Upstream LNG Technology
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Lecture – 37
Tutorial on vapour liquid separation

Welcome. After learning about the basics of the equilibrium vapour liquid separation. In this particular lecture, we shall be doing a few problems on the equilibrium vapour liquid separation.

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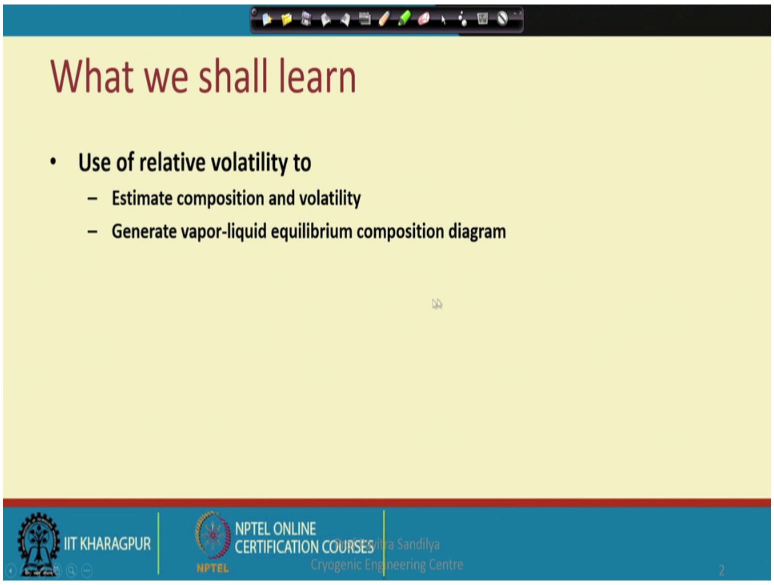

And what we shall see that we shall learn about the use of relative volatility for estimation, the composition and the volatility of a vapor liquid mixture in equilibrium and generate the vapor liquid equilibrium composition diagram.

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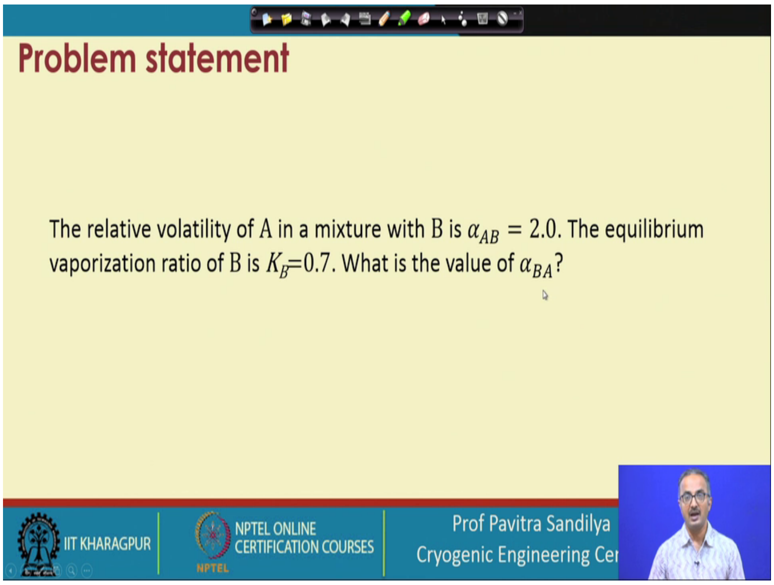

Now, first we shall see this problem, this problem states that we have the relative volatility of a component A in a mixture of B and we are given alpha A B as 2, this value shows that A is more volatile than B that because it is this alpha A B is more than 1, the equilibrium ratio A of B is KB is given as 0.7; that means, KB is the equilibrium vaporization ratio or the volatility. The volatility of B is 0.7 and we have been asked to figure out the value of alpha B A.

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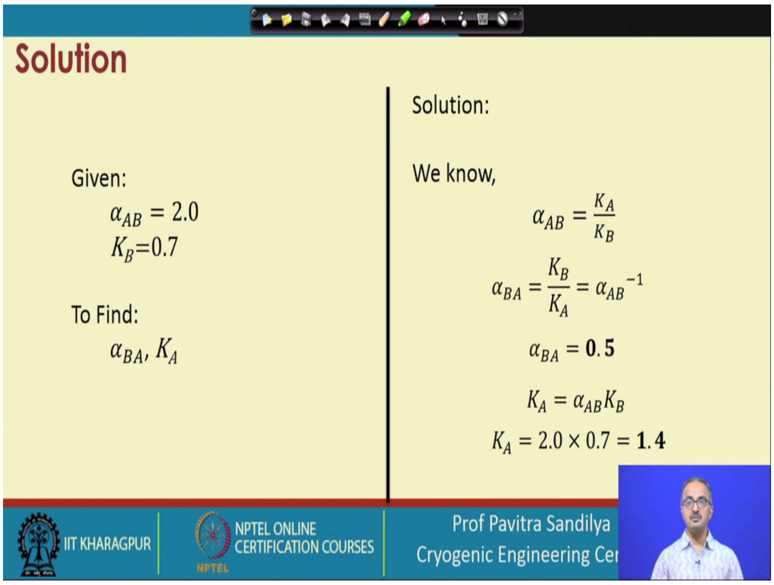

Now, these are the given values to us and we have to find out the value of the a B A and also, we can also find the value of the volatility of component A, here we have the solution that alpha A B is defined as K A by K B, whereas, alpha B A is the KB by K A; that means, alpha B A is reciprocal of alpha A B.

