A Solution Is Prepared By Dissolving 32.5 G Of A Nonvolatile Solute In 200. G Of Water. The Vapor Pressure

Understanding the Fundamentals of Solution Preparation and Vapor Pressure

A Solution Is Prepared By Dissolving 32.5 G Of A Nonvolatile Solute In 200. G Of Water. The Vapor Pressure of this solution is a fundamental concept in chemistry, especially when analyzing colligative properties. Such a process involves the interaction between the solute and solvent, which significantly influences the physical properties of the solution. This article explores the details of preparing such a solution, understanding vapor pressure, and examining how different factors affect vapor pressure lowering.

What Is a Nonvolatile Solute?

Definition and Characteristics

A nonvolatile solute is a substance that does not readily vaporize at a given temperature. Unlike volatile substances, which can easily transition into the vapor phase, nonvolatile solutes tend to remain in the liquid or solid state. Examples include salts like sodium chloride and sugars such as glucose.

Implications for Vapor Pressure

Since nonvolatile solutes do not vaporize, their presence in a solution impacts the vapor pressure of the solvent (water, in this case) by reducing it. This phenomenon is described by Raoult's Law, which states that the vapor pressure of the solvent decreases proportionally to the mole fraction of the solute.

Preparing the Solution: Step-by-Step Process

Materials Needed

- Nonvolatile solute (e.g., salt or sugar)
- Water (distilled or deionized)
- Accurate laboratory balance

- Volumetric flask or measuring cylinder
- Stirring rod or magnetic stirrer

Procedure

1. Weigh the Solute: Using a precise balance, measure 32.5 grams of the nonvolatile solute.
2. Measure the Water: Take 200 grams of water, which is approximately 200 mL (assuming the density of water is close to 1 g/mL).
3. Dissolution: Add the solute gradually to the water while stirring continuously to ensure complete dissolution.
4. Ensure Homogeneity: Continue stirring until the solution appears uniform without any visible particles.
5. Label and Store: Properly label the container with the contents and date of preparation for future reference.

Calculating the Molar Concentration of the Solution

Understanding the molarity of the solution is crucial for predicting its vapor pressure behavior.

Step 1: Determine the Moles of Solute

- Given Data:
- Mass of solute = 32.5 g
- Molar mass of solute = (depends on the specific substance, e.g., NaCl = 58.44 g/mol)

- Calculation:

$$
\text{Moles of solute} = \frac{\text{Mass of solute}}{\text{Molar mass of solute}}
$$

For example, if the solute is NaCl:

$$
\text{Moles} = \frac{32.5\, \text{g}}{58.44\, \text{g/mol}} \approx 0.556\, \text{mol}
$$

Step 2: Convert Water Mass to Volume (if necessary)

- Since 200 g of water roughly equals 200 mL, or 0.2 L, molarity can be calculated as:

$$
\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Volume of solution in liters}}
$$

$$
M = \frac{0.556\, \text{mol}}{0.2\, \text{L}} = 2.78\, \text{M}
$$

Understanding Vapor Pressure and Its Significance

What Is Vapor Pressure?

Vapor pressure is the pressure exerted by a vapor in equilibrium with its liquid or solid form at a given temperature. It reflects the tendency of molecules to escape from the liquid phase into the vapor phase.

Vapor Pressure of Pure Water

At room temperature (~25°C), pure water has a vapor pressure of approximately 23.8 mm Hg. This value indicates how readily water molecules escape into the vapor phase under standard conditions.

Impact of Nonvolatile Solutes on Vapor Pressure

Raoult's Law and Vapor Pressure Lowering

Raoult's Law states that the vapor pressure of a solvent in a solution is proportional to its mole fraction:

$$
P_{solution} = P_{pure\, solvent} \times X_{solvent}
$$

where:
- $P_{solution}$ is the vapor pressure of the solution
- $P_{pure\, solvent}$ is the vapor pressure of pure water
- $X_{solvent}$ is the mole fraction of water in the solution

Since the presence of a nonvolatile solute decreases $X_{solvent}$, the vapor pressure of water in the solution decreases accordingly.

