The Melting Point Of A Benzophenone Is Depressed By 2.3c When 0.358 G Of Solute Is Dissolved In 7.544

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Understanding how solutes influence the melting point of solvents is fundamental in fields such as chemistry, pharmaceutical sciences, and materials engineering. The phenomenon where the melting point of a pure substance decreases upon the addition of a solute is known as melting point depression, a colligative property that offers insights into the molecular interactions within solutions. In this article, we explore the specific case where benzophenone's melting point is depressed by 2.3°C when 0.358 grams of solute are dissolved in 7.544 grams of solvent, analyzing the underlying principles, calculations, and implications.

Introduction to Melting Point Depression

Melting point depression is a colligative property, meaning it depends on the number of solute particles in a solution rather than their identity. When a solute is added to a pure solvent, the presence of solute particles disrupts the crystalline lattice of the solvent, requiring less energy (lower temperature) to break apart the lattice and convert the solid into a liquid.

This property is significant in various applications:
- Purity assessment of substances
- Determination of molar masses
- Understanding solution behaviors
- Designing antifreeze solutions

The classic example involves salt dissolving in water, but in organic compounds like benzophenone, similar principles apply, albeit with some variations due to molecular interactions.

Understanding Benzophenone and Its Melting Point

Benzophenone is an organic compound commonly used in fragrances, sunscreens, and as a photoinitiator in polymerization processes. Its molecular formula is C13H10O, and it has a characteristic melting point around 48-50°C in pure form.

The melting point of benzophenone is an essential property because:

- It indicates the purity of the sample
- It influences its applications in various industries
- It provides insights into intermolecular forces within the solid state

In the context of melting point depression, understanding how the addition of a solute affects benzophenone's melting point can reveal details about molecular interactions, solution behavior, and the quantitative aspects of colligative properties.

Data Analysis: Melting Point Depression Calculation

Given data:
- Depression in melting point (ΔT_f): 2.3°C
- Mass of solute (benzophenone): 0.358 g
- Mass of solvent (benzophenone): 7.544 g

Our goal is to understand the relationship between these quantities and derive key parameters such as molar mass or the molality of the solution.

Step 1: Calculate Molality of the Solution

Molality (m) is defined as moles of solute per kilogram of solvent:

$$
m = \frac{\text{moles of solute}}{\text{kg of solvent}}
$$

First, we need to determine the molar mass of the solute, which is benzophenone ($C_{13}H_{10}O$). Its molar mass is calculated as:

$$
(13 \times 12.01) + (10 \times 1.008) + (16.00) = 156.13 + 10.08 + 16.00 = 182.21\, \text{g/mol}
$$

Now, calculate moles of solute:

$$
\text{moles of benzophenone} = \frac{0.358\, \text{g}}{182.21\, \text{g/mol}} \approx 0.001964\, \text{mol}
$$

Convert solvent mass to kilograms:

$$
7.544\, \text{g} = 0.007544\, \text{kg}
$$

Determine molality:

$$
m = \frac{0.001964\, \text{mol}}{0.007544\, \text{kg}} \approx 0.260\, \text{mol/kg}
$$

Step 2: Use the Melting Point Depression Formula

The relationship between melting point depression and molality is given by:

$$
\Delta T_f = K_f \times m \times i
$$

Where:
- ΔT_f is the depression in melting point (2.3°C)
- K_f is the cryoscopic constant (freezing point depression constant) of benzophenone
- i is the van 't Hoff factor (for benzophenone, a non-electrolyte, $i \approx 1$)

Assuming benzophenone is non-electrolyte, $i = 1$:

$$
K_f = \frac{\Delta T_f}{m} = \frac{2.3}{0.260} \approx 8.85\, \text{°C·kg/mol}
$$

This value of K_f can be compared with literature values to validate experimental data. For benzophenone, typical K_f values are around 6.0-8.5°C·kg/mol, indicating our calculation aligns well with expected behavior.

Implications and Applications of Melting Point Depression

Understanding melting point depression in benzophenone has several practical and theoretical implications:

1. Purity Assessment

- Impurities in benzophenone can alter its melting point, typically lowering it.
- Measuring the depression helps assess sample purity.

2. Molecular Weight Determination

- Colligative properties enable the calculation of molar masses of unknown solutes.
- By measuring melting point depression at known concentrations, researchers can deduce molecular weights.

3. Designing Solutions for Industrial Applications

- In chemical manufacturing, controlling melting points ensures stability and performance.
- Melting point depression data helps formulate solutions with desired physical properties.

4. Pharmaceutical and Material Science

- Melting point depression informs drug formulation and stabilization.
- It aids in understanding molecular interactions in organic compounds.

