THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Mass Transfer-I

Gas Absorption

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Gas Absorption

Examples of industrial gas absorption process

	Example	Industry/Purpose	Solvent
1.	Absorption of SO_3	Production of sulphuric acid and oleum	98% H_2SO_4/Concentrated H_2SO_4
2.	Absorption of H_2S	Treatment of sour natural gas	Mono- or diethanol amine
3.	Drying of a gas	Air for sulphur burning	Concentrated H_2SO_4
		Drying of natural gas	Di- and tri-ethylene glycol
4.	Absorption of ammonia	Ammoniation of brine in a soda ash plant	Brine
		Ammonia removal/recovery from the coke oven gas	Water or dilute H_2SO_4
5.	Absorption of SO_2 from flue gases	Pollution abatement	Lime slurry
6.	Absorption of NO_2	Nitric acid manufacture	Water
7.	Absorption of acrylonitrile	Manufacture of acrylonitrile by ammoxidation of propylene	Water
8.	Absorption of oxygen from air	Aerobic bioreactor	Fermentation broth, Waste water
9.	Absorption of ethylene oxide	Ethylene oxide manufacture	Water
10.	Absorption of HF	Pollution control in phosphoric acid and phosphatic fertilizer plants	Water, dilute alkali
11.	Absorption of HCl gas	Hydrochloric acid production	Water
12.	Absorption of CO_2	CO_2 removal from the synthesis gas in an ammonia plant	Aqueous alkanolamines, Sodium carbonate-bicarbonate buffer solution with a dissolved catalyst
13.	Absorption of light hydrocarbons	Refineries	Absorption oil
14.	Absorption of formaldehyde and methanol	Production of formaldehyde by air-oxidation of methanol	Water
15.	Absorption of aromatics (benzene, naphthalene, etc.)	Recovery of the substances from raw coal gas	Absorption oil

Absorption (gas absorption, gas scrubbing, gas washing)

- A gas mixture is contacted with a liquid (absorbent or solvent) to selectively dissolve one or more components (solutes or absorbates) by mass transfer from the gas to the liquid mass transfer from the gas to the liquid
- Used to separate gas mixtures; remove impurities, contaminants, pollutants, or catalyst poisons from a gas; or contaminants, pollutants, or catalyst poisons from a gas; or recover valuable chemicals
- ***Example:*** removal of H_2S and CO_2 from natural gas using MEA (mono-ethanolamine)

Stripping (desorption)

- A liquid mixture is contacted with a gas to selectively remove components by mass transfer from the liquid to the gas
- ***Example:*** removal of H_2S from sour crude oil

Absorber are frequently coupled with strippers to permit regeneration (or recovery) and recycling of the absorbent because stripping is not perfect, recycled absorbent contains solutes (absorbates)

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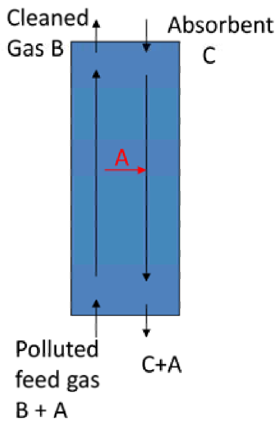

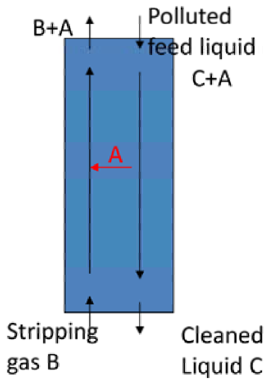

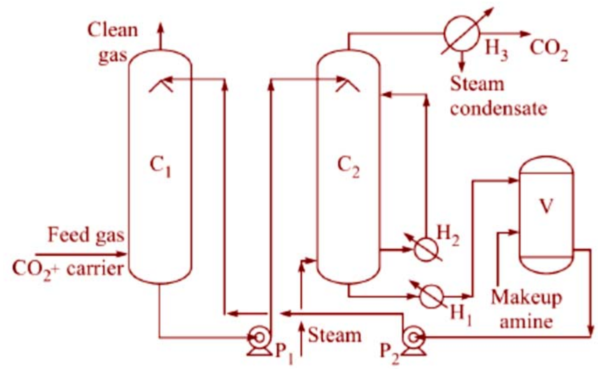

- **Three** components
  - Inert gas B (e.g., air)
  - Inert liquid C (e.g., water)
  - Solute A (e.g., CO2) goes from gas -> liquid
- Two feeds
- One pure product (at most)
- One section
- Non-boiling mixture
  - so p and T can be set independently; see Exercise

