

CHM111

PHYSICAL CHEMISTRY I

TOPIC: COLLIGATIVE PROPERTIES

Module 4: UNIT 1

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Colligative Properties of Solutions

Learning Objectives

The module aim to achieve the following Objectives



Explain colligative properties

Derive expressions explaining various types of colligative properties

Apply the equations derived in determining various parameters relating to colligative properties

Explain Raoult's law, Oswald and Walker process and other laws and experiments related to Colligative properties

Introduction

Previously, you may be familiar with:

- **miscible systems (substances interacts favourably)**
- **partially miscible systems (substances PARTIALLY interacts favourably) and**
- **nearly immiscible systems (substances DOES NOT interacts favourably)**

The properties of these systems have also been studied



Introduction..cont

- **What is a colligative property**
- The word **COLLIGATIVE** came from the Latin word **COLLIGOUS** which means “**BOUND TOGETHER**”
- **A Colligative property of a solution is a property observed as a result of the interaction of two or more miscible substances**



Introduction..cont

- **These properties help in determining the relative molecular mass of a non-volatile solute**
- **Colligative properties of Solution depend on the amount of solute particles in the solution, NOT the identity of particles**



Introduction..cont

The types of CPs include:

- **relative lowering of vapour pressure,**
- **elevation of boiling point,**
- **depression of freezing point, and**
- **osmotic pressure**

NOTE THAT

Colligative Properties depend on the amount of a substance not its identity, Hence MOLALITY



Molality

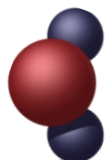
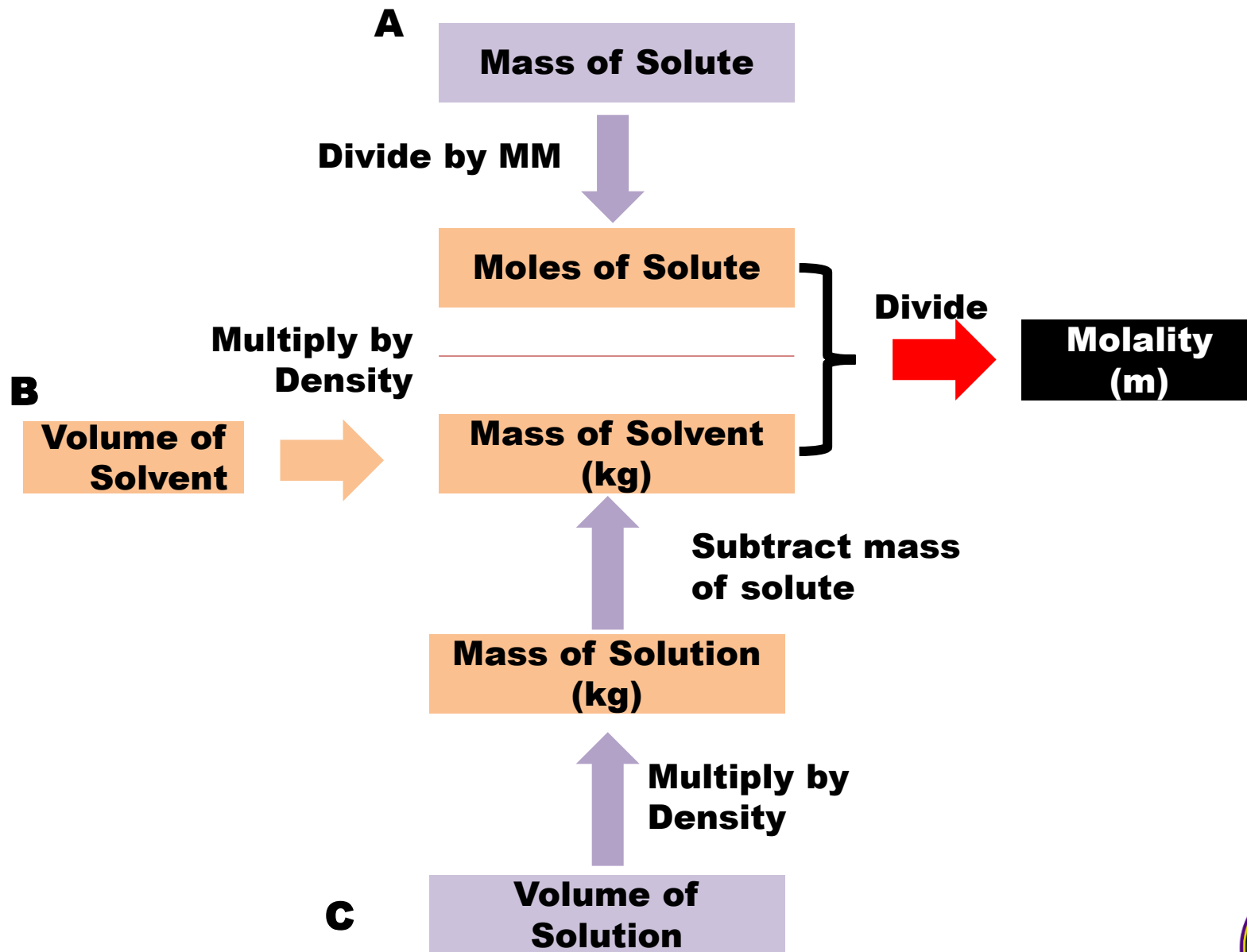
What is molality (m)?

$$m = \frac{n_{\text{Solute}}}{\text{mass solvent (kg)}}$$

✓ **Molality (m) is independent of temperature**

✓ **For a typical solutions: molality > molarity**

How to calculate Molality



Example #1: Molality calculation

Calculate the molality of a solution containing 0.875 mol of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) in 1.50 kg of water.

Collect and Organize:

- We know moles of solute (glucose) = **0.875 mol**

the mass of solvent (water) = **1.50 kg**

We want to find molality, $m = ?$



Example #1 : Molality calc.. cont.

