Basic Principles and Calculations in Chemical Engineering

Prof. S. K. Majumder
Chemical Engineering Department
Indian Institute of Technology-Guwahati

Lecture # 16

Process of Phase change Condensation and vaporization

Welcome to massive open online course on basic principles and calculations in chemical engineering. So, we are discussing about the basic principles of multi-phase systems under the module 5. Now, in this module, today is lecture will be on process of a change, basically, for the process of condensation. And vaporization and their calculations in the previous lecture we have described about the equilibrium laws like Raoult's law even principles of humidity.

And saturation there and based on which we have you know obtain how to you know find out that dew point in pressure even saturation temperatures even humid volume how to calculate the you know that moisture content in the open atmosphere and also how from the psychometrics chart. How to you know how to actually estimate or you can see find out they are humid volume even you know dew point and also relative saturation all those things we have discussed in the previous lecture in this lecture, you know the further extension on that equilibrium condition basically for dark you know condensation.

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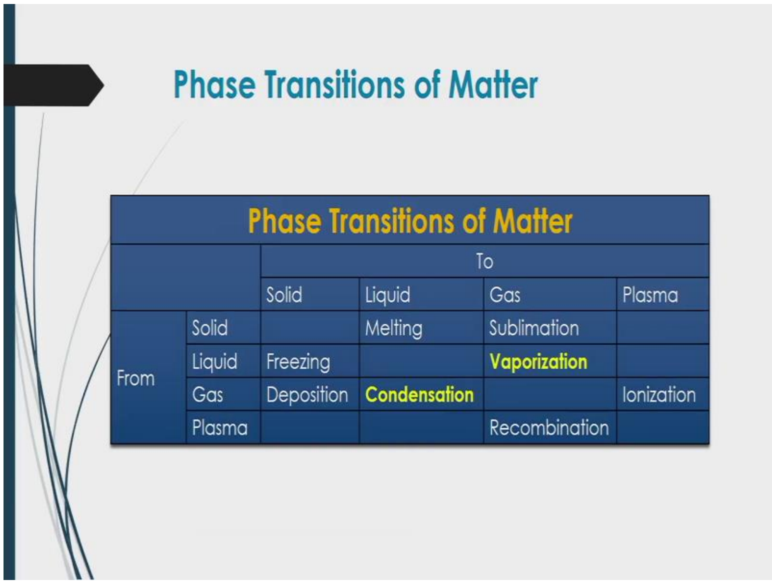

Phase Transitions of Matter

Phase Transitions of Matter

		To			
		Solid	Liquid	Gas	Plasma
From	Solid		Melting	Sublimation	
	Liquid	Freezing		Vaporization	
	Gas	Deposition	Condensation		Ionization
	Plasma			Recombination	

And vaporization process and in this case, since, you will see that page will be changing from 1 phase to the another phase So, phase condensation of method is you know, that is related to this you know topics like you know that the different you know states of the you know materials that will be called as phase also. So, in that case solid liquid gas and plasma all those are you know, different you know state and from this state or from this phase that will be you know converted into another phase of state like here.

You know that solid you know, can be converted to you know, a liquid after melting and solid maybe you know convert it into gash by sublimation process, even liquid you will see that it will be you know converting into solid state after freezing, even liquid can be converted into vapor after vaporization process and gas maybe you know, converted into you know solid after the position and it may be converted into the state of liquid after condensation also this gas of course, sometimes to be you know convert it into plasma state by ionization process.

But from the ionization you know how condition or plasma state condition it may be you know converted to gas by you know recombination process. So, these are the different you know that phase transition process here. So, that is you know that called you know that freezing the physician condensation sublimation, vaporization recombination ionization. So, these are the different you know processes. In this lecture are mainly will focus on then you know that condensation and also you know vaporization process.

