Mass Transfer Operations I
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Module - 4
Absorption
Lecture - 4
Packed Tower Design Part - 3

Welcome to the fourth lecture of module four; the module four is a n absorption. So, before going to this lecture, let us have a small recap of the previous lectures.

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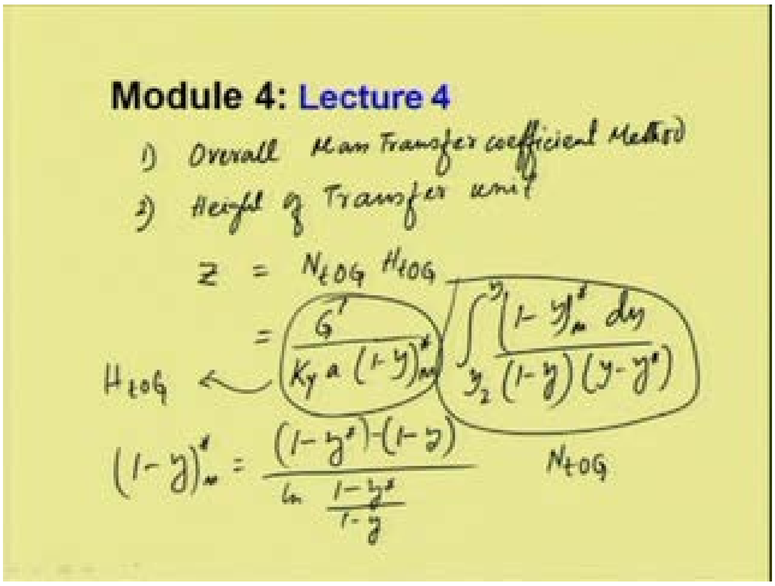

Module 4: Lecture 4

1) Overall Mass Transfer coefficient Method

2) Height of Transfer unit

$$Z = N_{tOG} H_{tOG}$$

$$= \underbrace{\frac{G'}{K_y a (1-y)^*_M}}_{H_{tOG}} \underbrace{\int_{y_2}^{y_1} \frac{(1-y)^*_M \, dy}{(1-y)(y-y^*)}}_{N_{tOG}}$$

$$(1-y)^*_M = \frac{(1-y^*)-(1-y)}{\ln \frac{1-y^*}{1-y}}$$

In the previous lecture, we have discussed the packed tower design based on overall mass transfer coefficient method; and the second, we have discussed the packed tower design based of height of transfer unit, height of transfer unit. And we have discussed the height Z is equal to N t O G in multiplied by S t O G; N t O G is the number of transfer unit, and H is the height of transfer unit.

So, the Z is the packed height, and which is defined as G dash by capital K y a 1 minus y M star integral y 2 to y 1 1 minus y M star dy divided by 1 minus y multiplied by y minus y star. And this 1 minus y M M star is is equal to log mean concentration gradient, which is 1 minus y star minus 1 minus y divided by ln 1 minus y star divided by 1 minus y. And this term is known as H t O G, and this term is known as N t O G.

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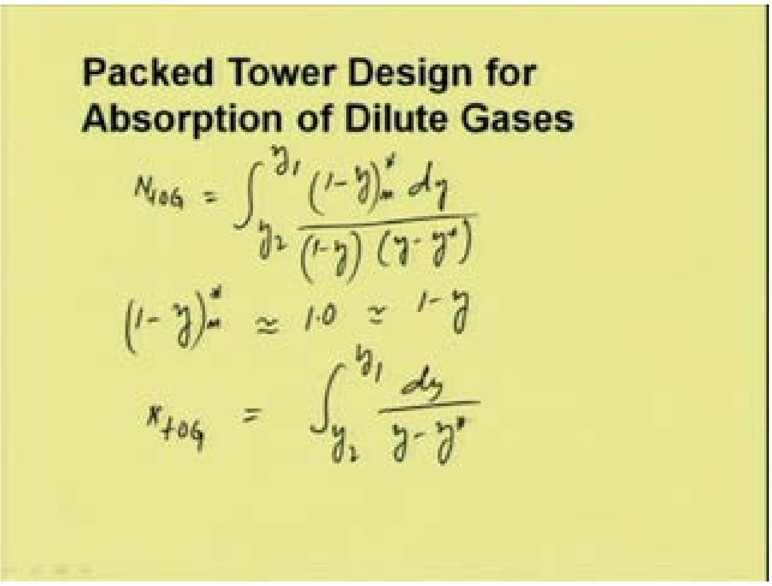

Packed Tower Design for Absorption of Dilute Gases

$$N_{tOG} = \int_{y_2}^{y_1} \frac{(1-y)^*_M \, dy}{(1-y)(y-y^*)}$$

$$(1-y)^*_M \simeq 1.0 \simeq 1-y$$

$$N_{tOG} = \int_{y_2}^{y_1} \frac{dy}{y-y^*}$$

Now, in this lecture we will discuss packed tower design for absorption of dilute gasses; for dilute gases, we know just now we have said N t O G is equal to integral y 2 to y 1 1 minus y M star dy divided by 1 minus y into y minus y star. For dilute solution, we can write 1 minus y M star approximately equal to 1. So, this equation will be N t O G would be integral y 2 to y 1 dy, this also equals to 1 minus y. So, this would be dy y minus y star.

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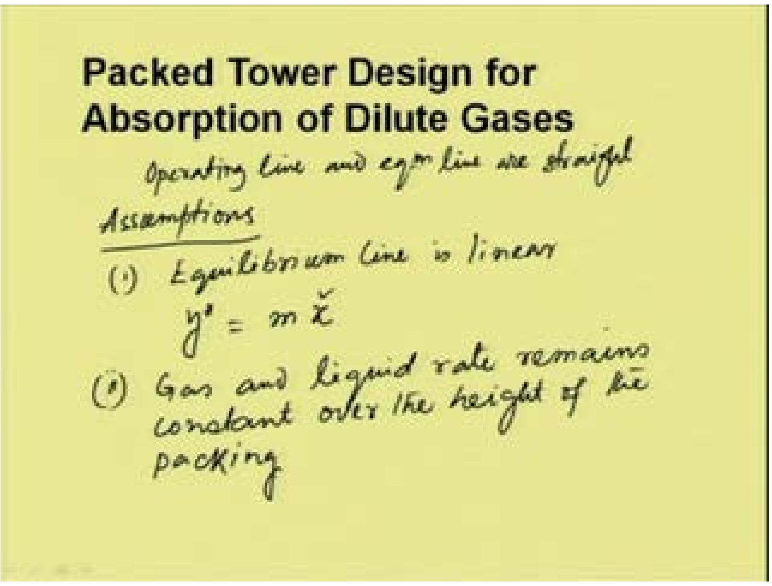

Packed Tower Design for Absorption of Dilute Gases

Operating line and eqm line are straight

Assumptions

(i) Equilibrium line is linear

$y^* = m x$

(ii) Gas and liquid rate remains constant over the height of the packing

For dilute solution both the operating line operating line line, and equilibrium line are straight, then it is possible to evaluate this integral graphically or numerically. So, the assumptions we have to take, assumptions one is equilibrium line is linear is linear; that means, y star is equal to M x, where y star is the mole fraction of solute in the gas stage which is in equilibrium with a solution having concentration of x.

So, this is the equilibrium relation and it is a equations of straight line, and then second is the gas and liquid rate remains constant over the height of the packing. Gas and liquid rate remains constant constant over the height of the packing of the packing.

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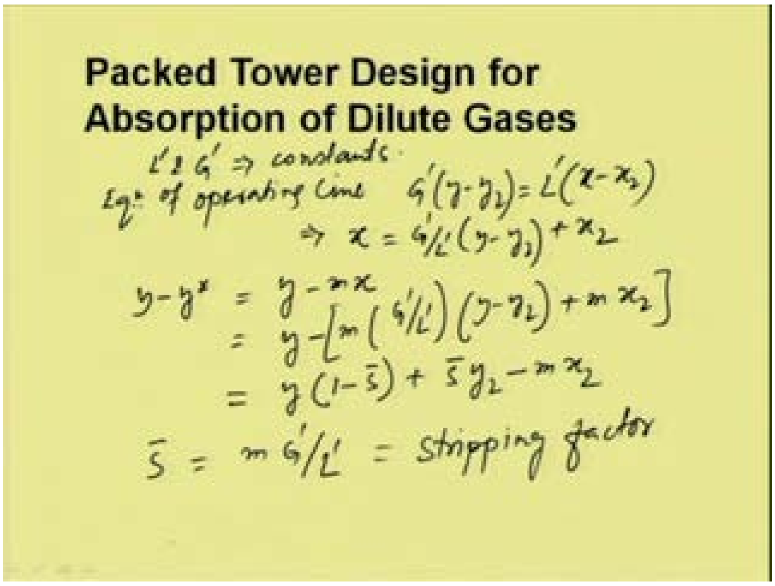

Packed Tower Design for Absorption of Dilute Gases

L' & G' ⇒ constants.

