Upstream LNG Technology
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Lecture - 63
Tutorial on multicomponent distillation –II

Welcome. In earlier's lectures, we have learnt about the analysis and some problems on the multicomponent distillation using shortcut methods and we have done one set of problems on that. Now, in this particular lecture, we shall be doing some other set of problems on this multicomponent distillation and the shortcut methods for their analysis. So, this is a Tutorial on the multicomponent distillation part 2.

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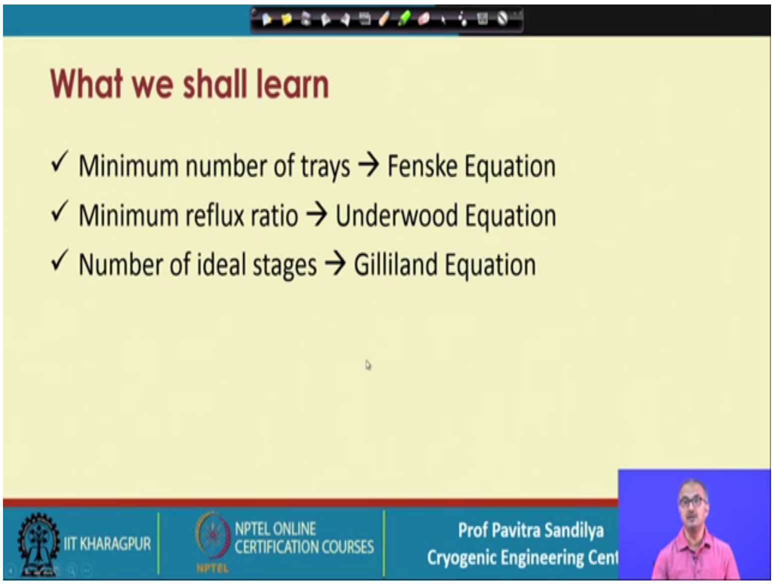

What we shall learn

- ✓ Minimum number of trays → Fenske Equation
- ✓ Minimum reflux ratio → Underwood Equation
- ✓ Number of ideal stages → Gilliland Equation

So, in this we shall be learning about the application of Fenske equation to find out the minimum number of stages and the Underwood equation to find out the reflux ratio minimum reflux ratio and the Gilliland equation to find out the number of the ideal stages.

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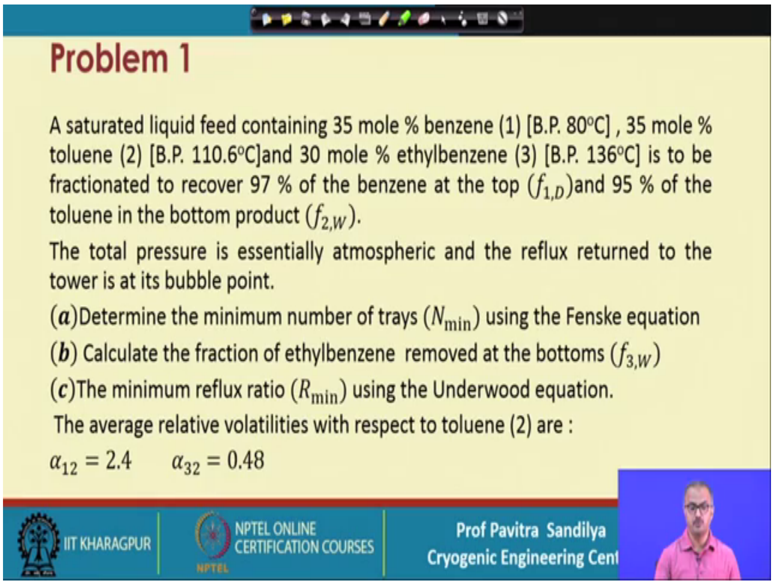

Problem 1

A saturated liquid feed containing 35 mole % benzene (1) [B.P. 80°C] , 35 mole % toluene (2) [B.P. 110.6°C]and 30 mole % ethylbenzene (3) [B.P. 136°C] is to be fractionated to recover 97 % of the benzene at the top ($f_{1,D}$)and 95 % of the toluene in the bottom product ($f_{2,W}$).

The total pressure is essentially atmospheric and the reflux returned to the tower is at its bubble point.

(***a***)Determine the minimum number of trays ($N_{\min}$) using the Fenske equation

(***b***) Calculate the fraction of ethylbenzene removed at the bottoms ($f_{3,W}$)

(***c***)The minimum reflux ratio ($R_{\min}$) using the Underwood equation.

The average relative volatilities with respect to toluene (2) are :

$\alpha_{12} = 2.4 \qquad \alpha_{32} = 0.48$

So, here we have the first problem. In this problem, we are given a feed which is saturated liquid that is the feed is at it is boiling bubble point and this feed has these components one is the component benzene and it is labelled as 1 and it is 35 mole percent and it has a boiling point of 80 degree Centigrade. Then, we have toluene, it is labelled with 2 it has a boiling point of 110.6 degree centigrade and the mole fraction is 35 and then mole percent is 35 and we have the ethyl benzene that is the component 3 with a boiling point of 136 degree Centigrade.

And the mole percent is 30 and this have to be fractionated and we have to recover 97 percent of the benzene at the top because among these three components, benzene has the lowest boiling point that is it will be has the highest volatility. So, it will be preferentially going with the distillate. On the other hand, ethyl benzene has the maximum boiling points among all the components here. So, it will tend to go more to the bottoms. So, here we have the benzene is recovery has to be 97 percent and the toluene recovery in the bottom has to be 95 percent.

So, because this problem has been stated the separation has been stated with respect to benzene and toluene. So, these two components will be taken as the heavy key and the light key. So, here we have the total pressure of the system is taken to be atmospheric and the reflux is return to the tower at its bubble point; that means we are getting the condenser, we are making simply the bubble point liquid. Now, here we have the determine the minimum number of trays by the Fenske equation and then we have to calculate the fraction of the ethyl benzene removed in the bottom product.