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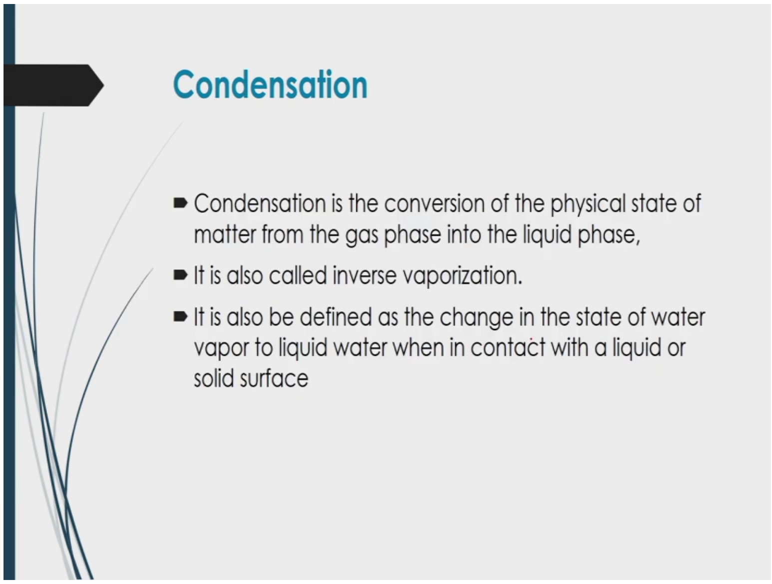

Condensation

- Condensation is the conversion of the physical state of matter from the gas phase into the liquid phase,
- It is also called inverse vaporization.
- It is also be defined as the change in the state of water vapor to liquid water when in contact with a liquid or solid surface

So, what is condensation we have already described this condensation basically is the conversion of the physical state of matter from the gas phase into the liquid phase and it is also called that inverse vaporization that may be you know that vapor to converting into you know liquid phase. So, that is why it is also called that inverse vaporization. It is also be defined as the change in the state of water vapor to you know liquid water when it contact with the liquid or you know that solid surface there. So, this is basically you know condensation process.

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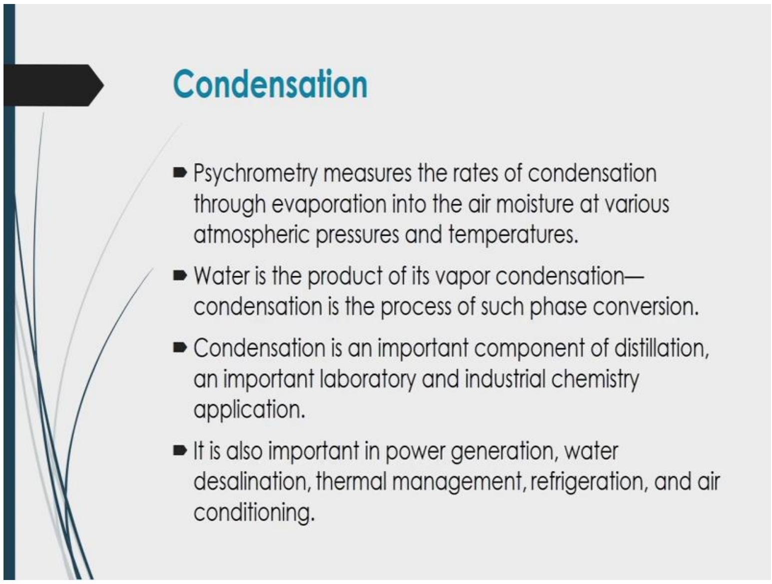

Condensation

- Psychrometry measures the rates of condensation through evaporation into the air moisture at various atmospheric pressures and temperatures.
- Water is the product of its vapor condensation—condensation is the process of such phase conversion.
- Condensation is an important component of distillation, an important laboratory and industrial chemistry application.
- It is also important in power generation, water desalination, thermal management, refrigeration, and air conditioning.

And you know that we have described that psychometry principles and also start their psychometry that measures the rate of condensation through evaporation into the air moisture at various atmospheric patients and temperatures. And in this case, you will see that water has the product of its vapor condensation. Condensation is the process of such phase conversion it is an important component of you know that the distillation process or you know that sometimes vapor component that is coming out from the distribution column.

It will be condensed to a liquid phase and again it will be sent to the distillation column at the liquid phase and some portion of that liquid phase will be unified there you know processed for you know useful product, it is also important in power generation water desalination process thermal management vaporization process and air conditioning process. So, all those processes are basically involved with this condensation process.

Now, before going to that calculation you have to know that what would be the partial condensation basically.