Eqn of operating line $G'(y-y_2) = L'(x-x_2)$

$$\Rightarrow x = G'/L'(y-y_2) + x_2$$

$$\begin{aligned} y - y^* &= y - mx \\ &= y - [m(G'/L')(y-y_2) + m x_2] \\ &= y(1-\bar{S}) + \bar{S} y_2 - m x_2 \end{aligned}$$

$\bar{S} = m G'/L'$ = stripping factor

Now, if L dash and G dash; L dash is the liquid rate and G dash is the gas rate; these are constants, then the equation of operating line line would be G dash into y minus y 2 is equal to L dash x minus x 2. So, from this we can write x is equal to G dash by L dash multiplied by y minus y 2 plus x 2, now the overall driving force y minus y star would be equal to y minus M x, y star is equal to M x. So, we can write this equal to y minus M and if we substitute x over here, this would be G dash by L dash multiplied by y minus y 2 plus M x 2.

So, we can write this is equal to y into 1 minus S bar plus S bar y 2 minus M x 2, this S bar is equal to M G dash divided by L dash is known as stripping factor stripping factor, and inverse of this is absorption factor.

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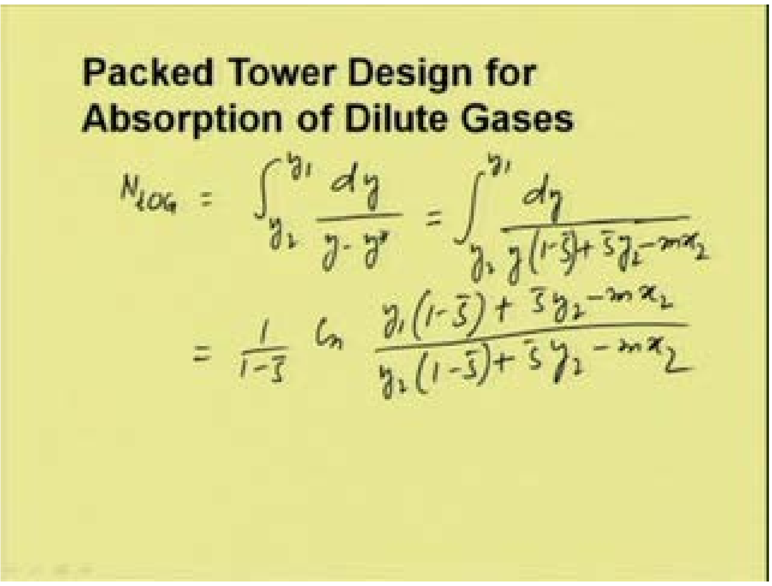

Packed Tower Design for Absorption of Dilute Gases

$$N_{tOG} = \int_{y_2}^{y_1} \frac{dy}{y-y^*} = \int_{y_2}^{y_1} \frac{dy}{y(1-\bar{S})+\bar{S}y_2-mx_2}$$

$$= \frac{1}{1-\bar{S}} \ln \frac{y_1(1-\bar{S})+\bar{S}y_2-mx_2}{y_2(1-\bar{S})+\bar{S}y_2-mx_2}$$

So, now N t O G is equal to integral y 2 to y 1 dy y minus y star. So, which is equal to integral y 2 to y 1 dy divided by y minus y star, we have got from this equation y into 1 minus S bar plus S bar y 2 minus M x 2. So, if we substitute this over here, it will be y 1 minus S bar plus S bar y 2 minus M x 2. So, which is equal to 1 by 1 minus S bar ln, if we integrate it will be y 1 1 minus S bar plus S bar y 2 minus M x 2 divided by y 2 into 1 minus S bar plus S bar y 2 minus M x 2.

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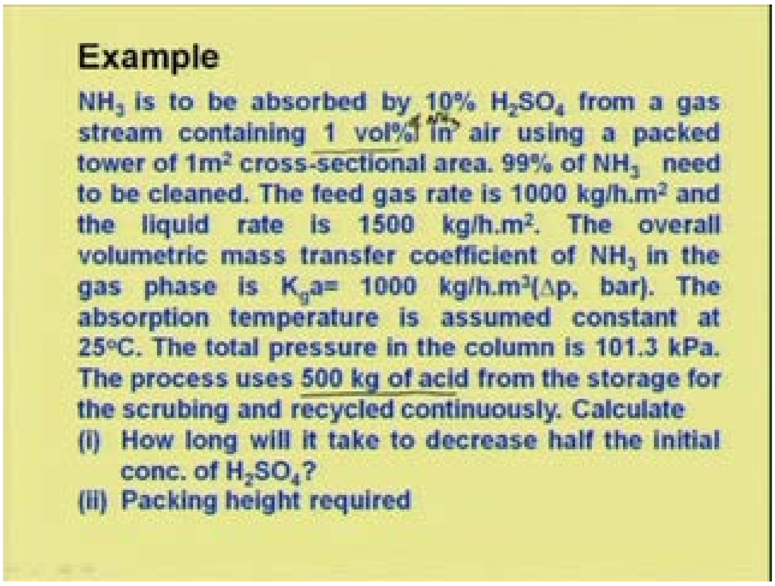

Example

NH_3 is to be absorbed by 10% H_2SO_4 from a gas stream containing 1 vol% in air using a packed tower of 1m^2 cross-sectional area. 99% of NH_3 need to be cleaned. The feed gas rate is 1000 kg/h.m^2 and the liquid rate is 1500 kg/h.m^2. The overall volumetric mass transfer coefficient of NH_3 in the gas phase is K_ga= 1000 kg/h.m^3(Δp, bar). The absorption temperature is assumed constant at 25°C. The total pressure in the column is 101.3 kPa. The process uses 500 kg of acid from the storage for the scrubing and recycled continuously. Calculate

(i) How long will it take to decrease half the initial conc. of H_2SO_4?

(ii) Packing height required

So, now let us take a simple example, where ammonia is to be absorbed by 10 percent sulfuric acid from a gas stream containing 1 volume percent of ammonia, this would be 1 volume percent of ammonia in air using a packed tower of 1 meter square cross sectional area, 99 percent of ammonia need to be cleaned. The feed gas rate is 1000 kg per hour meter square and the liquid is 1500 kg per hour meter square. So, both the gas flow rate and liquid flow rate are given, column dimensions are given, feed gas composition is given, and the liquid composition is given.

The overall volumetric mass transfer coefficient of ammonia in the gas phase k g a, which is equal to 1000 kg per hour meter square delta p which is in bar that is also given. The absorption temperature is assumed constant at 25 degree centigrade, the total pressure in the column is 1 atmosphere that is 101.3 kilopascal, and initially the process uses 500 kg of acid from the storage for the scrubbing and recycle continuously, calculate how long will it take to decrease half the initial concentration of H 2 S 0 4, and second the packing height required.

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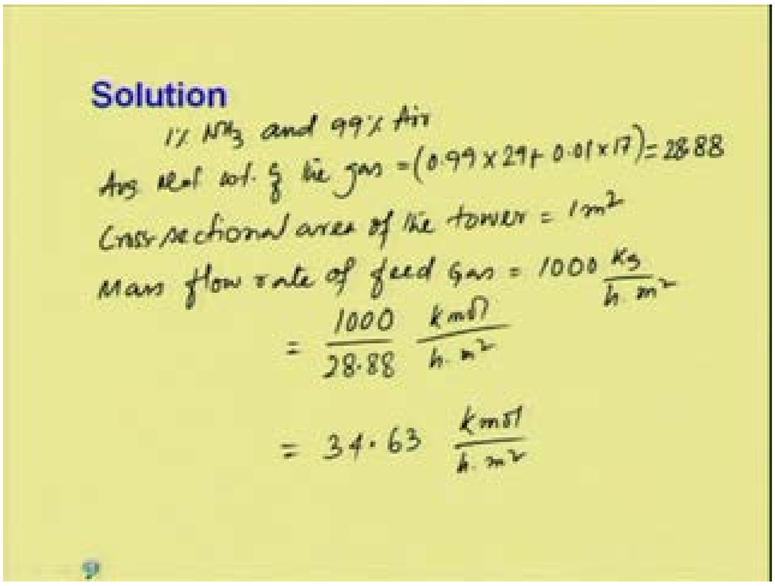

Solution

1% NH_3 and 99% Air

Avg. mol. wt. of the gas $= (0.99 \times 29 + 0.01 \times 17) = 28.88$

Cross sectional area of the tower $= 1 m^2$

Mass flow rate of feed gas $= 1000 \frac{Kg}{h.m^2}$

$$= \frac{1000}{28.88} \frac{kmol}{h.m^2}$$

$$= 34.63 \frac{kmol}{h.m^2}$$

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The gas composition is 1 percent ammonia, and 99 percent air. So, average molecular weight of the gas is equal to 0.99 air into 29 plus 0.01 into 17 molecular weight of ammonia equal to 28.88, cross sectional area of the tower area of the tower which is given is equal to 1 meter square, mass flow rate of feed gas feed gas is equal to 1000 kg per hour meter square. So, which is equal to 1000 divided by 28.88, this is the average molecular weight of the gas will be k mole per hour meter square, which is equal to 34.63 k mole per hour meter square.

