The Heat Of Fusion Of Benzene Is . Calculate The Change In Entropy When Of Benzene Freezes At . Be Sure

The Heat Of Fusion Of Benzene Is . Calculate The Change In Entropy When Of Benzene Freezes At . Be Sure

Understanding the thermodynamic properties of benzene is essential for chemists and students alike, particularly when analyzing phase changes such as melting and freezing. One fundamental parameter in this context is the heat of fusion of benzene, which signifies the amount of energy required to convert benzene from solid to liquid at its melting point. In this article, we will explore the heat of fusion of benzene, detail how to calculate the change in entropy during its freezing process, and emphasize the importance of these calculations in thermodynamics and material science.

The Heat Of Fusion Of Benzene: An Overview

The heat of fusion, also known as the enthalpy of fusion, is a thermodynamic quantity that measures the energy needed for a substance to transition from solid to liquid at its melting point without changing temperature. For benzene, this value is a critical parameter for understanding its phase behavior, especially since benzene is a common solvent and chemical intermediate.

What Is The Heat Of Fusion Of Benzene?

- The heat of fusion of benzene is approximately 6.3 kJ/mol.
- This value indicates the energy required to convert one mole of benzene from solid to liquid at its melting point, which is approximately 5.53°C (278.68 K).
- It is a crucial data point for thermodynamic calculations involving phase transitions, such as entropy and Gibbs free energy changes.

Significance of The Heat Of Fusion

Understanding the heat of fusion aids in:

- Calculating entropy changes during phase transitions
- Designing industrial processes involving benzene
- Understanding thermodynamic stability and phase equilibria
- Academic research related to molecular interactions in phase changes

Calculating The Change In Entropy When Benzene Freezes

Entropy, a measure of disorder or randomness in a system, changes as a substance transitions between phases. When benzene freezes from liquid to solid, its entropy decreases, reflecting a reduction in molecular disorder. To quantify this change, we employ thermodynamic equations that relate heat transfer to entropy.

Fundamental Equation for Entropy Change

The change in entropy (ΔS) during a phase transition at constant pressure can be calculated using:

$$
\Delta S = \frac{q_{rev}}{T}
$$

where:
- q_{rev} is the reversible heat exchanged during the process (equal to the heat of fusion in this case)
- T is the absolute temperature in Kelvin at which the phase change occurs

Since the phase change occurs at the melting point, the equation simplifies to:

$$
\Delta S_{fusion} = \frac{\Delta H_{fusion}}{T_{m}}
$$

- ΔH_{fusion}: heat of fusion (in Joules)
- T_{m}: melting temperature in Kelvin

Step-by-Step Calculation

Given data:
- ΔH_{fusion} of benzene = 6.3 kJ/mol = 6300 J/mol
- Melting point, T_{m} = 5.53°C = 278.68 K

Step 1: Convert heat of fusion to Joules per mole (already done).

Step 2: Apply the formula:

$$
\Delta S_{fusion} = \frac{6300\, \text{J/mol}}{278.68\, \text{K}} \approx

22.6\, \text{J/(mol·K)}
\]

This value represents the entropy change when benzene freezes from liquid to solid at the melting point.

Step 3: Interpret the result

- The negative of this value indicates the decrease in entropy during freezing, so:

\[
\Delta S_{freezing} = -22.6\, \text{J/(mol·K)}
\]

which signifies a reduction in disorder as benzene molecules become more ordered in the solid state.

Implications And Applications

Understanding the entropy change during freezing has numerous practical implications:

Thermodynamic Stability

- The entropy change helps determine the spontaneity of phase transitions. Since freezing of benzene involves a decrease in entropy, the process is typically spontaneous at temperatures below the melting point, provided the system's Gibbs free energy change is negative.

Designing Industrial Processes

- Accurate calculations of entropy changes assist chemical engineers in designing processes like crystallization, purification, and storage of benzene.

Material Science And Research

- Insights into molecular ordering and phase stability are crucial for developing new materials and understanding molecular interactions.

Additional Considerations In Thermodynamic Calculations

While the above calculations provide a good estimate of the entropy change, several factors can influence the actual values:

Pure vs. Impure Benzene

- Impurities can alter melting points and enthalpy values, affecting entropy calculations.

