Mass Transfer Operations-I
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Module - 2
Mass Transfer Coefficients
Lecture - 1
Concept of Mass Transfer Coefficient

Welcome to the first lecture of module two which is on mass transfer coefficient. So, before going to this lecture, let us have a small recap of the module one, what we have covered.

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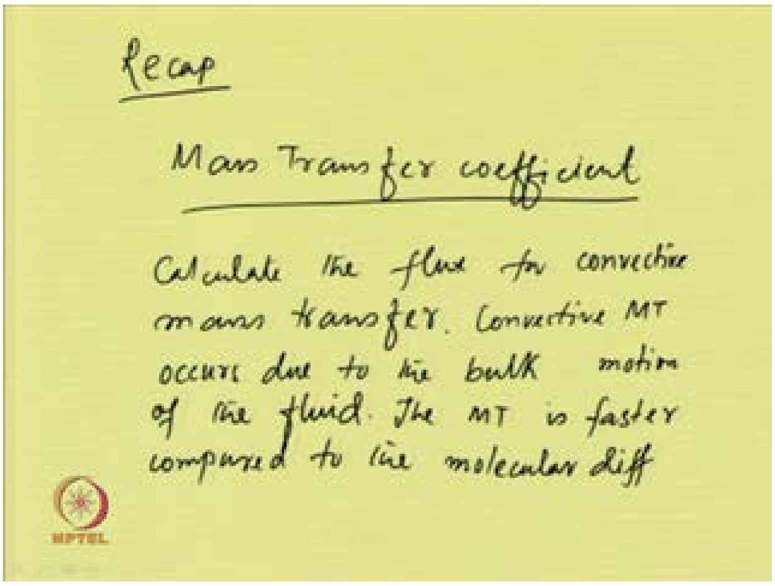

Recap

Mass Transfer coefficient

Calculate the flux for convective mass transfer. Convective MT occurs due to the bulk motion of the fluid. The MT is faster compared to the molecular diff

So, in module one, we have considered the diffusion mass transfer. The diffusion occurs mainly due to the molecular diffusions, and we know how to calculate the flux. And we have also discussed the difference between the molecular transfer or molecular diffusion, and the convective mass transferor or convective diffusion. In case of convective diffusions, we have seen that the rate of mass transfer is much faster compared to the molecular diffusion, and reason for higher rate of mass transfer in case of convective mass transfer is due to the bulk motion of the fluid. So, to account how to calculate the flux in case of convective mass transfer, we need to know a simpler method, which is the mass transfer coefficient method; mass transfer coefficient. So, by this way, we can simplify or we can very easily calculate the flux for convective mass transfer.

Convective mass transfer occurs due to the bulk motion of the fluid, and the mass transfer is faster compared to the molecular diffusion.

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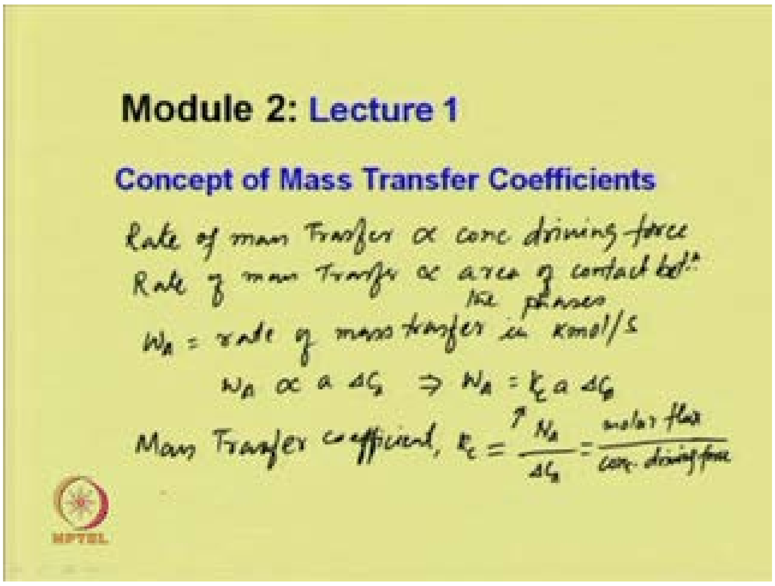

Module 2: Lecture 1

Concept of Mass Transfer Coefficients

Rate of mass Transfer $\propto$ conc driving force

Rate of mass Transfer $\propto$ area of contact betn the phases

W_A = rate of mass transfer in kmol/s

$$W_A \propto a\, \Delta C_A \Rightarrow W_A = k_c\, a\, \Delta C_A$$

$$\text{Mass Transfer coefficient, } k_c = \frac{N_A}{\Delta C_A} = \frac{\text{molar flux}}{\text{conc. driving force}}$$

So what are the concepts of mass transfer coefficients. The mass transfer coefficient can be defined, the rate of mass transfer, we know rate of mass transfer is proportional to the driving force, concentration driving force. And also the rate of mass transfer is also proportional to the area of contact between the phases. So, if we consider W A is the rate of mass transfer in K mole per second, then we can write W A is proportional to A into concentration gradient, delta C. So, from this we can write W A is equal to k c into A into concentration gradient. This k C is proportionality constant of this equation, and is known as the mass transfer coefficient. So, mass transfer coefficient k C is equal to flux divided by concentration gradient, which is equal to molar flux divided by concentration driving force. In this case, there are other mass transfer coefficients; one is called local mass transfer coefficient. The local mass transfer coefficient we can define by the local flux, divided by the local driving force.

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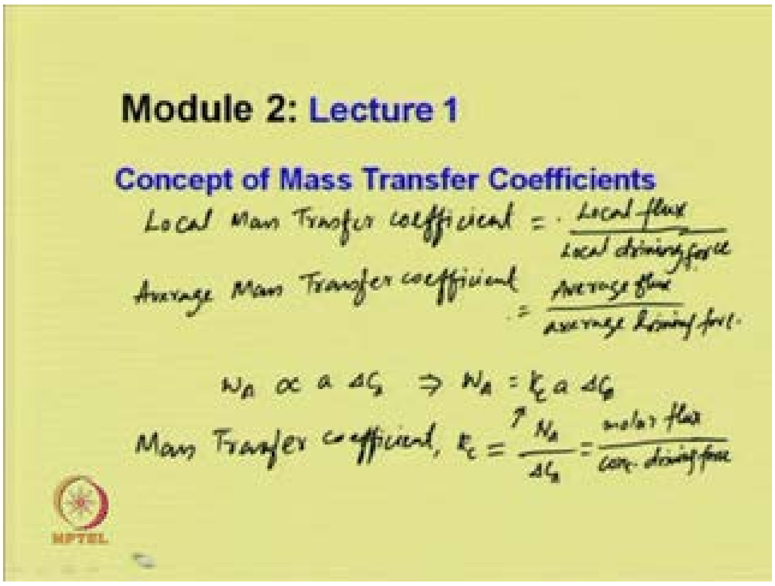

Module 2: Lecture 1

Concept of Mass Transfer Coefficients

Local Mass Transfer coefficient = $\frac{\text{Local flux}}{\text{Local driving force}}$

Average Mass Transfer coefficient = $\frac{\text{Average flux}}{\text{average driving force}}$

$$N_A \propto a\, \Delta C_A \Rightarrow N_A = k_c\, a\, \Delta C_A$$

Mass Transfer coefficient, $k_c = \frac{N_A}{\Delta C_A} = \frac{\text{molar flux}}{\text{conc. driving force}}$

Local mass transfer coefficient, we can write local flux divided by local driving force. And the average mass transfer coefficient, can be defined as the ratio of the average flux and the average driving force is equal to average flux, average flux over a surface, and the average driving force.