Calculating Vapor Pressure Depression

The change in vapor pressure (ΔP) can be estimated as:

$$
\Delta P = P_{pure\, water} - P_{solution}
$$

or more precisely,

$$
\Delta P = P_{pure\, water} \times (1 - X_{water})
$$

\]

where \(X_{water} \) is the mole fraction of water in the solution.

Step-by-Step Calculation of Vapor Pressure in the Prepared Solution

Step 1: Calculate the Mole Fraction of Water

- Moles of water:

\[
\text{Mass of water} = 200\, \text{g}
\]

\[
\text{Molar mass of water} = 18.015\, \text{g/mol}
\]

\[
\text{Moles of water} = \frac{200\, \text{g}}{18.015\, \text{g/mol}} \approx 11.1\, \text{mol}
\]

- Moles of solute: As calculated earlier, approximately 0.556 mol.

- Total moles in solution:

\[
11.1\, \text{mol} + 0.556\, \text{mol} \approx 11.656\, \text{mol}
\]

- Mole fraction of water:

\[
X_{water} = \frac{11.1}{11.656} \approx 0.952
\]

Step 2: Calculate the Vapor Pressure of the Solution

- Vapor pressure of pure water at 25°C: 23.8 mm Hg.
- Vapor pressure depression:

\[
\Delta P = 23.8\, \text{mm Hg} \times (1 - 0.952) \approx 23.8\, \text{mm Hg} \times 0.048 \approx 1.14\, \text{mm Hg}
\]

- Vapor pressure of the solution:

$$
P_{solution} = P_{pure\, water} - \Delta P \approx 23.8\, \text{mm Hg} - 1.14\, \text{mm Hg} \approx 22.66\, \text{mm Hg}
$$

Factors Affecting Vapor Pressure in Solutions

Nature of the Solute

- Nonvolatile solutes like salts and sugars lower vapor pressure more significantly due to their inability to vaporize.
- Volatile solutes can contribute to vapor pressure, complicating the analysis.

Concentration of the Solute

- Higher concentrations of nonvolatile solutes lead to a greater reduction in vapor pressure.
- The relationship is directly proportional, consistent with Raoult's Law.

Temperature

- Increasing temperature raises the vapor pressure of the solvent.
- The impact of solutes on vapor pressure becomes less pronounced at higher temperatures.

Nature of the Solvent

- Different solvents have different vapor pressures.
- The effect of solutes varies depending on solvent properties such as polarity and molecular interactions.

Applications of Vapor Pressure Lowering

Boiling Point Elevation

- The addition of nonvolatile solutes raises the boiling point of water.
- This principle is used in cooking, antifreeze formulations, and industrial processes.

Freezing Point Depression

- Similar to vapor pressure lowering, solutes depress the freezing point.

- Used in de-icing solutions and cryopreservation.

Osmotic Pressure

- The osmotic pressure depends on solute concentration.
- Critical in biological systems for cell function and medicine.

Summary and Key Takeaways

- Preparing a solution by dissolving 32.5 g of a nonvolatile solute in 200 g of water results in a measurable decrease in vapor pressure.
- The molarity and mole fractions are essential for quantifying this change.
- Vapor pressure lowering follows Raoult’s

Frequently Asked Questions

What is the significance of dissolving 32.5 g of a nonvolatile solute in 200 g of water?

Dissolving 32.5 g of a nonvolatile solute in 200 g of water helps in studying the effect of solute concentration on properties like vapor pressure, boiling point, and freezing point, and is useful in colligative property calculations.

How does the addition of a nonvolatile solute affect the vapor pressure of water?

Adding a nonvolatile solute decreases the vapor pressure of water because the solute particles reduce the number of water molecules escaping into the vapor phase, following Raoult's law.

How can the vapor pressure of the solution be calculated given the solute mass and solvent mass?

The vapor pressure can be calculated using Raoult's law: $P_{solution} = X_{water} P°_{water}$, where X_{water} is the mole fraction of water in the solution, which is determined from the masses and molar masses of solute and solvent.

What is the role of molar mass in determining the vapor pressure of the solution?