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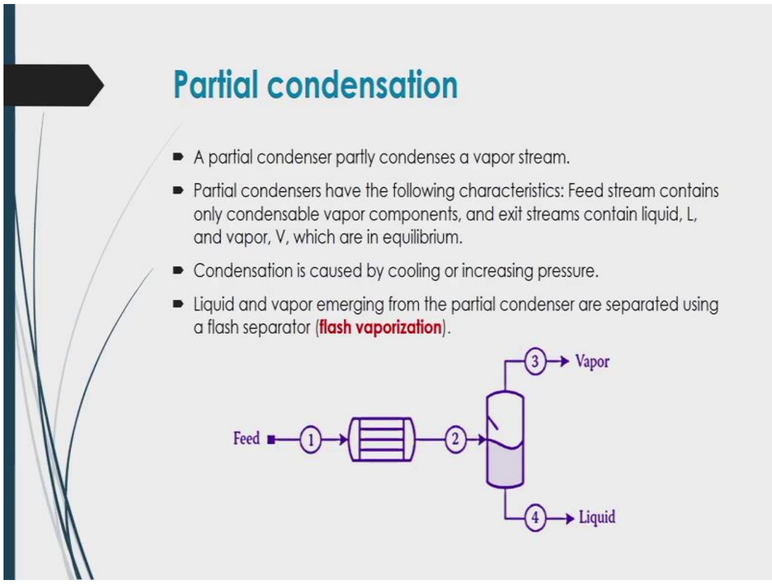

Partial condensation

- A partial condenser partly condenses a vapor stream.
- Partial condensers have the following characteristics: Feed stream contains only condensable vapor components, and exit streams contain liquid, L, and vapor, V, which are in equilibrium.
- Condensation is caused by cooling or increasing pressure.
- Liquid and vapor emerging from the partial condenser are separated using a flash separator (**flash vaporization**).

This is you know that the you know mechanism by who is that you know why that metal will be partly condenser into a vapor stream and in that case partial condensers generally being used and it will have the you know, characteristics like you know pre distribute contains only condensable vapor components and also it will you know have some existing streams that will contain the liquid and vapor have we who said in equilibrium.

So, condensation is caused by cooling or you know that increasing pressure and liquid and vapor that emerging from the partial condenser are separated using a flash separator. So, here you will see that you know that the liquid and vapor emerging from the partial you know condenser are separated using a flash separator here and in that case you will see that they are vapor and liquid will be coming up that you know our flash separation of flash vaporization process.

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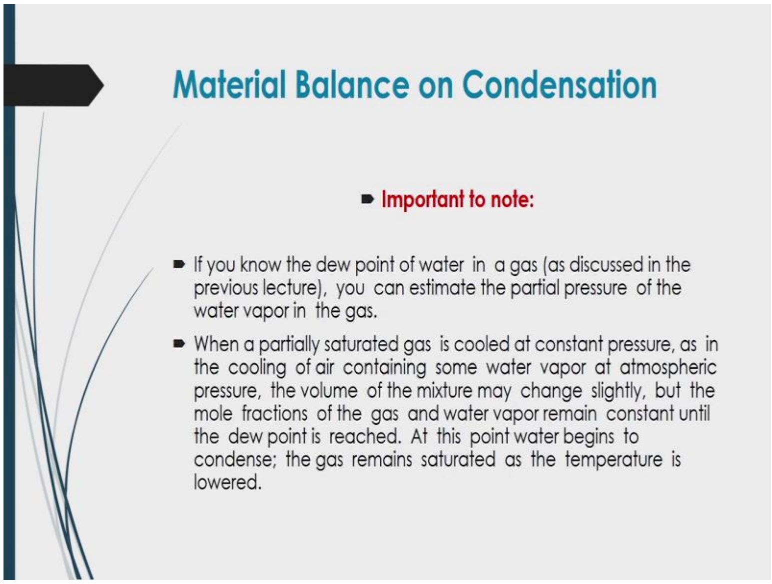

Material Balance on Condensation

- Important to note:
- If you know the dew point of water in a gas (as discussed in the previous lecture), you can estimate the partial pressure of the water vapor in the gas.
- When a partially saturated gas is cooled at constant pressure, as in the cooling of air containing some water vapor at atmospheric pressure, the volume of the mixture may change slightly, but the mole fractions of the gas and water vapor remain constant until the dew point is reached. At this point water begins to condense; the gas remains saturated as the temperature is lowered.