Temperature Deviations

- Real-world processes may occur over a temperature range, requiring integration over temperature.

Pressure Effects

- Although most calculations assume standard atmospheric pressure, variations can influence phase behavior.

Conclusion

In summary, the heat of fusion of benzene is approximately 6.3 kJ/mol, a vital parameter for understanding its phase change properties. Using this value, we calculated the change in entropy when benzene freezes at its melting point to be about -22.6 J/(mol·K). This negative entropy change signifies increased order within the system as benzene transitions from a liquid to a solid. Accurate thermodynamic data and calculations like these are fundamental for chemical research, industrial applications, and advancing our understanding of molecular phase behavior.

By mastering these concepts, students and professionals can better interpret phase transitions, optimize processes involving benzene, and contribute to innovations in chemical thermodynamics.

Frequently Asked Questions

What is the heat of fusion of benzene?

The heat of fusion of benzene is the amount of energy required to convert one mole of benzene from solid to liquid at its melting point, which is approximately 6.3 kJ/mol.

How do you calculate the change in entropy during the freezing of benzene?

The change in entropy (ΔS) during freezing can be calculated using the formula $\Delta S = \Delta H_{fusion} / T$, where ΔH_{fusion} is the heat of fusion and T is the temperature in Kelvin at which freezing occurs.

At what temperature does benzene freeze?

Benzene freezes at its melting point of approximately 278 K (5°C).

Why is understanding the entropy change important in phase transitions?

Understanding entropy change helps in determining the spontaneity of phase transitions and provides insight into the disorder and energy dispersal during the process.

How does the heat of fusion influence the entropy change during freezing?

A higher heat of fusion indicates more energy is required for the phase change, resulting in a larger decrease in entropy during freezing.

What units are used for calculating entropy change in this context?

Entropy change is typically expressed in joules per kelvin (J/K).

Can the entropy change be negative during the freezing of benzene?

Yes, the entropy change is negative because the system becomes more ordered as benzene transitions from liquid to solid.

How does temperature affect the entropy change during freezing?

The entropy change during freezing is inversely proportional to temperature; as temperature increases, the magnitude of entropy decrease becomes smaller.

What assumptions are made when calculating entropy change for benzene's phase transition?

Assumptions include that the heat of fusion is constant over the temperature range, the process occurs at equilibrium, and the phase change happens at a constant temperature.

Additional Resources

The Heat of Fusion of Benzene Is a fundamental thermodynamic property that describes the amount of energy required to convert benzene from its solid phase to its liquid phase at its melting point, without changing its temperature. Understanding this value and its implications is vital for chemists and engineers working with benzene in various applications, such as chemical synthesis, material science, and thermodynamic modeling. In this article, we will explore how to calculate the change in entropy when benzene freezes at its melting point, illustrating key concepts in thermodynamics and providing a comprehensive guide to the process.

Understanding the Heat of Fusion and Its Significance

What is the Heat of Fusion?

The heat of fusion, also known as enthalpy of fusion (ΔH_fus), is the energy required to change a substance from solid to liquid at its melting point under constant pressure. For benzene, this value is well-documented and essential for calculations involving phase changes.

Why Is the Heat of Fusion Important?

- Thermodynamic calculations: It helps determine the entropy change during phase transitions.
- Material processing: Knowledge of ΔH_fus guides the cooling and heating processes.
- Environmental considerations: Understanding phase changes impacts storage and transportation safety.

Key Data for Benzene

Before proceeding to calculations, let's gather the critical data:

- Melting point of benzene (T_m): approximately 278.5 K (5.35°C)
- Heat of fusion of benzene (ΔH_fus): approximately 9.9 kJ/mol

Note: These values are standard and can vary slightly depending on experimental conditions.

Calculating the Change in Entropy When Benzene Freezes

Fundamental Thermodynamic Relationship

The change in entropy (ΔS) associated with a phase change at constant pressure can be approximated using the relation:

$$
\Delta S = \frac{\Delta H}{T}
$$

where:

- ΔH is the enthalpy change of the process (here, the heat of fusion),
- T is the absolute temperature at which the phase change occurs (the melting point).

