Example (2):

Ammonia is to be removed from a 10 percent ammonia–air mixture by countercurrent absorption with water in a packed tower at 293 K. The outlet gas concentration from the top of the tower is 0.1%. The absorption tower is working at a total pressure of 101.3 kN/m^2. If the inlet gas is 0.034 $kmol/m^2.s$ and the liquid rate is 0.036 $kmol/m^2.s$, find the necessary height of the tower if the absorption coefficient KoG.a = 0.081 $kmol/m^3.s$. The equilibrium data is given by the following data:

kmol NH_3/kmol water:	0.021	0.031	0.042	0.053	0.079	0.106	0.159
Partial pressure NH_3 in gas phase (kN/m^2):	1.6	2.4	3.3	4.2	6.7	9.3	15.2

Solution:

First of all we have to convert the equilibrium data to mole ratio:

$$mole\ fraction\ of\ NH_3\ in\ gas\ phase\ , y_{NH_3} = \frac{P_A}{P_T} = \frac{\mathbf{1.6}}{101.3} = \mathbf{0.0158}$$

$$mole\ ratio\ of\ NH_3\ in\ gas\ phase\ , Y_{NH_3} = \frac{y_{NH_3}}{1 - y_{NH_3}} = \frac{0.0158}{1 - 0.0158} = \mathbf{0.0160}$$

The equilibrium data becomes:

$\mathbf{X_{NH_3}}$	0.021	0.031	0.042	0.053	0.079	0.106	0.159
$\mathbf{Y_{NH_3}}$	**0.0160**	0.0243	0.0337	0.0433	0.0708	0.1011	0.1765

$$HOG = \frac{\overline{G}_s}{KoG.a} = \frac{0.034}{0.081} = 0.419\ m$$

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

The equilibrium data may be not linear relation, so that the integration should be solved by plotting or by Simpson's rule as follows:

1. Draw the equilibrium data:
2. Draw the operating line from two points:
   (X_1, Y_1) and **(X_2, Y_2)**

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

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

Overall ammonia material balance:

$$\mathbf{\bar{G}_s\,(Y_1 - Y_2) = \bar{L}_s\,(X_1 - X_2)}$$

$$\mathbf{X_1} = \frac{\mathbf{\bar{G}_s}}{\mathbf{\bar{L}_s}}(\mathbf{Y_1} - \mathbf{Y_2}) + \mathbf{X_2} = \frac{\mathbf{0.034}}{\mathbf{0.036}}(\mathbf{0.11 - 0.001}) + \mathbf{0}$$

$$\mathbf{X_1} = 0.0935$$

Operating line:

(X_1, Y_1) = (0.0935, 0.11) = (9.35×10^{-2}, 10×10^{-2})

(X_2, Y_2) = (0, 0.001) = (0, 0.1×10^{-2})

We will solve the integration by Simpson's rule:

$$\mathbf{h} = \frac{\mathbf{Y_1 - Y_2}}{\mathbf{n}} \quad , \qquad \textit{We choose} \quad n = 4$$

$$\mathbf{h} = \frac{\mathbf{0.11 - 0.001}}{\mathbf{4}} = 0.02725$$

Calculate $\mathbf{Y^*}$ from the plot as follows:

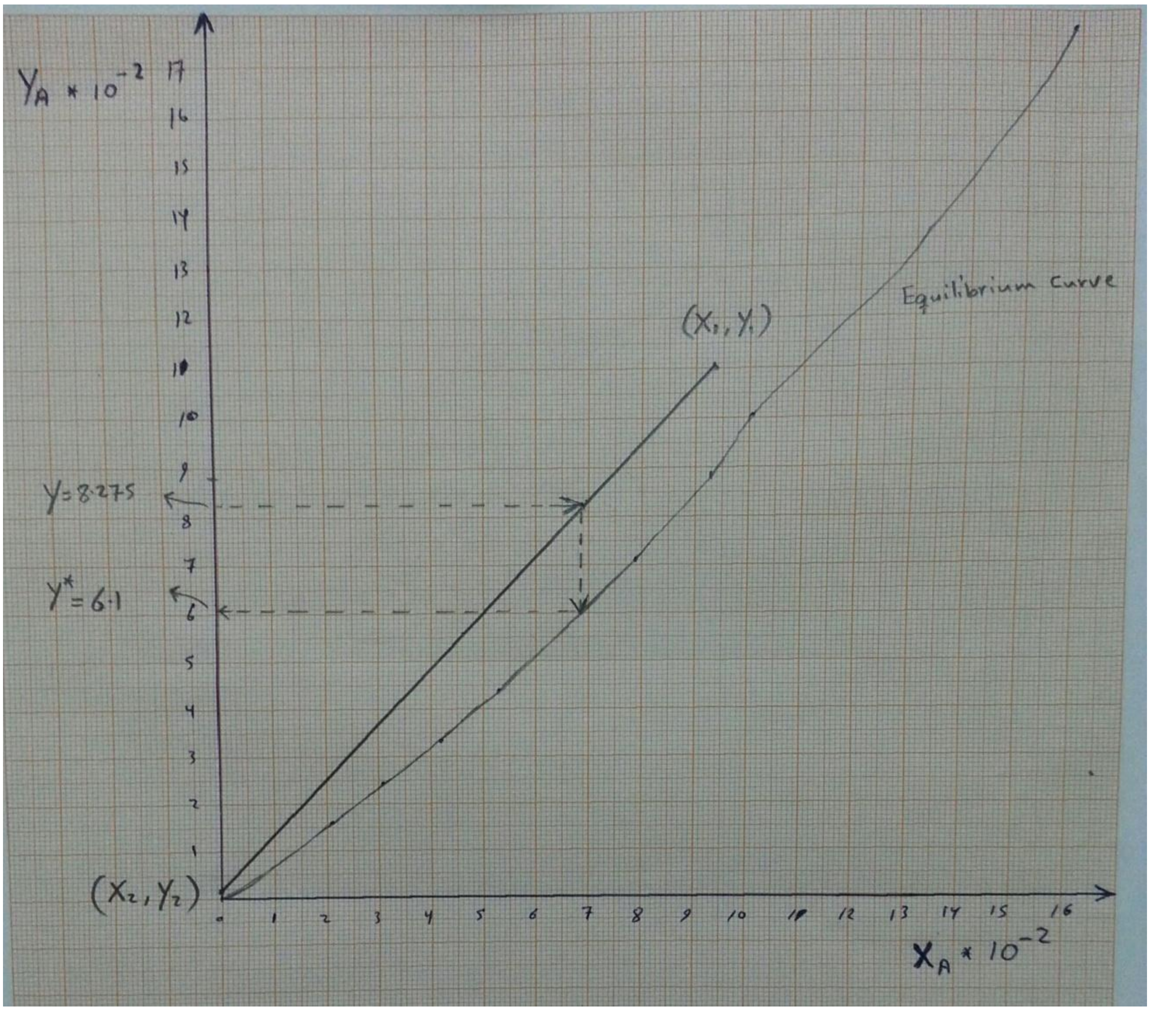
Y Assume points between (Y_1 - Y_2)	Y^* Calculated from plot	$\frac{1}{(Y - Y^*)}$
0.11	0.088	45.45 = f_0
0.08275	0.061	45.98 = f_1
0.05550	0.0375	55.56 = f_2
0.02825	0.0175	93.02 = f_3
0.001	0.00	1000 = f_n

$$\mathbf{NOG} = \frac{\mathbf{h}}{\mathbf{3}}\left[\mathbf{f_0} + \mathbf{f_n} + \mathbf{2}\sum \mathbf{f_{even}} + \mathbf{4}\sum \mathbf{f_{odd}}\right]$$

$$\mathbf{NOG} = \frac{0.02725}{\mathbf{3}}\ [\mathbf{45.45} + \mathbf{1000} + \mathbf{2}(\mathbf{55.56}) + \mathbf{4}[(\mathbf{45.98}) + (\mathbf{93.02})]]$$

$\mathbf{NOG} = 15.56$

Z = HOG * NOG = (0.419) (15.56) = 6.52 m



YA * 10^-2
XA * 10^-2
Equilibrium curve
(X1, Y1)
(X2, Y2)
Y = 8.275
Y* = 6.1