Limitations and Considerations

While melting point depression offers valuable insights, certain limitations must be considered:

- Non-ideal solutions: Deviations from ideal behavior can occur due to specific interactions.
- Van 't Hoff factor: Assumed to be 1 here; however, some solutes may dissociate or associate, affecting calculations.
- Measurement accuracy: Precise temperature control and measurement are crucial for reliable data.
- Purity of samples: Impurities can skew the observed melting point depression.

Conclusion

The depression of benzophenone's melting point by 2.3°C upon dissolving 0.358 grams of solute in 7.544 grams of solvent exemplifies the fundamental principles of colligative properties. Through careful calculations, we've determined the molality of the solution and estimated the cryoscopic constant, reinforcing the understanding of molecular interactions and solution behavior in organic compounds.

This analysis underscores the importance of melting point depression as a tool for chemical analysis, quality control, and material design. Whether assessing purity, determining molar masses, or designing industrial formulations, colligative properties like melting point depression continue to play a vital role in advancing chemical sciences.

Keywords: Melting point depression, benzophenone, colligative properties, molality, cryoscopic constant, solution chemistry, molecular interactions, purity analysis.

Frequently Asked Questions

What does a depression in the melting point of benzophenone indicate when a solute is added?

It indicates that the solution exhibits freezing point depression, a colligative property, due to the presence of the solute molecules disrupting the crystal lattice of benzophenone.

How is the molar mass of the solute related to the observed depression in benzophenone's melting point?

The molar mass of the solute can be calculated using the freezing point depression formula, which relates the depression to the molality of the solution and the molar mass of the solute.

What is the significance of the 2.3°C melting point depression in this context?

The 2.3°C depression signifies the extent to which the solute affects the freezing point of benzophenone, allowing calculation of the molar mass of the solute based on colligative property principles.

Which formula is used to determine the molar mass of the solute from the melting point depression data?

The formula used is $\Delta Tf = Kf \times$ molality, where ΔTf is the depression in melting point, and molality is moles of solute per kilogram of solvent; molar mass can then be derived from molality and the mass of solute and solvent.

Why is it important to know the melting point depression when studying solutions like benzophenone with a solute?

Knowing the melting point depression helps determine properties like molar mass of the solute, concentration of solutions, and understanding colligative properties, which are essential in solution chemistry analysis.

Additional Resources

The Melting Point Depression of Benzophenone: An In-Depth Analysis

Understanding the phenomenon of melting point depression when a solute is added to a solvent is fundamental in physical chemistry. The specific case of benzophenone experiencing a depression of 2.3°C upon dissolving a small amount of solute provides a compelling example to explore colligative properties, solution chemistry, and the underlying molecular interactions. This comprehensive review delves into the mechanisms, calculations, and implications of this melting point change.

Introduction to Melting Point Depression

What is Melting Point Depression?

Melting point depression is a colligative property observed when a solute is added to a pure solvent, leading to a decrease in the temperature at which the solvent transitions from solid to liquid. This phenomenon is directly proportional to the number of solute particles present in the solution, regardless of their identity.

Key aspects:

- Dependence on the number of particles: The effect hinges on the quantity of solute particles, not their chemical nature.
- Application in purification: Melting point depression is exploited in techniques like freezing point depression for purification and identification of substances.

Relevance in Organic Chemistry

In organic chemistry, understanding melting point depression assists in:

- Determining molar masses: By measuring how much the melting point drops upon adding a known amount of solute.

- Studying molecular interactions: Changes can indicate the nature of solute-solvent interactions.
- Analyzing purity: Impurities often depress and broaden melting points, offering diagnostic clues.

Case Study: Benzophenone and Melting Point Depression

Background on Benzophenone

Benzophenone is an aromatic ketone with the chemical formula $C_{13}H_{10}O$. It is widely used in organic synthesis, as a UV filter in sunscreens, and as a photoinitiator in polymer chemistry.

- Physical properties: It is a crystalline solid with a melting point around 48–49°C.
- Significance of its melting point: The sharp melting point of benzophenone makes it a good reference substance for colligative studies.

Experimental Observation

The specific experiment involves dissolving 0.358 g of an unspecified solute into a certain amount of benzophenone, resulting in a depression of the melting point by 2.3°C.

- Given data:
- Melting point depression, ΔT_m = 2.3°C
- Mass of solute, m_{solute} = 0.358 g
- Mass of benzophenone (solvent), $m_{solvent}$ = 7.544 g

This setup allows us to analyze the colligative behavior and determine the molar mass of the solute.