So, here to get the value of alpha B A, I simply take the reciprocal that is 1 by 2 and 1 by 2 gives 0.5. So, this is the relative volatility of B with respect to A and here I am finding the value of K A; K A; K A is alpha A B in to K B. So, we just put these values we find 2 into 0.7 that gives us 1.4. So, this shows that the component A is more volatile than component B and in case of any kind of separation based on the vapour liquid equilibrium, we will find A will be going more into the vapor phase than B; B will stay more in the liquid phase and that is how we can get separation between A and B.

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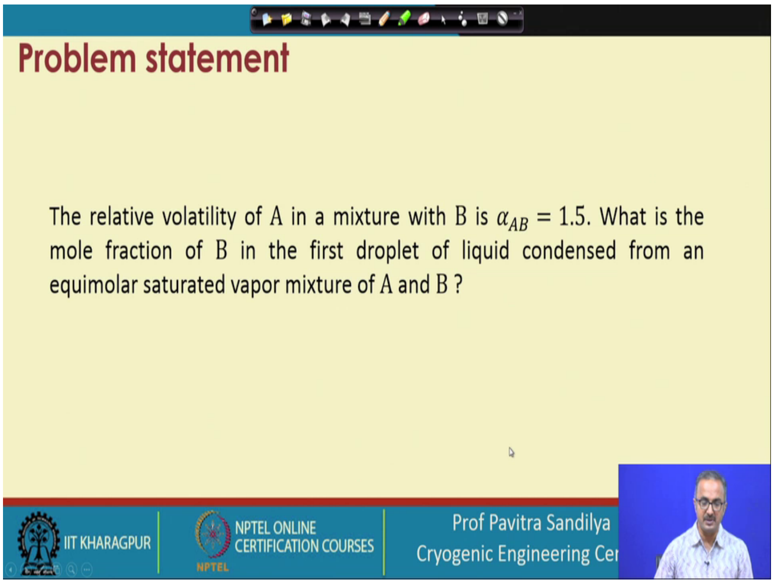

Next problem; we take in this problem; it is given that the relative volatility of A; A with respect to B is 1.5 and we have to find out the mole fraction of B in the first droplet of liquid condensed from an equimolar saturated vapor mixture of A and B. So, we have its mixture vapor mixture that is saturated of A and B and the first droplet of liquid will be form from this thing and because it is saturated we are assuming that A and B are in equilibrium. So, we have you figured out that the; what is the composition of the first liquid droplet formed from this particular vapor.

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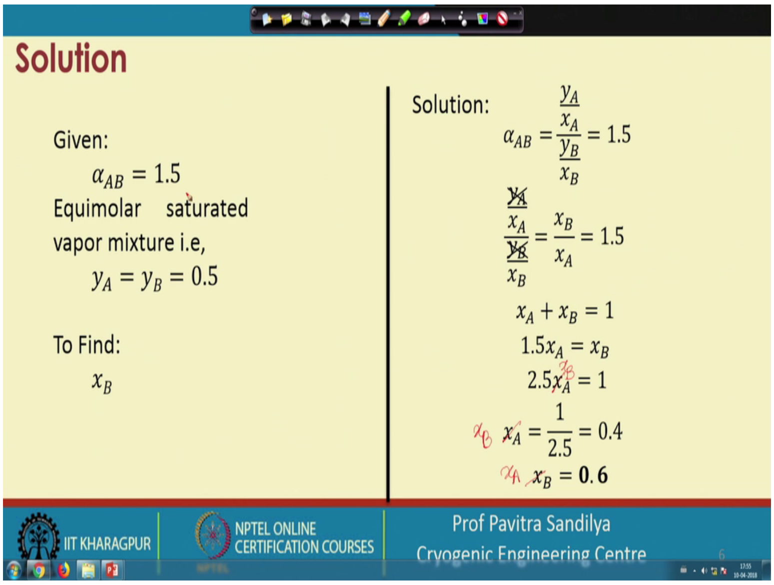

So, in this case what we do we go by this thing that alpha A B is 1.5 and the vapor mixture is equimolar; equimolar means the mole fraction of A is equal to mole fraction of B and because the summation of the mole fractions is always 1. So, we divide 1 by 2 and we get the mole fractions of A and B as 0.5 and what we have to find out; we have to find out the mole fraction of B in the liquid phase for solution of this problem.

