13.1 Quantitative Expressions of Concentration

Units of Concentration – Molarity, Molality, Mole Fraction, Weight %

Solution = Solute + Solvent

→ that which is present in the greatest amount

Molarity:

→ the only one you met in Chem 111

$$M = \frac{\text{Moles of solute}}{\text{Volume of the solution in L}}$$

DRAWBACK: We know nothing quantitative about the solvent.

Mole Fraction:

$$X = \frac{\text{moles of solute}}{\text{moles of solute + moles of solvent}}$$

Molality:

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

DRAWBACK: We know nothing quantitative about the solution.

Weight %:

$$\text{Wt \% of A} = \left(\frac{\text{mass of A}}{\text{mass of A + mass B + ...}}\right) 100$$

13.1 Quantitative Expressions of Concentration

Units of Concentration – Molarity, Molality, Mole Fraction, Weight %

What is the **molality** of a **chromium(II) nitrate** solution made by dissolving **27.1g** of chromium(II) nitrate (**MM= 176.02**) in **513g** of water?

3
0.?

Chromium(II) nitrate = $Cr(NO_3)_2$: MM = 176.02 g mol^{-1}

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

Moles of solute : $27.1\,g\ Cr(NO_3)_2 \left| \frac{1\ mol}{176.02\,g} \right. = 0.154$

Kg of solvent : $513\,g \left| \frac{1\ kg}{1000\,g} \right. = 0.513$

$$\text{Molality} = \frac{0.154}{0.513} = 0.300\ m$$

13.1 Quantitative Expressions of Concentration

Units of Concentration – Molarity, Molality, Mole Fraction, Weight %

An aqueous solution is **6.00 % by mass hydrochloric acid**. What is the **mole fraction** of **hydrochloric acid** in the solution?

$$6.00\%\ HCl = \frac{6.00\ g\ HCl}{100\ g\ solvent} \qquad X = \frac{moles\ of\ solute}{moles\ of\ solute + moles\ of\ solvent}$$

Assume: 100 g of solution.

$\therefore$ 6 g of HCl + 94 g of H_2O

MM: $H_2O = 18.02\ g.mol^{-1}$; $HCl = 36.5\ g.mol^{-1}$

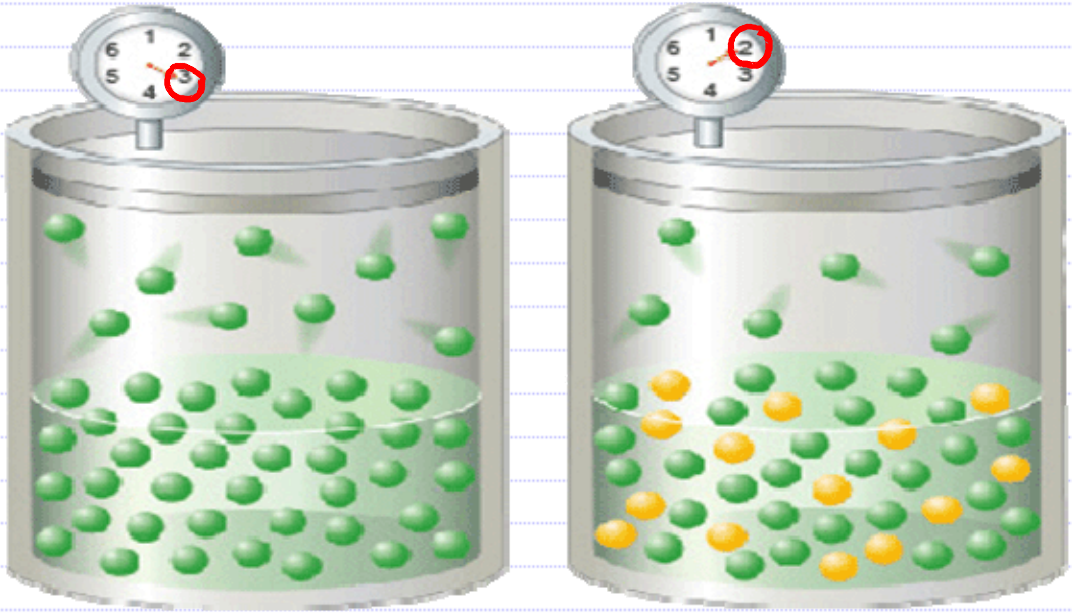
$$\text{Moles of solute: } \frac{6.00\ g\ HCl \mid 1\ mol}{36.5\ g} = 0.164$$

$$\text{Moles of solvent: } \frac{94.00\ g\ H_2O \mid 1\ mol}{18.02\ g} = 5.22$$

$$X = \frac{0.164}{0.164 + 5.22} = 0.0305$$

13.4 Colligative Properties

Vapor Pressure Lowering – Raoult's Law



Pure solvent

Solution with a nonvolatile solute

When a nonvolatile solute is added to a volatile solvent, the solute particles block some of the solvent molecules from escaping into the gas phase, thus lowering the Vapor Pressure.