Stripping: Reverse of absorption.
Solute A goes from liquid -> gas

Ideal Liquid Solutions

There are four significant characteristics of ideal solutions

1. The average intermolecular forces of attractions and repulsion in the solution are unchanged on mixing the constituents.
2. The volume of the solutions varies linearly with composition.
3. There is neither absorption nor evolution of heat in mixing the constituents (for gases dissolving in liquids. Heat of condensation is not included in this criterion).
4. The total vapor pressure of the solution varies linearly with composition expressed as mole fractions.

Choice of solvent

1. Solubility
2. Volatility
3. Viscosity
4. Corrosiveness
5. Cost
6. Hazard and toxicity

Finally The solvent should be nontoxic , nonflammable, chemically stable and should have a low freezing point

Gas Absorption-Single Stage

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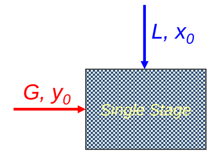
Absorption-Single Stage

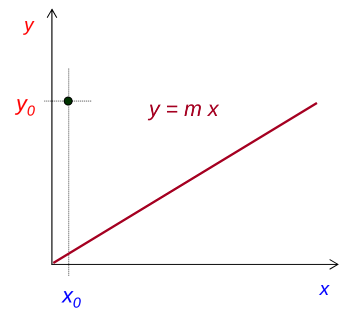
This is the gas inlet. The gas has a certain concentration of solute, represented by the molar fraction, yo.

The solvent is put in contact with the gas phase. The solvent can be pure or can have a certain concentration of solute, represented by x_o.

The equilibrium between phases can be represented in a x-y diagram for a given temperature and pressure. Sometimes the equilibrium is a straight line, $y = m\,x$

The inlet compositions of the two phases can be represented in the diagram





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The content of solute in the gas is now lower than at the entrance: $y < y_o$

The solvent is now charged in solute, so that $x > x_o$.

Because this is an ideal equilibrium stage, the equilibrium between phases is reached.

The mass balance equation is:

Total mass of solute at the inlet:

$$= L \cdot x_o + G \cdot y_0$$

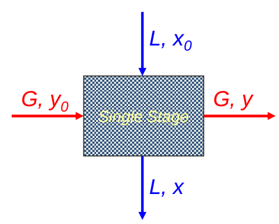
Total mass of solute at the outlet:

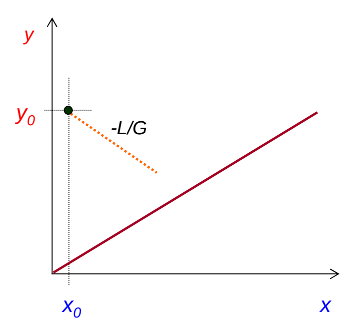
$$= L \cdot x + G \cdot y$$

Solving with respect to y yields:

$$\boxed{y = \left(y_0 + \frac{L}{G} \cdot x_0\right) - \frac{L}{G} \cdot x}$$

The slope of the operating line is then ($-L/G$)





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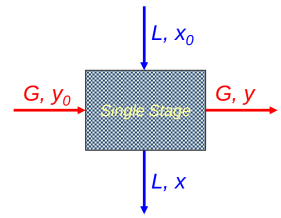
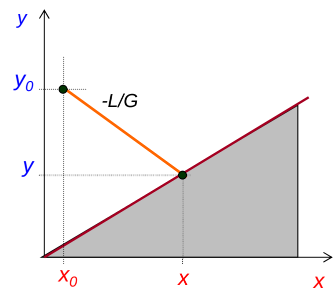
Because this is an equilibrium stage, the equilibrium between phases is reached, so the operating line goes to the equilibrium line.



$$y = \left(y_0 + \frac{L}{G}\cdot x_0\right) - \frac{L}{G}\cdot x$$

The equilibrium line represents a barrier and determines a region of values *(x, y)* that cannot be reached for any ratio *(L/G)*



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Using the equilibrium equation and the operating line, one can get the value of *y* corresponding to the intersection.