Now, please understand this ethyl benzene is the HNK that is the Heavier Non Key component and we have to find out the minimum reflux ratio by the under root equation and the average volatilities relative volatilities with respect to toluene component 2 are given here. As you can see it is alpha 1 2 is 2.4 and alpha 3 2 is 0.48. It shows that alpha 1 2 means that component 1 that is benzene is more volatile than component 2 that is toluene and here we find that ethyl benzene component 3 is less volatile than the component 2. And if you take a reciprocal of this particular alpha 1 2 that is you get alpha 2 1 and you will find that alpha 2 1 is also coming nearly 2.4, it will coming as 0.41 or so.

So, because this alpha 2 1 and alpha 3 2 are almost the nearby. So, it can be also justified from these values of the boiling point, you can see the difference in the boiling points between benzene toluene and ethyl benzene toluene are almost of the same order.

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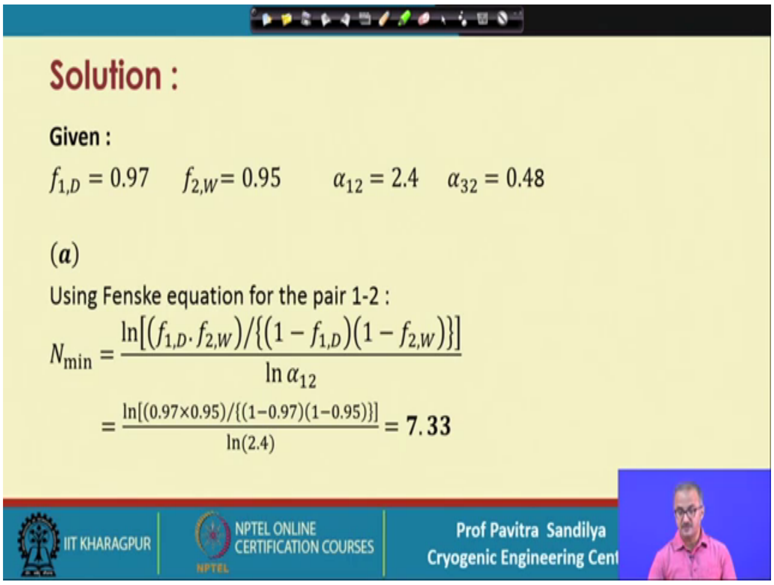

Solution :

Given :

$f_{1,D} = 0.97$ $f_{2,W} = 0.95$ $\alpha_{12} = 2.4$ $\alpha_{32} = 0.48$

(*a*)

Using Fenske equation for the pair 1-2 :

$$N_{\min} = \frac{\ln\left[\left(f_{1,D}\cdot f_{2,W}\right)/\left\{\left(1-f_{1,D}\right)\left(1-f_{2,W}\right)\right\}\right]}{\ln\alpha_{12}}$$

$$= \frac{\ln[(0.97\times0.95)/\{(1-0.97)(1-0.95)\}]}{\ln(2.4)} = 7.33$$

So, we expect that their relative volatilities will also be of the same order. Now, here are the data which are given to us about the recovery and relative volatilities and the first part we have to use the Fenske equation and we apply it to the pair 1 2 and ones we put this Fenske equation in terms of the recovery, now we plugin the various values of from this data and we find out that the this is the minimum number of ideal stages that is 7.33.

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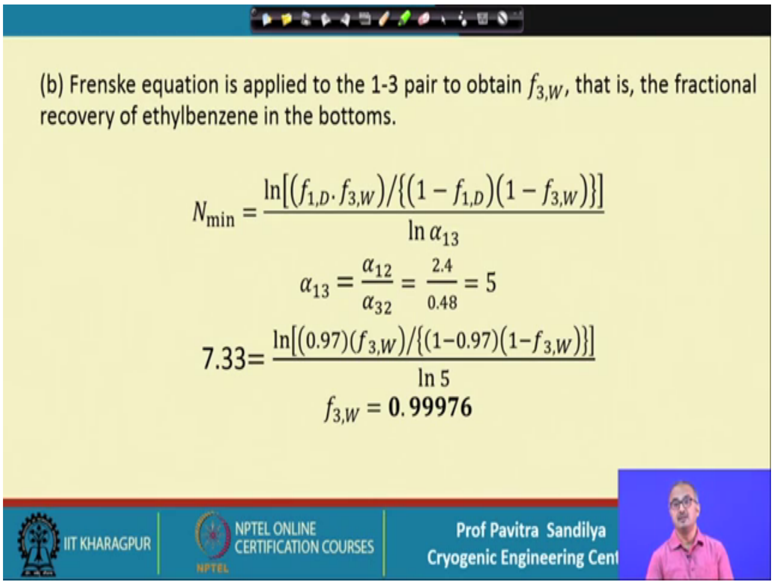

(b) Frenske equation is applied to the 1-3 pair to obtain $f_{3,W}$, that is, the fractional recovery of ethylbenzene in the bottoms.

$$N_{min} = \frac{\ln[(f_{1,D} \cdot f_{3,W})/\{(1-f_{1,D})(1-f_{3,W})\}]}{\ln \alpha_{13}}$$

$$\alpha_{13} = \frac{\alpha_{12}}{\alpha_{32}} = \frac{2.4}{0.48} = 5$$

$$7.33 = \frac{\ln[(0.97)(f_{3,W})/\{(1-0.97)(1-f_{3,W})\}]}{\ln 5}$$

$$f_{3,W} = 0.99976$$

And once we have done that, now we have to do, we put again take the same Fenske equation, but now we apply this equation to this pair of 1 and 3 because we have been asked to find out that; what is the amount of the ethyl benzene recovery in the bottom product. So, we put again in terms of 1 and 3 we write this equation now in this case we find that we need the value of alpha 1 3 which is not given directly in the problem. So, what we do we can easily find it out from the other values that alpha 1 3 you can do it yourself that alpha 1 3 equal to k 1 by k 3 and k 1 by k 3 what we do we divide and multiply by k 2; that means, what we do we do k 1 by k 2 into k 2 by k 3.

Now, k one by k 2 is nothing but alpha 1 2 and k 2 by k 3 is nothing but the reciprocal of alpha 3 2. So, that is how we are able to get the value of alpha 1 3 as 5. So, this 5 shows this shows that there is a much larger difference between the boiling points of the component 1 and component 3. So, we put get this value of the alpha 1 3 in this put it in this equation and we plugin the various values and from these by solve we can solve for f 3 w that is the recovery of component 3 that is ethyl benzene in the bottom product and that is coming out to be 0.99976.