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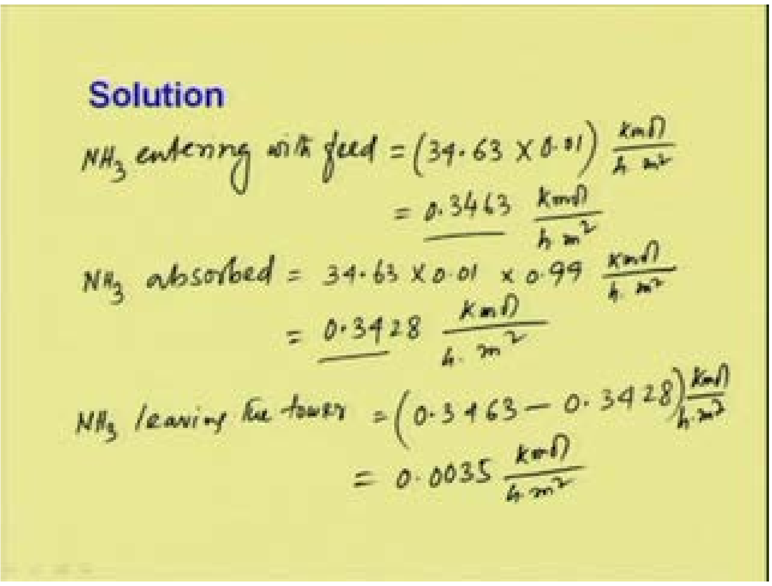

Solution

NH_3 entering with feed $= (34.63 \times 0.01) \frac{kmol}{h\,m^2}$

$= \underline{0.3463} \frac{kmol}{h\,m^2}$

NH_3 absorbed $= 34.63 \times 0.01 \times 0.99 \frac{kmol}{h.\,m^2}$

$= \underline{0.3428} \frac{kmol}{h.\,m^2}$

NH_3 leaving the tower $= (0.3463 - 0.3428) \frac{kmol}{h.\,m^2}$

$= 0.0035 \frac{kmol}{h.\,m^2}$

Now, the ammonia is entering with the feed ammonia entering with feed is equal to 34.63 multiplied by 1 percent k mole per hour meter square. So, this is equal to 0.3463 k mole per hour meter square. Now, ammonia is absorbed is 99 percent; 99 percent of this entering feed composition or ammonia should be absorbed. So, ammonia absorbed would be 34.63 into 0.1 multiplied by 0.99.

So, this mass kilo mole per hour meter square which is equal to 0.3428 k mole per hour meter square. Now, the ammonia leaving leaving the tower is equal to 0.3463 minus 0.3428, this minus this entering and absorbed which is leaving. So, this mass kilo mole per hour meter square, which is equal to 0.0035 k mole per hour meter square.

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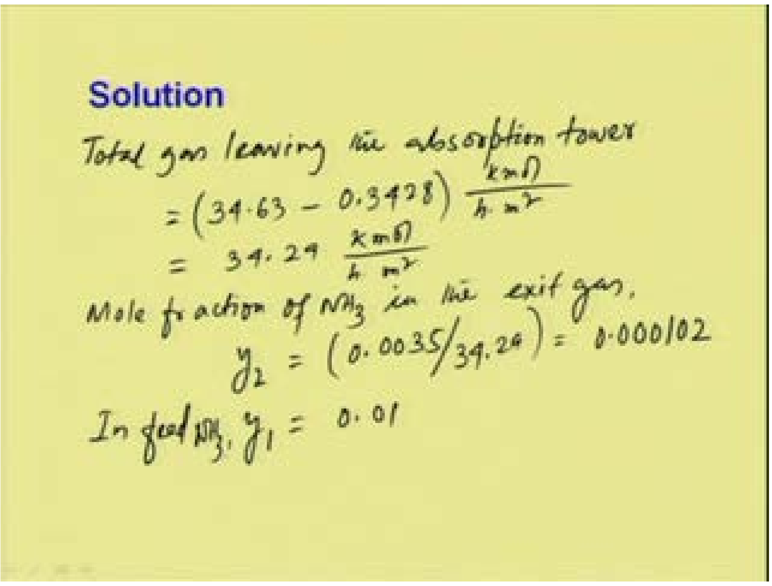

Solution

Total gas leaving the absorption tower

$= (34.63 - 0.3428)\ \frac{kmol}{h\ m^2}$

$= 34.29\ \frac{kmol}{h\ m^2}$

Mole fraction of NH_3 in the exit gas,

$y_2 = (0.0035/34.29) = 0.000102$

In feed NH_3, $y_1 = 0.01$

Now, the total gas leaving the tower is total gas leaving the absorption tower would be equal to the entering 34.63 minus the absorbed ammonia 0.3428, this mass k mole per hour meter square, so which is equal to 34.29 k mole per hour meter square. Now, the mole fractions of ammonia in the exit gas mole fraction of ammonia in the exit which is y 2 is equal to 0.0035 divided by 34.29, which is equal to 0.000102. And in feed y 1 is equal to 1 percent that is 0.01 in feed the ammonia is y 1 which is 0.01.

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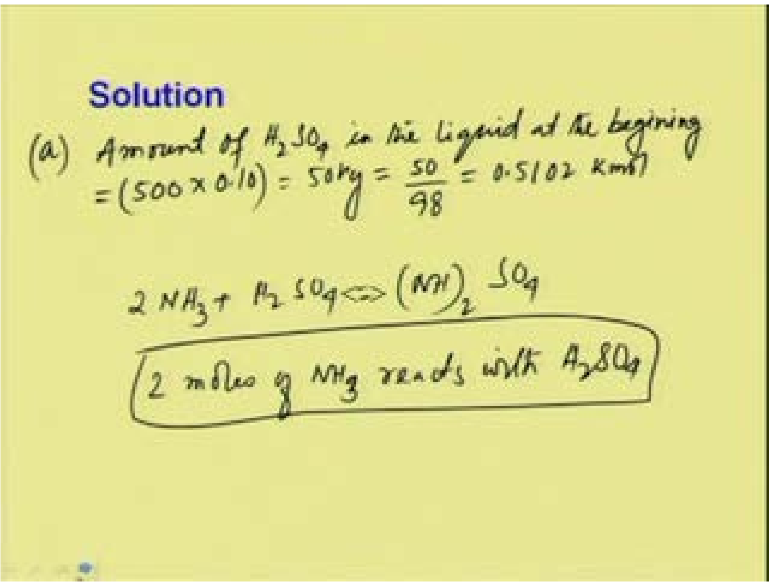

Solution

(a) Amount of H_2SO_4 in the liquid at the begining

$= (500 \times 0.10) = 50\,kg = \frac{50}{98} = 0.5102\ kmol$

$2\,NH_3 + H_2SO_4 \Leftrightarrow (NH)_2SO_4$

$\boxed{2 \text{ moles of } NH_3 \text{ reacts with } H_2SO_4}$

Now, we will calculate the time required to decrease concentration of the acid, which is sulphuric acid to its half of its value from the initial concentration; the initial concentration of sulphuric acid was 10 percent H 2 S o 4. Now, the amount of H 2 S o 4 amount of sulphuric acid in the liquid at the beginning is equal to 500 kg into 10 percent that is 0.10, which is equal to 50 kg which is equal to 50 divided by 98 is the molecular rate for sulphuric acid, so which is equal to 0.5102 kilo mole. Now, if we look into the reaction twice ammonia plus H 2 S o 4 N H 4 2 S o 4. So, two moles of ammonia, ammonia reacts with H 2 S o 4.