Molar mass is essential for converting the given mass of solute and solvent into moles, which allows calculation of mole fractions needed for applying Raoult's law to find vapor pressure.

If the vapor pressure of pure water is 23.76 mmHg at a certain temperature, how does dissolving 32.5 g of solute affect it?

The vapor pressure of water will decrease proportionally to the mole fraction of water in the solution, resulting in a vapor pressure less than 23.76 mmHg, depending on the amount and nature of the solute.

What assumptions are made when using Raoult's law for calculating vapor pressure in this scenario?

Raoult's law assumes ideal solution behavior, no interactions between solute and solvent that deviate from ideality, and that the solute is nonvolatile, meaning it does not contribute to vapor pressure directly.

How can this calculation be useful in real-world applications?

Understanding how solutes affect vapor pressure is important in designing processes like distillation, predicting boiling points, and formulating solutions in industries such as pharmaceuticals and chemicals.

What additional information is needed to precisely calculate the vapor pressure of the solution?

The molar mass of the solute, the molar mass of water, and the vapor pressure of pure water at the specific temperature are necessary to perform an accurate calculation.

What is the expected trend in vapor pressure when increasing the amount of nonvolatile solute in water?

Increasing the amount of nonvolatile solute will further decrease the vapor pressure of the solution, as more water molecules are displaced by solute particles, following colligative property principles.

Additional Resources

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Introduction

Solutions form the backbone of countless chemical, biological, and industrial processes. They are fundamental to understanding phenomena such as boiling, freezing, and vapor pressure—properties that influence everything from meteorology to pharmaceuticals. A particularly intriguing aspect of solutions involves dissolving a given amount of solute in a solvent and analyzing how this affects vapor pressure, a key colligative property.

This article aims to thoroughly investigate the scenario where a solution is prepared by dissolving 32.5 g of a nonvolatile solute in 200 g of water and to elucidate the resulting vapor pressure behavior. Our exploration will consider the principles of colligative properties, calculations of molar quantities, and the implications of the solution's composition on vapor pressure.

Understanding the Scenario

The core of this investigation involves understanding the fundamental parameters:

- Mass of solute: 32.5 grams (nonvolatile)
- Mass of solvent (water): 200 grams
- Nature of solute: Nonvolatile (does not vaporize at the temperature considered)
- Objective: To analyze the vapor pressure of the resulting solution, considering the effects of solute addition

This setup provides a typical example of colligative property evaluation, where the focus is on how the dissolved particles influence solvent vapor pressure.

Underlying Principles: Colligative Properties and Vapor Pressure

Colligative properties depend on the number of solute particles in a solution, not on their identity. These include vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure.

Vapor pressure lowering is governed by Raoult's Law, which states:

> The vapor pressure of the solvent in a solution ($P_{solution}$) is proportional to the mole fraction of the solvent ($X_{solvent}$) times the vapor pressure of the pure solvent (P°):

$$P_{solution} = X_{solvent} \times P^\circ$$

Where:

- P° is the vapor pressure of pure water at the temperature considered
- $X_{solvent}$ is the mole fraction of water in the solution

The addition of a nonvolatile solute decreases the mole fraction of water, thus lowering the vapor pressure.

Step 1: Calculating Moles of Water

Given:

- Mass of water = 200 g
- Molar mass of water (M_{H_2O}) = 18.015 g/mol

$$
\text{Moles of water} = \frac{200\, \text{g}}{18.015\, \text{g/mol}} \approx 11.10\, \text{mol}
$$

Step 2: Calculating Moles of Solute

Given:

- Mass of solute = 32.5 g
- Molar mass of solute (M_{solute}) is unknown; for calculation purposes, we can consider an example or leave it as a variable M_s.

Assuming a specific nonvolatile solute, for example, sodium chloride (NaCl), with $M_{NaCl} \approx 58.44 \, \text{g/mol}$, the moles would be:

$$
\text{Moles of solute} = \frac{32.5\, \text{g}}{58.44\, \text{g/mol}} \approx 0.556\, \text{mol}
$$

If the molar mass differs, the calculation adjusts accordingly.