It is almost very very near to one and this clearly shows that the ethyl benzene being the heaviest of all the components in this particular mixture tends to go more with the bottoms and not with the top that is why we are getting almost complete recovery of ethyl benzene in the bottom product. So, this is how we interpret the results obtained in this particular problem.

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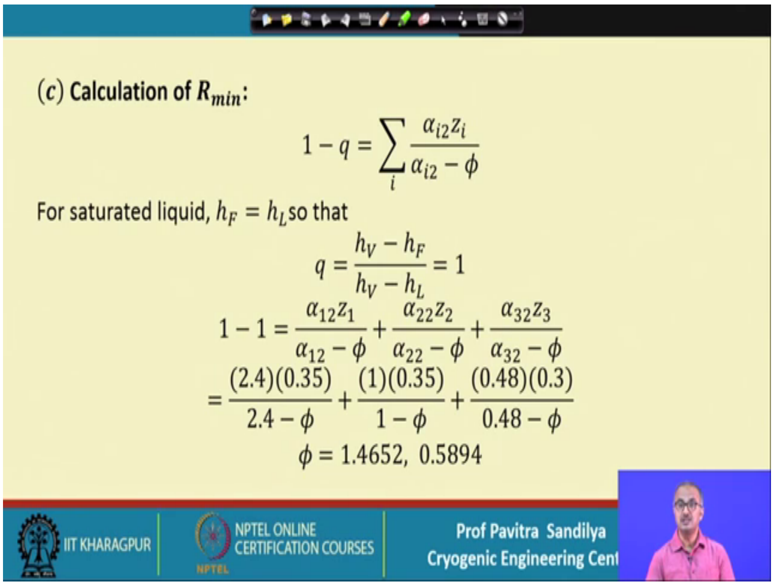

(*c*) **Calculation of R_{min}:**

$$1-q=\sum_i \frac{\alpha_{i2}z_i}{\alpha_{i2}-\phi}$$

For saturated liquid, $h_F = h_L$ so that

$$q=\frac{h_V-h_F}{h_V-h_L}=1$$

$$1-1=\frac{\alpha_{12}z_1}{\alpha_{12}-\phi}+\frac{\alpha_{22}z_2}{\alpha_{22}-\phi}+\frac{\alpha_{32}z_3}{\alpha_{32}-\phi}$$

$$=\frac{(2.4)(0.35)}{2.4-\phi}+\frac{(1)(0.35)}{1-\phi}+\frac{(0.48)(0.3)}{0.48-\phi}$$

$$\phi = 1.4652,\ 0.5894$$

Next, we have been asked to determine the minimum reflux ratio and for this, we are using the under root equation and this is the under root equation be learnt earlier. So, in this equation, we have the q value and q value has been learnt earlier has to be found out from the condition of the feed and we have been told in the problem that the feed is a saturated liquid.

So, we go to this definition of q that is h V minus h F by h V minus h L and this here we instead of this h F we are putting the h L value. So, we find this q is coming out to be unity. Now, we put the value of q over here in this equation and then plugin the values of the various the relative volatilities we first expand this summation for all the components and then plugin the values of all this this composition and alpha and we find that here we have an equation in terms of only phi and we see that this equation will result in a quadratic equation that is a polynomial equation with degree 2.

So, that means, we shall be having two roots of this particular equation and these two roots can be easily found out as these two. So, now, we find that we have two positive values of phi and phi has to be positive. So, now, the question comes how to choose the value of phi for further calculation.

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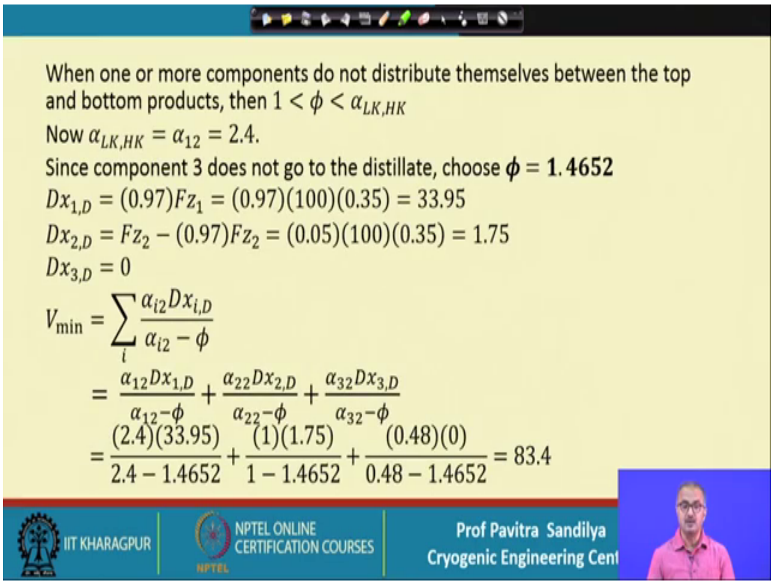

When one or more components do not distribute themselves between the top and bottom products, then $1 < \phi < \alpha_{LK,HK}$

Now $\alpha_{LK,HK} = \alpha_{12} = 2.4$.

Since component 3 does not go to the distillate, choose $\phi = \mathbf{1.4652}$

$$Dx_{1,D} = (0.97)Fz_1 = (0.97)(100)(0.35) = 33.95$$

$$Dx_{2,D} = Fz_2 - (0.97)Fz_2 = (0.05)(100)(0.35) = 1.75$$

$$Dx_{3,D} = 0$$

$$V_{\min} = \sum_i \frac{\alpha_{i2} Dx_{i,D}}{\alpha_{i2} - \phi}$$

$$= \frac{\alpha_{12} Dx_{1,D}}{\alpha_{12} - \phi} + \frac{\alpha_{22} Dx_{2,D}}{\alpha_{22} - \phi} + \frac{\alpha_{32} Dx_{3,D}}{\alpha_{32} - \phi}$$

$$= \frac{(2.4)(33.95)}{2.4 - 1.4652} + \frac{(1)(1.75)}{1 - 1.4652} + \frac{(0.48)(0)}{0.48 - 1.4652} = 83.4$$

Now, in this case, we make this kind of thing that without going into the details of the theories, it is sufficient to know that when we find that we have one or more components do not distribute themselves between top and bottom; that means, one or two component some components will stay exclusively with only in the top product or the bottom product, but not both.

