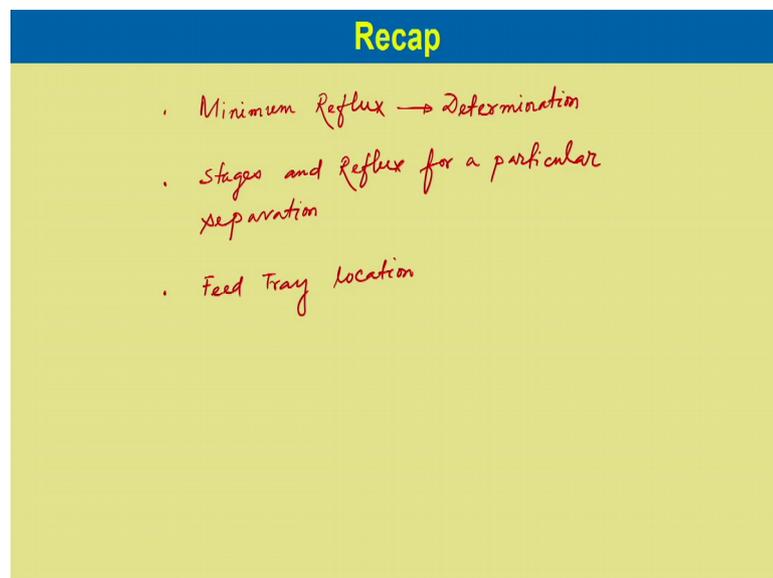


**Mass Transfer Operations -I**  
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**Distillation-V**  
**Lecture - 41**  
**Multicomponent batch distillation**

Welcome to the 16th lecture of module 5 on Mass Transfer Operation. In this module, we are discussing distillation operation. Before going to this lecture, let us have brief recap on our previous lecture.

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The slide features a blue header with the word "Recap" in yellow. Below the header, on a light green background, are three handwritten bullet points in red ink:

- Minimum Reflux  $\rightarrow$  Determination
- Stages and Reflux for a particular separation
- Feed Tray location

In our previous lecture, we have mainly considered, minimum reflux and we have seen how to determine the minimum reflux ratio. The second thing, we have considered stages and reflux for a particular separation and finally, we have considered the feed tray location.

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**Module 5: Lecture 16**

→ Batch Distillation of a Multicomponent Mixture

→ solve problem on batch distillation

So, in this lecture we will continue our discussion on multicomponent distillation. In this lecture we will mainly consider batch distillation of a multicomponent mixture. And we will try to discuss the fundamental concept of Multicomponent Batch Distillation and try to solve and work out problem.

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**Batch Distillation of a Multicomponent Mixture**

⇒ Consider  $L$  moles of a solution containing components 1, 2, 3, ...,  $n$  having mole fractions  $x_1, x_2, x_3, \dots, x_n$ , respectively.

⇒ So the moles of the individual components in the solution are:

$$\begin{aligned}L_1 &= Lx_1 \\L_2 &= Lx_2 \\L_3 &= Lx_3 \\&\vdots \\L_n &= Lx_n\end{aligned}$$

⇒ Assumption: The solution is ideal.

So, multicomponent batch distillation let us consider  $L$  moles of a solution, containing components 1 2 3 and so on up to  $n$  number of components. And these are having mole fractions  $x_1 x_2 x_3$  and so on up to  $x_n$  respectively.

Now, the moles of the individual component in the solution, we can calculate. So, the moles of the individual components in the solution are,  $L_1$  which would be  $L \times 1$ ,  $L_2$  which would be  $L \times 2$ ,  $L_3$  which would be  $L \times 3$  and so on up to  $L_n$  which would be  $L \times n$ . Now assume the solution is ideal.

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**Batch Distillation of a Multicomponent Mixture**

$\Rightarrow$  The relative volatility  $\alpha_{ij}$  of component  $i$  with respect to another component  $j$  is taken as constant

$\Rightarrow$  Further, take component  $j$  as the base or reference component to which the relative volatility of any other component in the mixture is defined.

Now, the relative volatility  $\alpha_{ij}$  that is relative volatility of component  $i$  with respect to another component  $j$  is taken as constant. Now further take component  $j$  as the base or reference components so, component  $j$  as the base or reference component to which the relative volatility of any other component in the mixture is defined.