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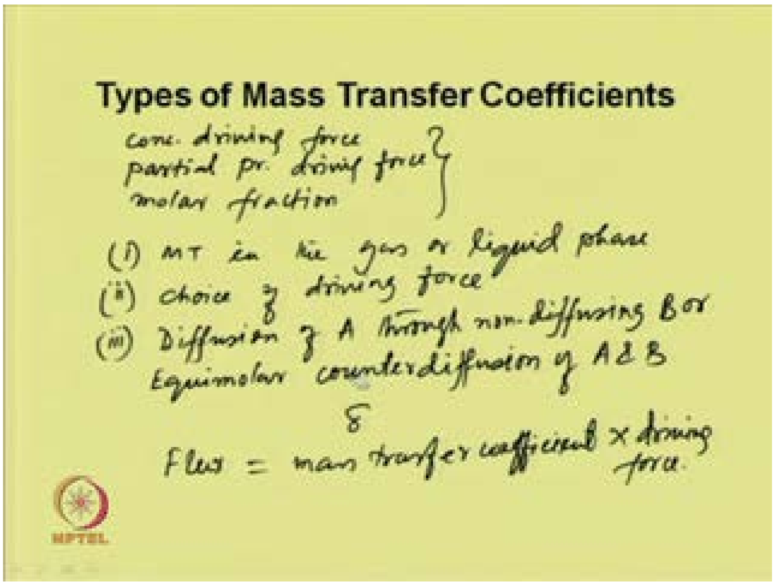

Types of Mass Transfer Coefficients

conc. driving force
partial pr. driving force
molar fraction

(i) MT in the gas or liquid phase
(ii) choice of driving force
(iii) Diffusion of A through non-diffusing B or
Equimolar counterdiffusion of A & B

&

Flux = mass transfer coefficient × driving force.

So, there are many of mass transfer coefficient, depending on the situations. In case of mass transfer, we can use concentration as the driving force. We can use the partial pressure, if it is in the gas phase, partial pressure as the driving force. And we can also use the molar fraction, molar fraction as the driving force and so on, but in case of heat transfer, only the temperature is the driving force. So, depending on the situation, we can define the mass transfer coefficient. So, on the following basis, mass transfer is in the gas or liquid phase. So, if it is gas phase, there is gas phase mass transfer coefficient. If it is in the liquid phase, it is liquid phase mass transfer coefficient, and also the choice of driving force. And third one is whether diffusion occurs, diffusion of a particular component, through non-diffusing B or equimolar counter current diffusion, counter diffusion of A and B. So depending on these situations, we can define the mass transfer coefficients, and as we know for a particular film thickness delta, the flux we can write as the mass transfer coefficient into the driving force.

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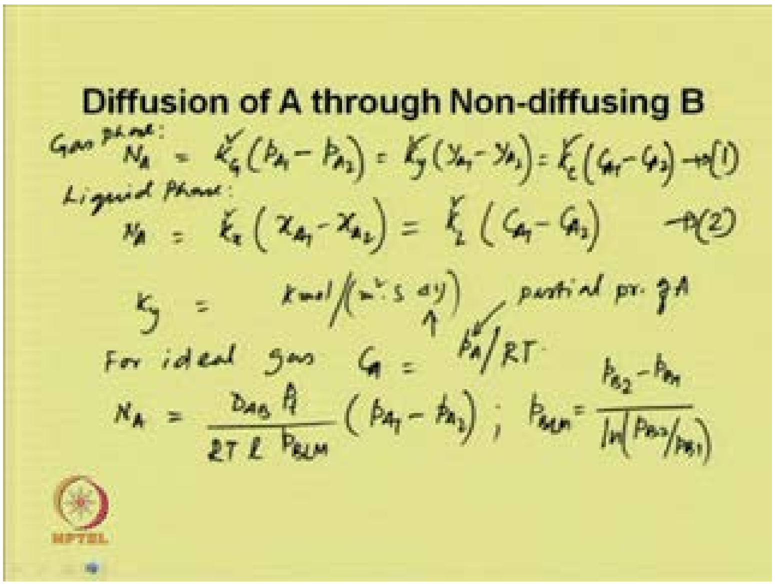

Diffusion of A through Non-diffusing B

Gas phase:

$$N_A = k_G (p_{A_1} - p_{A_2}) = k_y (y_{A_1} - y_{A_2}) = k_c (C_{A_1} - C_{A_2}) \rightarrow (1)$$

Liquid phase:

$$N_A = k_x (x_{A_1} - x_{A_2}) = k_L (C_{A_1} - C_{A_2}) \rightarrow (2)$$

$$k_G = \text{kmol}/(\text{m}^2\,\text{s}\,\text{atm})$$

partial pr. of A

For ideal gas $C_A = p_A/RT$

$$N_A = \frac{D_{AB}\,P}{RT\,l\,p_{BLM}} (p_{A_1} - p_{A_2}); \quad p_{BLM} = \frac{p_{B_2} - p_{B_1}}{\ln(p_{B_2}/p_{B_1})}$$

Let us consider a case of diffusion of A through non-diffusing B, how to calculate the mass transfer coefficient. So, for the case of diffusion of A through non-diffusing B, we can write flux, is equal to kg, the gas phase mass transfer coefficient between two points. If the partial pressure difference is p A 1 and p A 2, then it is kg p A 1 minus p A 2, is equal to k y into y A 1 minus y A 2. It is in mole fraction basis, molar fraction, or if in terms of concentration also we can write, mass transfer coefficient into C A 1 minus C A 2; say equation 1, this is for the gas phase. For liquid phase, we can write flux is equal to k x, x A 1 minus x A 2 is equal to k L, liquid phase mass transfer coefficient C A 1 in terms of the concentration driving force C A 2. So this is equation 2, where k g, k y and k c are the gas phase mass transfer coefficient. Here k x and k L are the liquid phase mass transfer coefficients. The k y has the unit like, k mole per meter square second into delta y; delta y is the mole fraction driving force. Now, if we compare for the ideal gas, we can write C A, C A is equal to p A by R T, where p A is the partial pressure of A. And if we considered the thickness between the 2 point is L, we know that the flux equations for diffusion of A, through non-diffusing B, we have earlier developed N A is equal to d A B p t divided by R T l p B l m into p A 1 minus p A 2, p B l m is the log mean pressure difference, which is p B 2 minus p B 1 divided by L N p B 2 by p B 1.

