

Calculation of Number of Transfer Unit (NOG):

A. For Linear Equilibrium Relationship ($Y^* = m X$):

$$\text{NOG} = \int_{Y_2}^{Y_1} \frac{dY}{(Y - Y^*)} \dots \dots \dots (1)$$

$$Y^* = m X \dots \dots \dots (2)$$

$$G_s (Y - Y_2) = L_s (X - X_2) \dots \dots \dots (3)$$

$$\implies X = \frac{G_s}{L_s} (Y - Y_2) + X_2$$

For pure liquid solvent used then, $X_2 = 0$

$$X = \frac{G_s}{L_s} (Y - Y_2) \dots \dots \dots (4)$$

Substitution Eq.(4) into Eq.(2) to get:

$$Y^* = \frac{m G_s}{L_s} (Y - Y_2) \dots \dots \dots (5)$$

Substitution Eq.(5) into Eq.(1) to get:

$$\text{NOG} = \int_{Y_2}^{Y_1} \frac{dY}{(Y - \frac{m G_s}{L_s} (Y - Y_2))}$$

Let: $\frac{m G_s}{L_s} = \phi = \frac{\text{Slope of equilibrium line}}{\text{Slope of operating line}} = \frac{m}{L_s/G_s} < 1.0$

$$\text{NOG} = \int_{Y_2}^{Y_1} \frac{dY}{Y - \phi Y + \phi Y_2}$$

$$\text{NOG} = \int_{Y_2}^{Y_1} \frac{dY}{(1 - \phi)Y + \phi Y_2}$$

$$\text{NOG} = \frac{1}{(1 - \phi)} \ln \left[\frac{(1 - \phi)Y_1 + \phi Y_2}{(1 - \phi)Y_2 + \phi Y_2} \right]$$

B. For Non-linear Equilibrium Relationship:

In this case the integration $[\text{NOG} = \int_{Y_2}^{Y_1} \frac{dY}{(Y-Y^*)}]$ will be solved using graphical method or

numerical method (Simpson rule) following steps below:

1. Draw the given equilibrium data.
2. Draw the operating line, from two points (X_1, Y_1) and (X_2, Y_2) or one point and slope of $(\frac{L_s}{G_s})$.
3. Create the table below by calculated (Y^*) from the plot as below:

Y	Y*	1
Assume points between (Y ₁ - Y ₂)	Calculated from plot	$\frac{1}{(Y - Y^*)}$
Y ₁	- calculated	$\sqrt{= f_0}$
- (assumed)	- calculated	$\sqrt{= f_1}$
- (assumed)	- calculated	$\sqrt{= f_2}$
- (assumed)	- calculated	$\sqrt{= f_3}$
Y ₂	- calculated	$\sqrt{= f_n}$

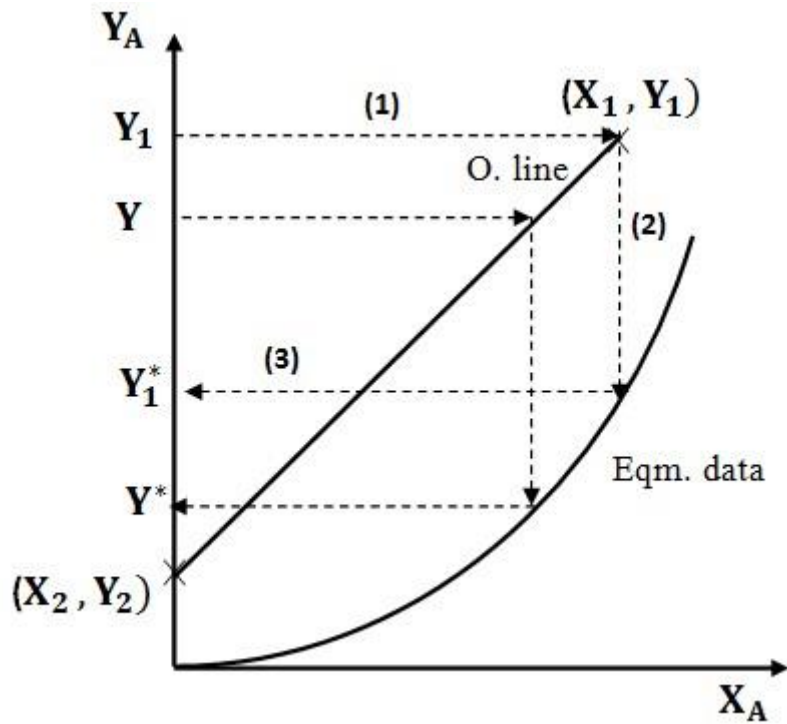
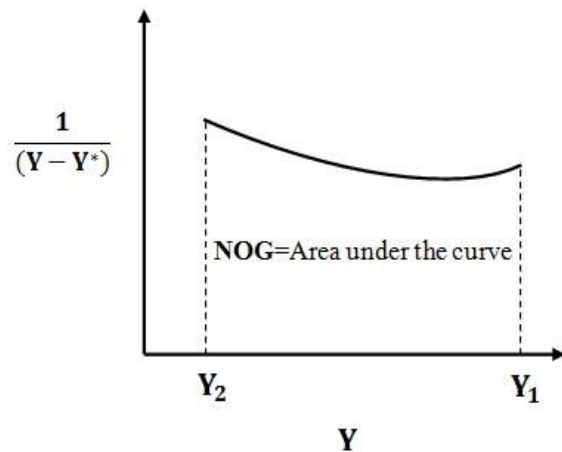