So, in this case if you have this then we will choose that phi which will be lying between this alpha LK HK and 1 in this case alpha HK is that is 1 2 is 2.4, so, and this 1. So, what we do that this because we see that the components 3 does not go to distillate ok. So, we have this particular situation and in this case, we choose this and we find that this particular value is satisfying this condition. So, we choose this value of the phi; the other value of phi does not give the satisfied condition.

Now, once we have decided the value of the phi, we go back to the this our basic definitions of the recovery and from that we find that we plugin this we get the value of the amount of the component 1 which is going the distillate and we put this value here and we find this is the flow rate of the component 1 in the distillate and similarly we can find the flow rate of component 2 in distillate and as we have said that we are saying that there is no one component 3 in the distillate and that also we found out earlier it is giving a recovery of 0.999 something in the bottoms.

Now, once we have obtained this values, we use this particular equation this is given by for the under root equation and again expand this summation and plugin the values of these various variables in this equation and we get the minimum volume volumetric this vapoured flow rate.

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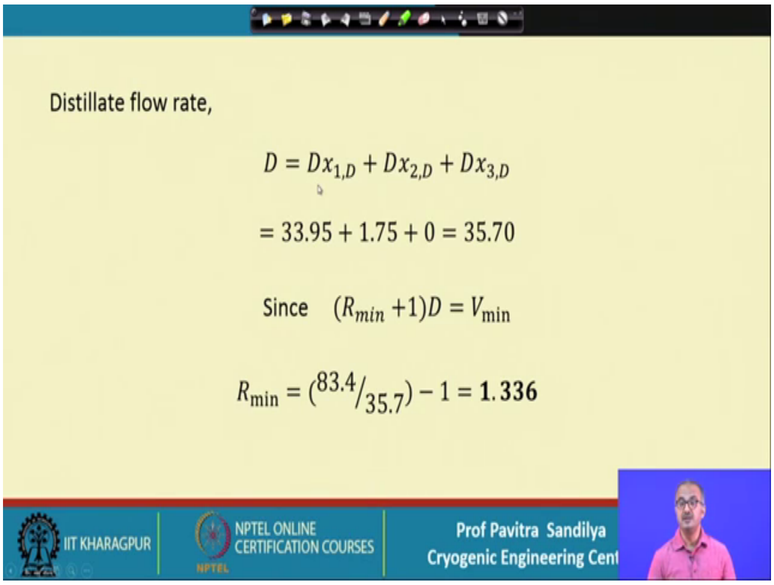

Distillate flow rate,

$$D = Dx_{1,D} + Dx_{2,D} + Dx_{3,D}$$

$$= 33.95 + 1.75 + 0 = 35.70$$

$$\text{Since} \quad (R_{min} + 1)D = V_{\min}$$

$$R_{\min} = \left({}^{83.4}\!/_{35.7}\right) - 1 = \mathbf{1.336}$$

And once we know this vapour flow rate and we find the distillate flow rate like this by adding the individual amounts individual flow rates of each of the components, we get the total distillate flow rate and we know that this is a basic definition L by D is the reflux ratio and in terms of V this is the equation so we plug in the values of D and V min and we get the R min as this value.

And this is your solution now question comes what if somebody uses the other value of the phi. Now, if somebody uses the other value of the phi you can also check it up yourself, but if you put the other value of phi then you will land up with some unrealistic value of this flow rates. You may get away negative value of the flow rate and that will clearly show that the choice of the phi was wrong. So, without going into those details it is that thing I have given you that from that I can figure out that how to choose the value of the phi and we are getting the value of the minimum reflux ratio.

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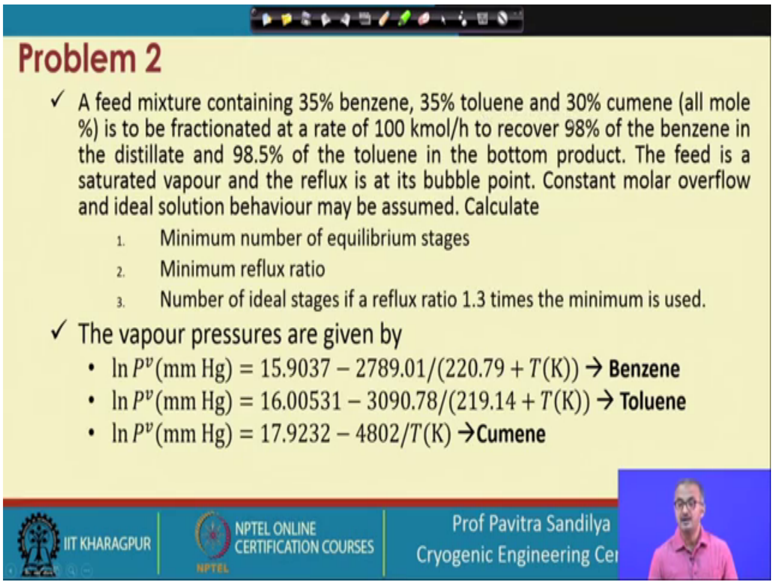

Problem 2

- ✓ A feed mixture containing 35% benzene, 35% toluene and 30% cumene (all mole %) is to be fractionated at a rate of 100 kmol/h to recover 98% of the benzene in the distillate and 98.5% of the toluene in the bottom product. The feed is a saturated vapour and the reflux is at its bubble point. Constant molar overflow and ideal solution behaviour may be assumed. Calculate
  1. Minimum number of equilibrium stages
  2. Minimum reflux ratio
  3. Number of ideal stages if a reflux ratio 1.3 times the minimum is used.
- ✓ The vapour pressures are given by
  - $\ln P^v(\text{mm Hg}) = 15.9037 - 2789.01/(220.79 + T(\text{K}))$ → **Benzene**
  - $\ln P^v(\text{mm Hg}) = 16.00531 - 3090.78/(219.14 + T(\text{K}))$ → **Toluene**
  - $\ln P^v(\text{mm Hg}) = 17.9232 - 4802/T(\text{K})$ →**Cumene**

Now, we come to a second problem. In this problem, we have been given a feed mixture with 35 mole percent of benzene 35 mole percent of toluene and rest is cumene and this has to be fractionated from a feed flow rate of 100 kilo mole per hour and we have to recover 98 percent of the benzene in the distillate and 98.5 percent of toluene in the bottom product. Now, because when benzene and toluene have been given as know that benzene is lighter than toulene and so, it has a boiling point which is lower than the toluene, so and because the separation have been defined in terms of these two components.

