

Mass Transfer-I

Interphase Mass Transfer



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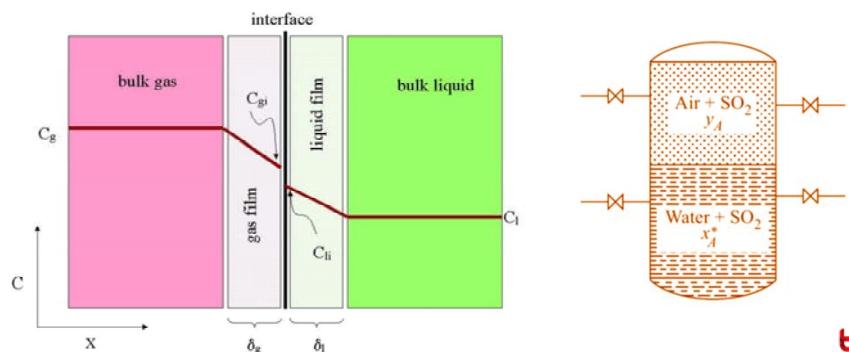
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Interphase Mass Transfer

Interphase mass transfer

The process of mass transfer from the bulk of one phase to the interphase surface and then from the interphase to the bulk of another phase is called interphase mass transfer.



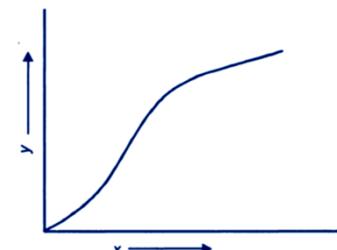
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Equilibrium

Equilibrium between phases: Equilibrium between phases in contact means a state in which there is no net transfer of the solute from one phase to the other. At equilibrium, the chemical potential of the solute in the two phases are equal.

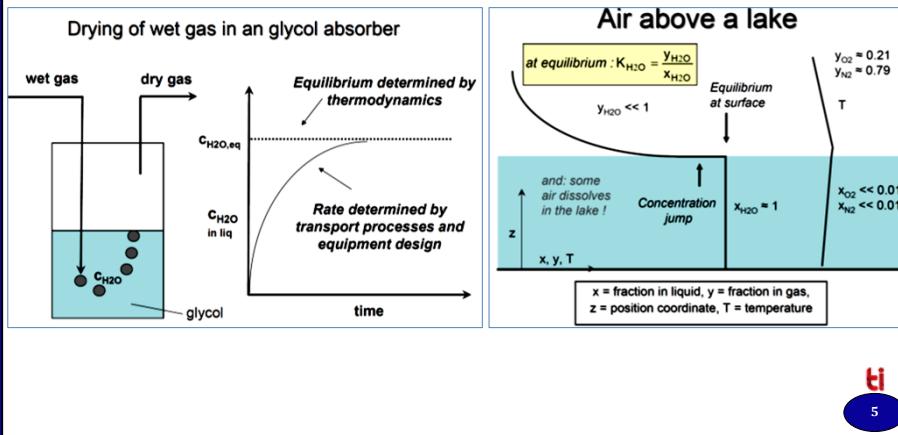
- The equilibrium data set are associated with temperature and pressure conditions and follow the **Phase rule**.
- If the two phases are at equilibrium there is no net transfer of the solute from one phase to the other.
- If the two phases are not in equilibrium, mass transfer from **phase I** to **phase II** occurs as long as the concentration of the solute in **phase II** is lower than the equilibrium concentration.



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Homogeneous mixture (Solution)

A solution is a homogeneous mixture of two or more substances. A solution can exist in any phase

The major component in a solution is termed solvent (A) and all other constituents are solute(s) (B, C...).

For solutes to be soluble in a solvent their intermolecular forces (IMF) holding the solvent molecules (A-A) to form the condensed state must be broken to accommodate the solute particles. Also the forces holding the solute together (B-B) must be broken as well. These steps demand energy. The solute and solvent molecules then should then interact to make the 'accommodation' possible. That requires a release of energy that would compensate or exceed the total energy demand.

Vapor: gas phase molecule evaporated from solvent.
Gas: gas phase molecule of a different type than from the solvent

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Ideal solution

- The average intermolecular forces of attraction and repulsion in the solution are unchanged on mixing the pure liquids
- The volume of the solution varies linearly with composition
- There is neither absorption nor evolution of heat in mixing the liquids
- The total vapour pressure of the solution varies linearly with composition (in mole fraction)
- Ideality requires that molecules be similar in size, structure, and chemical nature: the nearest approach is the optical isomers. In practice, for engineering purposes, many solutions or organic compounds in a homologous series considered approximately ideal.