We go to the basic definition of the relative volatility which is given by A alpha, A B as y A by x A divided by y B by x B, here what we do that and this is given as point five. So, we find that this y A and y B being same. So, we can cancel these twos 2 out and we get x B by x A equal to 0.5 and because x A plus x B is unity, then what we get 1.5 x A; that means, we are substituting for x B 1.5 x A plus x B will be equal to 2.5; 2.5 x A is equal to 1 and x A value is coming out to be coming out to be point 4 and then we get x B as 0.6.

Ah there is a small mistake here it will be 1.5 x A x B plus x B that this 2.5 x B the instead of x A, please read it as x B. So, this will be x B and this is x B and this is x A. Now this you can also check internally because the alpha value is 1.5. So, x A can has to be more than x B x B. So, we are finding this is a thing am I a right yeah

Hello, [FL] repeat. [FL]

[FL].

[FL].

[FL].

Repeat [FL].

[FL].

Huh.

It is correct.

Huh.

Right, it is correct.

Kabina, you never write 1.2 x equal to x B write x B equal to 1.2 x A [FL].

[FL].

[FL].

[FL].

[FL] huh.

Start.

Now we have the next problem in this problem, what we are given that there are again 2 mixtures of A and B and the relative volatility of this is given as alpha A B has 1.5 and we have to figure out the mole fraction of B which is which will be the when it is the this particular mixture A and B, if it is saturated vapor phase gets frozen and get condensed and forms the liquid. So, we have to find the mole fraction of B in the first droplet, when this saturated vapor of A and B is condensed.

Now please understand this that because it is saturated vapor is slight decrease, the temperature will cause the condensation and that what is call the dew point temperature at the given pressure and we have to figure out that when this first droplet is condensed naturally the droplet will be having more amount of the less volatile component and from the given data, we find that the A is more volatile than B. So, the liquid droplet which we formed will be having more of B than A.

So, this physical understanding this physical picture should also be reflected in our solution. So, let us go to solution we find that alpha abs give at 1.5 and because it is a equimolar mixture of A and B in the vapor phase. So, we find that the mole fractions of A and B will be is equal to 0.5 because the summation of the mole fractions is always unity and we have to figure out the value of the mole fraction of B in the liquid phase.

Now, for the solution, what we do we go to the definition of alpha A B and here we find that y A by x A divided by y B by x B and is equal to 1.5 because y A is equal to y B. So, we can cancel out y A and y B and we are left with x B by x A; that means, x B equal to 1.5 x A.

Now, because x A plus x B is equal to 1, what we do we substitute for x B from as 1.5 x A and we get 2.5 x A and this gives us x equal to 1 by 2.5 as 0.4 and we find x B equal to 0.6 and this says that because as we said earlier that because B is less volatile. So, it has more tendency to go to the liquid phase and that is how we also find that our solution shows that the mole fraction of B, in the liquid phase is more than that of a this give some internal check for you during the solution of the problem.

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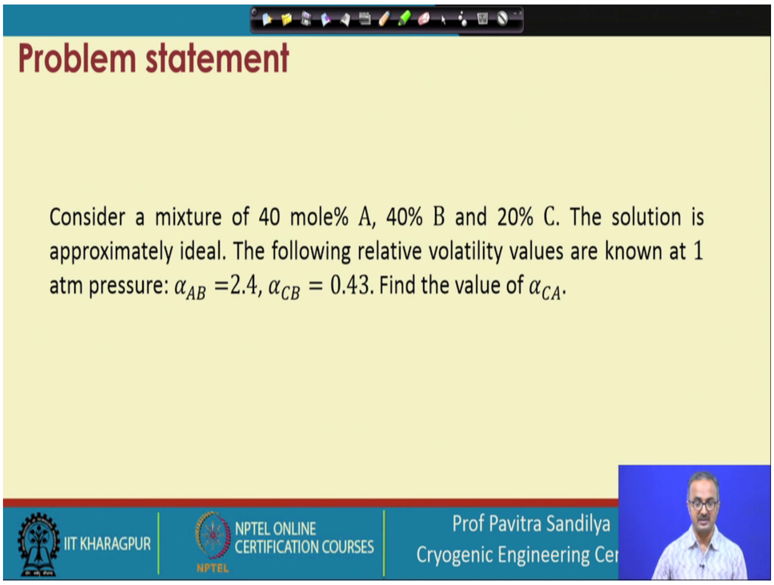

Next problem, we attempt is a mixture of A, B and C at this mole fractions, 40 mole fractions, mole percent of a 40 mole percent of B and 20 mole percent of C to check that whether these values are correct or not, you can simply add these values and check that whether they are coming to hundred since in this case, it is coming to hundred; that means, our given data is find and if it is not coming to 100, then we have to select something wrong with the data or maybe we are missing some other component.

The solution can be taken to be ideal and with this ideal assumption these are the relative volatilities alpha A B and alpha C B which are given alpha A B; that means, 2.4; that means, A is more volatile than B and alpha C B is 0.43, it means C is less volatile than B. So, overall picture is that A is more volatile than B and is also more volatile than C. So, A is the most volatile component, whereas, C is the least volatile component in the particular mixture and here you have to figure the value that value of alpha C A.