Raoult's Law:

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

$P_{solution}$: Vapor Pressure of the solvent in the solution.

$X_{solvent}$: Mole fraction of the solvent.

$P^{\circ}_{solvent}$: Vapor Pressure of the pure solvent.

13.4 Colligative Properties

Vapor Pressure Lowering – Raoult's Law

The vapor pressure of **benzene** (C_6H_6) at 25 °C is **73.0 mm Hg**. What is the **vapor pressure of a solution** consisting of **303 g of benzene** and **0.170 mol** of a **solute that is a nonvolatile nonelectrolyte**?

?0.0 mmHg

↳ ~ 7

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

C_6H_6 : $MM = 78.12\ g.mol^{-1}$

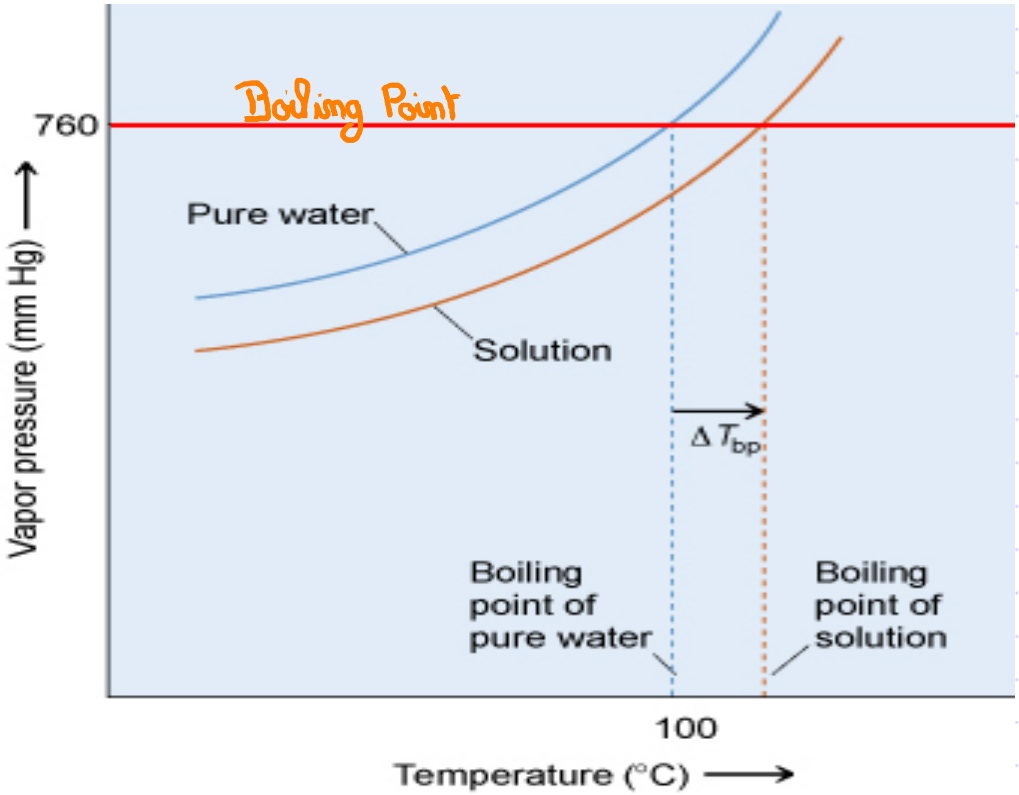
$$303\,g\ C_6H_6 \left| \frac{1\ mol}{78.12\,g} \right. = 3.88\ mol\ C_6H_6$$

$$X_{C_6H_6} = \frac{3.88}{3.88 + 0.17} = 0.958$$

$$P_{solution} = 0.958\,(73.0) = 69.9\ mm\ Hg$$

13.4 Colligative Properties

Vapor Pressure Lowering – Boiling Point Elevation



$\Delta T_{B.P.} = i \times K_{B.P.} \times m_{solute}$

$\Delta T_{B.P.}$: Change in Boiling Point.

$K_{B.P.}$: Boiling Point elevation constant for the solute.

m_{solute} : Molality of the solute.

i : van't Hoff Factor.
For a nonelectrolyte, $i = 1$