Now, how to do that material balance on the condensation in this case you have to you know, noted down that if you know the dew point of water we have already described that how to find out that you find from the psychometric chart higher that you know partial pressure will be equal to a vapor pressure of the you know a gas was component or any method or any you know that components.

So, in that case if you know that dew point of that water in a gas you know, you can estimate that partial pressure of the water vapor in a gas and also when you partially saturated gas is cooled at constant pressure as in the cooling of air containing some water vapor at atmospheric pressure, you will see that the volume of the mixture may change slightly. But the mole fractions of the gas and water vapor remains Constant until that you point is reached there.

So, at this point water begins to condense that is that that the dew point and the gas remains saturated as the temperature is lower to the air. So, this is to be remembered before going to you know do the material balance on condensation. Let us have.

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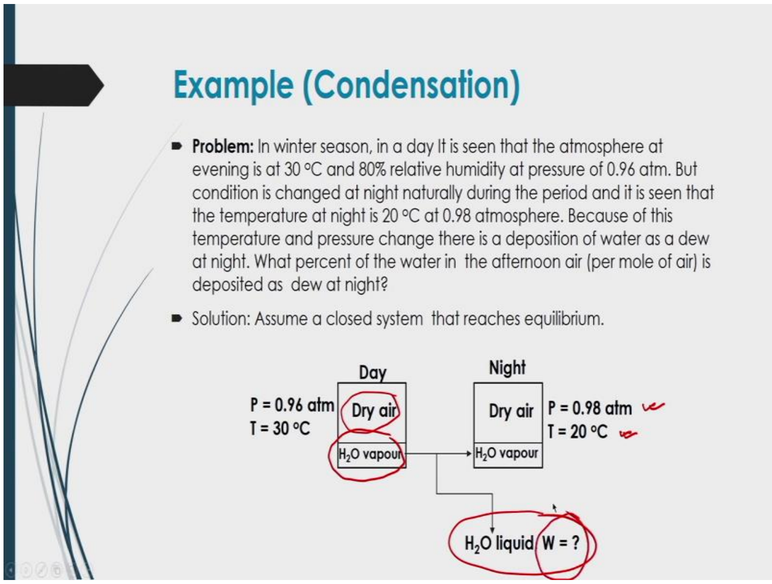

Example (Condensation)

- **Problem:** In winter season, in a day It is seen that the atmosphere at evening is at 30 °C and 80% relative humidity at pressure of 0.96 atm. But condition is changed at night naturally during the period and it is seen that the temperature at night is 20 °C at 0.98 atmosphere. Because of this temperature and pressure change there is a deposition of water as a dew at night. What percent of the water in the afternoon air (per mole of air) is deposited as dew at night?
- Solution: Assume a closed system that reaches equilibrium.

An example for this condensation process. Here in this case you will see that if suppose in winter season in a day it is seen that that atmosphere at evening is at 30 degrees Celsius and 80% relative humidity at a pressure of you know 0.96 atmospheric pressure. But condition it changed at night necessarily it is happening during the period of winter and it did not seem that the temperature at that, you know, night is 20 degrees Celsius at that 0.98 atmospheric pressure now.

You will see that here important that relative humidity at 80% at 30 degrees Celsius or pressure is 96, but at the night you will see that the temperature is start you know lowering to 20 degrees Celsius for after with Chris it also will be interested there are 0.98 atmosphere. Now, because of this temperature and pressure change, there is a depletion of water as you do at night. Now, at this condition you have to find out what should be the percentage of the water in the afternoon air per mole of air.

You have to calculate which is deposited as day add that night basically you have to find out what would be the amount of that is water in percentage that is constant condensed as dew at night. Here in this case simply that you temperature is lowering Pressure is increasing relative humidity that at the day you know, but for the relative humidity at night that also you do not know, but this let us see how to calculate these things that how much water is actually condensing as a do at night and that particular condition.

Now, in this case, we have to consider that this is a closed system that resists equilibrium. Now, they are in this case, if we draw the schematic diagram, supposing day this amount is dryer and here water vapor will be there. So, dry air contents water vapor at the you know temperature 30 degrees Celsius and pressure is 0.96 atmosphere. Whereas at night you will see that this you know that amount of you know vapor will be you know that lower that night after condensing out as a liquid, that amount is W.