Now, by physical understanding we see that alpha C A must be less than 1. So, this also we should find out from our solution.

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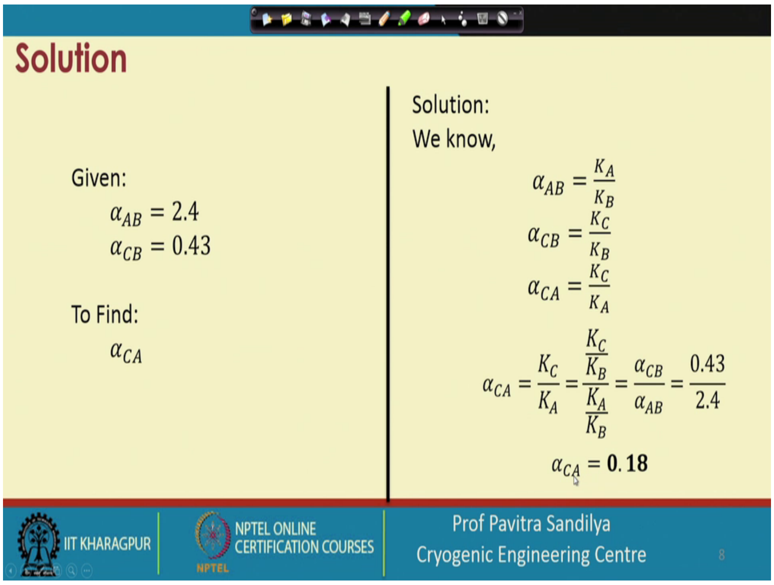

So, here is solution that we write alpha A B equal to 0.2; 0.4 alpha C B 0.43 and to get the value of alpha C A; what we do we write the basic definition alpha A B equal to K by K B, alpha C B is K C by K B and alpha C A is K C by K A to get K C by K A; what we do? We divide both the numerator and the denominator by K B and this K C by KB is nothing, but alpha C B and K A by K B is nothing, but alpha A B.

So, we put these values of this alpha C B and alpha A B and get this values as 0.18. So, as we said that this value of alpha C A as 0.18 tells us that the C is less volatile than A and if we compare these 3 values, we find this is a least value between C B and C A this is the lower. So, it tells us that C component C is the least volatile of the three components.

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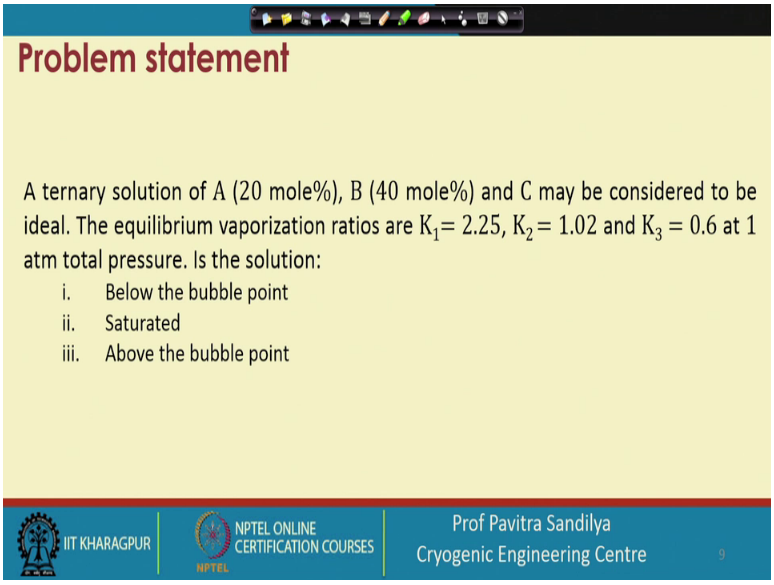

After learning about this calculation of relative volatility, what we now go that we have to go for a problem as I discussed earlier to know that what is the state of the mixture. Now we have learnt it that in when we want to carry out some flash, we need a two phase system not a single phase system that is we want a vapor liquid mixture and not just a sub cooled liquid or a superheated vapor. So, for this before we go for the flash calculation, we need to make sure that we have a two phase mixture. So, here is the problem to know that whether we have a two phase mixture or sub cooled liquid or superheated vapor.

So, here again we have a mixture of A, B and C and these are the respective mole fractions here mole fraction of A is 20 mole percent of A is 20 mole percent of B is 40 and we can now deduce the mole percentage of C by subtracting this 20 plus 40 from 100; that means, this 60; that means, C is 40 mole percent and here we are given the equilibrium ratio as 2.25 for K 1, K 12 is 1.02 and K 3 as 0.6 and as we learned earlier that because here some of the K is are more than 1; some of the K is are less than 1. So, it is not directly possible for us to ascertain; what is the state of the particular mixture.