Ideal solutions include:

- Very dilute solutions (no electrolyte/ions)
- Mixtures of similar compounds (benzene + toluene)
- Pure substance: Vapour Pressure P^* at particular T

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Raoult's law

Raoult's law has been named after *François-Marie Raoult*, a French chemist who while conducting an experiment found out that when substances were mixed in a solution, the vapour pressure of the solution decreased simultaneously. Raoult's law was established in the year 1887 and is also considered as the law of thermodynamics.

It states that

"The partial pressure of each component of an ideal mixture/ solution of liquids is equal to the vapour pressure of the pure component multiplied by its mole fraction in the mixture".

Raoult's law for a single component in an ideal solution is stated as

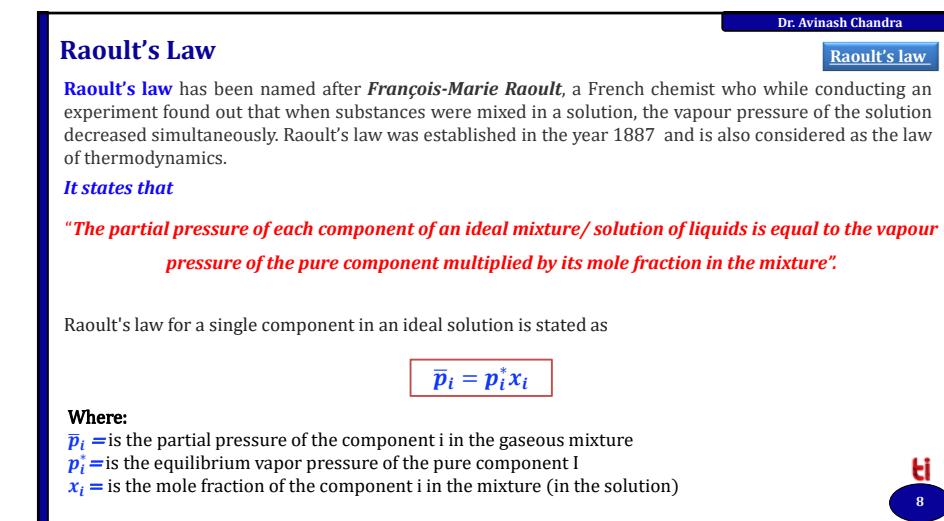
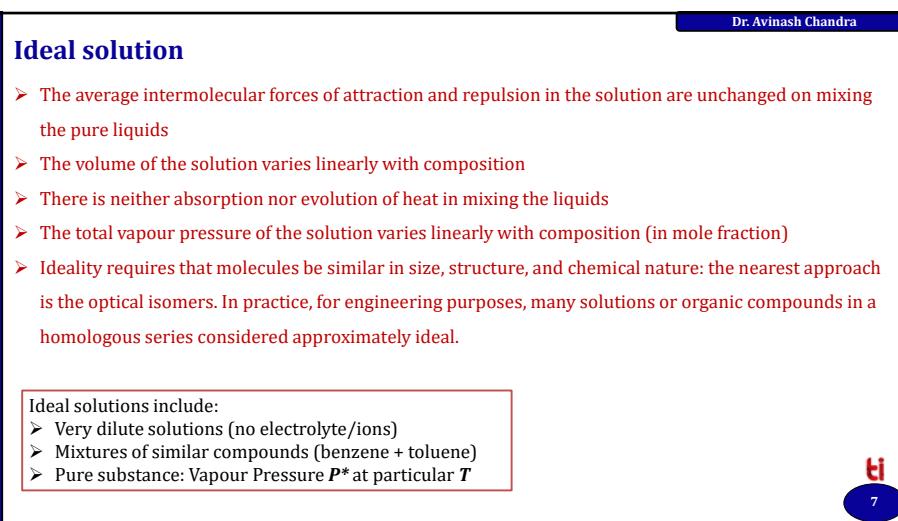
$$\bar{p}_i = p_i^* x_i$$

Where:

\bar{p}_i = is the partial pressure of the component i in the gaseous mixture

p_i^* = is the equilibrium vapor pressure of the pure component i

x_i = is the mole fraction of the component i in the mixture (in the solution)

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Where two volatile liquids A and B are mixed with each other to form a solution, the vapour phase consists of both components of the solution.

If P = Total pressure of the solution of component A & B

Dalton's law of partial pressures $P = \bar{p}_A + \bar{p}_B$

If the components in the solution reaches equilibrium, Then, the total vapor pressure of the solution can be determined by combining Raoult's law with Dalton's law

$$P = p_A^* x_A + p_B^* x_B$$

If a non-volatile solute (zero vapor pressure, does not evaporate) is dissolved into a solvent to form an ideal solution, the vapor pressure of the final solution will be lower than that of the solvent.