➤ Analyze:

- ✓ **moles of solute (n) and mass of solvent (kg), are known. So apply the equation:**

$$m = \frac{n_{\text{Solute}}}{\text{mass solvent (kg)}}$$

$$m = \frac{0.875 \text{ moles glucose}}{1.50 \text{ kg water}} = 0.583 \text{ molal}$$

Example #1: Molality calc...cont.

Calculate the molality of a solution containing 0.875 mol of glucose ($C_6H_{12}O_6$) in 1.50 kg of water.

- **Solve:**

$$m = \frac{0.875 \text{ moles glucose}}{1.50 \text{ kg water}} = 0.583 \text{ molal}$$



Example #1 : Molality cal.. (cont.)

Calculate the molality of a solution containing 0.875 mol of glucose ($C_6H_{12}O_6$) in 1.50 kg of water.

➤ **Note:**

❖ **The calculated result indicates that the solution contains approx. 0.6 mol of glucose per kg of water.**



Example #2: Molality calculation

➤ Seawater contains 0.5580 M Cl^- at the surface at 25°C . If the density of seawater is 1.022 g/mL , what is the molality of Cl^- in seawater?

➤ **Collect and Organize:**

❖ We know:

❖ **Molarity** of $\text{Cl}^- = 0.5580\text{ mol/L}$

❖ Density of seawater = 1.022 g/mL

❖ We want to calculate **molality** of Cl^- in seawater.



Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25 °C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Analyze:**

❖ **Molarity of Cl^- = 0.5580 mol/L**

❖ **Density of seawater = 1.022**

 **g/mL**

❖ **molality of Cl^- in seawater = ?**



Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25°C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Analyze:**

- ❖ **From the density we can calculate the mass of one liter of seawater.**
- ❖ **From the molarity and molar mass we can calculate the mass of Cl^- in a liter of seawater and the mass is of water.**
- ❖ **We can then calculate molality.**

Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25 °C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Solve:**

The solution was prepared in 1000 mL

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$1.022 \text{ g/mL} = \frac{\text{Mass}}{1000 \text{ mL}}$$

$$\text{Mass} = 1.022 \frac{\text{g}}{\text{mL}} \times 1000 \text{ mL}$$

$$\text{Mass} = \mathbf{1022 \text{ g Seawater}}$$

Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25 °C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Solve:**

Let us calculate the mass of Cl in the solution

$$\text{No. of moles (n)} = \frac{\text{Measured Mass}}{\text{Molar mass}}$$

$$0.5580 \text{ mol/LCl} = \frac{\text{Mass}}{35.453 \text{ g/molCl}}$$


$$\text{Mass} = 0.5580 \text{ mol/LCl} \times 35.453 \text{ g/molCl}$$

$$\text{Mass Cl} = 19.78 \text{ g Cl}$$

Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25 °C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Solve:**

Let us calculate the mass of water alone

Mass of seawater + Cl = 1022 g Seawater

Mass Cl (in seawater) = 19.78 g Cl

Mass of water alone = 1022 g Seawater – 19.78 g Cl

Mass of water alone = 1002 g Seawater




Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25 °C. If the density of seawater is 1.022 g/mL, what is the molality of Cl^- in seawater?

❖ **Solve:**

$$m = \frac{n_{\text{Solute}}}{\text{mass solvent (kg)}}$$


$$m = \frac{0.5580 \frac{\text{mol}}{\text{L}} \text{Cl}}{1.002 \text{ kg water}} = 0.5569 \text{ molal}$$



Example #2: Molality calculation...cont..

Seawater contains 0.5580 M Cl^- at the surface at 25°C . If the density of seawater is 1.022 g/mL , what is the molality of Cl^- in seawater?

Note:

❖ Since the density of seawater is only slightly greater than that of pure water (1.00 g/mL), we would expect that $1\text{ L of water} = 1\text{ kg of water}$, and

❖ the molality should be close to the molarity.

❖ This is consistent with our calculated answer.



❖ Molarity = 0.5580 M Cl^-

❖ Molality = 0.5569 m Cl^-



Colligative Property #1

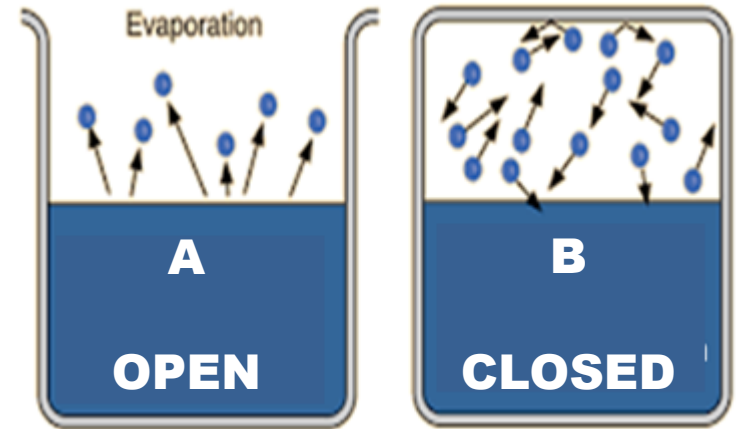
Relative lowering of Vapour Pressure



Vapor Pressure of Solutions

What is Vapor Pressure?

➤ **Consider Systems A and B**



- **Vapour from system B will exert a pressure on the container = VP**
- **VP is the pressure exerted by a gas at equilibrium with liquid, like System B**
- **Rates of evaporation and condensation are equal**

Vapor Pressure of Solutions..cont.

