capacity varies with physical state, hydration level, and temperature. Therefore, it’s important to:

1. Identify whether the barium chloride is hydrated or anhydrous.

2. Use the appropriate specific heat capacity value.

3. Account for possible phase changes if the temperature change crosses melting points or other phase transition thresholds, which can involve additional heat (enthalpy of fusion or vaporization).

Failure to consider these factors may lead to inaccurate energy estimations.

Additional Factors Influencing Heat Removal Calculations

While the basic formula provides a straightforward estimate, real-world applications may involve additional considerations:

1. Heat Loss to Surroundings

In practical scenarios, not all the heat removed from the substance goes into cooling it uniformly. Heat losses to the environment can affect the actual energy needed.

2. Thermodynamic Efficiency of Cooling Systems

The energy efficiency of cooling devices influences how much electrical energy or work is required to remove a certain amount of heat.

3. Heating or Cooling Medium

The medium used for heat transfer (water, air, refrigerants) affects the heat exchange rate and efficiency.

Summary and Practical Implications

To determine how much heat must be removed to cause a specified temperature change in barium chloride:

1. Identify the mass of the substance.
2. Determine or assume the specific heat capacity based on the physical state.
3. Decide on the temperature change desired.

4. Use the heat transfer formula $Q=mc\Delta T$ to compute the heat removal.

In our example, removing approximately 616 joules of heat would decrease the temperature of 112.0 grams of anhydrous barium chloride by 10°C. This calculation can be adapted for different temperature changes or physical states by adjusting the specific heat capacity and ΔT accordingly.

Conclusion

Understanding how much heat needs to be removed from barium chloride to achieve a specific temperature change is vital in various scientific and industrial contexts. By applying fundamental thermodynamic principles—particularly the specific heat capacity formula—one can accurately estimate the energy required for cooling processes. Remember that real-world applications should consider the substance's physical state, environmental factors, and system efficiencies to obtain precise and practical results. With this knowledge, engineers and chemists can optimize cooling procedures, design efficient thermal management systems, and better understand the energetic aspects of chemical processes involving barium chloride.

Frequently Asked Questions

What is the specific heat capacity of barium chloride that is needed to calculate the heat removed for a temperature change?

The specific heat capacity of barium chloride is approximately 0.49 J/g°C.

How do you calculate the amount of heat removed to change the temperature of barium chloride?

Use the formula Q = mcΔT, where Q is heat, m is mass, c is specific heat capacity, and ΔT is the temperature change.

What information is needed to determine how much heat must be removed from 112.0 g of barium chloride?

The initial and final temperatures of the barium chloride to find ΔT, along with its specific heat capacity.

If barium chloride’s temperature decreases by 10°C, how much heat must be removed from 112.0 g?

$Q = 112.0\ g \times 0.49\ J/g°C \times 10°C = 548.8$ Joules.

What is the significance of knowing the heat capacity when cooling barium chloride?

It allows precise calculation of the heat energy that needs to be removed to achieve a certain temperature change.

Can the heat removed be calculated without knowing the temperature change?

No, because the amount of heat depends directly on the temperature difference; without ΔT, the calculation cannot be completed.

What assumptions are made when calculating heat removal for barium chloride in this context?

Assumptions include uniform temperature distribution, no heat loss to surroundings, and that the specific heat capacity remains constant.

How does increasing the temperature change affect the heat removal calculation for barium chloride?

A larger temperature change (ΔT) results in a greater amount of heat being removed, as Q is directly proportional to ΔT.

Is the heat capacity of barium chloride affected by temperature changes during cooling?

While specific heat capacities can vary slightly with temperature, for most calculations, a constant value is used for simplicity.

What is the formula to determine the heat removed to cause a specific temperature change in barium chloride?

$Q = m \times c \times \Delta T$, where m is mass, c is specific heat capacity, and ΔT is the temperature change.

Additional Resources

Understanding the Heat Required to Change the Temperature of 112.0 g of Barium Chloride

When delving into the realm of thermodynamics and heat transfer, one common question that arises involves quantifying how much heat must be removed or added to bring about a specific temperature change in a given substance. In this case, we focus on barium chloride ($BaCl_2$), a crystalline salt often used in laboratories, which undergoes temperature changes during heating or cooling processes. Our goal is to determine how much heat must be removed to cause 112.0 grams of barium chloride to experience a particular temperature change—though the specific temperature change isn't specified in the question, we'll explore the process comprehensively, providing insights applicable to various scenarios.

Fundamentals of Heat and Temperature Change

Before diving into calculations, it’s crucial to understand the fundamental concepts:

- Heat (Q): The energy transferred between systems due to a temperature difference, measured in joules (J) or calories.
- Temperature Change (ΔT): The difference between the final and initial temperatures, typically expressed in degrees Celsius (°C) or Kelvin (K).
- Specific Heat Capacity (c): The amount of heat required to raise the temperature of 1 gram of a substance by 1°C, expressed in J/(g·°C).

The basic relation connecting these quantities is:

$$
Q = mc\Delta T
$$

where:
- Q = heat transferred (J),
- m = mass of the substance (g),
- c = specific heat capacity (J/(g·°C)),
- ΔT = temperature change (°C or K).

Properties of Barium Chloride Relevant to Heat

Calculations

To proceed, accurate data on the thermophysical properties of barium chloride are essential.

Physical State and Forms

Barium chloride can exist in different forms:

- Anhydrous barium chloride ($BaCl_2$): A white crystalline salt.
- Hydrated barium chloride (e.g., $BaCl_2 \cdot 2H_2O$): Contains water molecules, affecting its heat capacity.

For most thermal calculations, the anhydrous form is used unless specified otherwise.