Theoretical Foundations

Raoult's Law and Colligative Properties

The melting point depression is explained by the colligative property relationship:

$$
\Delta T_m = i \times K_f \times m
$$

Where:

- ΔT_m = change in melting point (°C)
- i = van't Hoff factor (for non-electrolytes, $i \approx 1$)
- K_f = cryoscopic constant of the solvent (benzophenone)
- m = molality of the solution (mol of solute per kg of solvent)

Understanding the Van't Hoff Factor (i)

Since benzophenone is likely dissolved as a non-electrolyte, the van't Hoff factor i is approximately 1.

Calculations and Derivations

Step 1: Determine Molality (m)

Molality (m):

$$
m = \frac{\text{moles of solute}}{\text{kg of solvent}}
$$

Given:
- Mass of benzophenone = 7.544 g = 0.007544 kg

Let’s denote:
- M_{solute} = molar mass of the solute (unknown)

The number of moles of solute:

$$
n = \frac{0.358\, \text{g}}{M_{solute}}
$$

Molality:

$$
m = \frac{n}{0.007544\, \text{kg}} = \frac{0.358 / M_{solute}}{0.007544}
$$

Step 2: Use Melting Point Depression to Find Molar Mass

Rearranged from the colligative property equation:

$$
M_{solute} = \frac{0.358\, \text{g}}{n}
$$

But since:

$$
\Delta T_m = i \times K_f \times m
$$

Assuming i ≈ 1:

$$
m = \frac{\Delta T_m}{K_f}
$$

To calculate Msolute, we need the cryoscopic constant K_f for benzophenone.

Step 3: Determining the Cryoscopic Constant K_f of Benzophenone

The K_f value for benzophenone isn't as commonly tabulated as for water, but literature suggests it to be approximately 5.12°C kg/mol. Using this value:

$$
m = \frac{2.3^\circ C}{5.12^\circ C\, \text{kg/mol}} \approx 0.4492\, \text{mol/kg}
$$

Step 4: Calculate Molar Mass of the Solute

Number of moles of solute:

$$
n = m \times \text{kg of solvent} = 0.4492\, \text{mol/kg} \times 0.007544\, \text{kg} \approx 0.003392\, \text{mol}
$$

Now, molar mass:

$$
M_{solute} = \frac{\text{mass of solute}}{\text{moles of solute}} = \frac{0.358\, \text{g}}{0.003392\, \text{mol}} \approx 105.5\, \text{g/mol}
$$

Result:

- The molar mass of the dissolved solute is approximately 105.5 g/mol.

Implications and Significance

Understanding the Nature of the Solute

- The molar mass (~105.5 g/mol) suggests the solute is a relatively small organic molecule.
- Possibility of being a compound like phenol derivatives or similar molecular weights.

Practical Applications of Melting Point Depression Data

- Purity analysis: Confirming the purity of benzophenone or the solute.
- Molecular weight determination: As demonstrated, colligative properties provide a straightforward approach.
- Solute-solvent interactions: The extent of melting point depression can shed light on the nature of interactions, such as hydrogen bonding or van der Waals forces.

Limitations and Considerations

- Exact value of K_f: Variations in literature can lead to small discrepancies.
- Assumption of ideal behavior: Real solutions may deviate from ideality, especially at higher concentrations.
- Van't Hoff factor: If the solute ionizes or associates, i would differ from 1, affecting calculations.

Broader Context and Related Concepts

Other Colligative Properties

- Boiling point elevation: Analogous to melting point depression, used for similar analysis.
- Vapor pressure lowering: Fundamental in phase equilibrium studies.
- Osmotic pressure: Critical in biological systems and membrane science.

Additional Experimental Techniques

- Differential scanning calorimetry (DSC): Precise measurement of melting points and phase transitions.
- Spectroscopic methods: To analyze the nature of the solute and its interactions.

Advanced Topics

- Effect of ionic versus non-ionic solutes: Ionic compounds typically have higher van't Hoff factors, affecting the depression magnitude.

- Non-ideal solutions: Deviations from ideality can be modeled using activity coefficients.

Conclusion

The observed melting point depression of 2.3°C in benzophenone upon dissolving 0.358 g of a solute exemplifies the fundamental colligative property principles. Through meticulous calculations, we deduced that the molar mass of the solute is approximately 105.5 g/mol, aligning with common organic molecules. This case underscores the utility of melting point depression as a tool for molecular characterization, purity assessment, and understanding molecular interactions.

By integrating theoretical concepts with practical data, chemists can leverage colligative properties not only for academic insights but also for real-world applications in pharmaceuticals, materials science, and analytical chemistry. The case of benzophenone serves as a didactic example of how subtle changes in physical properties can reveal profound information about molecular composition and solution behavior.

In summary, the melting point depression caused by dissolving

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