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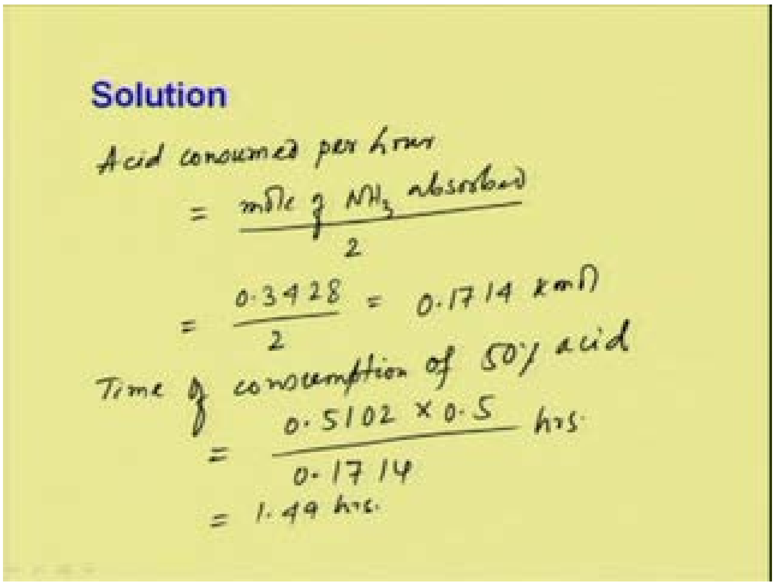

Solution

Acid consumed per hour

$$= \frac{\text{mole of } NH_3 \text{ absorbed}}{2}$$

$$= \frac{0.3428}{2} = 0.1714 \text{ kmol}$$

Time of consumption of 50% acid

$$= \frac{0.5102 \times 0.5}{0.1714} \text{ hrs.}$$

$$= 1.49 \text{ hrs.}$$

Now, the acid consumed per hour is equal to mole of ammonia absorbed divided by 2. So, mole of ammonia absorbed is if we go back, we can see the mole of ammonia absorbed is 0.3428, this is the mole of ammonia absorbed. So, 0.3428 divided by 2 is equal to 0.1714 k mole. So, the time of consumption of 50 percent acid time of consumption of 50 percent acid would be equal to 0.5102 into 0.5 divided by 0.1714 hours, which is equal to 1.49 hours.

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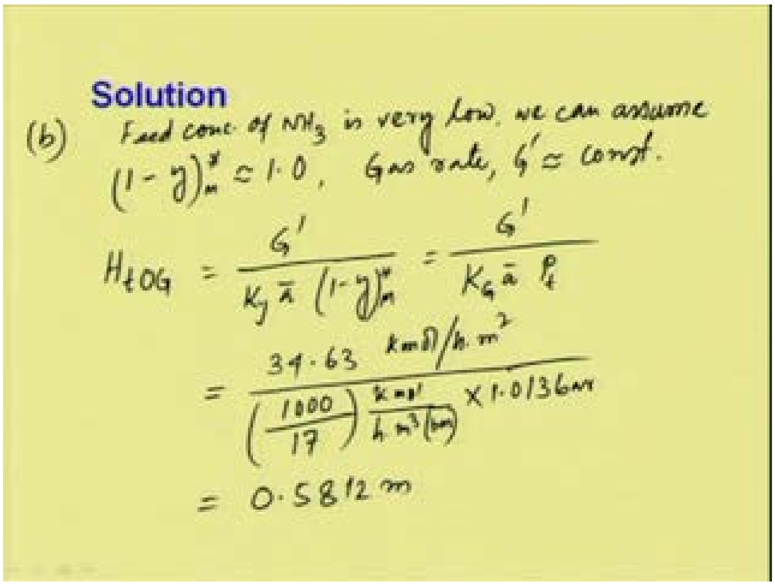

Solution

(b) Feed conc. of NH_3 is very low. we can assume $(1-y)^*_m \simeq 1.0$, Gas rate, $G' \simeq$ const.

$$H_{tOG} = \frac{G'}{K_y \bar{a}\,(1-y)^*_m} = \frac{G'}{K_G \bar{a}\, P_t}$$

$$= \frac{34.63 \ \text{kmol/h.m}^2}{\left(\frac{1000}{17}\right)\frac{\text{kmol}}{\text{h m}^3 (\text{bar})} \times 1.0136 \text{bar}}$$

$$= 0.5812 \text{ m}$$

Next, the second part we will discuss to calculate the height of the absorption tower, we will discuss part b feed concentration of ammonia is very low. So, we can assume 1 minus y M star approximately equal to 1, and the gas rate which is G dash that is also approximately constant. So, we can calculate H t O G - H t O G which is equal to G dash divided by k capital K y a bar into 1 minus y star M, which we can write G dash divided by K G a bar P t. So, if we substitute which is 34.63 G dash k mole per hour meter square divided by K G a is 1000 divided by 17 k mole per hour meter cube bar into 1.013 bar, so which is equal to 0.5812 meter.

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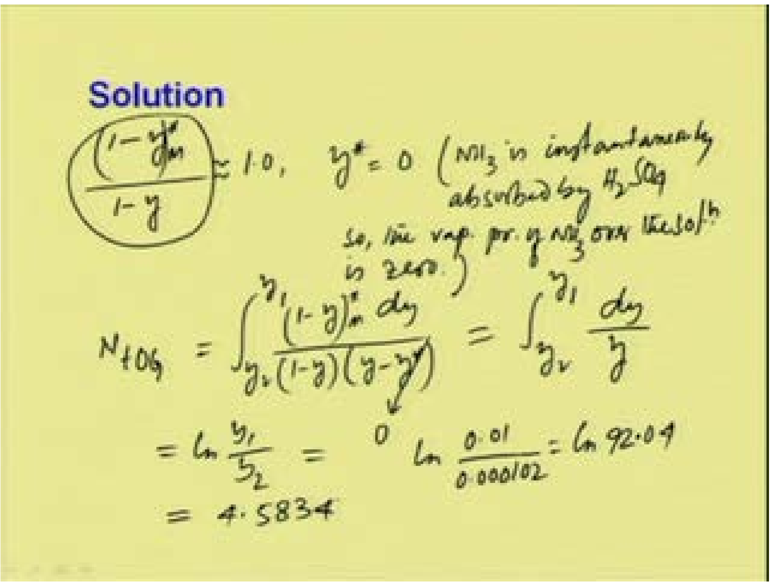

Solution

$\frac{(1-y)^*_m}{1-y} \simeq 1.0$, $y^* = 0$ (NH_3 is instantaneously absorbed by H_2SO_4. So, the vap. pr. of NH_3 over the soln is zero.)

$$N_{tOG} = \int_{y_2}^{y_1} \frac{(1-y)^*_m \, dy}{(1-y)(y-\underset{0}{y^*})} = \int_{y_2}^{y_1} \frac{dy}{y}$$

$$= \ln \frac{y_1}{y_2} = \ln \frac{0.01}{0.000102} = \ln 92.04$$

$$= 4.5834$$

Now, we have to calculate N t O G, then we can calculate the height of the packing required. Since, ammonia concentration in the solution is very low we can write 1 minus y star M divided by 1 minus y approximately equal to 1, and y star is equal to 0. Since the ammonia is instantaneously absorbed by sulfuric acid is instantaneously absorbed by H 2 S o 4. So, the vapor pressure of ammonia over the solution is 0. So, the vapor pressure of ammonia over the solution is 0. Now, N t O G is equal to integral y 2 to y 1 1 minus y star M dy divided by 1 minus y into y minus y star, now this part is 1 1 minus y star M by 1 minus y, this part is 1.

So, this part going to be 1 and y star is 0, so we can this is 0. So, this would be integral y 2 to y 1 dy by y. So, which is equal to ln y 1 by y 2 which is we can write ln 0.1 divided by 0.000102, which is equal to ln 92.04 and the N t O G would be 4.5834.

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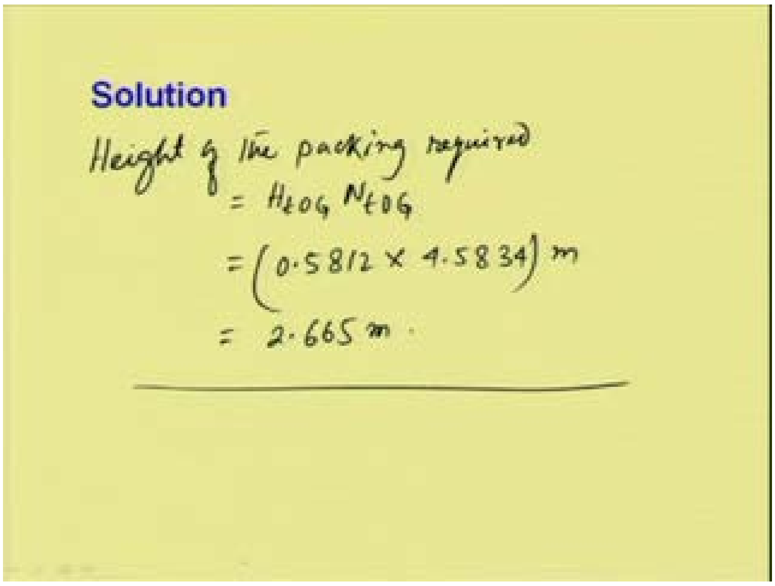

Solution

Height of the packing required

$= H_{tOG} N_{tOG}$

$= (0.5812 \times 4.5834)\ m$

$= 2.665\ m.$

So, the height of the packing required required is equal to S t O G into N t O G, which is equal to 0.5812 multiplied by 4 0.5334 meter, which is essentially 2.665 meter, this way for dilute solution with some assumptions, we can calculate the packing height required for the particular operations.