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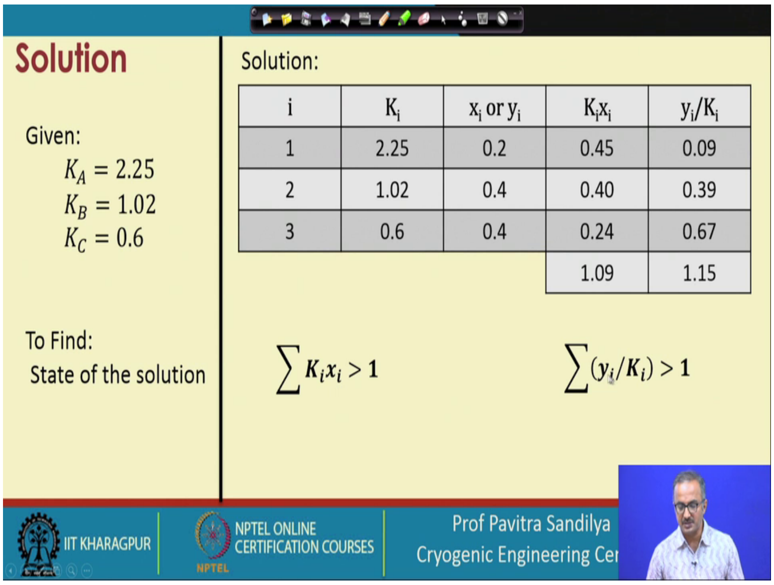

So, what we do that we take this thing that we find the put the I; this table we make in this i is the component name 1, 2, 3 and then we put these components are nothing, but A, B, C and then we have the K i values at 2.25 1.02 and 0.6 and x or y i will say what is x or y because this percentage is give may be taken either to be the liquid phase composition or to be the vapor phase composition because initially, we do not know that whether this particular mixture is residing in the vapor phase or in liquid phase or both the phases.

So, we say that this is x i or y i and then what we do we simply multiply this K i with this these values and we get K i x i is this and y i by K i as this. So, we multiply and divide this kind of the things to get these values of K i x i and yi by K i and then sum them up. So, after summing them up what we do that we refer to this particular logic that summation K i xi more than one and summation y i by K i is also more than 1.

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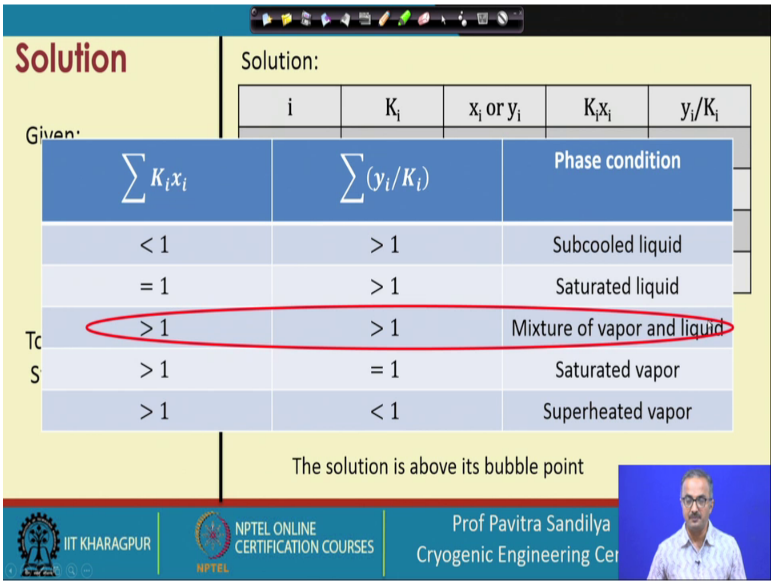

And when we refer to this particular table we find that this particular condition that is summation K i, x i more than 1 and summation y i by K i more than 1 gives us a mixture of vapor and liquid; that means, the for the given condition in the system we have a system which is more than this bubble point, but less than the dew point so; that means, the we have a two phase mixture, which is there between the dew point and bubble point.

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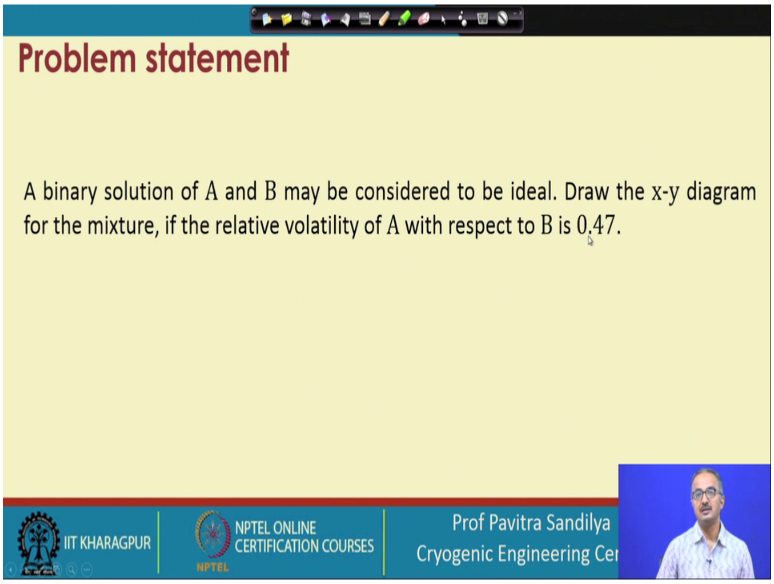

Now, next problem statement comes like this here we are trying to use the knowledge of the relative volatility to generate the composition diagram of a vapor liquid equilibrium system. Here, we are given a binary system A and B which is taken to be ideal and we have to draw the x y that is the x is the mole fraction in the liquid and y is the mole fraction in the vapor and for the given value of the relative volatility in this case we find that it is 0.47, it means the A is less volatile than B.

