Osmosis is the diffusion of a fluid through a semipermeable membrane. When a semipermeable membrane (animal bladders, skins of fruits and vegetables) separates a solution from a solvent, then only solvent molecules are able to pass through the membrane. The osmotic pressure of a solution is the pressure difference needed to stop the flow of solvent across a semipermeable membrane. The osmotic pressure of a solution is proportional to the molar concentration of the solute particles in solution.

\[
\Pi = \frac{nRT}{V} = MM \cdot RT
\]

where

- \(\Pi\) is the osmotic pressure,
- \(R\) is the ideal gas constant (0.0821 L atm / mol K),
- \(T\) is the temperature in Kelvin,
- \(n\) is the number of moles of solute present,
- \(V\) is the volume of the solution (\(\frac{n}{V}\) is then the molar concentration of the solute), and
- \(MM\) is the molar mass of the solute.

**Introduction**

**What is osmotic pressure?** Semipermeable membranes do not let the solute pass through. (Think of the sugar example). A solvent will move to the side that is more concentrated to try to make each side more similar! Since there is a flow of solvents, the height of each side changes, which is *osmotic pressure*. When we work with aqueous solutions, we use mm of H\(_2\)O to describe the difference.

**Lowered Vapor Pressure**

Liquid molecules at the top of a liquid can switch into the gas phase if enough energy breaks their intermolecular forces. But vaporization can go either way when this happens. We don't need to know what the solvent or the solute is made up of, to know that the vapor pressure has to be lower for a solution compared to the pure solvent. So the reason vapor pressure lowering is a colligative property is because we are only interested in how many solute particles dissolve! As *Raoult's law* states that the vapor pressure depends on all the elements of each chemical and the mole fraction that make up the total solution. We can see that lowering the vapor pressure is related to concentration.

Example

What is the vapor pressure of the pure solvent if the vapor pressure of a solution of 10 g of glucose \((C_6H_{12}O_6)\) in 100 g of ethanol \((C_2H_6O)\) is 55 mmHg?

**SOLUTION**

1. Use *Raoult's law*
2. Rearrange the equation to solve for the pressure of the pure solvent, \(P_0\).
3. After converting the gram amounts to moles we find that the mole fraction of the solvent ethanol is 0.975.
4. Solution = vapor pressure of the solvent is 56.4 mmHg.
Problems

1. Calculate osmotic pressure for 0.10 M $\text{Na}_3\text{PO}_4$ at 20°C.

2. Calculate molarity if solution in water (300 K) has osmotic pressure of 3.00 atm.

3. Hemoglobin is a large molecule that carries oxygen in human blood. A water solution that contains 0.263 g of hemoglobin (Hb) in 10.0 mL of solution has an osmotic pressure of 7.51 torr at 25°C. What is the molar mass of the hemoglobin?

Solution

1. $M = \dfrac{\Pi}{RT} = \dfrac{3.00\text{atm}}{(0.0821 \text{ atm.L/mol.K})(300\text{K})} = 0.122\text{M}$

2. Since $\text{Na}_3\text{PO}_4$ ionizes into 4 particles (3 Na+1 + $\text{PO}_4^{-3}$), the ion concentration is 0.40 M $\Pi = MRT$

   \[ = (0.40)(0.0821)(293) = 9.6 \text{ atm} \]

3. $6.51 \times 10^4 \; \text{g/mol}$

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