So, we choose the benzene as a light key and toluene as the heavy key. That is how we go about and then the feed is a saturated vapour. So, now, in this case the feed is saturated vapour and if we are going to use the value of q, we know that this q will be now 0 and the reflux is at its bubble point and we have to assume that constant molar overflow as we have done it for the (Refer Time: 13:33) method. If you go back to your notes, the (Refer Time: 13:36) method we have used in that also we are having the constant molar overflow assumption and we are also assuming the solutions to be ideal.

And based on this assumption, we have been asked to find out the minimum number of equilibrium stages, the minimum reflux ratio and the number of ideal stages if the reflux ratio is 1.3 times the minimum reflux ratio. Now, for this calculations we had been given the vapour pressure equations that is the K that is the volatility is taken as P I sat by P.

So, K I equal to P I sat by P. So, we have that is why we need the value of the vapour pressure and these are the various equation for benzene, toluene and cumene. Now, in this you have to just to mention it that the vapour pressure is in terms of millimetre mercury and the temperature has to be in Kelvin.

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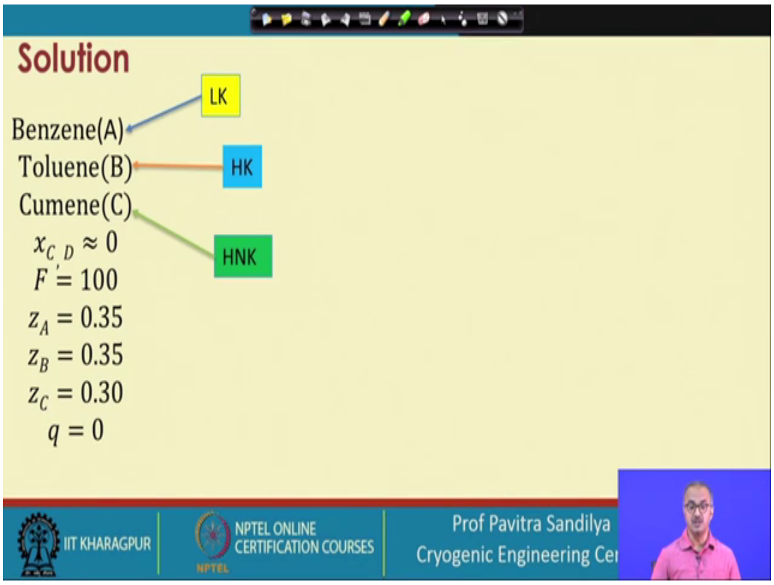

Solution

Benzene(A) — LK

Toluene(B) — HK

Cumene(C) — HNK

$x_{C\,D} \approx 0$

$F = 100$

$z_A = 0.35$

$z_B = 0.35$

$z_C = 0.30$

$q = 0$

So, here are the various data available to us. So, what we first do that we first label this various components benzene as A, toluene as B and cumene as C and assuming that there is no Cumene going into distillate. So, we are taking the mole fraction of cumene in the distillate as 0. This is the feed flow rate and these are the other compositions and q is equal to 0 as I just told you because the feed is a saturated vapour. So, here we chose choose the light key and the heavy key and this cumene will now be treated as the heavy non-key.

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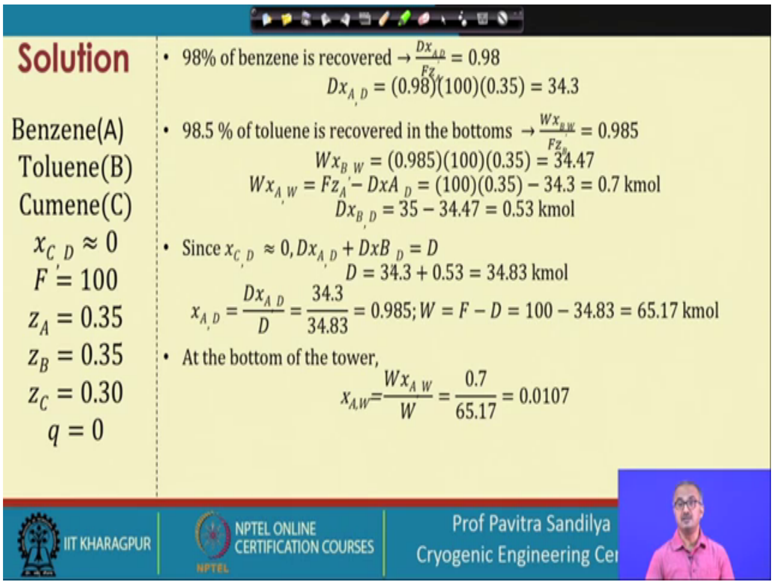

Solution

Benzene(A)
Toluene(B)
Cumene(C)
$x_{C\,D} \approx 0$
$F = 100$
$z_A = 0.35$
$z_B = 0.35$
$z_C = 0.30$
$q = 0$

- 98% of benzene is recovered → $\frac{Dx_{A\,D}}{Fz_A} = 0.98$
  $$Dx_{A\,D} = (0.98)(100)(0.35) = 34.3$$
- 98.5 % of toluene is recovered in the bottoms → $\frac{Wx_{B\,W}}{Fz_B} = 0.985$
  $$Wx_{B\,W} = (0.985)(100)(0.35) = 34.47$$
  $$Wx_{A\,W} = Fz_A - DxA_D = (100)(0.35) - 34.3 = 0.7 \text{ kmol}$$
  $$Dx_{B\,D} = 35 - 34.47 = 0.53 \text{ kmol}$$
- Since $x_{C\,D} \approx 0, Dx_{A\,D} + DxB_D = D$
  $$D = 34.3 + 0.53 = 34.83 \text{ kmol}$$
  $$x_{A\,D} = \frac{Dx_{A\,D}}{D} = \frac{34.3}{34.83} = 0.985; W = F - D = 100 - 34.83 = 65.17 \text{ kmol}$$
- At the bottom of the tower,
  $$x_{A,W} = \frac{Wx_{A\,W}}{W} = \frac{0.7}{65.17} = 0.0107$$