In consequence, the relative lowering of vapour pressure of a dilute solution of nonvolatile solute is equal to the mole fraction of solute in the solution.

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Henry's Law

Henry's Law

Henry's law has been named after English chemist *William Henry* (1803).

It states that

"The equilibrium partial pressure of component A of a non-ideal gas-liquid system at low concentration is directly proportional to its mole fraction of component A in the liquid".

$$p_A^* = H x_A$$

Where:

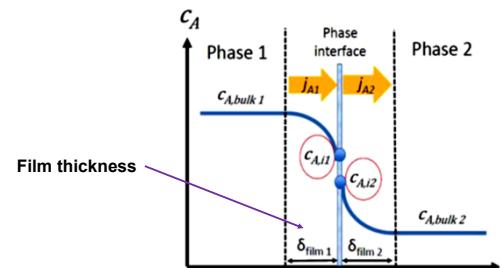
H = Henry constant

p_A^* = is the equilibrium partial pressure of the pure component I

x_A = is the mole fraction of the component A in the mixture (in the solution)

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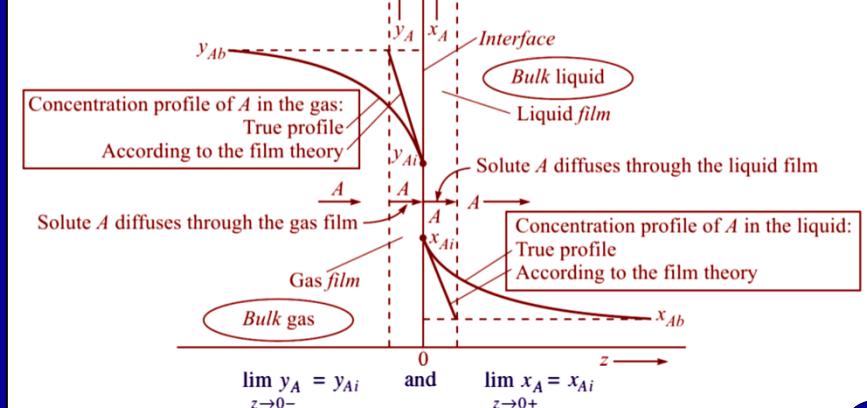
- On two sides of the interface, there exist two effective films of certain thickness, component A passes through these two film by molecular diffusion.
- At the interface, the gas is in equilibrium with liquid.
- The concentration gradients in the two bulk phases equal to zero.

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Interfacial concentration

As per two-film theory:

- The equilibrium concentrations y_{Ai} and x_{Ai} are obtained from the standard equilibrium distribution curve.

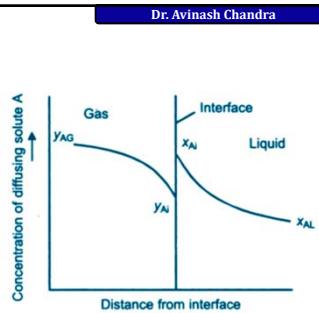
$$y_{Ai} = f(x_{Ai})$$

- At steady state, the mass transfer rate at which A reaches the interface from the gas must be equal to the rate at which it diffuses to the bulk liquid, so that no accumulation or depletion of A at the interface occurs.
- Therefore the mass transfer flux of A in terms of mass transfer film coefficient for each phase can be written as

$$N_A = k_y(y_{AG} - y_{Ai}) = k_x(x_{Ai} - x_{AL})$$

Where

N_A = Flux at interface
 k_x, k_y = Mass transfer coefficients in liquid phase and gas phase
 x_{Ai}, y_{Ai} = Concentration mass (mole) friction



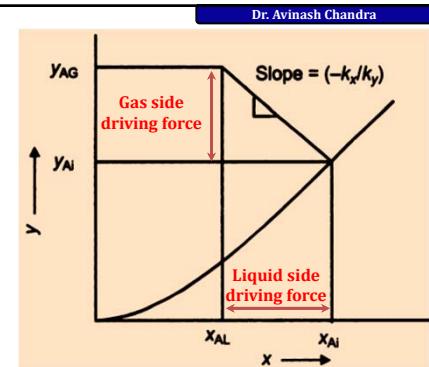
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$$N_A = k_y(y_{AG} - y_{Ai}) = k_x(x_{Ai} - x_{AL})$$

After rearrangement

$$\frac{(y_{AG} - y_{Ai})}{(x_{Ai} - x_{AL})} = -\frac{k_x}{k_y}$$



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- Since the equilibrium distribution curve for the system is unique at a fixed temperature and pressure.
- The entire two phase mass transfer effect can be measured in terms of an **overall mass-transfer coefficient, K**.

References

- Lecture notes/ppt of Dr. Yahya Banat (ybanat@qu.edu.qa)

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Thank you for your kind attention!!!