- **If we add a non-volatile solute into System B, the equilibrium vapour pressure of the liquid over the solution is found to be less than that of the pure liquid.**
- **this was explained by Raoult**

Factors Affecting Vapor Pressure

➤ **Temperature**

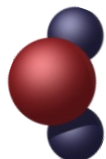
- ✓ **As T increases, KE increases, vapor pressure increases**

➤ **Intermolecular forces**

- ✓ **Stronger forces, higher KE needed to enter gas phase—vapor pressure decreases**

➤ **Presence of nonvolatile solute**

- ✓ **Affects rate of evaporation, decreases vapor pressure of solution compared to pure solvent**



Raoult's Law

➤ Raoult's law

- Vapor pressure of solution is equal to the vapor pressure of the pure solvent multiplied by the mole fraction (X_{solvent}) of the solvent in the solution.
- $P_{\text{solution}} = X_{\text{solvent}} \cdot P^{\circ}_{\text{solvent}} \quad (1)$

 ➤ **Ideal solution: One that obeys Raoult's law**

Raoult's Law..cont.

Note: the lowering of VP is

- $P_{\text{Lowering}} = P^0 - P \quad (2)$

- $P^0 - P = P^0 - X_1 \cdot P^0 \quad (3)$

- $P^0 - P = P^0 (1 - X_1) \quad (4)$

- **But $X_1 + X_2 = 1$ (5)**

- $P^0 = \text{VP of pure solvent;}$
- $P = \text{VP solution}$
 - X_1 MF solvent and X_2 MF solute



Raoult's Law ..cont.

- so $X_2 = 1 - X_1$ (6)

- Substitute in (4)

- $P^0 - P = P^0 X_2$ (7)

- Thus VP lowering is depends on the VP of pure solvent and MF of solute



So Vapor pressure lowering is a colligative property of solutions



Raoult's Law ..cont.

this equation: $P^0 - P = P^0 X_2$ can be written as

$$\frac{P^0 - P}{P^0} = X_2 \quad (8)$$

Meaning: The lowering of VP is = to the MF of solute



Mole Fraction

- **What is mole fraction?**
- **If we have a mixture containing A and B with number of moles n_A and n_B respectively**

- **mole fraction of A = $n_A = \frac{n_A}{n_A + n_B}$ (11)**

- **mole fraction of B = $n_B = \frac{n_B}{n_A + n_B}$ (12)**

- **Mole fraction of A = moles of A divided by moles of A + Moles of B**

Example: VP from Raoult's Law

➤ **Calculate the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol in 250.0 g of water at 30°C.**

(The vapor pressure of pure water at 30°C is 31.8 mmHg; MM Ethylene glycole = 62.1 g/mol)



Example : VP form Raoult's Law

Calculate the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol (62.1 g/mol) in 250.0 g of water at 30°C. (The vapor pressure of pure water at 30°C is 31.8 mmHg.)

➤ **Collect and Organize:**

- **62.1 g ethylene glycol**
- **250.0 g of water**
- **VP of pure water = 31.8 mmHg.**
- **Calculate the moles of water and glycol**
- **Find the mole fraction of water and**
- **Calculate the VP of the solution**




Example: VP from Raoult's Law (cont.)

What would be the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol (62.1 g/mol) in 250.0 g of water at 30°C? (The vapor pressure of pure water at 30°C is 31.8 mmHg.)

➤ Compute the moles of each component:

$$\blacksquare \mathbf{n_{Glycol} = \frac{62.1 \text{ g glycol}}{62.1 \frac{g}{mol} \text{ glycol}} = 1.00 \text{ mol glycol}}$$


$$\blacksquare \mathbf{n_{water} = \frac{250.0 \text{ g water}}{18.02 \frac{g}{mol} \text{ water}} = 13.87 \text{ mol } H_2O}$$



Example: VP from Raoult's Law...cont.

What would be the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol (62.1 g/mol) in 250.0 g of water at 30°C? (The vapor pressure of pure water at 30°C is 31.8 mmHg.)

- **Calculate the mole fraction of water using**

- $$n_{\text{water}} = \frac{n_{\text{water}}}{n_{\text{Glycol}} + n_{\text{water}}}$$



$$n_{\text{water}} = \frac{13.87 \text{ mol H}_2\text{O}}{13.87 \text{ mol water} + 1.00 \text{ mol. glycol}}$$



Example: VP from Raoult's Law...cont.

- What would be the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol (62.1 g/mol) in 250.0 g of water at 30°C? (The vapor pressure of pure water at 30°C is 31.8 mmHg.)
- To calculate VP of Sol. use the equation:

$$P_{\text{solution}} = X_{\text{H}_2\text{O}} P^{\circ}_{\text{H}_2\text{O}}$$

$$P_{\text{Solution}} = \left(\frac{13.87 \text{ mol H}_2\text{O}}{13.87 \text{ mol water} + 1.00 \text{ mol. glycol}} \right) \times 31.8 \text{ mmHg}$$



$$P_{\text{Solution}} = 29.7 \text{ mmHg}$$



Example: VP Raoult's Law...cont.

- **What would be the vapor pressure of water over a solution that contains 62.1 g of ethylene glycol (62.1 g/mol) in 250.0 g of water at 30°C? (The vapor pressure of pure water at 30°C is 31.8 mmHg.)**

➤ **Note:**

- **The mole fraction is less than 1.00 so the pressure of a solution should be less than that of pure water.**
- **Since the solution was mostly water, the pressure should not go down by much.**