After doing so now we go to this thing that we have been given 98 percent recovery of benzene so, we use the formula to get the value of the benzene in the distillate and then from this given data 98.5 percent toluene recovery in the bottom. So, we get the amount of toluene in the bottoms and here we get the amount of the component that is benzene in the bottom from the material mass balance of A for the overall column. So, this is the amount of the benzene in the bottom product and from that again we find out that how much of the toluene is going into the distillate and these are all we are using the mass balances in this two cases and because we have been given that x c d is equal to 0.

So, we are making this finding the distillate flow rate by adding the individual flow rates of the each components and here we have the distillate flow rate and once we know distillate flow rate and here we get the x A D value that is the mole fraction of benzene in the distillate by this D x A D by D and this is the mole fraction we get. And now, we can also find out the bottom flow rate by the overall mass balance for the whole column from that is F minus D. So, this is the mass bottom mass flow in kilo mole per hour. So, this is kilo mole per hour.

So, at the bottom of the tower, we have this value of x A W and this is also we are found out at x W A X A W here and W we have found out here by using this two values we get the amount of the benzene in the bottoms and we can see clearly from this that only about 1 percent, 1 mole fraction of benzene is obtained in the bottom product.

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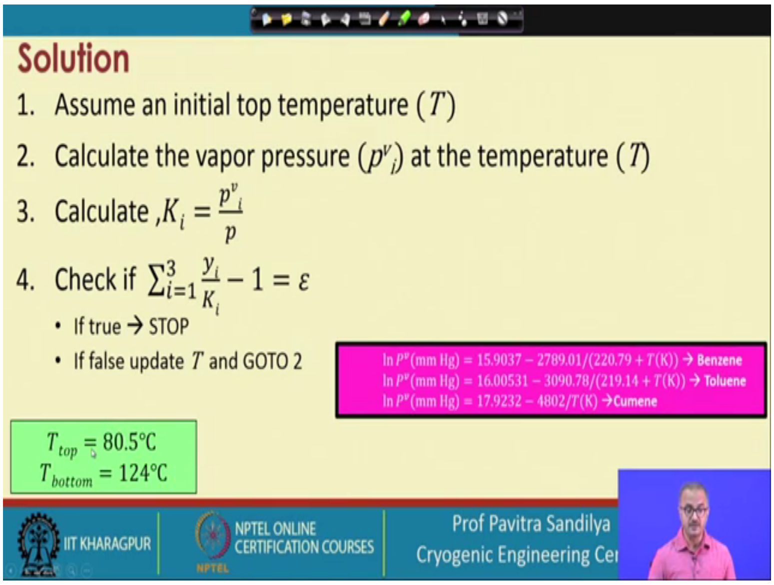

Solution

1. Assume an initial top temperature (T)
2. Calculate the vapor pressure (p^v_i) at the temperature (T)
3. Calculate ,$K_i = \frac{p^v_i}{p}$
4. Check if $\sum_{i=1}^{3} \frac{y_i}{K_i} - 1 = \varepsilon$
   - If true → STOP
   - If false update T and GOTO 2

$\ln P^v(\text{mm Hg}) = 15.9037 - 2789.01/(220.79 + T(\text{K}))$ → **Benzene**
$\ln P^v(\text{mm Hg}) = 16.00531 - 3090.78/(219.14 + T(\text{K}))$ → **Toluene**
$\ln P^v(\text{mm Hg}) = 17.9232 - 4802/T(\text{K})$ →**Cumene**

$T_{top} = 80.5°\text{C}$
$T_{bottom} = 124°\text{C}$

Now, for the list of the calculations what we do first, we take the upper section rectifying section of the column and for that we take the we know that the condenser will be giving us the minimum temperature and we assume that initial sorry, in this case, we are first doing the for the bottom part the streaming part so we initially we do the initial bottom temperature T and based on that temperature we have to calculate the vapour pressure at the temperature and we are using this equation and this particular equation we shall be using to find out the value of the K and we have to check that whether our solution is right or not. So, we have to do this kind of checkings and if true we have to stop and if false we have to again update the value of T and to we have to repeat these calculations.

So, this is now we are going for top house top section. Here also we will be assuming some temperature and then we shall be finding vapour flow rate and we find the value and vapour pressure and the and the temperature and this is the way we are finding the value of K and was you find the value of K, we shall be plugging in this particular thing and to check that whether it is within some kind of competence or not and then what we shall do that if they are true it is stop otherwise we have to keep updating the value. And so, we find this we can easily find out that what is the top temperature bottom temperature. So, this is the first guess we have taken.

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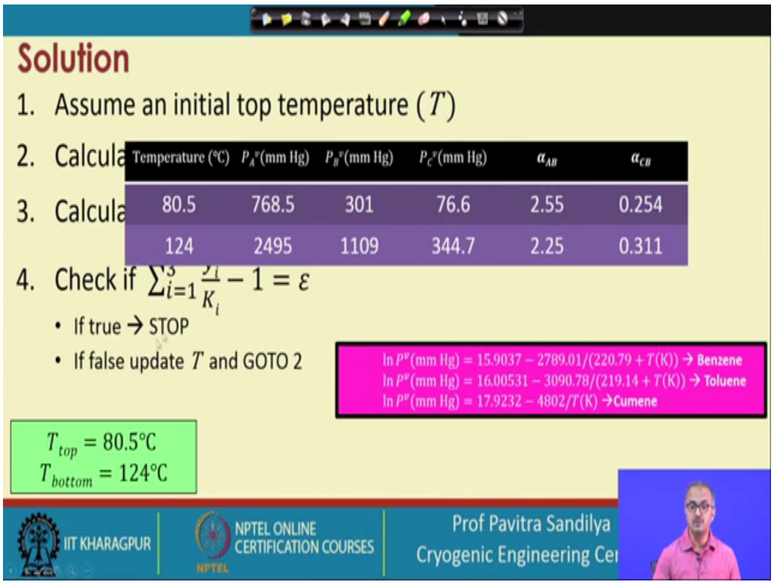