Figure: Calculation of (Y^*) for packed column.

4. To calculate **NOG** we draw $\left[\frac{1}{(Y-Y^*)}\right]$ Vs. $[Y]$ to find the area under the curve:

Where:

NOG = Area under the curve



Simpson rule for calculation of NOG:

NOG = Area under the curve

$$\text{NOG} = \frac{h}{3} f_0 + f_n + 2 f_{\text{even}} + 4 f_{\text{odd}}$$

Where:

$$h = \frac{Y_1 - Y_2}{n} \quad , \quad n = 2, 4, 6, 8, \dots \text{ etc}$$

Notes:

* If the entering solute concentration is dilute ($Y < 5\%$), then:

$$Y_A = y_A \quad , \quad X_A = x_A \quad , \quad G_s = G \quad , \quad L_s = L$$

* If the tower type is not mention in the problem we can take it as a packed tower.

Example (1):

Ammonia is to be removed from a 10 percent ammonia–air mixture by countercurrent scrubbing with water in a packed tower at 293 K so that 99 percent of the ammonia is removed when working at a total pressure of 101.3 kN/m². If the gas rate is 0.95 kg/m².s of tower cross-section and the liquid rate is 0.65 kg/m². s, find the necessary height of the tower if the absorption coefficient $K_{OG.a} = 0.008 \text{ kmol/m}^3\text{.s. kPa.}$, The equilibrium data are:

$$Y^* = 0.8 X .$$

Solution:

$$y_2 = (1 - \text{recovery}) y_1 = (1 - 0.99)(0.1) = 0.001$$

Convert mole fraction to mole ratio:

$$Y_1 = \frac{y_1}{1 - y_1} = \frac{0.1}{1 - 0.1} = 0.11$$

$$Y_2 = \frac{y_2}{1 - y_2} = \frac{0.001}{1 - 0.001} = 0.001$$

We can see that at low conc. (mole ratio = mole fraction):

$$\begin{aligned} \text{The gas mole flux, } \bar{G} &= \frac{\text{gas mass flux}}{\text{average gas molecular weight}} \\ &= \frac{0.95}{[(0.1)(17) + (0.9)(29)]} = 0.0341 \frac{\text{kmol}}{\text{m}^2 \cdot \text{s}} \end{aligned}$$

$$\begin{aligned} \text{The liquid mole flux, } \bar{L} &= \frac{\text{liquid mass flux}}{\text{average liquid molecular weight}} \\ &= \frac{0.65}{(18)} = 0.0361 \frac{\text{kmol}}{\text{m}^2 \cdot \text{s}} \end{aligned}$$

$$\text{the mole flux of the inert gas, } \bar{G}_s = \bar{G}(1 - y_1) = (0.0341)(1 - 0.1) = 0.0307 \frac{\text{kmol}}{\text{m}^2 \cdot \text{s}}$$

$$\text{the mole flux of the inert liquid, } \bar{L}_s = \bar{L}(1 - x_2) = (0.0361)(1 - 0) = 0.0361 \frac{\text{kmol}}{\text{m}^2 \cdot \text{s}}$$

Therefore, for pure solvent: $\bar{L}_s = \bar{L}$

$$\text{HOG} = \frac{\bar{G}_s}{K_o G. a. P_T} = \frac{0.0307}{(0.0008)(101.3)} = 0.38 \text{ m}$$

Since the equilibrium is linear:

$$\phi = \frac{m \bar{G}_s}{\bar{L}_s} = \frac{(0.8)(0.0307)}{(0.0361)} = 0.68$$

$$\mathbf{Z = HOG * NOG = (0.38)(11.19) = 4.25 \text{ m}}$$