Deviation from Raoult's law

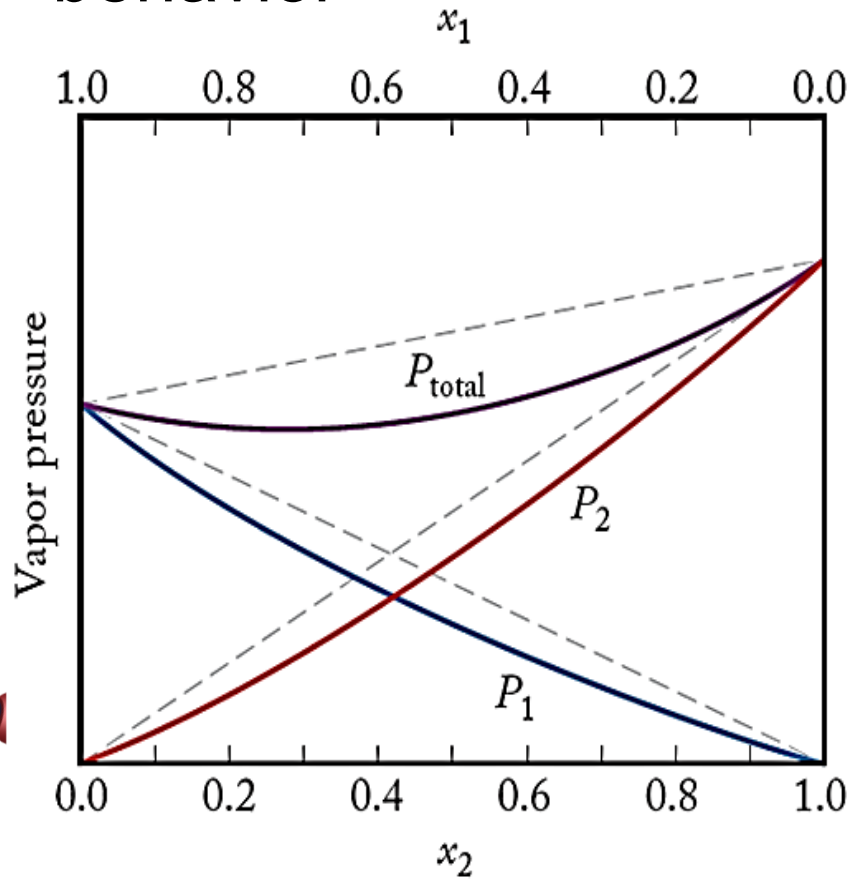
Due to differences in solute–solvent and solvent–solvent interactions deviation from Raoult's can be observed.

Ideal Solutions obey Raoult's law but Real solutions does not obey the law

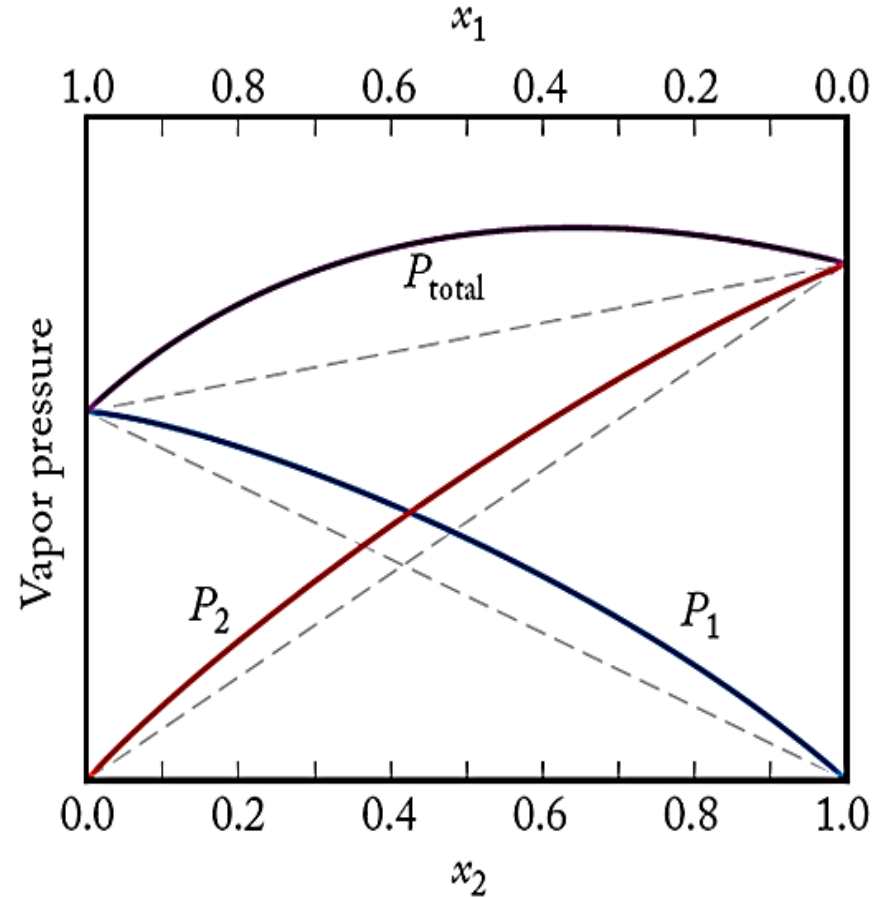


Deviations from Raoult's law

- from this diagrams the dashed lines represents ideal behavior



Negative deviation



Positive deviation



Solutions of Volatile Components

➤ **For mixtures containing more than one volatile component:**

➤ **Partial pressure of each volatile component contributes to total vapor pressure of solution.**

➤ **$P_{\text{total}} = X_1 P_1 + X_2 P_2 + X_3 P_3 + \dots X_n P_n$**

➤ **Where X_i = mole fraction of component i , and P_i^\square = equilibrium vapor pressure of pure volatile component at a given temperature**



Practice: VP of Solution of volatile components

A solution contains 100.0 g of water (MM = 18.02 g/mol) and 25.00 g of ethanol (MM = 46.07 g/mol). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C?

($P^{\circ}_{\text{water}} = 23.8 \text{ torr}$; $P^{\circ}_{\text{ethanol}} = 58.7 \text{ torr}$)

➤ **Collect and Organize: we know:**

- **100.0 g of water; 25.00 g of ethanol**



- **$P^{\circ}_{\text{water}} = 23.8 \text{ torr}$; $P^{\circ}_{\text{ethanol}} = 58.7 \text{ torr}$**

- **We want to calculate the VP of the solution**



Practice: VP of Solution volatile comp. (cont.)

• A solution contains 100.0 g of water ($M = 18.02 \text{ g/mol}$) and 25.00 g of ethanol ($M = 46.07 \text{ g/mol}$). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C? ($P^\circ_{\text{water}} = 23.8 \text{ torr}$; $P^\circ_{\text{ethanol}} = 58.7 \text{ torr}$)

Analyze:

- **We want to calculate**
 - i. **The mole fraction of water**
 - ii. **The mole fraction of ethanol and**
- **The Total VP of the solution**




Practice: Vapor Pressure of Solution (cont.)