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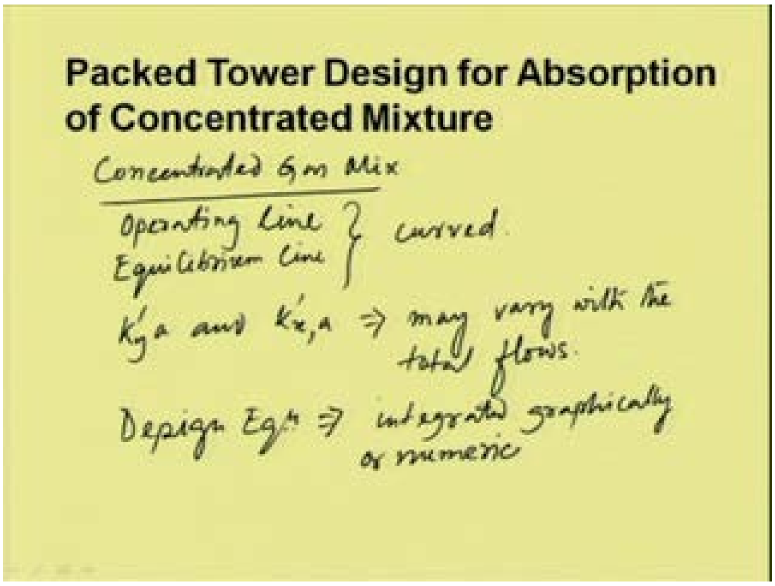

Packed Tower Design for Absorption of Concentrated Mixture

Concentrated Gas Mix

Operating Line } curved
Equilibrium Line }

$K'_y a$ and $K'_{x,}a$ ⇒ may vary with the total flows.

Design Eqn ⇒ integrated graphically or numeric

Now, we will start the packed tower design for absorption of concentrated mixture, the simplified (( )), which we have discussed for dilute gas mixture is applicable for the solid concentration both in gas phase, and in the liquid phase less than 10 percent; that is mole fractions less than 0.1. Because at that concentration the operating line and the equilibrium line, we can assume straight line and we can do the calculation. For concentrated gas mixture, operating line and equilibrium line; they are not linear or straight line they are curved. And the values of overall mass transfer volumetric mass transfer coefficient that is k y dash a, and k x a, these may vary with the total flows. So, design equations must be integrated either graphically or numerically design equation must be integrated graphically or numerically.

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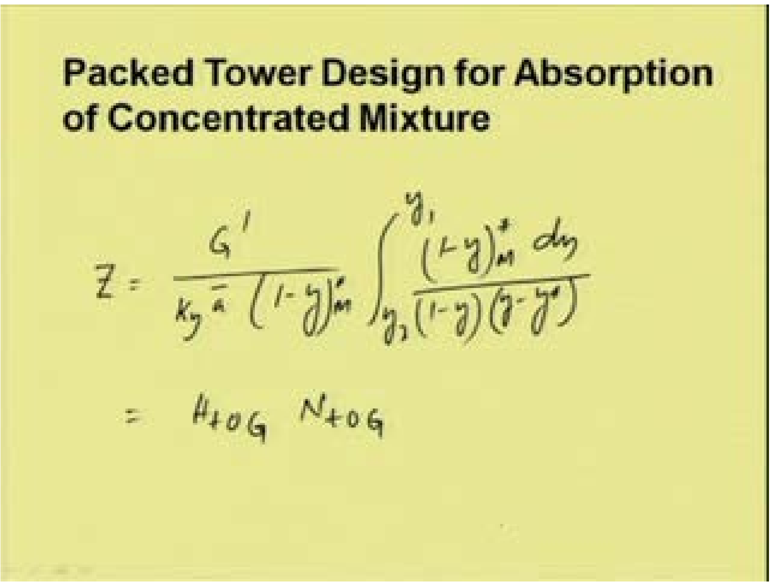

Packed Tower Design for Absorption of Concentrated Mixture

$$Z = \frac{G'}{k_y \bar{a} (1-y)^*_M} \int_{y_2}^{y_1} \frac{(1-y)^*_M \, dy}{(1-y)(y-y^*)}$$

$$= H_{tOG} \; N_{tOG}$$

We know that Z is equal to G dash divided by k y a bar 1 minus y star M, this is H t O G multiplied by N t O G y 2 to y 1 1 minus y star M into dy divided by 1 minus y y minus y star which is equal to we can write H t O G into N t O G.

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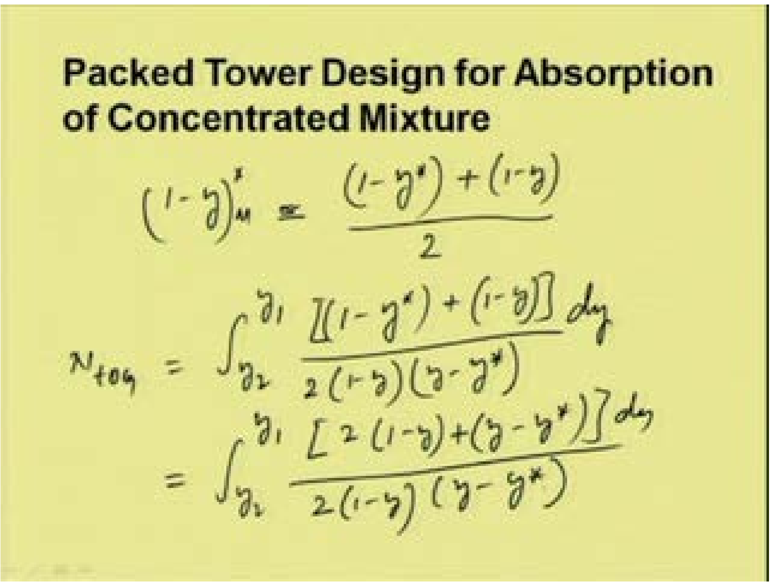

Packed Tower Design for Absorption of Concentrated Mixture

$$(1-y)^*_M \approx \frac{(1-y^*)+(1-y)}{2}$$

$$N_{tOG} = \int_{y_2}^{y_1} \frac{[(1-y^*)+(1-y)]\,dy}{2(1-y)(y-y^*)}$$

$$= \int_{y_2}^{y_1} \frac{[2(1-y)+(y-y^*)]\,dy}{2(1-y)(y-y^*)}$$

A simplified form of this equation we can obtain by approximating 1 minus y star M, if we approximated this to the logarithmic mean which is equal to 1 minus y star plus 1 minus y divided by 2. So, then N t O G will be simplified, and we can write integral y 2 to y 1 into 1 minus y star plus 1 minus y divided by 2 into 1 minus y into y minus y star dy, which we can write is equal to integral y 2 to y 1 2 into 1 minus y plus y minus y star dy divided by 2 into 1 minus y into y minus y star.

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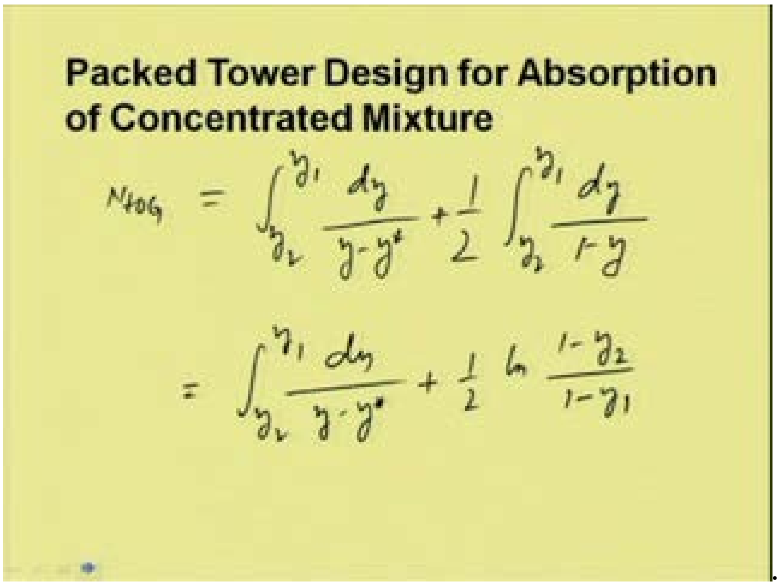

Packed Tower Design for Absorption of Concentrated Mixture

$$N_{tOG} = \int_{y_2}^{y_1} \frac{dy}{y-y^*} + \frac{1}{2}\int_{y_2}^{y_1} \frac{dy}{1-y}$$

$$= \int_{y_2}^{y_1} \frac{dy}{y-y^*} + \frac{1}{2} \ln \frac{1-y_2}{1-y_1}$$

So, from this N t O G, we can write integral y 2 to y 1 dy divided by y minus y star plus half integral y 2 to y 1 dy by 1 minus y. So, we can write integral y 2 to y 1 dy y minus y star plus half ln 1 minus y 2 divided by 1 minus y 1.