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### Batch Distillation of a Multicomponent Mixture

⇒ The differential mass balance:  
For component i:  $-dL_i = y_i^* dL$   
For component j:  $-dL_j = -y_j^* dL$

⇒  $\frac{dL_i}{dL_j} = \frac{y_i^*}{y_j^*} = \alpha_{ij} \frac{x_i}{x_j} = \alpha_{ij} \frac{L_i}{L_j}$

⇒ Integrating from the initial to the final state:  
 $\ln \frac{(L_i)_{\text{initial}}}{(L_i)_{\text{final}}} = \alpha_{ij} \ln \frac{(L_j)_{\text{initial}}}{(L_j)_{\text{final}}}$

So, let us do the differential mass balance. Now if we do the mass balance for component i, it would be minus d L i is equal to y i D star d L. For component j, we can write minus d L j is equal to minus y j D star d L. Now from this two equation we can write d L i divided by d L j would be equal to y i D star divided by y j D star and then we can write this is alpha i j alpha i j is the relative volatility of component i with respect to j into x j sorry into x i divided by x j which is equal to alpha i j into L i by L j.

Now, integrating from the initial to the final state, we can obtain ln L i initial divided by L i final is equal to alpha i j ln L j initial divided by L j final.

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**Batch Distillation of a Multicomponent Mixture**

⇒ The eqn can be written for all possible pairs with the component j as common to get:

$$\left[ \frac{(L_i)_{\text{initial}}}{(L_i)_{\text{final}}} \right]^{\alpha_{ji}} = \frac{(L_j)_{\text{initial}}}{(L_j)_{\text{final}}} = \dots = \left[ \frac{(L_n)_{\text{initial}}}{(L_n)_{\text{final}}} \right]^{\alpha_{jn}}$$

[ since  $\alpha_{ij} = \frac{1}{\alpha_{ji}}$  ]

⇒ The above eqn together with the condition  $x_1 + x_2 + x_3 + \dots + x_n = 1$ , can be used to solve multicomponent batch distillation.

Now, the equation which we have developed by the integration, this can be written for all possible pairs with the component j as common to get the following equation.  $L_i$  initial divided by  $L_i$  final to the power  $\alpha_{ji}$  is equal to  $L_j$  initial divided by  $L_j$  final and so on. You will get  $L_n$  initial divided by  $L_n$  final to the power  $\alpha_{jn}$ .

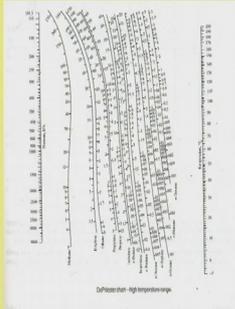
This is because since  $\alpha_{ij}$  is equal to  $1/\alpha_{ji}$ , this above equation which we have derived together with the condition which we know for this system components for this components can be solve the multicomponent batch distillation. So, the above equation together with the condition  $x_1 + x_2 + x_3 + \dots + x_n = 1$  can be used to solve multicomponent batch distillation. Let us look into an example and how we can implement this equation.

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### Example 1

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85



A mixture of 0.25 kilo mole n-pentane which is component 1 0.35 kilo mole; n-hexane which is component 2 and 0.40 kilo mole n-octane which is component 3, is batch distilled at 1 atmosphere pressure to remove 90 percent of n-pentane that is normal pentane. Now calculate the amount and composition of the distillate the Antoine equation can be used to calculate the vapour pressure the Antoine constant are given in the table. So, this is the table where we will get for n-pentane n-hexane and n-octane the Antoine constant. The K values can be obtained from the DePriester chart so this is the chart which are given and available in the standard book.

(Refer Slide Time: 12:53)

### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

n-pentane (1) = 0.25 kmol = (L)<sub>in</sub>  
 n-hexane (2) = 0.35 kmol = (L)<sub>in</sub>  
 n-octane (3) = 0.40 kmol = (L)<sub>in</sub>

M<sub>avg</sub> = (0.25 × 72) + (0.35 × 86) + (0.4 × 114) = 93.7

Taking n-hexane as reference component

From Antoine eq<sup>n</sup>

$$\ln(P_i^v) = A - \frac{B}{C + \theta}$$

1 bar = 760 mm Hg.

$$\Rightarrow \ln(760) = 15.9155 - \frac{2738.42}{226.1 + \theta}$$

$$\Rightarrow 6.63 - 15.9155 = - \frac{2738.42}{226.1 + \theta} \Rightarrow \theta = 68.8^\circ\text{C}$$

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

So, let us write down the components and their compositions given. So, n-pentane component 1 which is 0.25 k mole and call as L 1 in n-hexane component 2 as 0.35 kilo mole and call as L 2 in and n-octane which is component 3 and having composition 0.40 kilo mole which is L 3 in. Now we can calculate the average molecular weight. So, M average would be equal to 0.25 into 72 is the molecular weight of n-pentane, then 0.35 into 86 plus 0.4 into 114. So, this would be about 93.7.