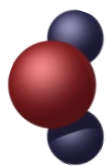
A solution contains 100.0 g of water ($M = 18.02 \text{ g/mol}$) and 25.00 g of ethanol ($M = 46.07 \text{ g/mol}$). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C ? ($P^\circ_{\text{water}} = 23.8 \text{ torr}$; $P^\circ_{\text{ethanol}} = 58.7 \text{ torr}$)

Solve:

$$\text{Moles of H}_2\text{O} = \frac{100 \text{ g}}{18.02 \left(\frac{\text{g}}{\text{mol}}\right)} = 5.549 \text{ mols H}_2\text{O}$$


$$\text{Moles of Ethanol} = \frac{25 \text{ g}}{46.07 \left(\frac{\text{g}}{\text{mol}}\right)} = 0.543 \text{ mols ethanol}$$

$$n_{\text{TOTAL}} = 5.549 \text{ mols water} + 0.543 \text{ mols Ethanol}$$


$$n_{\text{Total}} = 6.092 \text{ mol}$$

Practice: Vapor Pressure(cont.)

- A solution contains 100.0 g of water ($M = 18.02 \text{ g/mol}$) and 25.00 g of ethanol ($M = 46.07 \text{ g/mol}$). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C ? ($P^\circ_{\text{water}} = 23.8 \text{ torr}$; $P^\circ_{\text{ethanol}} = 58.7 \text{ torr}$)

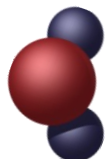
- Solve:

$$\text{Mole Fract. of Water } (X_{\text{Water}}) = \frac{5.549 \text{ mol}}{6.092 \text{ mol}} = 0.0891$$

- Similarly,**



$$\text{Mole Fract. of Ethanol } (X_{\text{Ethanol}}) = \frac{0.543 \text{ mol}}{6.092 \text{ mol}} = 0.9109$$



Practice: Vapor Pressure(cont.)

A solution contains 100.0 g of water ($M = 18.02 \text{ g/mol}$) and 25.00 g of ethanol ($M = 46.07 \text{ g/mol}$). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C ? ($P^\circ_{\text{water}} = 23.8 \text{ torr}$; $P^\circ_{\text{ethanol}} = 58.7 \text{ torr}$)

- **Solve:**
- **Partial pressure of components are**

$$P_{\text{water}} = 0.9109 \times 23.8 \text{ torr} = 21.6794 \text{ torr}$$

$$P_{\text{Ethanol}} = 0.0891 \times 58.7 \text{ torr} = 5.2302 \text{ torr}$$



Total VP of the solution is

$$P_{\text{TOTAL}} = 5.2302 \text{ torr} + 21.6794 \text{ torr} = 26.91 \text{ torr}$$



Practice: Vapor Pressure(cont.)

- A solution contains 100.0 g of water ($M = 18.02 \text{ g/mol}$) and 25.00 g of ethanol ($M = 46.07 \text{ g/mol}$). What are the mole fractions of water and ethanol, and the vapor pressure of the solution at 25°C? ($P^\circ_{\text{water}} = 23.8 \text{ torr}$; $P^\circ_{\text{ethanol}} = 58.7 \text{ torr}$)

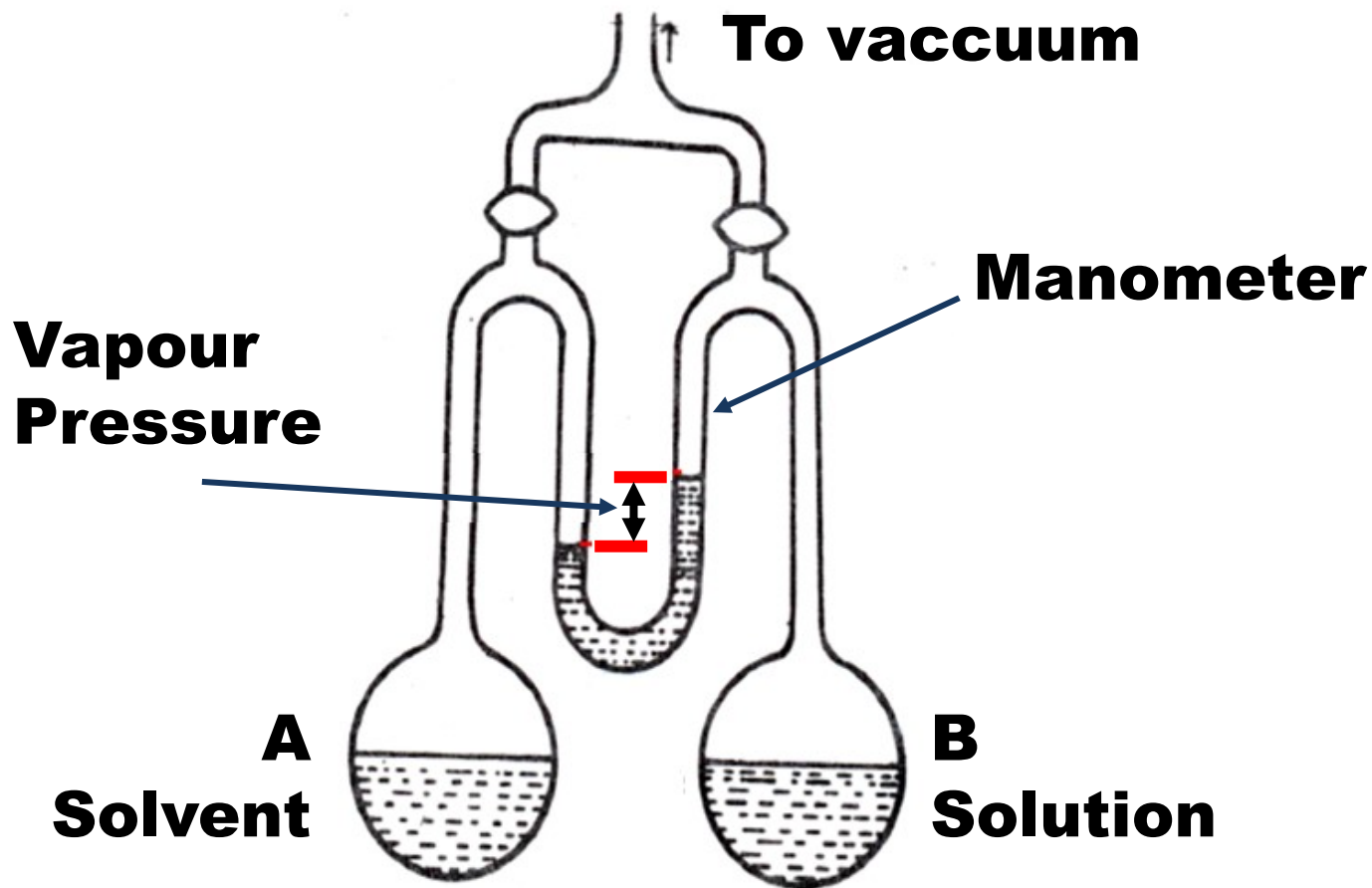
- NOTE:

➤ The **vapor pressure** of the solution (26.91 torr), is now **intermediate between** the vapor pressure of pure water (**23.8 torr**) and pure ethanol (58.7 torr).

➤ That the **VP solution** is closer to the **VP of water** is consistent with the fact that the solution consists of over **90% water** (mole fraction).

How to determine VP

Method 1: Static method

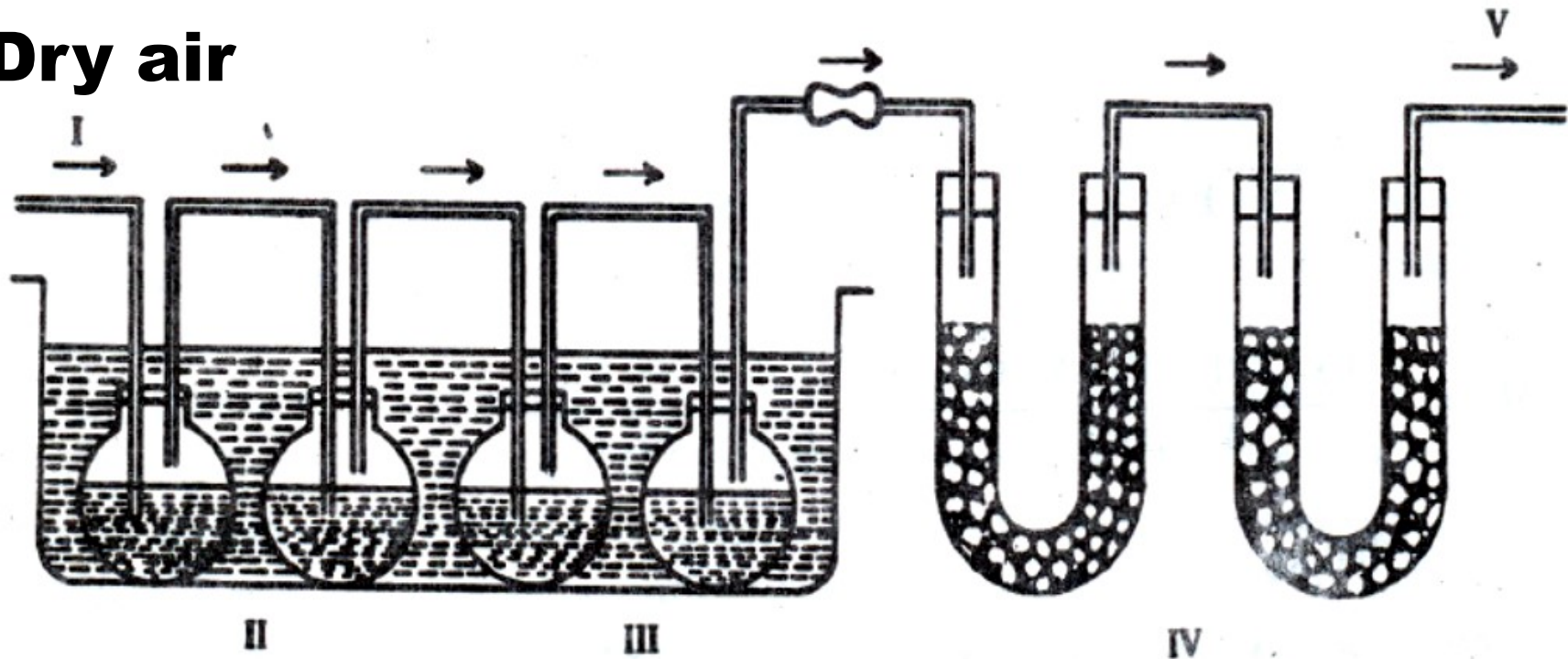


How to determine VP...cont.