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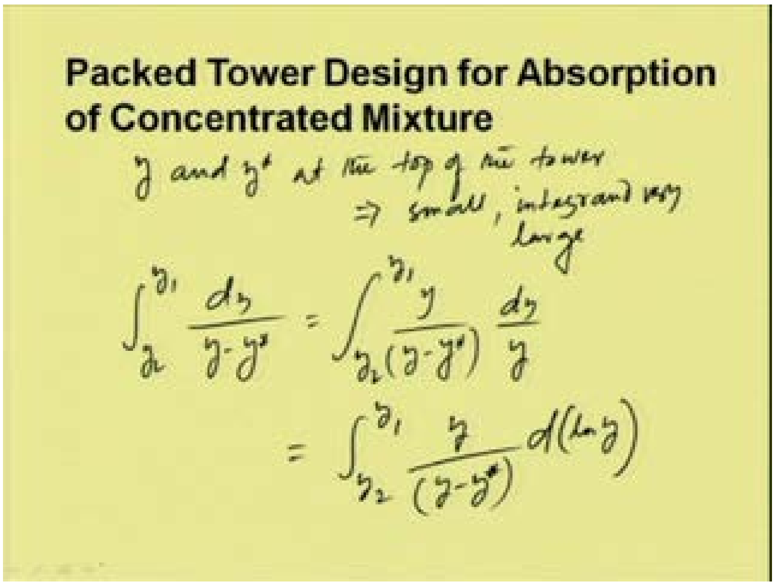

Packed Tower Design for Absorption of Concentrated Mixture

y and y^* at the top of the tower $\Rightarrow$ small, integrand very large

$$\int_{y_2}^{y_1} \frac{dy}{y-y^*} = \int_{y_2}^{y_1} \frac{y}{(y-y^*)} \frac{dy}{y}$$

$$= \int_{y_2}^{y_1} \frac{y}{(y-y^*)} d(\ln y)$$

So, at the top of the tower both y and y star at the top of the tower, these are very small small, then integrant of the previous equation would be very large, integrant very large. So, the integration becomes very difficult, in this case numerical integration would be convenient if we define the term y 2 to y 1 dy divided by y minus y star is equal to integral y 2 to y 1 multiplied y numerator and denominator. So, we multiply y by y minus y star into dy by y. So, we can write integral y 2 to y 1 y by y minus y star into d of ln y.

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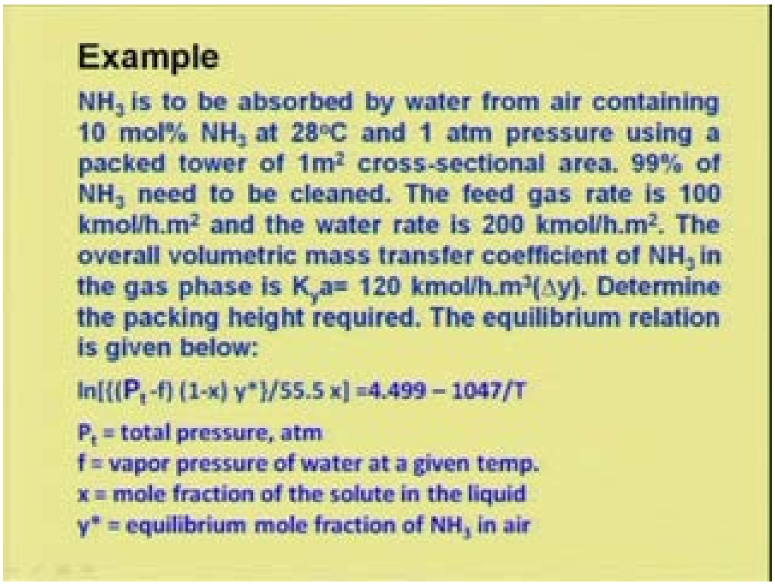

Example

NH_3 is to be absorbed by water from air containing 10 mol% NH_3 at 28°C and 1 atm pressure using a packed tower of $1 m^2$ cross-sectional area. 99% of NH_3 need to be cleaned. The feed gas rate is 100 kmol/h.m^2 and the water rate is 200 kmol/h.m^2. The overall volumetric mass transfer coefficient of NH_3 in the gas phase is $K_y a$= 120 kmol/h.$m^3(\Delta y)$. Determine the packing height required. The equilibrium relation is given below:

$\ln[\{(P_t - f)(1-x) y^*\}/55.5 x] = 4.499 - 1047/T$

P_t = total pressure, atm
f = vapor pressure of water at a given temp.
x = mole fraction of the solute in the liquid
y^* = equilibrium mole fraction of NH_3 in air

Now, let us take a similar example as we discussed for dilute solution, we will take the concentrated solutions of ammonia; the ammonia is to be absorbed by water from here containing 10 mole percent of ammonia at 28 degree centigrade, and 1 atmosphere pressure using the similar packed tower of 1 meter square cross sectional area, and 99 percent of ammonia removal is desirable. The feed gas rate is 100 kilo mole per hour meter square, the water rate is 2100 kilo mole per hour meter square; the overall volumetric mass transformer coefficient of ammonia in the gas phase k y a is given, 120 kilo mole per hour meter cube delta y.

Now, we have to determine the packing height required, since it is concentrated solution we need to have the equilibrium relations, because the equilibrium line curved in nature. So, this is the equilibrium relation, where P t is the total pressure in atmosphere, a b is the vapor pressure of water at a given temperature; that means at 28 centigrade, x is the mole fractions of the solute in the liquid phase, and y star is the equilibrium mole fractions of ammonia in air.

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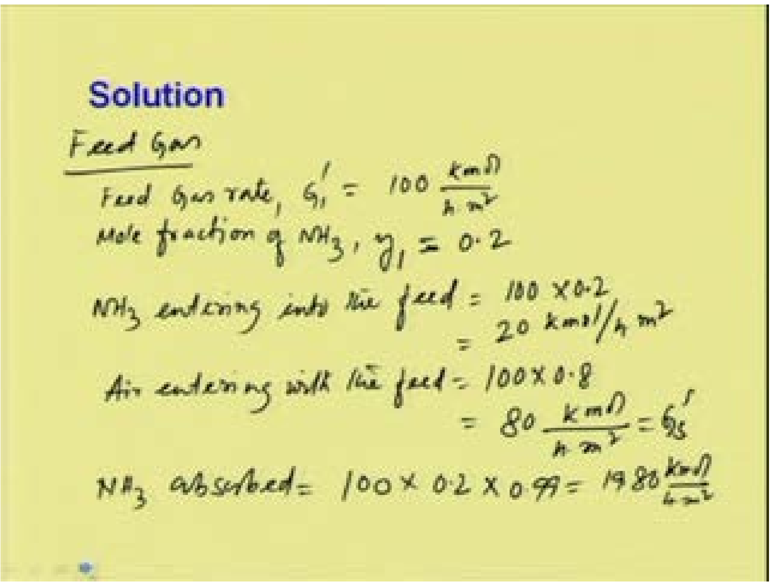

Solution

Feed Gas

Feed gas rate, $G_1' = 100 \frac{kmol}{h \cdot m^2}$

Mole fraction of NH_3, $y_1 = 0.2$

NH_3 entering into the feed $= 100 \times 0.2$
$= 20\ kmol/h\ m^2$

Air entering with the feed $= 100 \times 0.8$
$= 80 \frac{kmol}{h\ m^2} = G_S'$

NH_3 absorbed $= 100 \times 0.2 \times 0.99 = 19.80 \frac{kmol}{h\ m^2}$

Now, let us see for the feed gas; for feed gas the feed gas rate which is given G 1 dash which is given 100 k mole per hour meter square, mole fractions of ammonia mole fraction of ammonia in the feed is equal to which is y 1 is equal to 0.2. So, this is 20 percent. So, 0.2 is the mole fractions of ammonia and ammonia entering into the feed; ammonia entering into the feed is equal to 100 into 0.2, which is equal to 20 k mole per hour meter square. Now, air entering with the feed is 80 percent air is 80 percent, air entering with the feed is100 into 0.8 is equal to 80 k mole per hour meter square, which is equal to G S dash. Now, ammonia absorbed is equal to 100 multiplied by 0.2 into 0.99 is equal to 19.80 k mole per hour meter square.