Now, taking n-hexane as reference component so from Antoine equation we can write  $\ln P_A^V$  is equal to A minus B by C plus theta the pressure here is 1 bar or 1 atmosphere which is 760 millimeter Hg. Now if we put the Antoine constants which are given over here for n-pentane, it would be  $\ln 760$  would be equal to 15.9155 minus 2738.42 divided by 226.1 plus theta. So, if we solve this thing it would be 6.63 minus 15.9155 would be equal to minus 2738.42 divided by 226.1 plus theta. And from here we can obtain theta is equal to 68.8 degree Centigrade.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

**Solution:**

*similarly, for n-pentane:*

$$\ln(P_1^V) = 15.8365 - \frac{2477.07}{233.21 + 68.8}$$

$$\Rightarrow \ln(P_1^V) = 7.634 \Rightarrow P_1^V = 2068.44 \text{ mmHg} = 2.756 \text{ bar}$$

*For n-octane:*

$$\ln(P_3^V) = 15.9635 - \frac{3128.75}{209.85 + 68.8}$$

$$\Rightarrow P_3^V = 113.892 \text{ mmHg} = 0.152 \text{ bar}$$

Now, similarly for n-pentane we can obtain the vapor pressure that is  $\ln P_1^V$  would be equal to 15.8365 minus 2477.07 divided by 233.21 plus 68.8 which we have obtained for the reference component. Now from here we can obtain  $\ln P_1^V$  is equal to 7.634 and hence we can get  $P_1^V$  is equal to 2068.44 millimeter Hg. So, which would be about 2.756 bar.

Now, for n-octane we can write  $P_3^V$  would be equal to 15.9635 minus 3128.75 divided by 209.85 plus 68.8. So, from here we can write  $P_3^V$  is about 113.892 millimeter Hg which is 0.152 bar.

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**Example 1: Solution**

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

**Solution:**

$$\text{Now, } \alpha_{12} = \frac{P_1^V}{P_2^V}, \quad \alpha_{32} = \frac{P_3^V}{P_2^V}$$

$$= \frac{2.756}{1} = 2.756 \quad = \frac{0.152}{1} = 0.152$$

$$K_r = \frac{1}{(2.756 \times 0.25) + 1 \times 0.35 + 0.4 \times 0.152}$$

$$= 0.948$$

Now we can calculate the relative volatility  $\alpha_{12}$  would be  $P_1^V$  by  $P_2^V$   $\alpha_{32}$  would be  $P_3^V$  divided by  $P_2^V$ . So, if we substitute the values of vapour pressure we have obtained, it would be 2.756 divided by 1. And this would be equal to 0.152 divided by 1 which is equal to 0.152 and this would be equal to 2.756.

Now, you can obtain  $K_r$  that is reference component K values would be equal to 1 by 2.756 into 0.25 plus 1 into 0.35 plus 0.4 into 0.152 and if we do that, we will obtain the  $K_r$  is 0.948.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

Using this revised  $K_r$ :

$$K_r = \frac{P_i^v}{P} \Rightarrow 0.948 = \frac{P_i^v}{1}$$

$$\Rightarrow P_i^v = 0.948$$

Recalculating the b.p. of n-hexane at  $P_i^v$ :

$$\ln(711) = 15.9155 - \frac{2738.42}{226.2 + \theta}$$

$$\Rightarrow \theta + 226.2 = 292.91 \Rightarrow \theta = 66.715^\circ\text{C}$$

We have, amount of n-pentane to be removed 90% of 0.25 kmol = 0.225 kmol. Amount of n-pentane remained: 0.025 kmol

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

Now, if we use this  $K_r$  so, this revised  $K_r$  we can use  $K_r$  would be equal to  $P_i^v$  by  $P$  which is equal to we can write 0.948 would be equal to  $P_i^v$  divided by 1. So, from here we can write  $P_i^v$  would be equal to 0.948.