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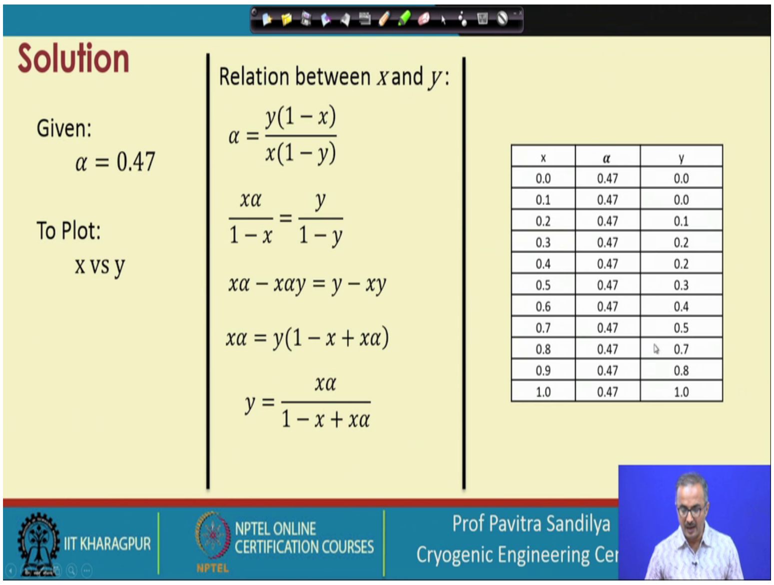

So, what we now do that alpha is given as 0.47, we have to plot x and y and we go with this particular equation in which find that y by x is taken to be that of a and 1 minus x and 1 minus y are the liquid phase and vapor phase compositions of b.

So, here we simply rearrange the equation and we get this particular equation y in terms of x. Now once we get this, now by putting the value of alpha and for different value of x like we can put from 0.0, 1.2 and we know that the mole fractions will always be between 0 and 1 0 is when x is 0 it means it is pure b when x is 1, it will be pure a. So, between 0 and 1 this is i and we get this value of x put the value of x here and alpha is constant for all of them and for each of these pairs.

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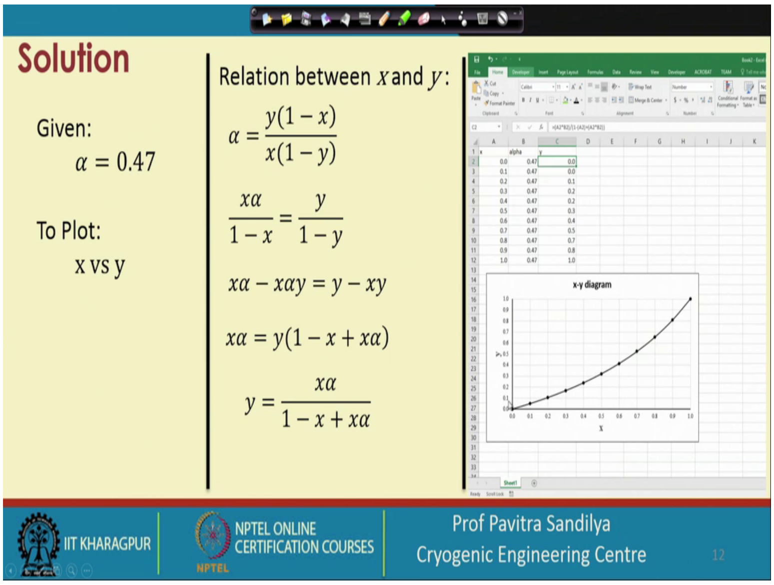

We can find the value of y and this is how we can. Now, plot these x and y values and you for this plotting you can use any kind of software here, we have shown a snapshot which has been done with excel. So, you can use any software to generate these kind of plots. So, here we find that the this is the on the x axis, we make the x and on y axis, we make the y and you can see that scales are from 0.1.2, etcetera and similarly point 1.2, etcetera on the y axis and we find that this is the nature of the curve.

Now, please note that these it may be concave or convex upward in this case we find it is concave upward. Now whenever you have the curve which is made for the low volatile component you will always get a concave upward and if instead of A, suppose you are plotting B, what you will find you will find a plot like this that will be concave downward. So, when you are drawing these curves, if your logic is right then we are looking at the curve generated you should be able to decide that whether you have plotted this thing rightly or not since this is concave upward. So, it is clear that we have calculated the values of x and y correctly.