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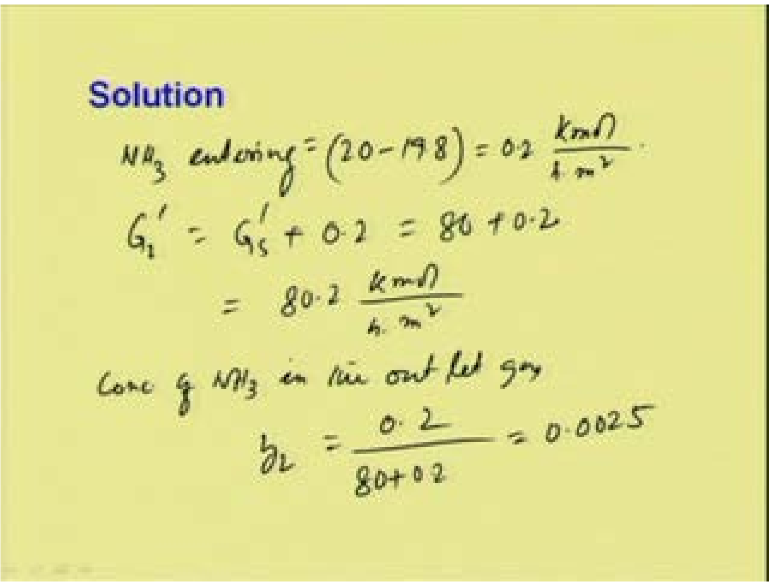

Solution

NH_3 entering $= (20 - 19.8) = 0.2 \, \frac{kmol}{h.m^2}$.

$G_2' = G_S' + 0.2 = 80 + 0.2$

$= 80.2 \, \frac{kmol}{h.m^2}$

Conc of NH_3 in the outlet gas

$y_2 = \frac{0.2}{80+0.2} = 0.0025$

Now, if we look into the ammonia which is entering ammonia entering would be 20 minus 19.8 which is equal to 0.2 k mole per hour meter square. So, exit gas rate G 2 dash would be G S dash plus 0.2 which would be 80 plus 0.2, and is would be equal to 80.2 k mole per hour meter square. Now, concentration of the ammonia in the outlet that is y 2 would be 0.2 divided by 80 plus 0.2 which is equal to 0.0025.

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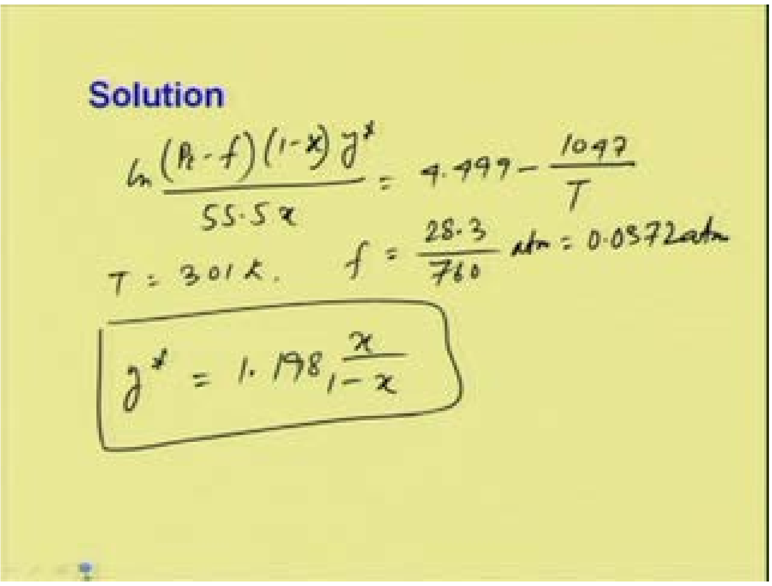

Solution

$\ln \frac{(P_t - f)(1-x) y^*}{55.5 x} = 4.499 - \frac{1047}{T}$

$T = 301 k$. $f = \frac{28.3}{760} atm = 0.0372 atm$

$\boxed{y^* = 1.198 \frac{x}{1-x}}$

Now, the equilibrium relation is given. So, which is ln P t minus f into 1 minus x y star divided by 55.5 x is equal to 4.499 minus 1047 divided by T. So, T is here 301 k, and f is vapor pressure at 28 degree centigrade which is 28.3 by 760 atmosphere which is around 0.0372 atmosphere. So, if we put these values we will get the equilibrium relation is y star would be equal to 1.198 x by 1 minus x. So, this is the equilibrium relation.

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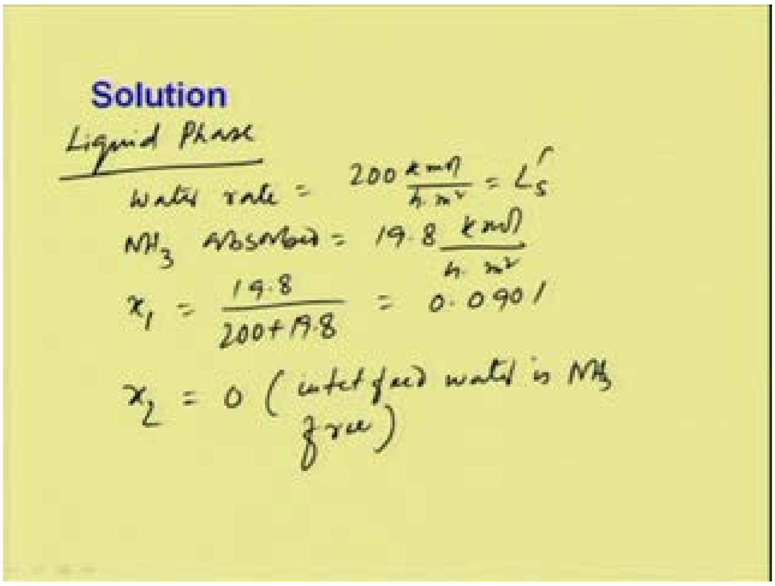

Solution

Liquid Phase

water rate = $200 \frac{kmol}{h.m^2} = L_S'$

NH_3 absorbed = $19.8 \frac{kmol}{h.m^2}$

$x_1 = \frac{19.8}{200+19.8} = 0.0901$

$x_2 = 0$ (inlet feed water is NH_3 free)

And then we can look into the liquid phase, the liquid phase water rate. So, liquid phase water rate is given 2100 k mole per hour meter square, which is L S dash, and ammonia absorbed 19.8 k mole per hour meter square, liquid phase concentration x 1 is 19.8 divided by 200 plus 19.8 which is 0.0901, and x 2 is 0; since the inlet concentration inlet feed water is ammonia free.

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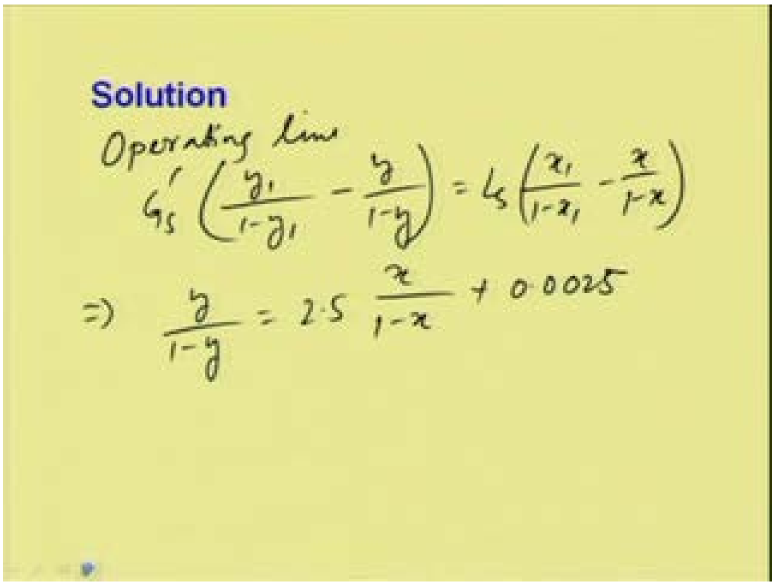

Solution

Operating line

$$G_S'\left(\frac{y_1}{1-y_1}-\frac{y}{1-y}\right)=L_S\left(\frac{x_1}{1-x_1}-\frac{x}{1-x}\right)$$

$$\Rightarrow \frac{y}{1-y}=2.5\,\frac{x}{1-x}+0.0025$$

So, now if we look into the operating line; operating line is G S dash y 1 by 1 minus y 1 minus y by 1 minus y is equal to L S x 1 by 1 minus x 1 minus x by 1 minus x, if we substitute we will get y by 1 minus y is equal to 2.5 x by 1 minus x plus 0.0025.

