colligative properties practice problems with answers

Colligative properties practice problems are essential for students studying chemistry, particularly when delving into the behaviors of solutions. Understanding these properties is crucial for grasping how solutes affect solvent characteristics, such as boiling point elevation, freezing point depression, vapor pressure lowering, and osmotic pressure. This article will provide a comprehensive overview of colligative properties, followed by practice problems and their solutions to reinforce learning.

Understanding Colligative Properties

Colligative properties depend on the number of solute particles in a solution rather than the nature of the solute itself. They are particularly significant in various scientific and industrial applications, from predicting the behavior of antifreeze solutions to understanding biological systems.

Key Colligative Properties

The main colligative properties include:

1. Boiling Point Elevation: The increase in boiling point of a solvent when a solute is added.
2. Freezing Point Depression: The decrease in freezing point of a solvent when a solute is added.
3. Vapor Pressure Lowering: The reduction of vapor pressure of a solvent when a solute is dissolved in it.
4. Osmotic Pressure: The pressure required to stop the flow of solvent into a solution through a semipermeable membrane.

Each of these properties can be quantitatively described using specific formulas, primarily involving molality (m), the van 't Hoff factor (i), and constants unique to the solvent.

Formulas for Colligative Properties

Understanding the formulas is essential for solving practice problems. Here are the key equations:

1. Boiling Point Elevation:

\[
\Delta T_b = i \cdot K_b \cdot m
\]

2. Freezing Point Depression:
\[
\Delta T_f = i \cdot K_f \cdot m
\]

3. Vapor Pressure Lowering:
\[
\Delta P = P^0 \cdot X_{solute}
\]
Where \(P^0 \) is the vapor pressure of the pure solvent, and \(X_{solute} \) is the mole fraction of the solute.

4. Osmotic Pressure:
\[
\Pi = i \cdot M \cdot R \cdot T
\]
Where \(\Pi \) is the osmotic pressure, \(M \) is the molarity of the solution, \(R \) is the gas constant, and \(T \) is the temperature in Kelvin.

Practice Problems

Now, let's delve into practice problems that will help solidify your understanding of colligative properties.

Problem 1: Boiling Point Elevation

A solution is prepared by dissolving 50 grams of sodium chloride (NaCl) in 500 grams of water. The boiling point elevation constant (K_b) for water is 0.512 °C/m. Calculate the boiling point of the solution.

Given:
- Mass of NaCl = 50 g
- Mass of water = 500 g
- K_b = 0.512 °C/m
- Molar mass of NaCl = 58.44 g/mol

Solution:

1. Calculate the number of moles of NaCl:
\[
\text{Moles of NaCl} = \frac{50 \text{ g}}{58.44 \text{ g/mol}} \approx 0.856 \text{ mol}

\]

2. Calculate the mass of water in kg:
\[
\text{Mass of water} = 500 \text{ g} = 0.5 \text{ kg}
\]

3. Calculate the molality (m):
\[
m = \frac{0.856 \text{ mol}}{0.5 \text{ kg}} = 1.712 \text{ m}
\]

4. Calculate the boiling point elevation:
\[
\Delta T_b = i \cdot K_b \cdot m
\]
Here, \(i \) for NaCl is 2 (since it dissociates into Na^+ and Cl^-):
\[
\Delta T_b = 2 \cdot 0.512 \cdot 1.712 \approx 1.76 °C
\]

5. Calculate the new boiling point:
\[
\text{New boiling point} = 100 °C + 1.76 °C = 101.76 °C
\]

Problem 2: Freezing Point Depression

Determine the freezing point of a solution made by dissolving 20 grams of glucose ($C_6H_{12}O_6$) in 200 grams of water. The freezing point depression constant (K_f) for water is 1.86 °C/m.

Given:
- Mass of glucose = 20 g
- Mass of water = 200 g
- K_f = 1.86 °C/m
- Molar mass of glucose = 180.18 g/mol

Solution:

1. Calculate the number of moles of glucose:
\[
\text{Moles of glucose} = \frac{20 \text{ g}}{180.18 \text{ g/mol}} \approx 0.111 \text{ mol}
\]

2. Convert the mass of water to kg:
\[
\text{Mass of water} = 200 \text{ g} = 0.2 \text{ kg}

\]

3. Calculate the molality (m):
\[
m = \frac{0.111 \text{ mol}}{0.2 \text{ kg}} = 0.555 \text{ m}
\]

4. Calculate the freezing point depression:
\[
\Delta T_f = i \cdot K_f \cdot m
\]
Here, \(i \) for glucose is 1:
\[
\Delta T_f = 1 \cdot 1.86 \cdot 0.555 \approx 1.03 °C
\]

5. Calculate the new freezing point:
\[
\text{New freezing point} = 0 °C - 1.03 °C = -1.03 °C
\]

Problem 3: Vapor Pressure Lowering

What is the vapor pressure of a solution made by dissolving 10 grams of urea (NH_2CONH_2) in 100 grams of water at 25 °C? The vapor pressure of pure water at this temperature is 23.76 mmHg. The molar mass of urea is 60.06 g/mol.