Step 3: Calculating Mole Fraction of Water

The mole fraction of water, X_{H_2O}, is:

$$
X_{H_2O} = \frac{\text{moles of water}}{\text{moles of water} + \text{moles of solute}}
$$

Substituting the calculated values:

$$
X_{H_2O} = \frac{11.10}{11.10 + 0.556} \approx \frac{11.10}{11.66} \approx 0.951
$$

This indicates that water comprises approximately 95.1% of the total mole population in the solution.

Step 4: Analyzing Vapor Pressure Depression

The vapor pressure of pure water at a typical reference temperature (say, 25°C) is about:

$$
P^\circ_{H_2O} \approx 23.8\, \text{kPa}
$$

Applying Raoult's Law:

$$
P_{solution} = X_{H_2O} \times P^\circ_{H_2O} \approx 0.951 \times 23.8\, \text{kPa} \approx 22.6\, \text{kPa}
$$

Vapor pressure depression (ΔP):

$$
\Delta P = P^\circ_{H_2O} - P_{solution} \approx 23.8 - 22.6 = 1.2\, \text{kPa}
$$

This indicates the vapor pressure of water in the solution is lowered by approximately 1.2 kPa due to the dissolved nonvolatile solute.

Deep Dive: Factors Influencing Vapor Pressure

Effect of Solute Type and Concentration

The magnitude of vapor pressure lowering depends primarily on the number of solute particles in the solution. Since the solute is nonvolatile and dissociates (if ionic), the actual impact varies. For example:

- Electrolytes (like NaCl) dissociate into ions, increasing particle count.
- Non-electrolytes (like glucose) do not dissociate, so the number of particles equals the molar amount.

In our example, assuming NaCl, which dissociates into Na^+ and Cl^-:

$$
\text{Effective particles} = 0.556\, \text{mol} \times 2 = 1.112\, \text{mol}
$$

This effectively doubles the particle count, leading to a larger vapor pressure depression.

Temperature Dependence

Vapor pressure is temperature-dependent; as temperature increases, vapor pressure rises. The calculations are valid at a specific temperature, typically 25°C, unless specified otherwise.

Practical Implications and Applications

Understanding and calculating vapor pressure changes are vital in various fields:

- Pharmaceuticals: Stability and solubility of drugs depend on vapor pressure and colligative properties.

- Chemical Engineering: Design of distillation and separation processes relies on vapor pressure data.
- Meteorology: Vapor pressure influences humidity and weather patterns.
- Food Industry: Preservation methods consider vapor pressure and osmotic effects.

Limitations and Assumptions

- The calculations assume ideal behavior; real solutions may exhibit deviations.
- The solute's dissociation behavior influences the number of particles; actual dissociation must be considered.
- Temperature effects are not explicitly incorporated; vapor pressure varies with temperature.
- The molar mass of the solute affects calculations; here, NaCl was used as an example.

Conclusion

Dissolving 32.5 g of a nonvolatile solute in 200 g of water significantly influences the vapor pressure of the solution. Based on molar calculations and Raoult’s Law, the vapor pressure decreases proportionally to the mole fraction of water, which itself decreases as solute particles are added.

This scenario exemplifies how colligative properties serve as powerful tools in chemistry for understanding solution behavior. Whether optimizing industrial processes or designing pharmaceuticals, quantifying vapor pressure depression provides essential insights into the molecular interactions at play.

The interplay between solute amount, dissociation behavior, and temperature underscores the complexity of real-world solutions, reinforcing the importance of precise measurements and calculations in scientific and engineering applications.

References

- Atkins, P., & de Paula, J. (2010). Physical Chemistry. Oxford University Press.
- Laidler, K. J., Meiser, J. H., & Sanctuary, B. C. (1999). Physical Chemistry. Houghton Mifflin.
- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry. Cengage Learning.
- Perry, R. H., & Green, D. W. (2008). Perry’s Chemical Engineers’ Handbook. McGraw-Hill.

Note: For precise vapor pressure calculations at different temperatures or with different solutes, consult empirical data and specific dissociation factors.

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