Now, if we recalculate the boiling point of n-hexane at this pressure. So, recalculating the boiling point of n-hexane, at  $P_i^v$  we can obtain  $\ln(711)$  would be equal to  $15.9155$  minus  $2738.42$  divided by  $226.2$  plus  $\theta$ . So, from here we can calculate  $\theta$  plus  $226.2$  would be about  $292.91$  and hence we can calculate  $\theta$  would be  $66.715$  degree Centigrade this is the boiling point of the reference component.

We have amount of n-pentane to be removed 90 percent of 0.25 kilo mole which was in the feed. So, this would be 0.225 kilo mole. So, the amount of pentane remains is 0.025 kilo mole.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

Now, at  $66.715^\circ\text{C}$

$$\ln(P_1^V) = 15.8365 - \frac{2477.07}{66.715 + 233.21}$$

$$\Rightarrow P_1^V = 1953.8 \text{ mmHg} = 2.6 \text{ bar}$$

$$\ln(P_3^V) = 15.9635 - \frac{3128.75}{66.715 + 209.85}$$

$$\Rightarrow P_3^V = 104.64 \text{ mmHg} = 0.139 \text{ bar}$$

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

Now at 66.715 degree Centigrade we can calculate the vapour pressure for component 1 and component 3 that is pentane and n-octane. So,  $\ln P_1^V$  would be equal to 15.8365 minus 2477.07 divided by 66.715 plus 233.21. So, this would be  $P_1^V$  would be about 1953.8 millimeter Hg which is about 2.6 bar.

Similarly,  $\ln P_3^V$  would be equal to 15.9635 minus 3128.75 divided by 66.715 plus 209.85. Then we can calculate  $P_3^V$  from here would be equal to 104.64 which is millimeter Hg which is equal to 0.139 bar.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

So,  $K_1 = \frac{P_1^V}{P_2^V} = \frac{2.6}{0.948} = 2.74$

$K_2 = 0.948$

$K_3 = 0.1466$

$\alpha_{21} = \frac{P_2^V}{P_1^V} = 0.364, \alpha_{12} = 2.74$

$\alpha_{23} = \frac{P_2^V}{P_3^V} = 6.466, \alpha_{32} = 0.1466$

$\sum_{i=1}^3 K_i x_i = 0.25 \times 2.74 + 0.948 \times 0.35 + 0.4 \times 0.1466 = 1$

Antoine const.	A	B	C
n-pentane	15.8365	2477.07	233.21
n-hexane	15.9155	2738.42	226.1
n-octane	15.9635	3128.75	209.85

So,  $K_1$  we can calculate is equal to  $P_1 V$  divided by  $P_2 V$  which is equal to 2.6 divided by 0.948 which is equal to 2.74.  $K_2$  is 0.948 and  $K_3$  similarly we can get 0.1466.

Once we obtained  $K_2$  and  $K_3$  we can obtain  $\alpha_{21}$  which is equal to  $P_2 V$  by  $P_1 V$  which is equal to 0.364.  $\alpha_{12}$  is 2.74.  $\alpha_{23}$  is  $P_2 V$  by  $P_3 V$  which is equal to 6.466, and  $\alpha_{32}$  is 0.1466. Now we can check the values of  $\sum k_i x_i$  over  $i$  is equal to 1 to 3. So, this would be 0.25 into 2.74 plus 0.948 into 0.35 plus 0.4 into 0.1466 so which is equal to 1. So that means, the temperature which we have obtained is correct as a bubble point.

(Refer Slide Time: 28:18)

### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

Assume  $b.p. = 95^\circ C$

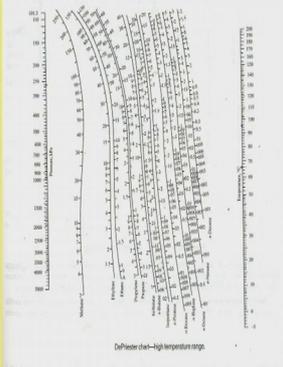
$K_1 = 4.65, K_2 = 2.03, K_3 = 0.45$

$\alpha_{21} = \frac{2.03}{4.65} = 0.437, \alpha_{23} = 4.51$

Average values of  $\alpha$

$\alpha_{21} = \frac{0.364 + 0.437}{2} = 0.4005$

$\alpha_{23} = \frac{6.466 + 4.51}{2} = 5.488$



Now, assume bubble point is equal to 95 degree Centigrade; at this temperature from this DePriester chart temperature and pressure at the initial pressure of the system is 1 atmosphere that is 101.3 from this temperature and pressure we can obtain the values for n-pentane n-hexane and n-octane the K-values. So, if we use the chart, we will obtain  $K_1$  is equal to 4.665,  $K_2$  is 2.03 and  $K_3$  is equal to 0.45.