After this problem we shall be nine going to a problem on the flash separation.

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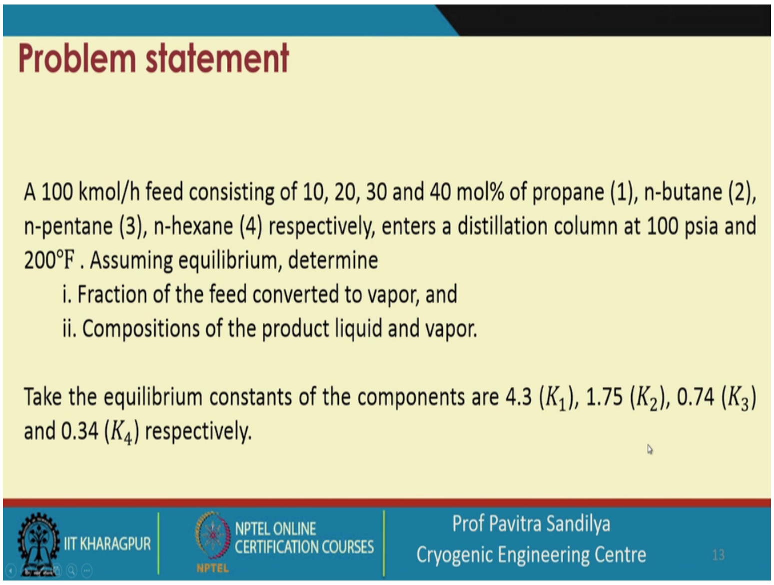

So, here we have the problem here we have 4 components propane butane pentane and hexane identified by some tags 1, 2, 3 and 4 with this composition in terms of the mole percentage like this is z 1, z 2, z 3, z 4 and this is the flow rate of the feed and this is given at this particular pressure and this particular temperature and we have been asked to determine the fraction of the feed converted to vapor and the composition of the product liquid and vapor assuming equilibrium. So, we need the equilibrium data and these are the values of the equilibrium constants for the 4 components.

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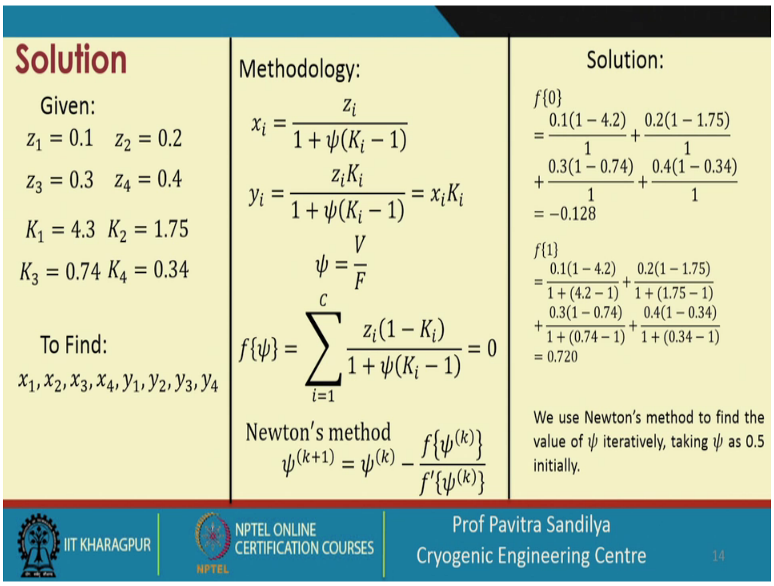

So, what we do for solution, first we write out the information which we have been provided with and then these x and y represent the compositions of the product liquid and the product vapor here we are going to use these two equations which we derived earlier to find out the flash problem and the vapor composition or liquid composition after the flash and this is the equation which we shall be solving to get the value of the vapor fraction that is psi and the K value have been given to us and we shall be using the Newton's method and in this Newton's method, this is the recurrence formula to update the value of the root in this case this a psi is the root which we have to find out

So, before we go for the solution we have to first ensure that the given values are for two phase mixture. So, for that what we do as we learnt earlier we first put the value of psi as 0 and find the value of phi xi and then we put the value of psi as one and find the value of f one and we found find from these values of f 0 and f 1 that this is a two phase mixture. Now after making sure that this is a two phase mixture we go for the solution and here the solution is that because we know that psi is going to lie between 0 and 1. So, to start our iteration we assume a value of point five and we know that the Newton's method works very well if we have a good initial guess.

So, here we are bound by the value of psi value of psi. So, we are taking it as 0.5 and with this 0.5.