And at night that condition is pressure is 0.98 atmosphere and temperature is you know 20 degrees Celsius. So, this is your problem in this case what a part of the amount of water that is you know condensed as it do you have at night.

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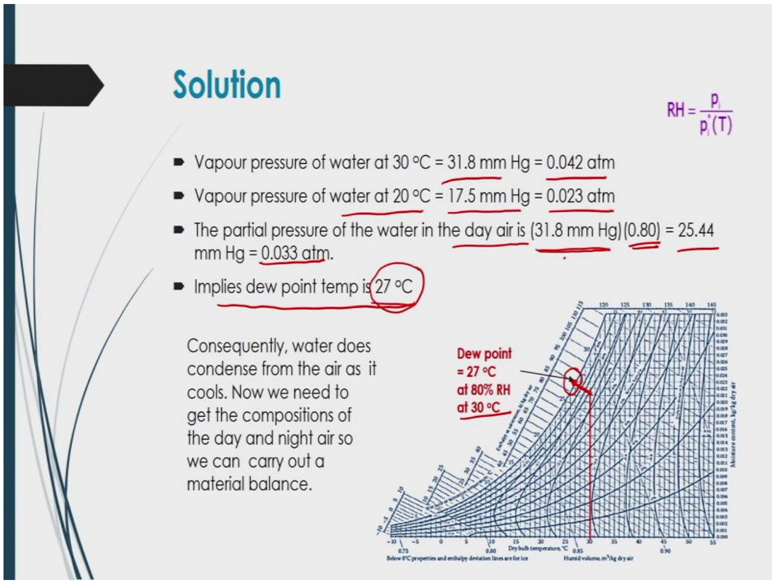

Solution

$RH = \frac{p_i}{p_i^*(T)}$

- Vapour pressure of water at 30 °C = 31.8 mm Hg = 0.042 atm
- Vapour pressure of water at 20 °C = 17.5 mm Hg = 0.023 atm
- The partial pressure of the water in the day air is (31.8 mm Hg)(0.80) = 25.44 mm Hg = 0.033 atm.
- Implies dew point temp is 27 °C

Consequently, water does condense from the air as it cools. Now we need to get the compositions of the day and night air so we can carry out a material balance.

Dew point = 27 °C at 80% RH at 30 °C

That you have to find out now, as a solution what we can say that first of all you have to find out what should be the vapor pressure of the water at 30 degrees Celsius. So, this vapor pressure of water at 30 degrees Celsius it is you know that given here 31.8 millimeter mercury that is in atmosphere 0.042 harass this vapor pressure of water at night that is at 20 degrees Celsius. This will be equal to 17.5 millimeter mercury that was 0.023 atmosphere.

Now, the partial pressure of the water in that day air that will be equal to what 31.8 millimeter mercury into 0.8 because 0.8 is the relative humidity, this relative humidity basically that you know, it ratio of you know ratio of what is that means, here pressure to the vapor pressure. So, from pressure you can say that what should be the washer pressure of the water that will be simply you know that 31.8 this is vapor pressure into humidity.

So, it will be coming as 25.44 millimeter mercury it is around 0.033 atmospheric pressure. Now, in this case is implies that dew point temperature will be 27 degrees Celsius. So, at this you know partial pressure at you know in the day that here in this case at this particular partial pressure, it is seen that this the dew point temperature will be 27 degree Celsius from this because you can get also some you know from that you know 20 degrees Celsius or 30 degrees Celsius at that day condition from the psychometric site.

If you go to that, you know 80% relative humidity and from that, what should be that dew point that you go to that you know up to that hundred percent saturation, it is seen that dew point to be = 27 degrees Celsius at 80% relative humidity at 30 degrees Celsius. So, from this psychometrics art you can calculate here what should be the, you know dew point there. Now, consequently, you can say that what does condense from the air as it cools. Now, we need to get the composition of the dry and night so, the composition of the day and night here so, we can carry out the material balance there.