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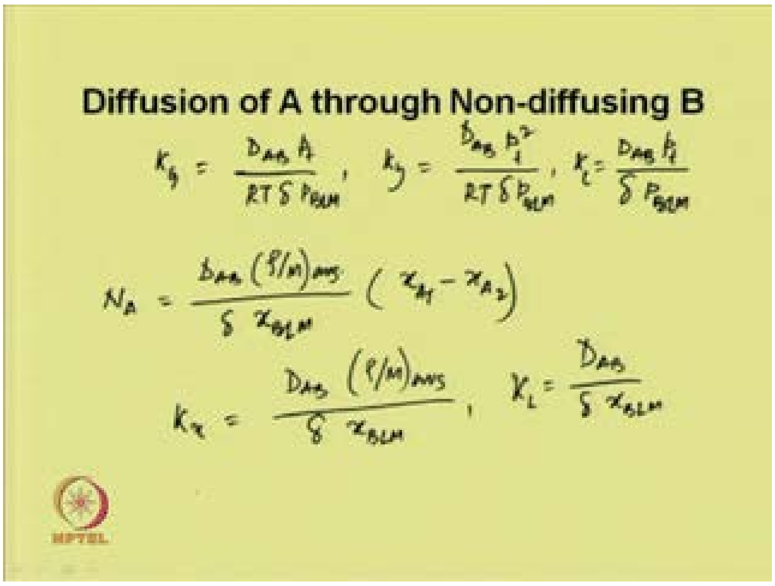

Diffusion of A through Non-diffusing B

$$k_g = \frac{D_{AB} p_t}{RT \delta p_{BLM}}, \quad k_y = \frac{D_{AB} p_t^2}{RT \delta p_{BLM}}, \quad k_c = \frac{D_{AB} p_t}{\delta p_{BLM}}$$

$$N_A = \frac{D_{AB} (\rho/M)_{avg}}{\delta x_{BLM}} (x_{A1} - x_{A2})$$

$$k_x = \frac{D_{AB} (\rho/M)_{avg}}{\delta x_{BLM}}, \quad k_L = \frac{D_{AB}}{\delta x_{BLM}}$$

So, if we compare this equation with equation one, we can obtain k g is equal to D A B p t, divided by R T L or delta p B L M k y D A B p t square divided by R T delta p B L M, and k c is D A B p t by delta p B L M. Similarly for the liquid phase, the diffusion of A through non-diffusing B, we know that flux equation N A is equal to D A B rho by m average, divided by delta x B L , into x A 1 minus x A 2. So, if we compare this equation, with this equation 2, we can obtain, so the relations this will be say delta. So, we have compared this equations with equation one, to obtain the correlations of gas phase mass transfer coefficient k g k y and k c. Now, if we compare these equations for the liquid phase flux, with the second equation, we can obtain the correlations between the liquid phase mass transfer coefficients. So, from that we can write k x is equal to D A B rho by m average, divided by delta x B L M, and k L is equal to d A B by delta x B L M.

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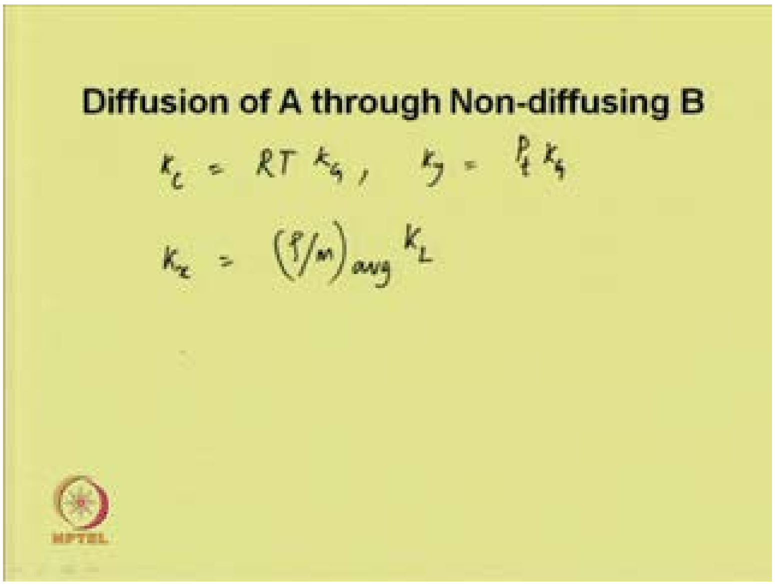

Diffusion of A through Non-diffusing B

$k_c = RT\,k_G, \quad k_y = P_t\,k_G$

$k_x = (\rho/M)_{avg}\,k_L$

We can relate among the mass transfer coefficient we can write k c is R T kg. So, from this we can clearly see that d A B p t by delta p B L M, this part is k c. So, the k c is equal to R T kg. Similarly, k y is equal to p t kg, and k x we can write rho by m average into k L, so the relations between the mass transfer coefficient in the gas phase, as well as in the liquid phase.

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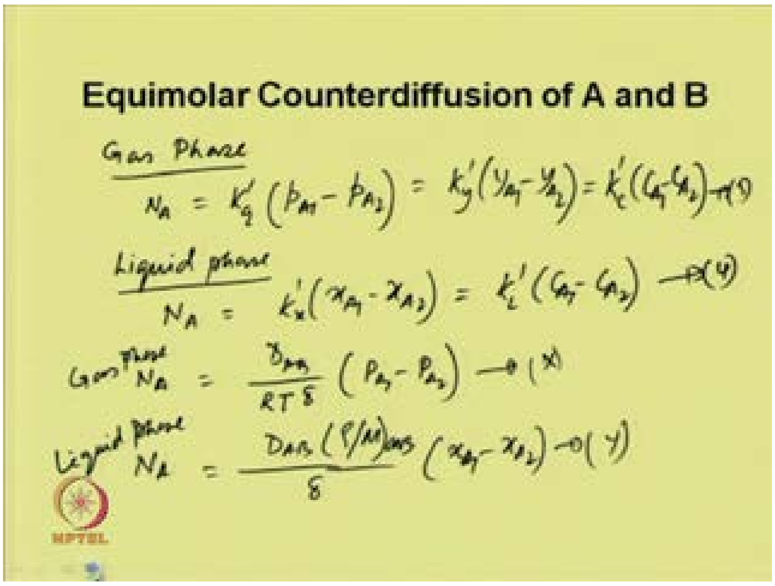

Equimolar Counterdiffusion of A and B

Gas Phase

$N_A = k'_G(p_{A_1} - p_{A_2}) = k'_y(y_{A_1} - y_{A_2}) = k'_c(C_{A_1} - C_{A_2}) \rightarrow (3)$

Liquid phase

$N_A = k'_x(x_{A_1} - x_{A_2}) = k'_L(C_{A_1} - C_{A_2}) \rightarrow (4)$

Gas Phase

$N_A = \dfrac{D_{AB}}{RT\delta}(P_{A_1} - P_{A_2}) \rightarrow (x)$

Liquid phase

$N_A = \dfrac{D_{AB}\,(\rho/M)_{avg}}{\delta}(x_{A_1} - x_{A_2}) \rightarrow (y)$

Now, consider another case, where equimolar counter diffusion of A and B. If we consider the flux for the gas phase, we can write flux is equal to k g dash. So, the dash which we distinguish between the equimolar counter diffusion, and the diffusion of A through non-diffusing B. So, into pressure driving force p A 2 is equal to k y dash, y A 1 minus y A 2, is equal to k c dash, c A 1 minus c A 2. And for the liquid phase, we can write flux is equal to k x dash x A 1 minus x A 2 is equal to k L dash c A 1 minus c A 2. So, say, this is equation number three and this is equation number four. Now, for equimolar counter diffusion, we know that flux N A is equal to d A B by R T delta p A 1 minus p A 2. So, if we compare this relation; say x with equation number three, we could be able to obtain the relations between k g, k y and k c.