Method 2: Dynamic method

**dry air
solution**

Dry air



**solution
bulbs**

W_A

**solvent
bulbs**

W_B

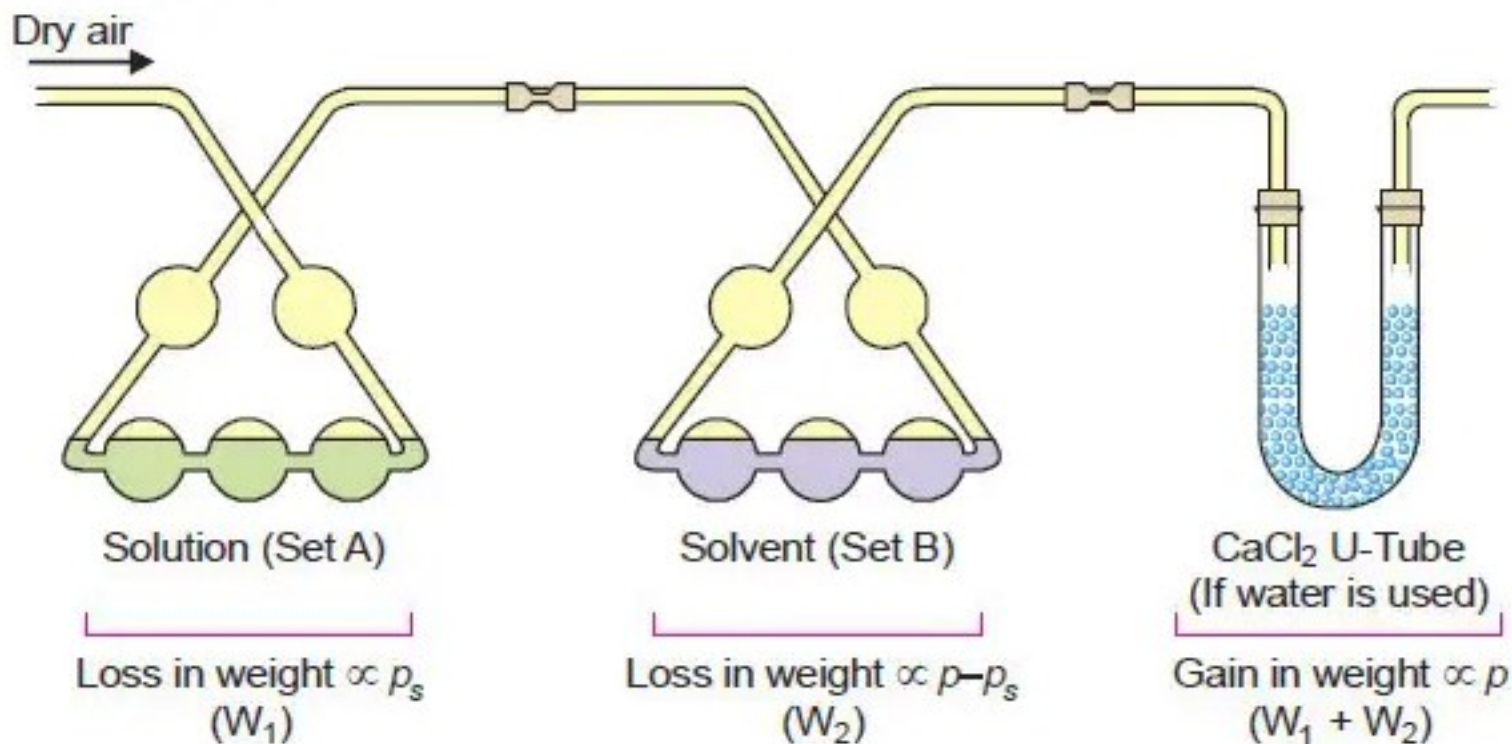
**weighed CaCl₂
tubes**

$W_A + W_B$



How to determine VP...cont.

Method 2: Dynamic method



Ostwald-Walker method of measuring the relative lowering of vapour pressure.



Determine VP...Method 2...cont.

If w_B is the wt loss by solvent bulbs and P° is the VP of the pure solvent, then

$$W_A \propto P \quad (1)$$


$$W_B \propto P^\circ - P \quad (2) \quad \text{OR}$$

$$W_B = P^\circ - P \quad (3) \quad \text{Add (1) and (2)}$$

$$(W_A + W_B) \propto P + (P^\circ - P) \quad (4)$$

$$W_A + W_B \propto P^\circ \quad (5) \quad \text{OR}$$


$$W_B + W_B = P^\circ \quad (6) \quad \text{Equation (3) divided by (6)}$$


$$\left(\frac{P^\circ - P}{P^\circ}\right) = \left(\frac{W_B}{W_A + W_B}\right) \quad (7)$$

If we know W_A and W_B we can find P (VP Lowering)


• Determination of MM from VP

• Remember.....

$$\frac{p^0 - p}{p^0} = X_2 = \frac{n_2}{n_1 + n_2}$$

**n = moles of solute
or solvent**

For a **very dilute solution n_2 is negligible and can be ignored in the denominator)**


$$n_2 = \frac{n_2}{n_1} = \frac{\left(\frac{m_2}{MM_2}\right)}{\left(\frac{m_1}{MM_1}\right)} = \frac{m_2 \times MM_1}{MM_2 \times m_1}$$

**M = measured mass (g)
MM = molar mass (g/mol)
1 = Solvent
2 = Solute**


$$\frac{p^0 - p}{p^0} = \frac{m_2 \times MM_1}{MM_2 \times m_1}$$

Example 1: Calc. MM from VP...

The vapour pressure of a solution containing 0.012 kg of a solute dissolved in 0.100 kg of water at 300 K is 3.50×10^3 Pa. Calculate the molar mass of the solute, if the vapour pressure of water at 300 K is 3.70×10^3 Pa.

Analyse:

$$M_1 = 0.1 \text{ kg}; \quad M_2 = 0.012 \text{ kg}$$


$$MM_1 = 0.018 \text{ kg/mol}; \quad MM_2 = ??$$

$$P^\circ = 3.7 \times 10^3 \text{ Pa}; \quad P = 3.5 \times 10^3 \text{ Pa}$$



Example 1: Calc. MM from VP....

The vapour pressure of a solution containing **0.012 kg** of a solute dissolved in **0.100 kg of water** at 300 K is **$3.50 \times 10^3 \text{ Pa}$** . Calculate the molar mass of the solute, if the vapour pressure of water at 300 K is **$3.70 \times 10^3 \text{ Pa}$** .

Solve:

Remember the equation:

$$\left(\frac{P^0 - P}{P^0} \right) = \left(\frac{m_2 \times MM_1}{MM_2 \times m_1} \right)$$

$$\left(\frac{3.70 \times 10^3 \text{ Pa} - 3.50 \times 10^3 \text{ Pa}}{3.70 \times 10^3 \text{ Pa}} \right) = \left(\frac{0.012 \text{ kg} \times 0.018 \text{ kg/mol H}_2\text{O}}{MM_2 \times 0.1 \text{ kg H}_2\text{O}} \right)$$


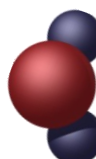
Example 1: Calc. MM from VP....