Solution

1. Assume an initial top temperature (T)
2. Calcula
3. Calcula
4. Check if $\sum_{i=1}^{3} \frac{y_i}{K_i} - 1 = \varepsilon$
    - If true → STOP
    - If false update T and GOTO 2

Temperature (°C)	P_A^v(mm Hg)	P_B^v(mm Hg)	P_C^v(mm Hg)	α_{AB}	α_{CB}
80.5	768.5	301	76.6	2.55	0.254
124	2495	1109	344.7	2.25	0.311

$\ln P^v(\text{mm Hg}) = 15.9037 - 2789.01/(220.79 + T(\text{K}))$ → Benzene
$\ln P^v(\text{mm Hg}) = 16.00531 - 3090.78/(219.14 + T(\text{K}))$ → Toluene
$\ln P^v(\text{mm Hg}) = 17.9232 - 4802/T(\text{K})$ →Cumene

$T_{top} = 80.5°\text{C}$
$T_{bottom} = 124°\text{C}$

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And here, what we do that we write a write all the vapour pressures for each of the components from this.

And so, this 80.5 and 124 that is based using the low key and high key heavy key component, we find out this temperatures from the respective vapour pressure equations and this is how we get these values and we get this how the vapour pressure values and we find the alpha a b as K 1 by K 2 and alpha c b K c by K b.

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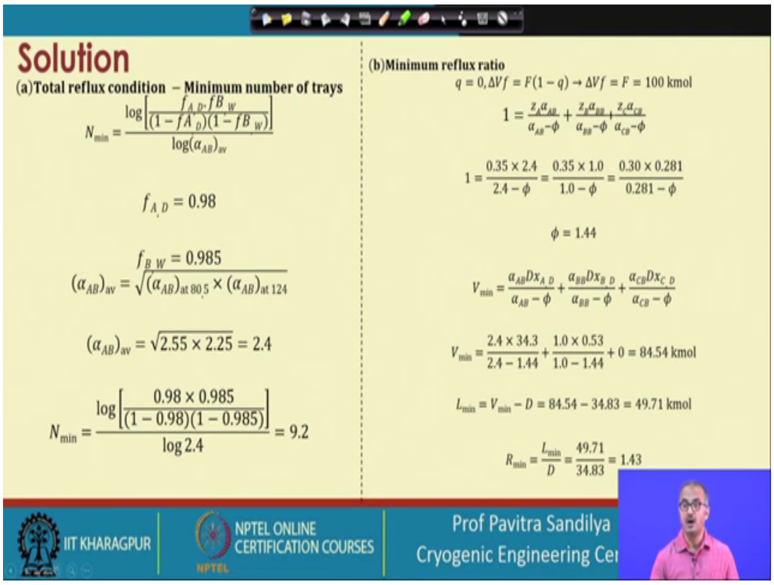

Solution

(a)Total reflux condition – Minimum number of trays

$$N_{\min} = \frac{\log\left[\frac{f_{A,D} \cdot fB_W}{(1-fA_D)(1-fB_W)}\right]}{\log(\alpha_{AB})_{av}}$$

$$f_{A,D} = 0.98$$

$$f_{B\,W} = 0.985$$

$$(\alpha_{AB})_{av} = \sqrt{(\alpha_{AB})_{\text{at }80.5} \times (\alpha_{AB})_{\text{at }124}}$$

$$(\alpha_{AB})_{av} = \sqrt{2.55 \times 2.25} = 2.4$$

$$N_{\min} = \frac{\log\left[\frac{0.98 \times 0.985}{(1-0.98)(1-0.985)}\right]}{\log 2.4} = 9.2$$

(b)Minimum reflux ratio

$$q = 0, \Delta Vf = F(1-q) \rightarrow \Delta Vf = F = 100 \text{ kmol}$$

$$1 = \frac{z_A\alpha_{AB}}{\alpha_{AB}-\phi} + \frac{z_B\alpha_{BB}}{\alpha_{BB}-\phi} + \frac{z_C\alpha_{CB}}{\alpha_{CB}-\phi}$$

$$1 = \frac{0.35 \times 2.4}{2.4-\phi} = \frac{0.35 \times 1.0}{1.0-\phi} = \frac{0.30 \times 0.281}{0.281-\phi}$$

$$\phi = 1.44$$

$$V_{\min} = \frac{\alpha_{AB}Dx_{A\,D}}{\alpha_{AB}-\phi} + \frac{\alpha_{BB}Dx_{B\,D}}{\alpha_{BB}-\phi} + \frac{\alpha_{CB}Dx_{C\,D}}{\alpha_{CB}-\phi}$$

$$V_{\min} = \frac{2.4 \times 34.3}{2.4-1.44} + \frac{1.0 \times 0.53}{1.0-1.44} + 0 = 84.54 \text{ kmol}$$

$$L_{\min} = V_{\min} - D = 84.54 - 34.83 = 49.71 \text{ kmol}$$

$$R_{\min} = \frac{L_{\min}}{D} = \frac{49.71}{34.83} = 1.43$$

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So, after getting all these values of the alpha A B and alpha C B at the top and the bottom, what we do that we find out this minimum reflux from this equation alpha A B average we take; that means, you take the average of the top and bottom alpha lie; in this way we have taken the geometric average at the two ends of the column, we plug in the values, we get the average value of the alpha A B and then take the value over here.

And we put the value of this f A D over here and the f B W over there and we get ultimately the minimum number of stages as 9.2. Now, once we get this values what we do we go to find out the minimum reflux ratio. So, we write the q is coming to be 0. So, we find that the amount of this the change in this thing is also coming at this. This is the amount of the change in the vapour flow rate and that is coming out to be this F by F that we can find out later and we know that this is the equation we that 1 minus q that equation the under root equation is we are right under root equation and plugging in the values of these various components over here and again we find out the phi is coming out to be 1.44.