Now, we can calculate  $\alpha_{21}$  would be equal to 2.03 by 4.65 which is equal to 0.437 and  $\alpha_{23}$  would be equal to 4.51. Now if we use the average values of alpha, we can write  $\alpha_{21}$  would be equal to 0.364 plus 0.437 divided by 2 which is equal to 0.4005. Similarly  $\alpha_{23}$  would be equal to 6.466 plus 4.51 divided by 2 which is equal to 5.488.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

$$\begin{aligned} \text{Now: } \frac{(L_1)_i}{(L_1)_f} &= \left[ \frac{(L_1)_i}{(L_1)_f} \right]^{\alpha_{21}} = \left[ \frac{(L_3)_i}{(L_3)_f} \right]^{\alpha_{23}} \\ \Rightarrow \frac{0.25}{(L_1)_f} &= 10^{0.4005} \Rightarrow (L_1)_f = 0.139 \text{ kmol} \\ \left[ \frac{(L_3)_i}{(L_3)_f} \right]^{5.488} &= 10^{0.4005} \Rightarrow \frac{0.4}{(L_3)_f} = 1.183 \\ \Rightarrow (L_3)_f &= 0.338 \text{ kmol} \end{aligned}$$

Now,  $L_2$  initial divided by  $L_2$  final initial and final would be equal to  $L_1$  by  $L_1$  initial divided by  $L_2$   $L_1$  final to the power  $\alpha_{21}$  would be equal to  $L_3$  initial is  $L_3$  final to the power  $\alpha_{23}$ . Now if we substitute the values 0.35 by  $L_2$   $f$  would be equal to 10 to the power 0.4005. And from here we can obtain 0.139 this 10 is the ratio of  $L_1$  initial divided by  $L_1$  final  $L_1$  initial was 0.25 kilo mole of n-pentane and the remaining which is final is 0.025 kilo mole so the ratio  $L_1$  initial by  $L_1$  final is 10.

Similarly, if we consider  $L_2$  initial by  $L_2$  final with respect to  $L_3$  components over here. So, we can obtain  $L_3$  initial divided by  $L_3$  final to the power 5.488 would be equal to 10 to the power 0.4005. 0.4 divided by  $L_3$  final would be equal to 1.183 and from here we can write  $L_3$   $f$  would be 0.338 kilo mole and this is  $L_2$   $f$  is equal to 0.139.

(Refer Slide Time: 33:32)

### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:** Check for the assumed final temp. of  $95^{\circ}\text{C}$   
Total no. of moles at the end:  
 $= 0.025 + 0.139 + 0.338$   
 $= 0.502$   
 $\therefore x_1 = 0.0497, x_2 = 0.2768, x_3 = 0.673$   
 $\sum_{i=1}^3 k_i x_i = (4.65 \times 0.0497) + (2.03 \times 0.2768) + (0.673 \times 0.45)$   
 $= 1.095 > 1$   
So the assumed temp is a bit high.

Now, to check the assumed final temperature of 95 degree Centigrade let us consider the number of moles at the end. So, we need to check for the assumed final temperature of 95 degree Centigrade. So, total number of moles at the end which is equal to 0.025 plus 0.139 plus 0.338 so which is equal to 0.502. So, the mole fraction we can calculate  $x_1$  is 0.0497,  $x_2$  is 0.2768 and  $x_3$  is 0.673. Now if we calculate summation over  $i$  is equal to 1 to 3  $k_i x_i$  which is 4.65 into 0.0497, plus 2.03 into 0.2768 plus 0.673 into 0.45 which would be equal to 1.095 which is greater than 1.

So, the assumed temperature is a bit high. So, what we need to consider little lower temperature than 95 degree Centigrade.