The vapour pressure of a solution containing **0.012 kg** of a solute dissolved in **0.100 kg of water** at 300 K is **3.50×10^3 Pa**. Calculate the molar mass of the solute, if the vapour pressure of water at 300 K is **3.70×10^3 Pa**.

Solve:

$$\left(\frac{200 \text{ Pa}}{3.70 \times 10^3 \text{ Pa}} \right) = \left(\frac{0.012 \text{ kg} \times 0.018 \text{ kg H}_2\text{O}}{\text{MM}_2 \times 0.1 \text{ kg H}_2\text{O}} \right)$$

Cross multiply and divide by the partner of MM_2


$$\text{MM}_2 = \left(\frac{3.70 \times 10^3 \text{ Pa H}_2\text{O} \times 0.012 \text{ kg} \times 0.018 \text{ kg/mol H}_2\text{O}}{200 \text{ Pa} \times 0.1 \text{ kg H}_2\text{O}} \right)$$


Example 1: Calc. MM from VP....

The vapour pressure of a solution containing **0.012 kg** of a solute dissolved in **0.100 kg of water** at 300 K is **3.50×10^3 Pa**. Calculate the molar mass of the solute, if the vapour pressure of water at 300 K is **3.70×10^3 Pa**.

Solve:

$$MM_2 = \left(\frac{3.70 \times 10^3 \text{ Pa H}_2\text{O} \times 0.012 \text{ kg} \times 0.018 \text{ kg/mol H}_2\text{O}}{200 \text{ Pa} \times 0.1 \text{ kg H}_2\text{O}} \right)$$

$$MM_2 = \left(\frac{0.7992}{0.02} \right) = 0.03996 \frac{\text{kg}}{\text{mol}}$$

$$MM_2 = 39.96 \frac{\text{g}}{\text{mol}} \text{ solute}$$



Example 2: MM from VP...cont

A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.

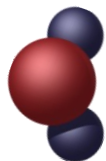
The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g. The Molar Mass of ether is 74 g/mol

What is the molecular mass of benzoic acid?

Analyze

 **$W_2 = 0.0345$ g Benzoic acid ; $W_1 = 0.645$ g Ether**

MM ether = 74 g/mol; MM benzoic acid = ??



Practice 2: MM from VP...cont

A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.


The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g.


What is the molecular mass of benzoic acid ?

Solve: Remember the equation???

$$\left(\frac{P^o - P}{P^o} \right) = \left(\frac{W_B}{W_A + W_B} \right)$$

Substitute


$$\left(\frac{P^o - P}{P^o} \right) = \left(\frac{0.0345 \text{ g Benzoic acid}}{0.645 \text{ g Ether} + 0.0345 \text{ g Benzoic acid}} \right)$$


$$\left(\frac{P^o - P}{P^o} \right) = 0.0507$$

Practice 2: MM from VP...cont



A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.

The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g.

What is the molecular mass of benzoic acid ?

Remember the Raoult's Law???

$$\frac{p^0 - p}{p^0} = x_2 = \frac{\left(\frac{m_2}{MM_2} \right)}{\left(\frac{m_1}{MM_1} + \frac{m_2}{MM_2} \right)}$$


$$0.0507 = \frac{\left(\frac{m_B}{MM_B} \right)}{\left(\frac{m_A}{MM_A} + \frac{m_B}{MM_B} \right)}$$

M = measured mass

MM = Molar mass

A = Solvent = Ether

B = Solute = Benzoic acid



Practice 2: MM from VP...cont

A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.

The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g.

What is the molecular mass of benzoic acid ?

Substitute values into Raoult's equation

$$0.0507 = \frac{\left(\frac{2.64}{MM_B} \right)}{\left(\frac{30}{74} + \frac{2.64}{MM_B} \right)}$$

$$\frac{2.64}{MM_B} = 0.0507 \left(\frac{30}{74} + \frac{2.64}{MM_B} \right)$$

Practice 2: MM from VP...cont

A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.

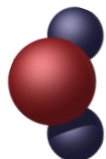
The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g.

What is the molecular mass of benzoic acid ?

$$\frac{2.64}{MM_B} = 0.0507 \frac{2.64}{MM_A} + 0.0507 \frac{30}{74}$$

Collect like terms

$$\frac{2.64}{MM_B} - \frac{0.1338}{MM_B} = \frac{1.521}{74}$$



Practice 2: MM from VP...cont

A current of dry air was passed through a solution of 2.64 g of benzoic acid in 30.0 g of Ether and then through pure ether.

The loss in weight of the solution was 0.645 g and that of the Ether was 0.0345 g.

What is the molecular mass of benzoic acid ?

$$\frac{2.64}{MM_B} - \frac{0.1338}{MM_A} = \frac{1.521}{74}$$

$$\frac{2.5064}{MM_B} = 0.0206$$



$$MM_B = \frac{2.5064}{0.0206} = 121.66 \text{ g/mol Benzoic acid}$$



Exercise: MM from VP...cont

A stream of dry air was passed through a bulb containing a solution of 7.50 g of an aromatic compound in 75.0 g of water and through another globe containing pure water. The loss in mass in the first globe was 2.810 g and in the second globe it was 0.054 g.

Calculate the molecular mass of the aromatic compound. (Mol mass of water = 18

Solve:

Answer = 93.6 g/mol Aromatic compound



Conclusion

REMEMBER the following:

What colligative property is

Types of colligative properties

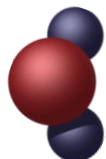
Molality

Raoult's law

Vapour pressure (VP)

How to determine VP

MM from VP



Conclusion

See you next class.

Watch the video as many times as possible and practice the questions

Thank you