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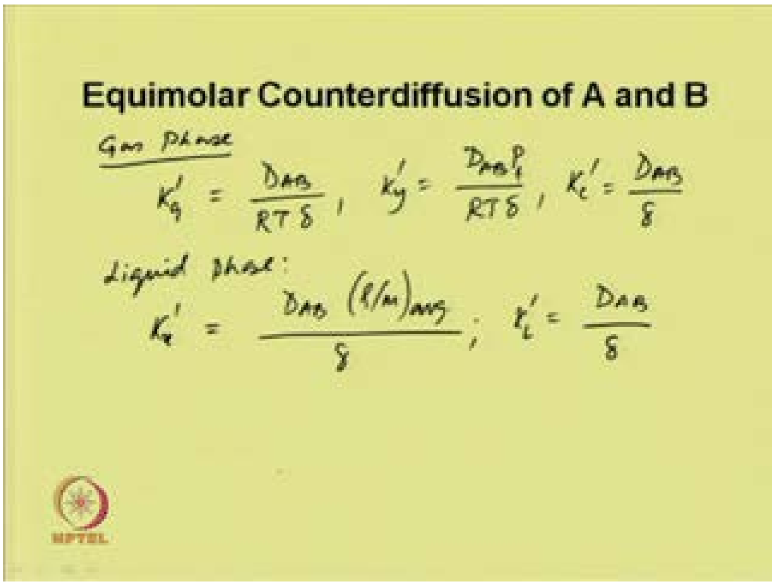

Equimolar Counterdiffusion of A and B

Gas phase

$$k'_g = \frac{D_{AB}}{RT\delta}, \quad k'_y = \frac{D_{AB} P_t}{RT\delta}, \quad k'_c = \frac{D_{AB}}{\delta}$$

Liquid phase:

$$k'_x = \frac{D_{AB} (\rho/M)_{avg}}{\delta}; \quad k'_L = \frac{D_{AB}}{\delta}$$

So, the equation for the gas phase, we obtain kg dash will be D A B by R T delta, and k y dash is D A B p t by R T delta, and k c dash is equal to D A B by delta. Similarly, for the case of liquid phase, we know that flux. This is for gas phase, and this is for liquid phase, flux is equal to D A B into rho by m average by delta into x A 1 minus x A 2. So, if we compare this equation y with equation four, we could be obtain the relations between k x and k L. So, for liquid phase, k x dash would be D A B rho by m average, divided by delta and k L dash D A B by delta.

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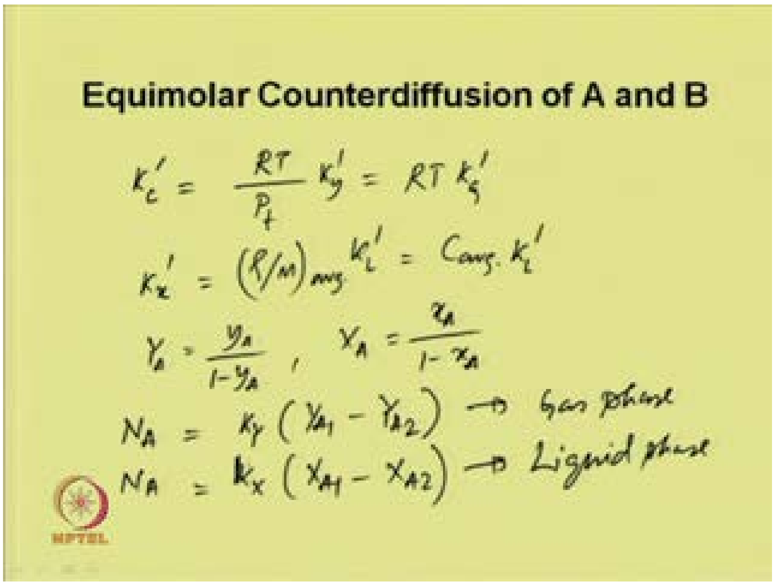

Equimolar Counterdiffusion of A and B

$$k_c' = \frac{RT}{P_t} k_y' = RT\, k_G'$$

$$k_x' = (\rho/M)_{avg}\, k_L' = C_{avg}\, k_L'$$

$$Y_A = \frac{y_A}{1-y_A}, \quad X_A = \frac{x_A}{1-x_A}$$

$$N_A = k_Y (Y_{A1} - Y_{A2}) \rightarrow \text{Gas phase}$$

$$N_A = k_X (X_{A1} - X_{A2}) \rightarrow \text{Liquid phase}$$

So, we could convert between the k c dash is equal to R T by p t, k y dash is equal to R T k g dash. Similarly, k x dash is rho by m average into k L dash is equal to C average into k L dash, so this is the conversion. Now, if the concentration terms are defined in terms of mole ratio unit; that means, y A is equal to y A divided by 1 minus y A, and that is the mole ratio basis, and to x A is equal to x A by 1 minus x A. If we define this way, the flux equation N A we can write k capital Y A 1 minus Y A 2, and incase this is for gas phase, and flux N A is equal to k x capital X we can write X A 1 minus X A 2, this is for liquid phase, this is mole ratio unit that is air free basis.

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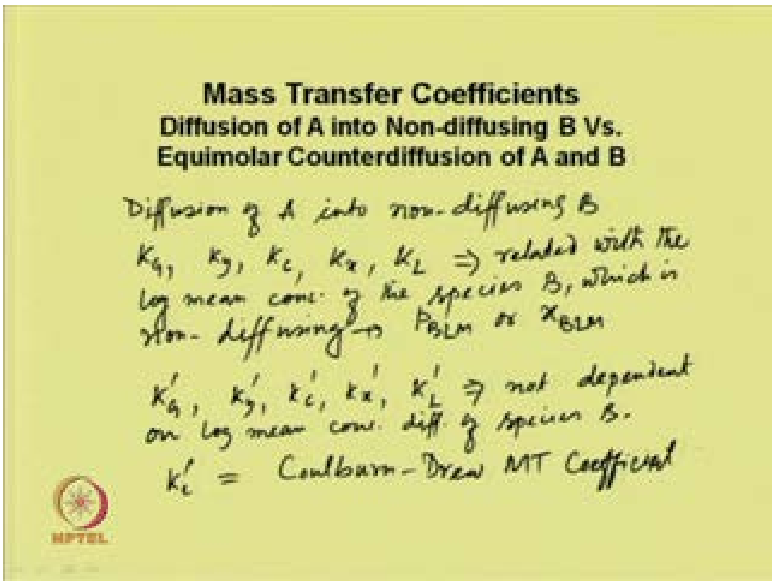

Mass Transfer Coefficients
Diffusion of A into Non-diffusing B Vs. Equimolar Counterdiffusion of A and B

Diffusion of A into non-diffusing B

k_G, k_y, k_c, k_x, k_L ⇒ related with the log mean conc. of the species B, which is non-diffusing → P_{BLM} or x_{BLM}

k_G', k_y', k_c', k_x', k_L' ⇒ not dependent on log mean conc. diff. of species B.

k_c' = Coulburn-Drew MT Coefficient

Now, the mass transfer coefficients between the two systems; diffusion of A into non-diffusing B, and equimolar counter diffusion of A and B, what are the difference? In case of diffusion of A into non-diffusing B, the mass transfer coefficients which are k g, k y, k c, k x and k l, these are the related with the log mean concentrations of the species, log mean concentration of the species B which is non-diffusing. So, the mass transfer in this case, depends on p B L M or x B L M. But on the other hand for the equimolar counter diffusion of A and B, the mass transfer coefficient k g dash k y dash and k c dash k x dash k l dash, these are not dependent on log mean concentration difference of species B. This type of mass transfer coefficient is known as Colburn Drew mass transfer coefficients.