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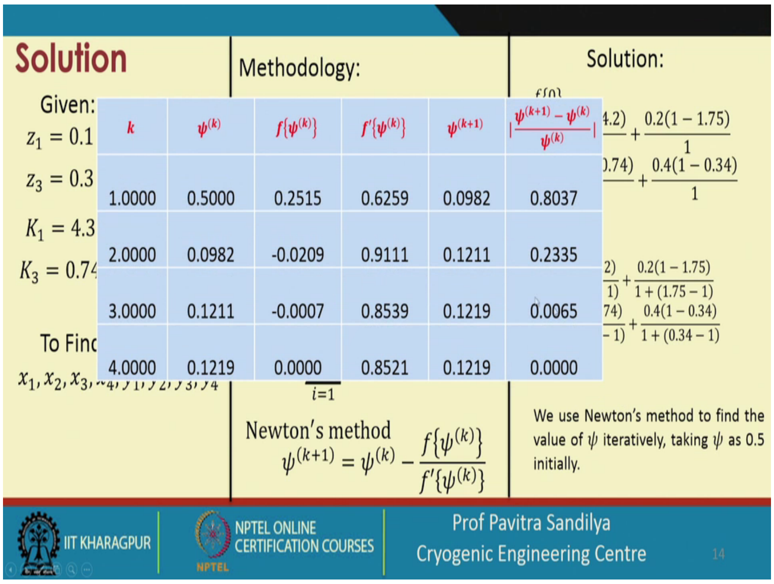

We do the iteration and we find that the value of this f psi and the f prime psi with this psi and we update the value of the psi to psi K K plus 1 and then we find the percentage deviation and then we go using this later psi. Again we find the value of f psi and f prime psi to update the value of psi and we find the percentage deviation between the 2 consecutive roots and we find that the deviation is coming down and we continue this thing here and we find that slowly and slowly the percentage deviation is coming down and ultimately it goes to a very acceptable limit. So, what we do we take this value of psi as our root?

After finding the value of psi and what we do we take these equations these 2 equations, put the value of psi here and incorporate the values of the K i to get the compositions of the liquid and the vapor in terms of the mole fractions of each of the components.

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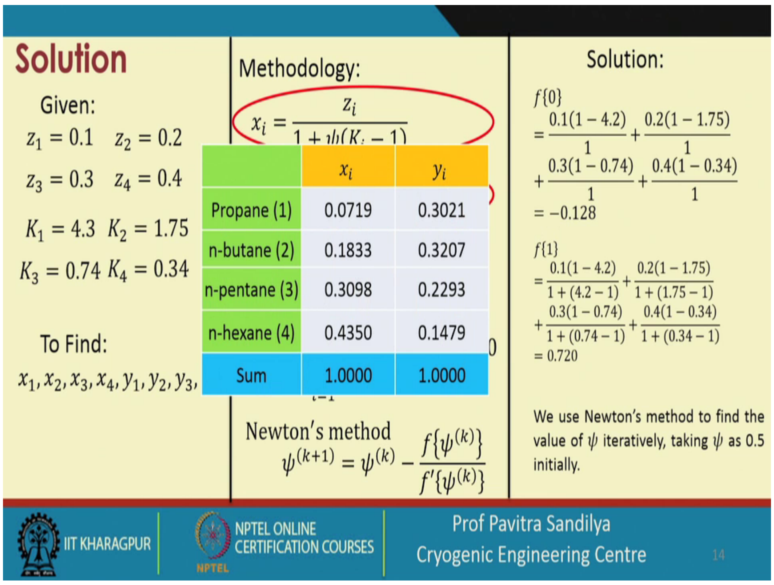

And here we find in this table we find the value of x i and y i for each of the components to check whether our solution is right or not what we do we sum up the xi values and sum of the y i values and we find that their sum is coming to one. So, this gives us an internal check about the validity of our solution. So, with this we are able to solve this flash problem and we find the fraction vaporized is 0.12 something and then we are the, we have the compositions.

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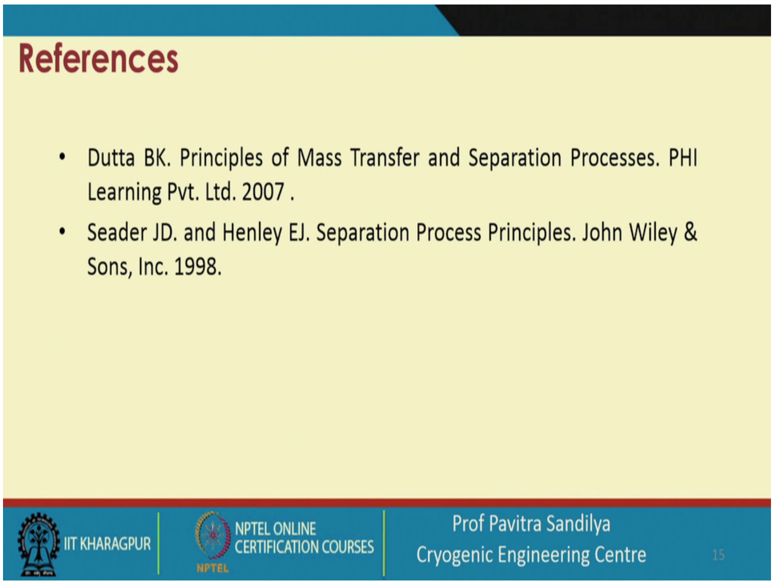

So, these are the books which you can refer to for more detail.

Thank you.