And once we get the value of the phi, with also can find out this value of the V min from the phi value plugging in this particular equation and we get the value of the V min here and then we take the mass balance around is rectifying section and we get the value of the L min and then once you get the L min, we can find out the minimum reflux ratio as L min by D and this is coming out to be 1.43. So, this is we how we have applied the unload equation to find out the minimum reflux ratio.

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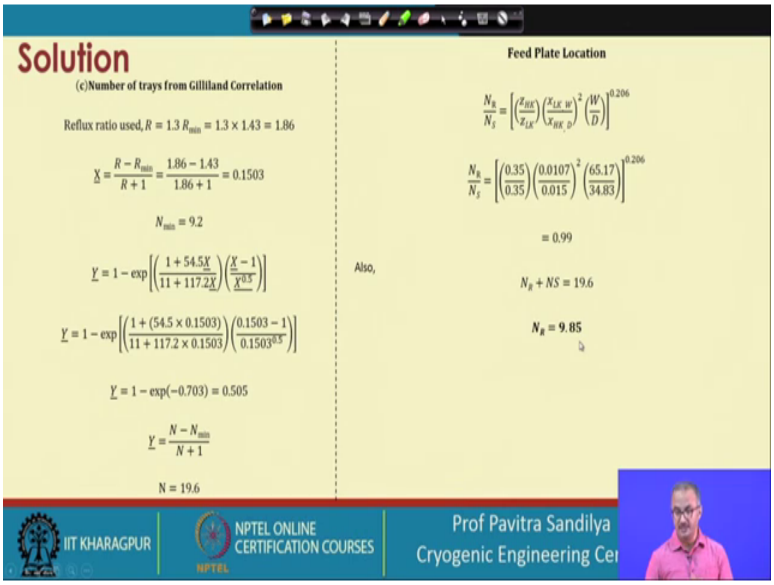

Solution

(c)Number of trays from Gilliland Correlation

Reflux ratio used, $R = 1.3\,R_{min} = 1.3 \times 1.43 = 1.86$

$$\underline{X} = \frac{R - R_{min}}{R+1} = \frac{1.86 - 1.43}{1.86 + 1} = 0.1503$$

$$N_{min} = 9.2$$

$$\underline{Y} = 1 - \exp\left[\left(\frac{1 + 54.5\underline{X}}{11 + 117.2\underline{X}}\right)\left(\frac{\underline{X} - 1}{\underline{X}^{0.5}}\right)\right]$$

$$\underline{Y} = 1 - \exp\left[\left(\frac{1 + (54.5 \times 0.1503)}{11 + 117.2 \times 0.1503}\right)\left(\frac{0.1503 - 1}{0.1503^{0.5}}\right)\right]$$

$$\underline{Y} = 1 - \exp(-0.703) = 0.505$$

$$\underline{Y} = \frac{N - N_{min}}{N+1}$$

$$N = 19.6$$

Feed Plate Location

$$\frac{N_R}{N_S} = \left[\left(\frac{z_{HK}}{z_{LK}}\right)\left(\frac{x_{LK\,W}}{x_{HK,\,D}}\right)^2\left(\frac{W}{D}\right)\right]^{0.206}$$

$$\frac{N_R}{N_S} = \left[\left(\frac{0.35}{0.35}\right)\left(\frac{0.0107}{0.015}\right)^2\left(\frac{65.17}{34.83}\right)\right]^{0.206}$$

$$= 0.99$$

Also,

$$N_R + NS = 19.6$$

$$\mathbf{N_R = 9.85}$$

And then, we have been given that the actual reflux ratio is 1.3 times the minimum. So, here we find out in the lecture you will find that we have defined some kind of variable x under bar and we find the value of this x under bar and we know the value of the n min from the Frenske question and we find the value of the y under bar from the x under bar and we get the value of the y under bar over here.

So, with this x under bar and y under bar we go to the definition of the y under bar and we find that this y under bar we put as of y under bar over here this and then this, we put the value of the N min and we find out the actual number of the ideal stages required for the actual reflux. So, this is how we are using the Gilliland correlation. Let me also mention here that you can also use the graph which is given in the lecture to find out this N value.

Next, to find out the feed location we this we use this equation given in the lecture and in this equation now things become very simple we, you see that we have all the values with us in the equation we keep plugging in the various values and then we find out this is the N R by N S that is the number of the ideal stages in the rectifying section the number of the ideal stages in the stripping section. Now, also we know that N R equal N S will be equal to 19.6. So, that is or if we do that this is the total number of this n this will be equal to 19.6. So, we put this we have two equations and two unknowns and from this we are getting the value of the number of stages in the rectifying section and once we get this; that means, we can say the feed is introduced from 9.85 stages from the top. So, that is how we are able to locate the feed point in the distillation column using the shortcut method of Frenske under root and Gilliland.

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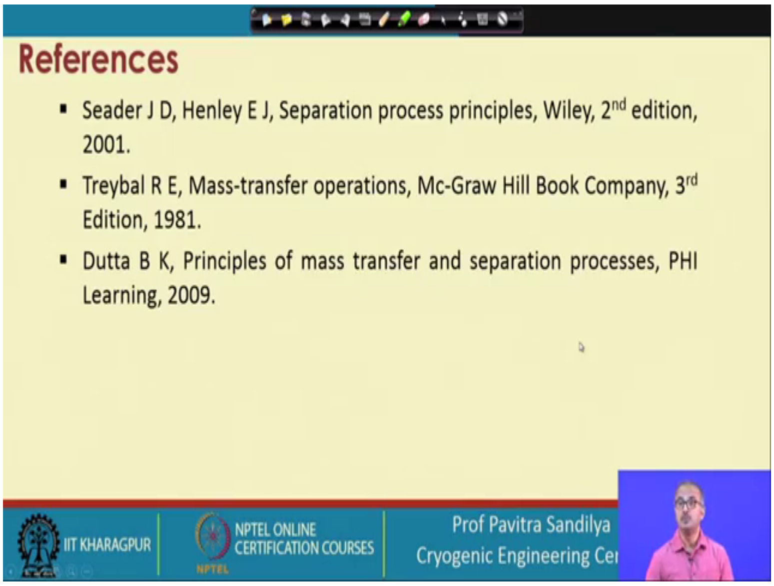

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The more details can we found out in this references.

Thank you.