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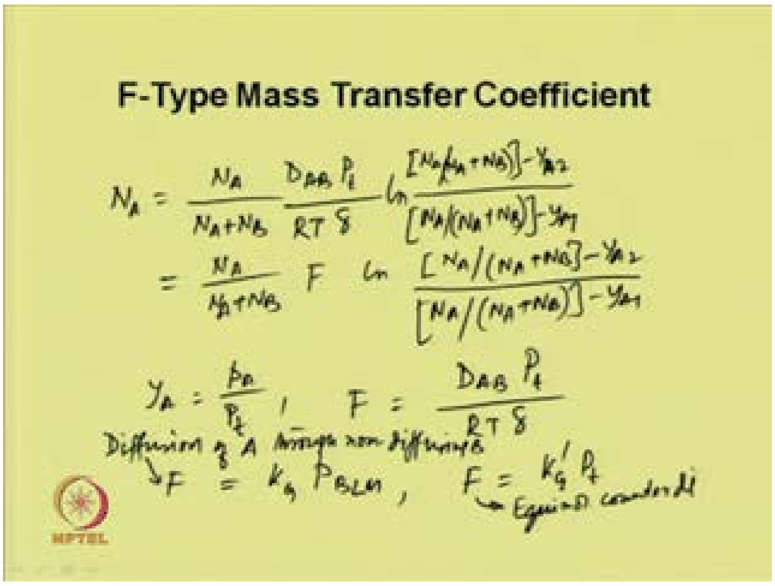

F-Type Mass Transfer Coefficient

$$N_A = \frac{N_A}{N_A+N_B}\frac{D_{AB}P_t}{RT\delta}\ln\frac{[N_A/(N_A+N_B)]-y_{A2}}{[N_A/(N_A+N_B)]-y_{A1}}$$

$$= \frac{N_A}{N_A+N_B} F \ln\frac{[N_A/(N_A+N_B)]-y_{A2}}{[N_A/(N_A+N_B)]-y_{A1}}$$

$$y_A = \frac{p_A}{P_t}, \quad F = \frac{D_{AB}P_t}{RT\delta}$$

Diffusion of A through non-diffusing B

$$\rightarrow F = k_G p_{BLM}, \quad F = k'_G P_t$$

$\rightarrow$ Equimol counterdi

Now, there is another type of mass transfer coefficient, which is f type mass transfer coefficient, and we know earlier we have derived the flux equation N A, is equal to N A by N A plus N B D A B p t divided by R T delta L N, N A divided by N A plus N B minus Y A 2 divided by N A by N A plus N B, minus Y A 1. So, this we can write equal to N A by N A plus N B into F L N N A by N A plus N B minus Y A 2 divided by N A by N A plus N B minus Y A 1. In this case we can write Y A is equal to p A by p t, and F is equal to D A B p t by R T delta. Similarly, for diffusion of A through non-diffusing B, this correlations can be obtained F is equal to k g p B L M. And also for equimolar counter diffusion F, we can write k g dash p t, this is diffusion of A through non-diffusing B, and this is for equimolar counter diffusion.

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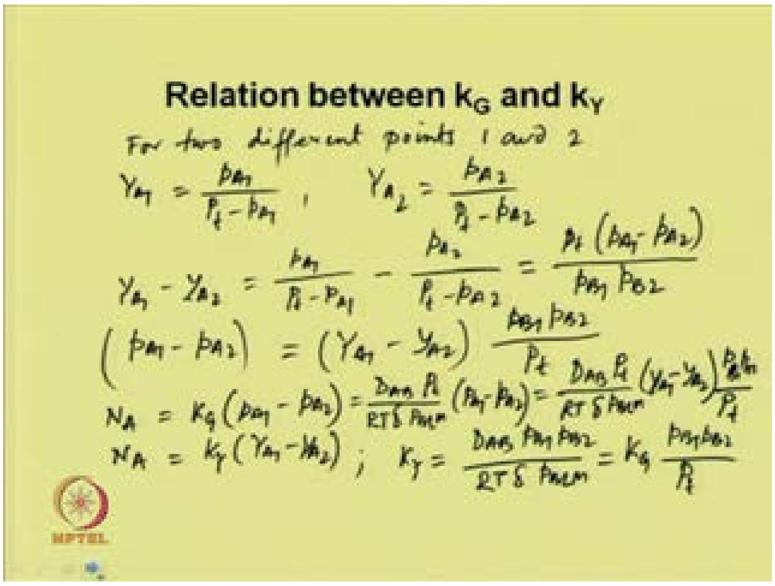

Relation between k_G and k_Y

For two different points 1 and 2

$$Y_{A_1} = \frac{p_{A_1}}{P_t - p_{A_1}}, \quad Y_{A_2} = \frac{p_{A_2}}{P_t - p_{A_2}}$$

$$Y_{A_1} - Y_{A_2} = \frac{p_{A_1}}{P_t - p_{A_1}} - \frac{p_{A_2}}{P_t - p_{A_2}} = \frac{P_t(p_{A_1} - p_{A_2})}{p_{A_1} p_{B_2}}$$

$$(p_{A_1} - p_{A_2}) = (Y_{A_1} - Y_{A_2}) \frac{p_{B_1} p_{B_2}}{P_t}$$

$$N_A = k_G(p_{A_1} - p_{A_2}) = \frac{D_{AB} P_t}{RT\delta p_{BLM}}(p_{A_1} - p_{A_2}) = \frac{D_{AB} P_t}{RT\delta p_{BLM}}(Y_{A_1} - Y_{A_2}) \frac{p_{B_1} p_{B_2}}{P_t}$$

$$N_A = k_Y(Y_{A_1} - Y_{A_2}); \quad k_Y = \frac{D_{AB} p_{B_1} p_{B_2}}{RT\delta p_{BLM}} = k_G \frac{p_{B_1} p_{B_2}}{P_t}$$

So, what is the relation between k g and k y, we know that for two different points 1 and 2, we can write y A 1 p A 1 p t minus p A 1 and y A 2 p A 2 by p t minus p A 2. So, the difference y A 1 minus y A 2 will be equal to p A 1 by p t minus p A 1 minus p A 2 by p t minus p A 2, which will be equal to p t into p A 1 minus p A 2, divided by p B 1 into p B 2. So, we can write p A 1 minus p A 2 would be equal to y A 1 minus y A 2 into p B 1 and p B 2 p B 1 p B 2 divided by p t. Now, we know that flux N A is equal to k g p A 1 minus p A 2 is equal to D A B p t by R T delta p B L M into p a 1 minus p A 2 is equal to D A B p t by R T delta p B L M into y A 1 minus y A 2 into p B 1 p B 2 divided by p t. So, we know that N A is equal to k y into y A 1 minus y A 2. So, we can write k y is equal to D A B p B 1 p B 2 divided by R T delta p B L M. So, we can write k g into p B 1 p B 2 divided by p t. Similarly, we can derive the relations between k g dash and k y dash.