$$y = m\,x \qquad y = \left(y_0 + \frac{L}{G}x_0\right) - \frac{L}{G}x$$

$$y = \left(y_0 + \frac{L}{G}x_0\right) - \frac{L}{G}\frac{y}{m}$$

$$y = \left(y_0 + \frac{L}{G}\frac{m\,x_0}{m}\right) - \frac{L}{G}\frac{y}{m}$$

By definition the ratio (*L/Gm*) is called absorption factor A.

$$A = \frac{L}{G\,m}$$

So the expression can be written in terms of *A*.

$$y = (y_0 + A\,m\,x_0) - A\,y$$

Using the equilibrium equation, the product $m.x_o$ can be replaced by y_o*, or composition of a gas at equilibrium with a liquid of composition x_o.

$$y_0^* = m\,x_0 \qquad y = (y_0 + A\,y_0^*) - A\,y$$

So the outlet composition of the gas, y is now given in terms of *A*.

$$\boxed{y = \frac{y_0 + A\,y_0^*}{1 + A}}$$

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Cont…

Using the equilibrium equation and the operating line, one can get the value of *y* corresponding to the intersection.

$$y=\left(y_0+\frac{L}{G}x_0\right)-\frac{L}{G}\frac{y}{m}$$

$$y=\left(y_0+\frac{L}{G}\frac{m\,x_0}{m}\right)-\frac{L}{G}\frac{y}{m}$$

By definition the ratio (L/Gm) is called absorption factor A.

$$A=\frac{L}{G\,m}$$

So the expression can be written in terms of *A*. $y_0^*=m\,x_0$

$$y=(y_0+A\,m\,x_0)-A\,y$$

Using the equilibrium equation, the product $m.x_o$ can be replaced by y_o^*, or composition of a gas at equilibrium with a liquid of composition x_o.

$$y=(y_0+A\,y_0^*)-A\,y$$

So the outlet composition of the gas, y is now given in terms of *A*.

$$\boxed{y=\frac{y_0+A\,y_0^*}{1+A}}$$

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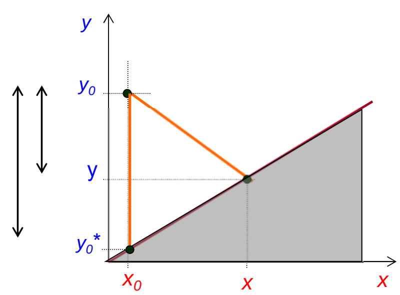
Cont…

The fraction of absorption α is defined as the ratio:

$$\boxed{\alpha=\frac{y_0-y}{y_0-y_0^*}}$$



Where the numerator is the distance between y_o and *y* And the denominator is the distance between y_o and the composition of gas at equilibrium with x_0. This represents the maximum solute exchange.

$$\alpha=\frac{y_0-y}{y_0-y_0^*}=1-\frac{1}{1+A}$$

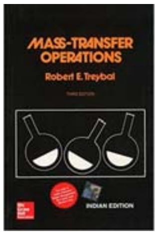
The fraction of absorption can also be written in terms of the absorption factor, A

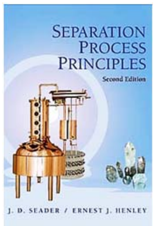
$$A\to 0 \qquad \alpha\to 0 \qquad y\to y_0$$

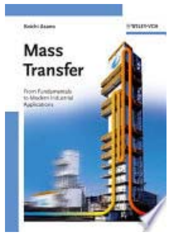
$$A\to\infty \qquad \alpha\to 1 \qquad y\to y_0^*$$

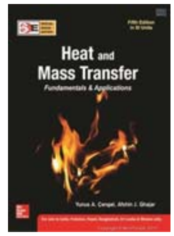
y_0^* represents the minimum concentration of solute in the gas phase, so the maximal absorption (*A* tends to infinity)

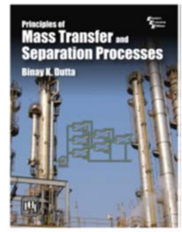
References

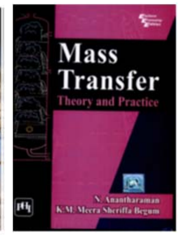












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Mass Transfer

Theories for Mass Transfer Coefficients

Lecture 9, 15.11.2017, Dr. K. Wegner

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

CHEMICAL ENGINEERING AND CHEMICAL PROCESS TECHNOLOGY – Vol. II - *Mass Transfer Operations: Absorption And Extraction* - José Coca, Salvador Ordóñez and Eva Díaz

MASS TRANSFER OPERATIONS: ABSORPTION AND EXTRACTION

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