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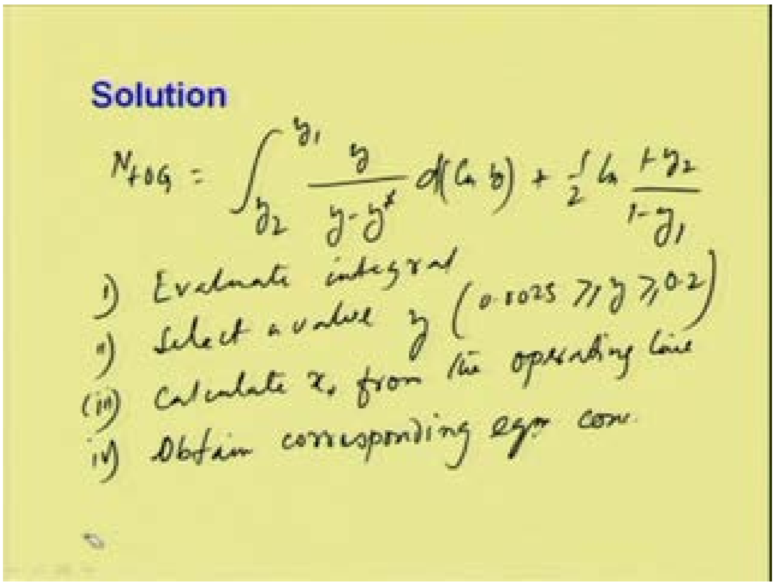

Solution

$$N_{tOG}=\int_{y_2}^{y_1}\frac{y}{y-y^*}\,d(\ln y)+\frac{1}{2}\ln\frac{1-y_2}{1-y_1}$$

i) Evaluate integral

ii) Select a value y $(0.0025 \geq y \geq 0.2)$

(iii) Calculate x, from the operating line

iv) Obtain corresponding eqm conc.

Now, N t O G is equal to integral y 2 to y 1 y by y minus y star d ln y plus half ln 1 minus y 2 by 1 minus 1. So, we have to evaluate this integral and then select a value evaluate integral select a value y, which is between 0.0025 greater than equal to y greater than equal to 0.2. Then we can calculate the bath liquid concentration calculate x from the operating line equation, and then include in the equilibrium relation obtain corresponding equilibrium concentration.

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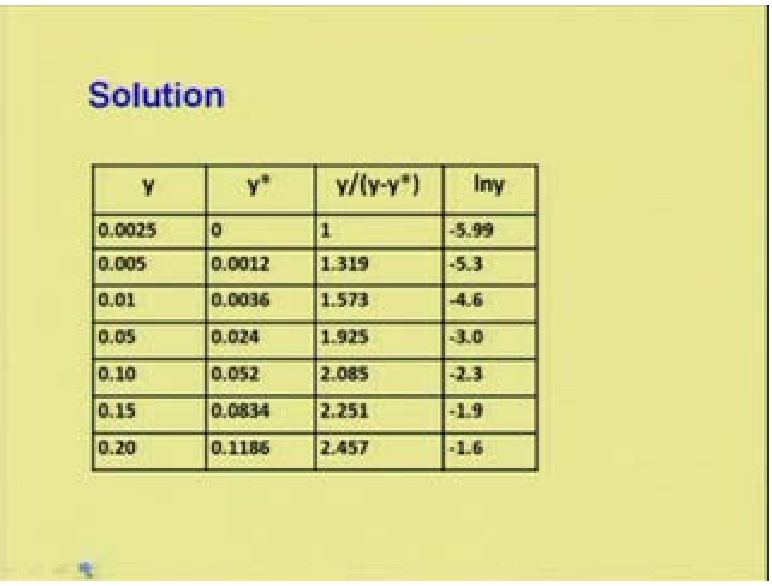

Solution

y	y*	y/(y-y*)	lny
0.0025	0	1	-5.99
0.005	0.0012	1.319	-5.3
0.01	0.0036	1.573	-4.6
0.05	0.024	1.925	-3.0
0.10	0.052	2.085	-2.3
0.15	0.0834	2.251	-1.9
0.20	0.1186	2.457	-1.6

Now, if we do this; these are the values we can assume, this is the y star we can get and this is y y y minus y star and this is L and y.

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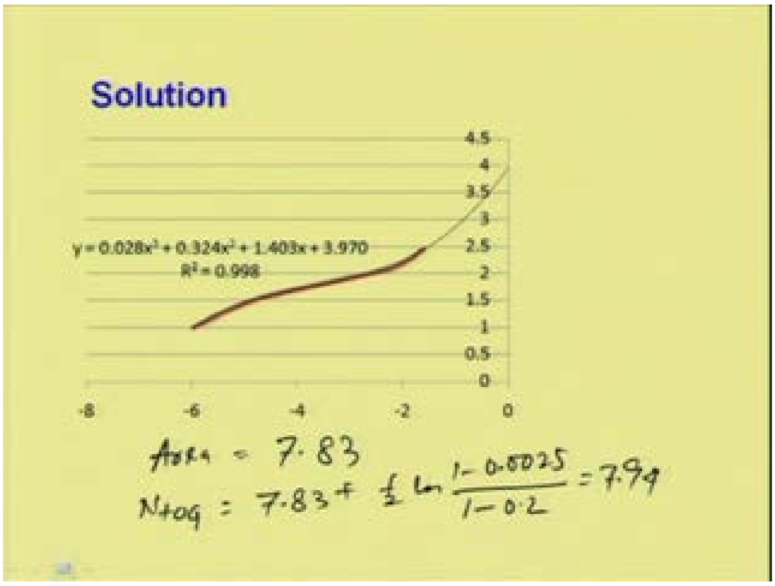

Solution

Area = 7.83

$N_{tog} = 7.83 + \frac{1}{2} \ln \frac{1-0.0025}{1-0.2} = 7.94$

If we graphically integrate, then we can get area under the curve; area is equal to 7.83 So, N t O G would be 7.83 plus half ln 1 minus 0.0025 divided by 1 minus 0.2, which would be 7.94.

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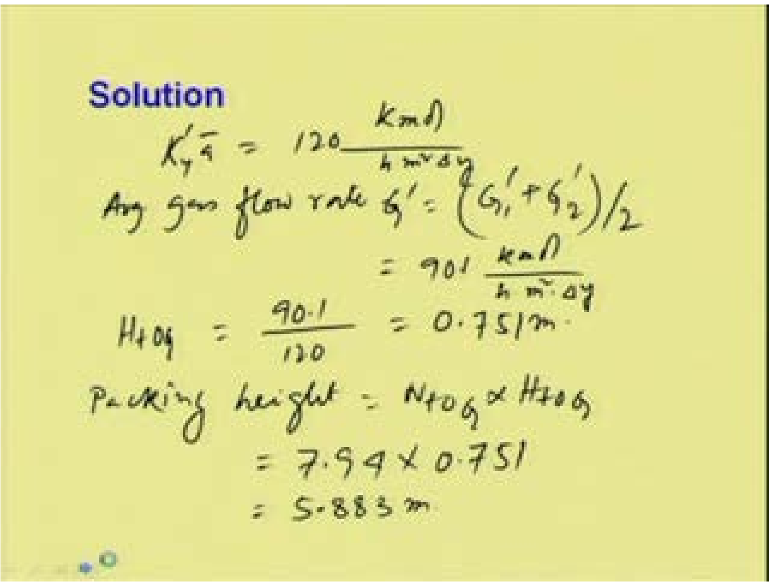

Solution

$K'_y\bar{a} = 120 \frac{kmol}{h\,m^2\,\Delta y}$

Avg gas flow rate $G' = (G'_1 + G'_2)/2$

$= 90.1 \frac{kmol}{h\,m^2\,\Delta y}$

$H_{tOG} = \frac{90.1}{120} = 0.751 m$

Packing height $= N_{tOG} \times H_{tOG}$

$= 7.94 \times 0.751$

$= 5.883 m$

Now, K y bar a, which is given 120 k mole per hour meter square delta y. So, we can calculate average gas flow rate, which is G dash would be G 1 dash plus G 2 dash divided by 2, and this if we include will be 90.1 k mole per hour meter square delta y. So, S t O G would be 90.1 divided by 120, which is 0.751 meter. So, the packing height - packing height would be N t O G into H t O G, which is equal to 7.94 multiplied by 0.751, and we will get around 5.883 meter.

Thank you.