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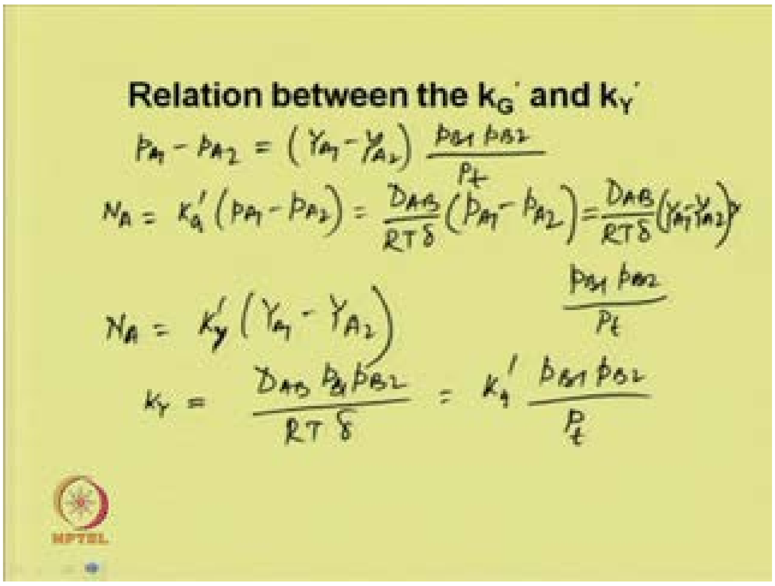

Relation between the k_G' and k_Y'

$$p_{A1} - p_{A2} = (y_{A1} - y_{A2}) \frac{p_{B1} p_{B2}}{p_t}$$

$$N_A = k_G'(p_{A1} - p_{A2}) = \frac{D_{AB}}{RT\delta}(p_{A1} - p_{A2}) = \frac{D_{AB}}{RT\delta}(y_{A1} - y_{A2}) \frac{p_{B1} p_{B2}}{p_t}$$

$$N_A = k_y'(y_{A1} - y_{A2})$$

$$k_y = \frac{D_{AB} p_{B1} p_{B2}}{RT\delta} = k_G' \frac{p_{B1} p_{B2}}{p_t}$$

As we know the relations between p A 1 minus p A 2 is equal to y A 1 minus y A 2 into p B 1 p B 2 by p t. We can write flux N A is equal to k g dash p A 1 minus p A 2 is equal to d A B by R T delta, and into p partial pressure of A minus partial pressure of 0.1 at and at 0.2, p A 2 will be equal to D A B by R T delta y A 1 minus y A 2, multiplied by p p B 1 p B 2 divided by p t. And we know that N A is equal to k y k y dash into y A 1 minus y A 2. So, we can write k y is equal to d A B p B 1 and p B 2 divided by R T delta is equal to k g dash p B 1 p B 2 by p t. So, similar correlations like k g and k y, we can also obtain the relations between k g dash and k y dash.

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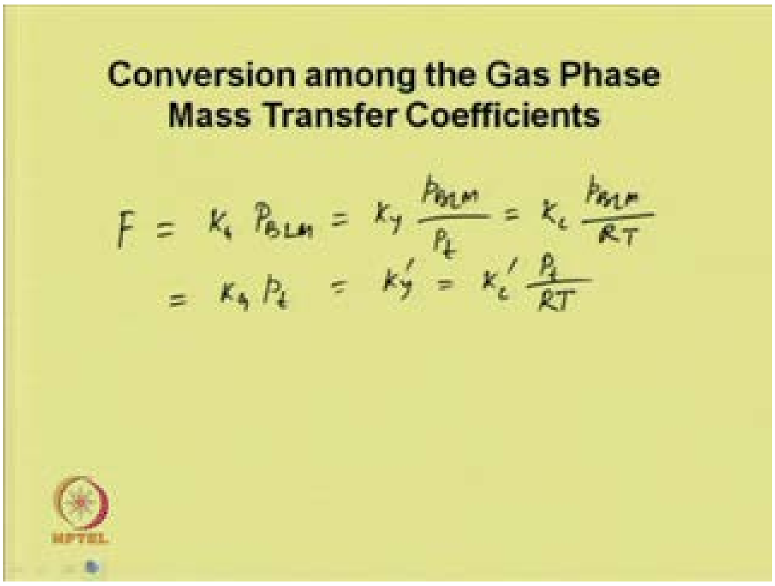

Conversion among the Gas Phase Mass Transfer Coefficients

$$F = k_G p_{BLM} = k_y \frac{p_{BLM}}{p_t} = k_c \frac{p_{BLM}}{RT}$$

$$= k_G p_t = k_y' = k_c' \frac{p_t}{RT}$$

Now, the conversion among the gas phase mass transfer coefficients. So, we know F is equal to k g p B L M, and this related with k y; k y p B L M by p t is equal to k c p B L M by R T which we can write k g p t is equal to k y dash is equal to k c dash p t divided by R T. Similarly, we can get the relations among the liquid phase mass transfer coefficients.

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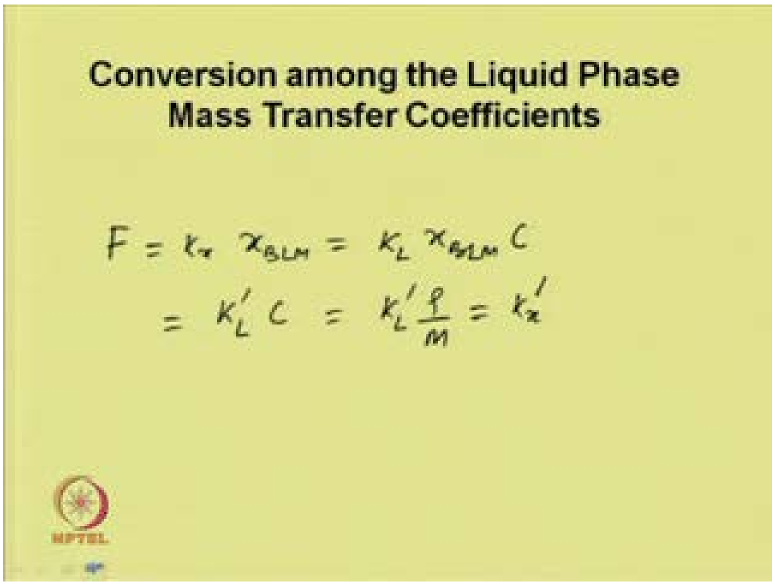

Conversion among the Liquid Phase Mass Transfer Coefficients

$$F = k_x x_{BLM} = k_L x_{BLM} C$$
$$= k_L' C = k_L' \frac{\rho}{M} = k_x'$$

So, that is also related with F time mass transfer coefficients, which is equal to k x X B L M is equal to k L X B L M into concentration is equal to k L dash C is equal to k L dash rho by m is equal to k x dash. So, these are the relation among the mass transfer coefficient, in the gas phase and the liquid phase.