Solution:

1. Calculate the number of moles of urea:
\[
\text{Moles of urea} = \frac{10 \text{ g}}{60.06 \text{ g/mol}} \approx 0.166 \text{ mol}
\]

2. Convert the mass of water to kg:
\[
\text{Mass of water} = 100 \text{ g} = 0.1 \text{ kg}
\]

3. Calculate the molality (m):
\[
m = \frac{0.166 \text{ mol}}{0.1 \text{ kg}} = 1.66 \text{ m}
\]

4. Calculate the mole fraction of urea:
- Moles of water (molar mass = 18.02 g/mol):
\[
\text{Moles of water} = \frac{100 \text{ g}}{18.02 \text{ g/mol}} \approx

5.55 \text{ mol}
\]
- Total moles:
\[
\text{Total moles} = 0.166 + 5.55 \approx 5.716 \text{ mol}
\]
- Mole fraction of urea:
\[
X_{urea} = \frac{0.166}{5.716} \approx 0.029
\]

5. Calculate the vapor pressure lowering:
\[
\Delta P = P^0 \cdot X_{solute} = 23.76 \cdot 0.029 \approx 0.69 \text{ mmHg}
\]

6. Calculate the new vapor pressure:
\[
P_{solution} = P^0 - \Delta P = 23.76 \text{ mmHg} - 0.69 \text{ mmHg} \approx 23.07 \text{ mmHg}
\]

Problem 4: Osmotic Pressure

Calculate the osmotic pressure of a solution containing 0.5 moles of sodium chloride in 2 liters of solution at 25 °C (298 K). Use the gas constant \(R = 0.0821 \text{ L·atm/(K·mol)} \).

Solution:

1. Identify the van 't Hoff factor for NaCl, which is 2 (due to dissociation into Na^+ and Cl^-).

2. Calculate the molarity (M):
\[

Frequently Asked Questions

What are colligative properties, and how do they depend on solute concentration?

Colligative properties are physical properties of solutions that depend on the number of solute particles in a given amount of solvent, rather than the identity of the solute. These properties include vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure.

How do you calculate the boiling point elevation when 0.5 moles of NaCl are dissolved in 1 kg of water?

The boiling point elevation can be calculated using the formula ΔT_b = i K_b m, where i is the van 't Hoff factor (2 for NaCl), K_b for water (0.512 °C kg/mol), and m is the molality (0.5 moles/1 kg = 0.5 m). Thus, ΔT_b = 2 0.512 0.5 = 0.512 °C. The new boiling point will be 100 °C + 0.512 °C = 100.512 °C.

If a solution has a freezing point of -5 °C, what is the molality of the solute in the solution assuming water as the solvent?

Using the formula ΔT_f = i K_f m, where K_f for water is 1.86 °C kg/mol, we have ΔT_f = 0 °C - (-5 °C) = 5 °C. Assuming the solute does not dissociate (i=1), we can rearrange to find m: m = ΔT_f / (i K_f) = 5 / (1 1.86) ≈ 2.688 mol/kg.

What is the osmotic pressure of a solution containing 0.3 moles of glucose (C6H12O6) in 1 liter of water at 25 °C?

Osmotic pressure (π) can be calculated using the formula π = i CRT, where C is the concentration in mol/L, R is the ideal gas constant (0.0821 L·atm/(K·mol)), and T is the temperature in Kelvin (25 °C = 298 K). For glucose, i = 1. Therefore, π = 1 0.3 0.0821 298 ≈ 7.39 atm.

How does the presence of a non-volatile solute affect the vapor pressure of a solvent?

The presence of a non-volatile solute lowers the vapor pressure of the solvent due to the solute particles occupying space at the surface, reducing the number of solvent molecules that can escape into the vapor phase. This can be quantified using Raoult's Law, which states that the vapor pressure of the solvent above a solution is equal to the vapor pressure of the pure solvent multiplied by the mole fraction of the solvent in the solution.

Colligative Properties Practice Problems With Answers

Colligative Properties Practice Problems With Answers

Back to Home: https://staging.liftfoils.com