Specific Heat Capacity of Barium Chloride

The specific heat capacity of crystalline $BaCl_2$ varies slightly depending on temperature and form. Based on experimental data:

- Approximate specific heat capacity (c): 0.80 J/(g·°C)

This value is suitable for moderate temperature ranges typical in laboratory conditions.

Melting Point and Phase Changes

Barium chloride melts at around 730°C. If the temperature change involves crossing the melting point, phase change energy (enthalpy of fusion) must be considered, adding complexity to the calculation.

Determining the Heat Removed for a Given Temperature Change

Assuming the process involves cooling barium chloride from an initial temperature T_i to a final temperature T_f, the fundamental calculation simplifies to:

$$
Q = m c \Delta T
$$

where:

$$
\Delta T = T_f - T_i
$$

Notably, if the process involves cooling, ΔT is negative, and the heat transferred Q will also be negative, indicating heat removal.

Example Scenario

Suppose we want to find the heat removed to lower 112.0 g of $BaCl_2$ from 100°C to 25°C.

Calculations:

$$
\Delta T = 25°C - 100°C = -75°C
$$

$$
Q = 112.0\, \text{g} \times 0.80\, \text{J/(g·°C)} \times (-75\, °C) = -6720\, \text{J}
$$

The negative sign indicates heat is removed during cooling.

Factors Affecting the Heat Removal Calculation

While the straightforward application of $Q=mc\Delta T$ provides a baseline, real-world scenarios often involve additional considerations:

1. Phase Changes and Latent Heat

If the temperature change involves crossing the melting point (~730°C), the energy required includes:

- Latent heat of fusion (L_f): The energy needed to convert solid to liquid at melting point, without temperature change.

For $BaCl_2$, the enthalpy of fusion is approximately 7.0 kJ/mol.

Calculating the molar mass:

$$
\text{Molar mass of BaCl}_2 = 137.33\, (\text{Ba}) + 2 \times 35.45\, (\text{Cl}) = 208.23\, \text{g/mol}
$$

Number of moles in 112.0 g:

$$
n = \frac{112.0\, \text{g}}{208.23\, \text{g/mol}} \approx 0.538\, \text{mol}
$$

Energy to melt:

$$
Q_{fusion} = n \times L_f = 0.538\, \text{mol} \times 7.0\, \text{kJ/mol} \approx 3.77\, \text{kJ} = 3770\, \text{J}
$$

This energy must be added or removed if crossing the melting point.

2. Heating or Cooling Through Phase Changes

- If cooling from above 730°C to below 730°C: The process involves removing the latent heat at the melting point.
- If heating from below 730°C to above: The energy must include the latent heat plus sensible heat.

3. Non-Linear Specific Heat Capacities

In some temperature ranges, the specific heat capacity varies. For precise calculations, temperature-dependent data should be used, often available from thermodynamic tables or experimental measurements.

4. Heat Losses and Environmental Factors

In practical situations, heat loss to surroundings, conduction, convection, and radiation can influence the actual amount of heat removed or supplied.

Step-by-Step Approach to Calculating Heat Removal

To accurately determine the heat removed for a specific temperature change:

Step 1: Identify initial and final temperatures (T_i, T_f).

Step 2: Determine if the temperature change crosses phase transition points (melting point, boiling point).

Step 3: Break down the process into segments:

- Heating/cooling within a phase (solid, liquid, vapor): Use $Q = mc\Delta$

T\).
- Crossing phase boundaries: Add or subtract latent heats accordingly.

Step 4: Sum all energy contributions:

$$
Q_{total} = \sum Q_{sensibles} + \sum Q_{latent}
$$

Practical Example: Cooling 112.0 g of $BaCl_2$ from 100°C to 25°C

Let's consider the example process:

- Initial temperature: 100°C
- Final temperature: 25°C
- No phase change: Both temperatures are below melting point (~730°C), so only sensible heat transfer is involved.

Calculations:

$$
\Delta T = 25°C - 100°C = -75°C
$$

$$
Q = 112.0\, \text{g} \times 0.80\, \text{J/(g·°C)} \times (-75\, °C) = -6720\, \text{J}
$$

Interpretation:

- To cool the barium chloride from 100°C to 25°C, 6720 joules of heat must be removed.
- The negative sign indicates heat removal.

Complexity When Crossing Melting or Boiling Points

Suppose the substance is initially at 800°C and cooled down to 25°C, crossing the melting point (730°C):

1. Cooling from 800°C to 730°C (solid or molten):

$$
Q_1 = 112.0\, \text{g} \times c_{high} \times (730°C - 800°C)
$$

2. Latent heat at 730°C:

$$
Q_{fusion} = n \times L_f \approx 3770\, \text{J}
$$

3. Cooling from 730°C to 25°C:

$$
Q_2 = 112.0\, \text{g} \times c_{low} \times (25°C - 730°C)
$$

Total heat removed:

$$
Q_{total} = Q_1 + Q_{fusion} + Q_2
$$

This process illustrates the importance of considering phase changes in heat calculations.

Additional Considerations in Real-World Applications

While theoretical calculations are straightforward, real experimental setups involve various factors:

- Heat losses to environment: Insulation can reduce, but not eliminate, heat exchange.
- Instrument calibration: Accurate temperature measurement is essential.
- Material purity: Impurities can alter specific heat capacity and phase change energies.
- Sample geometry: Surface area influences heat transfer rates.

In industrial or laboratory settings, precise calorimetry techniques are employed to measure the actual heat transfer, often involving calorimeters that account for environmental interactions.

Conclusion: Summarizing the Process

To determine how much heat needs to be removed to cause 112.0 g of barium chloride to experience a certain temperature

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