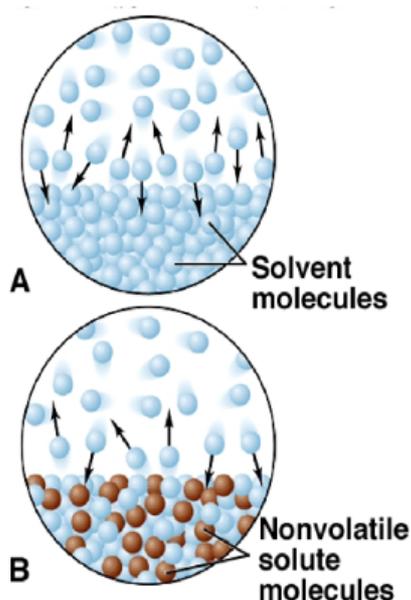


Question:

At 25 degree Celsius the vapor pressure of pure water is 27.76 mmHg and that of a dilute solution aqueous urea solution is 22.98 mmHg. Estimate the molality of solution.

Answer:

Vapor pressure of solvent decreases with the presence of solute because of the reduction of evaporation surface. This phenomenon is illustrated with a picture below.



The decrease in vapor pressure is defined by Raoult's law:

$$P_{\text{solvent}} = \chi_{\text{solvent}} \times P_{\text{solvent}}^0 \quad (1)$$

where P_{solvent}^0 is a vapor pressure under pure solvent and χ is a molar fraction, defined as:

$$\chi_{\text{solvent}} = \frac{n_{\text{solvent}}}{n_{\text{solvent}} + n_{\text{solute}}} \quad (2)$$

One can calculate the molar fraction of the given solution from equation (1):

$$\chi_{\text{solvent}} = \frac{P_{\text{solvent}}}{P_{\text{solvent}}^0} = \frac{22.98\text{mmHg}}{27.76\text{mmHg}} = 0.8278$$

Molality can be defined as the amount of moles of solute per one kilogram of solvent:

$$C_m = \frac{1000 \times n_{\text{solute}}}{m_{\text{solvent}}} \quad (3)$$

Equation (3) is for mass in grams.

We can show that the molar fraction of solute is related to molar fraction of solvent with the following equation:

$$\chi_{solute} = \frac{n_{solute}}{n_{solvent} + n_{solute}} = 1 - \chi_{solvent} \quad (4)$$

Molality (3) is related with molar fraction of solute (4) according to the equation:

$$C_m = \frac{1000 \chi_{solute}}{(1 - \chi_{solute}) M_{solute}} = \frac{1000(1 - \chi_{solvent})}{\chi_{solvent} M_{solvent}} \quad (5)$$

In our case solvent is water H_2O and solute is urea $CO(NH_2)_2$. According to the equation (5):

$$C_m(CO(NH_2)_2) = \frac{1000(1 - \chi_{H_2O})}{\chi_{H_2O} M_{CO(NH_2)_2}} = \frac{1000 \times (1 - 0.8278)}{0.8278 \times 18g/mol} = 3.47 mol/kg$$