This approximation assumes the heat of fusion is relatively constant over the temperature range and the process occurs reversibly at the melting point.

Step-by-Step Calculation

Step 1: Convert ΔH_{fus} to consistent units

Given:

$$
\Delta H_{fus} = 9.9\, \text{kJ/mol}
$$

Convert to Joules per mole:

$$
9.9\, \text{kJ/mol} = 9900\, \text{J/mol}
$$

Step 2: Use the melting point temperature (T_m)

$$
T_m = 278.5\, \text{K}
$$

Step 3: Apply the entropy change formula

$$
\Delta S_{freeze} = - \frac{\Delta H_{fus}}{T_m}
$$

Note the negative sign because freezing (liquid to solid) is an exothermic process (releases heat), and the entropy decreases.

Calculating:

$$
\Delta S_{freeze} = - \frac{9900\, \text{J/mol}}{278.5\, \text{K}} \approx -35.54\, \text{J/(mol·K)}
$$

The negative value indicates a decrease in entropy as benzene transitions from liquid to solid.

Interpreting the Results

Significance of the Entropy Change

- Magnitude: The entropy decreases by approximately 35.54 J/(mol·K) when benzene solidifies at its melting point.
- Thermodynamic implication: The decrease reflects increased order in the solid phase compared to the liquid.

Practical Considerations

- The calculated change assumes ideal conditions and no supercooling or superheating.
- In real-world scenarios, impurities and kinetic factors can slightly alter the actual entropy change.

Broader Context: Thermodynamics of Phase Changes

Entropy and Enthalpy in Phase Transitions

The phase transition involves a balance between enthalpy and entropy. When a substance freezes:

- Energy is released (exothermic).
- The system becomes more ordered (entropy decreases).

Conversely, melting absorbs heat, increasing entropy.

Clausius-Clapeyron Equation

For more precise calculations over a range of temperatures, the Clausius-Clapeyron equation relates the vapor pressure and temperature:

\[

$$
\frac{dP}{dT} = \frac{\Delta H_{vap}}{T \Delta V}
$$

While primarily used for vaporization, analogous principles help understand phase equilibrium.

Additional Considerations

Variations in Heat of Fusion

- The value of ΔH_{fus} can vary with pressure and purity.
- Experimental measurements are necessary for precise calculations in sensitive applications.

Temperature Dependence

- The approximation $\Delta S = \Delta H/T$ holds best at the melting point.
- For processes occurring over temperature ranges, integral approaches considering variable ΔH and ΔS are needed.

Summary and Final Remarks

- The heat of fusion of benzene is approximately 9.9 kJ/mol.
- The change in entropy when benzene freezes at its melting point is approximately -35.54 J/(mol·K).
- This calculation illustrates core thermodynamic principles, demonstrating how energy and entropy are intertwined during phase transitions.
- Understanding these concepts is crucial for chemical engineers, material scientists, and chemists working with benzene or similar substances.

References

- Atkins, P., & de Paula, J. (2010). Physical Chemistry (9th Edition). Oxford University Press.
- Linstrom, P. J., & Mallard, W. G. (Eds.). (2001). NIST Chemistry WebBook, NIST Standard Reference Database Number 69.
- CRC Handbook of Chemistry and Physics, 97th Edition.

Final Thoughts

The process of calculating the change in entropy during freezing is a fundamental aspect of thermodynamics, offering insights into the microscopic order and energy changes during phase transitions. By understanding and

```
applying these principles to benzene, scientists can predict and control
processes involving phase change, ensuring safety, efficiency, and innovation
in chemical applications.
```

The Heat Of Fusion Of Benzene Is Calculate The Change In Entropy When Of Benzene Freezes At Be Sure

The Heat Of Fusion Of Benzene Is Calculate The Change In Entropy When Of Benzene Freezes At Be Sure

Related Articles

- The Garland Company Sold Land For $140,000 Cash, Purchased Equipment For $40,000 Cash, And Issued Bonds
- The __________ Works Closely With Federal And Sometimes State And Local Officials To Communicate Tribal
- The Transport Of A Substance Across A Plasma Membrane Of A Specific Organelle Requires Energy. The Rate

Back to Home