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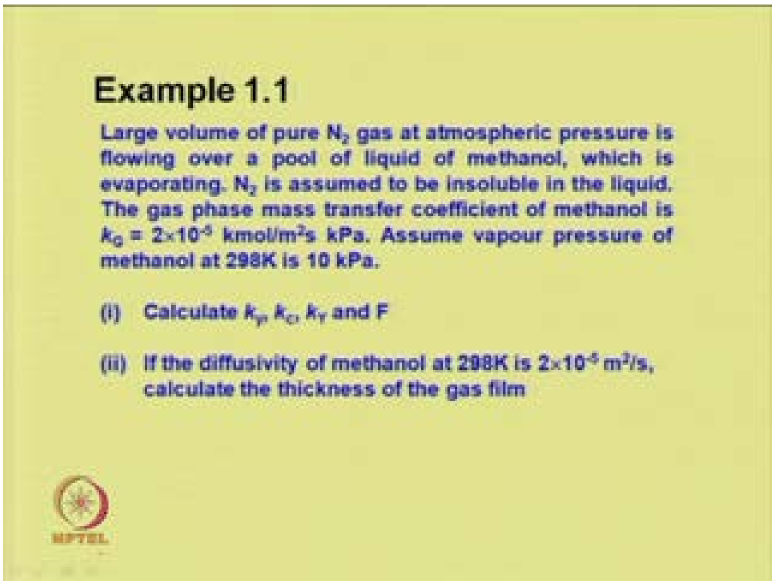

Example 1.1

Large volume of pure N_2 gas at atmospheric pressure is flowing over a pool of liquid of methanol, which is evaporating. N_2 is assumed to be insoluble in the liquid. The gas phase mass transfer coefficient of methanol is $k_G = 2\times10^{-5}$ kmol/m^{2}s kPa. Assume vapour pressure of methanol at 298K is 10 kPa.

(i) Calculate k_y, k_C, k_Y and F

(ii) If the diffusivity of methanol at 298K is 2×10^{-5} m^2/s, calculate the thickness of the gas film

So, let us consider an example, to calculate mass transfer coefficients in the gas phase, and also the film thickness, or the gas film thickness. So, consider large volume of pure nitrogen gas, at atmospheric pressure is flowing over a pool of liquid of methanol, which is evaporating, and nitrogen is assumed to be insoluble in liquid. The gas phase mass transfer coefficient of methanol is given; assume vapor pressure of methanol at 298 kelvin is 10 kilopascal. Calculate k y, k small y, k c k capital y and f, and the second problem, if the diffusivity of methanol at 298 kelvin is 2 into 10 to the power minus 5 meter square per second. Calculate the thickness of the gas film.

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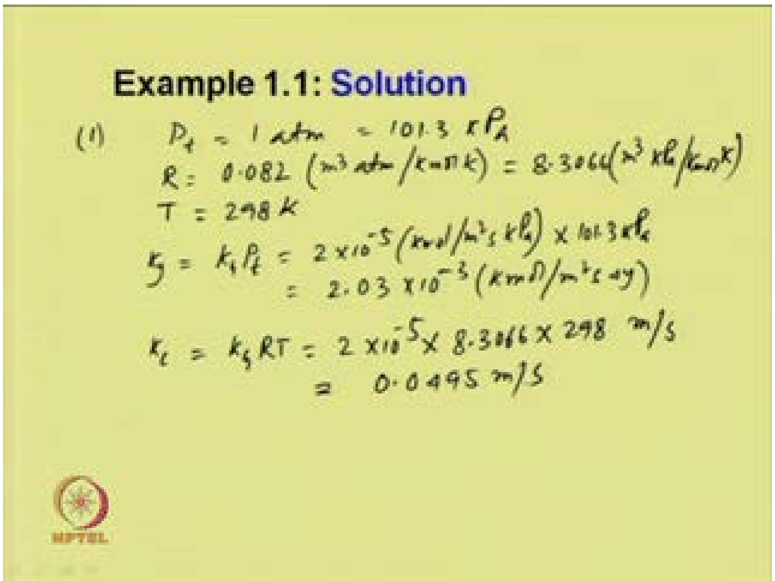

Example 1.1: Solution

(i)

$P_t = 1\ atm = 101.3\ kPa$

$R = 0.082\ (m^3\,atm/kmol\,K) = 8.3066\ (m^3\,kPa/kmol\,K)$

$T = 298\ K$

$k_y = k_G P_t = 2\times10^{-5}\ (kmol/m^2 s\, kPa) \times 101.3\ kPa$

$= 2.03\times10^{-3}\ (kmol/m^2 s\, \Delta y)$

$k_c = k_G RT = 2\times10^{-5} \times 8.3066 \times 298\ m/s$

$= 0.0495\ m/s$

Now, let us consider for the first case, this is the case of diffusion of A through non-diffusing B, and given p t is one atmosphere, which is 101.3 kilopascal, R is 0.082 meter cube atmosphere per k mole Kelvin, which is equal to 8.3066 meter cube kilopascal per k mole Kelvin, and T is given 298 kelvin. Now k small y is equal to k g p t from the conversion equation. So, we can write 2 into 10 to the power minus 5 k mole per meter square second, kilopascal into p t 101.3 kilopascal. So, this will give you 2.03 into 10 to the power minus 3 k mole per meter square second delta y. Similarly, we can calculate k c, which is k g R T. So, k g is 2 into 10 to the power minus 5, R is equal to 8. 3066, and temperature is 298 kelvin, this is meter per second, which is equal to 0.0495 meter per second.

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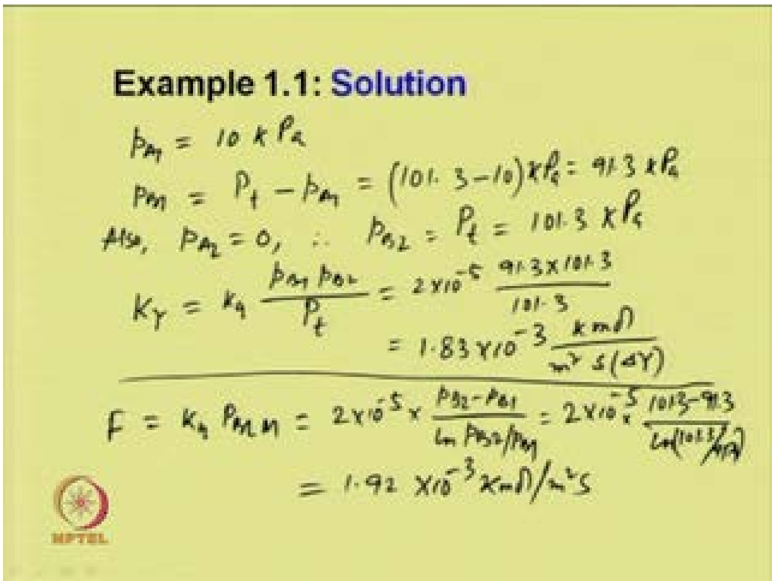

Example 1.1: Solution

$p_{A1} = 10\ kPa$

$p_{B1} = P_t - p_{A1} = (101.3 - 10)\ kPa = 91.3\ kPa$

Also, $p_{A2} = 0, \therefore\ p_{B2} = P_t = 101.3\ kPa$

$$K_Y = k_g \frac{p_{B1} p_{B2}}{P_t} = 2\times10^{-5}\ \frac{91.3\times101.3}{101.3}$$

$$= 1.83\times10^{-3}\ \frac{kmol}{m^2\, s(\Delta Y)}$$

$$F = k_g\, p_{BM} = 2\times10^{-5}\times\frac{p_{B2}-p_{B1}}{\ln p_{B2}/p_{B1}} = 2\times10^{-5}\times\frac{101.3-91.3}{\ln(101.3/91.3)}$$

$$= 1.92\times10^{-3}\ kmol/m^2 s$$

Another is k capital y. So, p A 1, the partial pressure at point at the surface is 10 kilopascal. So, p B 1 is equal to p t minus p A 1, which is equal to 101.3 minus 10 kilopascal, which is 91.3 kilopascal, and also p A 2 is equal to 0. Therefore, p B 2 is equal to p t, is equal to 101.3 kilopascal. So, k Y capital Y is equal to k g p B 1, p B 2 by p t, we have derived this equation. So, if we substitute 2 into 10 to the power minus 5, 91.3 into 101.3 divided by 101.3, this is equal to 1.83 into 10 to the power minus 3 k mole per meter square second delta y. And we know the relations between F and k g p B L M. So, this is 1, and we can calculate F, which is equal to 2 into 10 to the power minus 5 into p B 2 minus p B 1 by L N, p B 2 by p B 1 is equal to 2 into 10 to the power minus

5, 101.3 minus 91.3 by L N 101.3 by 91.3. So, this will give the value of 1.92 into 10 to the power minus 3 k mole per meter square second.