(Refer Slide Time: 36:08)

### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

so taking a revised k-value:  

$$K_2 = \frac{2.03}{1.095} = 1.85$$
 Corresponding temp. = 91°C  
 So, at 91°C:  $K_1 = 4.4, K_3 = 0.39$

$$\alpha_{21} = \frac{1.85}{4.4} = 0.42$$

$$\alpha_{23} = \frac{1.85}{0.39} = 4.74$$

So, let us assume or calculate the revised K-values. So, taking a revised K-values that is K 2 would be equal to 2.03 divided by 1.095 which is 1.85. And then from the chart we can obtain the corresponding temperature which is equal to 91 degree Centigrade. So, at 91 degree Centigrade K 1 is equal to 4.4 and K 3 is equal to 0.39. So, we can calculate alpha 2 1 which is equal to 1.85 divided by 4.4 which is equal to 0.42 alpha 2 3 which is equal to 1.85 divided by 0.39 which is equal to 4.74.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

Average  $\alpha$  values:  

$$\alpha_{21} = \frac{0.364 + 0.42}{2} = 0.392$$

$$\alpha_{23} = \frac{6.466 + 4.74}{2} = 5.6$$

Re-calculating the values:  

$$\frac{(L_2)_{in}}{(L_2)_f} = 10^{0.292}$$

$$\Rightarrow (L_2)_f = 0.141 \text{ kmol}$$

$$\left[ \frac{(L_3)_{in}}{(L_3)_f} \right]^{5.6} = 10^{0.392} \Rightarrow (L_3)_f = 0.340 \text{ kmol}$$

We can calculate the average alpha values that is  $\alpha_{21}$  is equal to 0.364 plus 0.42 divided by 2 which is equal to 0.392 and  $\alpha_{23}$  would be equal to 6.466 plus 4.74 divided by 2 which is equal to 5.6. Now recalculating the values we can write  $L_2$  initial divided by  $L_2$  final would be equal to 10 to the power 0.292. So, from here we can calculate  $L_2$  final would be 0.41 0.141 kilo mole.

Similarly, if we consider  $L_2$  or  $L_3$  in divided by  $L_3$  final to the power 5.6 which is equal to 10 to the power 0.392 and from here we can get  $L_3$  f is equal to 0.340 kilo mole.

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**Example 1: Solution**

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

Total moles in the final liquid  
 $= 0.025 + 0.141 + 0.340 = 0.506 \text{ kmol}$

Fractions:  $x_1 = 0.049$ ,  $x_2 = 0.278$ ,  $x_3 = 0.672$

$$\sum_{i=1}^3 k_i x_i = (0.049 \times 4.4) + (0.278 \times 1.85) + (0.672 \times 0.39)$$

$$= 0.99 \approx 1$$

So, the estimate of the final temp. 91°C is good enough

Now the total moles in the final liquid we can calculate total moles in the final liquid, which would be equal to 0.025 plus 0.141 plus 0.340 which would be equal to 0.506 kilo mole. Then we can calculate the mole fractions,  $x_1$  would be 0.049,  $x_2$  would be 0.278 and  $x_3$  would be 0.672.

So, now we can calculate summation over  $k_i x_i$  is equal to 1 to 3 which would be equal to 0.049 into 4.4 plus 0.278 into 1.85 plus 0.672 into 0.39. So, this would give about 0.99 which is close to 1. So, the estimate of the final temperature that is 91 degree Centigrade is good enough.

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### Example 1: Solution

A mixture of 0.25 kmol n-pentane (component 1), 0.35 kmol n-hexane (component 2), 0.40 kmol n-octane (component 3) is batch distilled at 1 atm pressure to remove 90% of n-pentane. Calculate the amount and composition of the distillate. The Antoine equation can be used to calculate the vapour pressure. The Antoine constants are given in the Table. Take the K-values from the DePriester chart.

**Solution:**

$$\begin{aligned} \text{No. of moles in the distillate} \\ = 1 - 0.506 = 0.494 \text{ kmol} \end{aligned}$$

$$\begin{aligned} \text{Composition } (x_1)_D &= 0.455 \\ (x_2)_D &= 0.423 \\ (x_3)_D &= 0.1185 \end{aligned}$$

And hence the composition we have to calculate, so the number of moles in the distillate would be equal to 1 minus 0.506 which is 0.494 kilo mole. And then composition in the distillate would be  $x_1 D$  is equal to 0.455  $x_2 D$  0.423 and  $x_3 D$  would be 0.1185.

So, this is how we can solve batch distillation problems. Thank you for attending this lecture as well as the mass transfer course and this is the end of our lecture for all the modules. I hope you have enjoyed the course, if you have any queries we can sort out during the online discussion.

Thank you very much.