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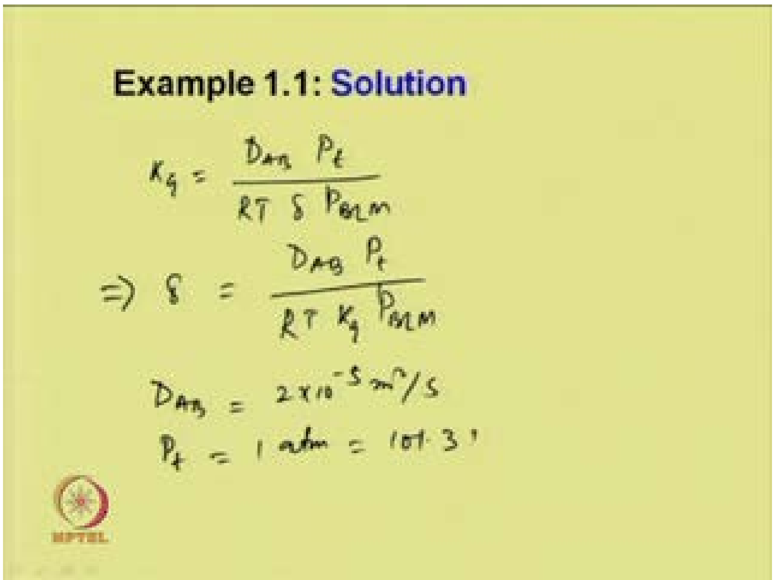

Example 1.1: Solution

$$k_g = \frac{D_{AB}\ P_t}{RT\ \delta\ P_{BLM}}$$

$$\Rightarrow \delta = \frac{D_{AB}\ P_t}{RT\ k_g\ P_{BLM}}$$

$D_{AB} = 2\times10^{-5}\ m^2/s$

$P_t = 1\ atm = 101.3$

So, to calculate the film thickness, we know k g is D A B p t divided by R T delta p B L M. So, delta, we can write is equal to D A B p t divided by R T k g p B L M. D A B is given 2 into 10 to the power minus 5 meter square per second, p t is 1 atmosphere is equal to 101.3 kilopascal.

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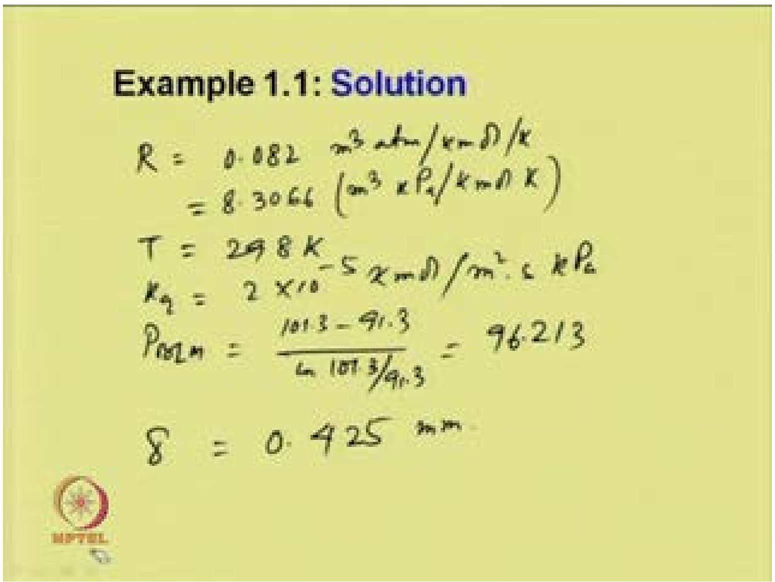

Example 1.1: Solution

$R = 0.082\ m^3\ atm/kmol/K$

$= 8.3066\ (m^3\ kPa/kmol\ K)$

$T = 298\ K$

$k_g = 2\times10^{-5}\ kmol/m^2.s\ kPa$

$$P_{BLM} = \frac{101.3-91.3}{\ln 101.3/91.3} = 96.213$$

$\delta = 0.425\ mm$

And R is 0.082 meter cube atmosphere per k mole Kelvin is equal to 8.3066 meter cube kilopascal k mole Kelvin. So, T is 298 Kelvin. So, k g is equal to 2 into 10 to the power minus 5 k mole per meter square second kilopascal, P B L M we have already calculated 101.3 minus 91.3 L N 101.3 by 91.3 is equal to 96.213. So, after substitution delta will be 0.425 millimeter. So, this is the typical film thickness.

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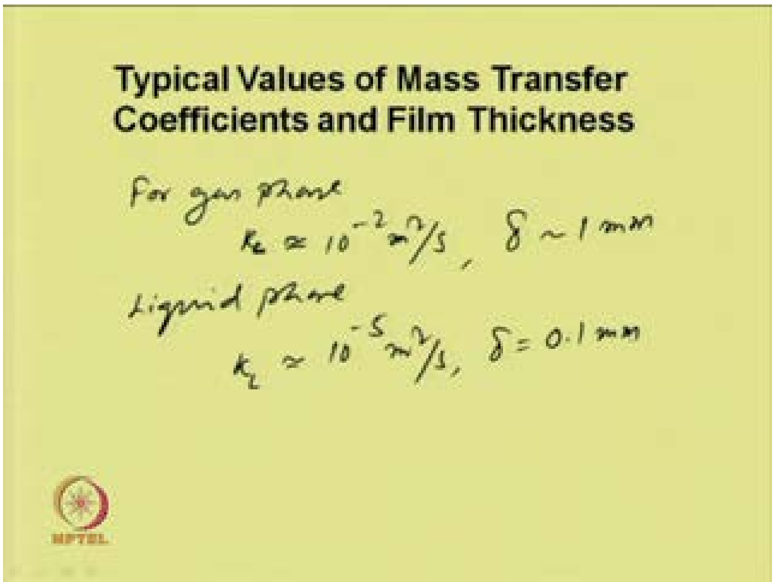

Typical Values of Mass Transfer Coefficients and Film Thickness

For gas phase

$k_c \simeq 10^{-2}\ m^2/s$, $\delta \sim 1\ mm$

Liquid phase

$k_L \simeq 10^{-5}\ m^2/s$, $\delta = 0.1\ mm$

So, the typical values for the mass transfer coefficient and the film thickness, in case of the gas phase, k c is equal to about 10 to the power minus 2 meter square per second, and film thickness delta is approximately 1 millimeter. In case of liquid phase k L is approximately 10 to the power minus 5 meter square per second, and delta is film thickness is around 0.1 millimeter. So, this is end of lecture 1 of module 2.

Thank you.