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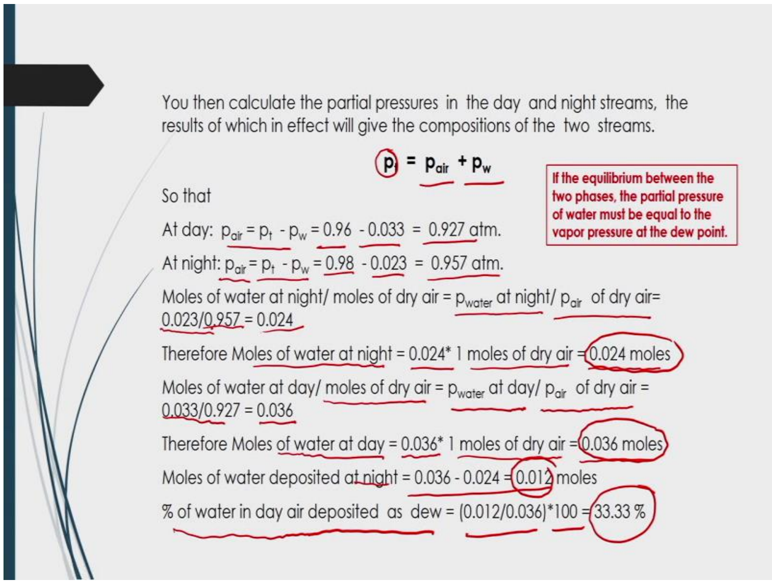

You then calculate the partial pressures in the day and night streams, the results of which in effect will give the compositions of the two streams.

$$p_t = p_{air} + p_w$$

If the equilibrium between the two phases, the partial pressure of water must be equal to the vapor pressure at the dew point.

So that

At day: $p_{air} = p_t - p_w = 0.96 - 0.033 = 0.927$ atm.

At night: $p_{air} = p_t - p_w = 0.98 - 0.023 = 0.957$ atm.

Moles of water at night/ moles of dry air = p_{water} at night/ p_{air} of dry air= 0.023/0.957 = 0.024

Therefore Moles of water at night = 0.024* 1 moles of dry air = 0.024 moles

Moles of water at day/ moles of dry air = p_{water} at day/ p_{air} of dry air = 0.033/0.927 = 0.036

Therefore Moles of water at day = 0.036* 1 moles of dry air = 0.036 moles

Moles of water deposited at night = 0.036 - 0.024 = 0.012 moles

% of water in day air deposited as dew = (0.012/0.036)*100 = 33.33 %

You then calculate the partial pressures in the day and night is streams and result off which is in effect, we will give it up composition of the 2 streams. So, here we know that total pressure will be equal to what partial pressure of air and partial pressure of whatever. Now at today, so, you can see that partial pressure of will be equal to here total temperature is given 0.96 for a partial pressure of water at day 0.032. We have already.

You know, calculated and then it will be finally after subtraction from the total pressure, then partial pressure of air will be equal to 0.927 and then at night also what through the partial pressure of water that also can be calculated from this total pressure by subtracting the water you know, partial pressure, so, it will be coming as 0.98 - 0.023 then it will be coming at 0.957 atmosphere. Now, from this we can say that moles of water at night by moles of dry air.

That will be equal to push pressure of water at night by partial pressure of you know or dryer. So, that will be equal to 0.023 0. Divided by 0.957 that will be 0.024. Similarly, moles of water at night that will be = then 0.024 into 1 holes of dry air then it will be at 0.024 moles there and the moles of water a day by moles of dry air you know that will be sure to you know partial pressure of water at day divided by you know partial pressure of dryer there then it will be coming as air 2.036 and therefore, moles of water a day it will be as what is that 2.036 into 1 mole of dry air than it will be coming at 0.036 moles.

So, moles of water that will deposited at night it would be what is that simply this is your you know that daytime and this water moles at nighttime is here. So, if you subtract these you know 0.024 moles at night from the you know what are moles of the day that is from 0.036 then you can get this you know that he had 0.012 moles of water are deposited at night. So, this will actually will be you know, that coming out as a deal at night. Now percent is of water in that day air then deposited as a deal that will be equal to 0.01 to this amount divided by 4 to visa.

You know that amount of, you know that moles of water in the day, so, it will be coming as you are like this suit will be around 33.3% so, in this way you can calculate that how to be the amount of water that is you know, deposited into you at night there.

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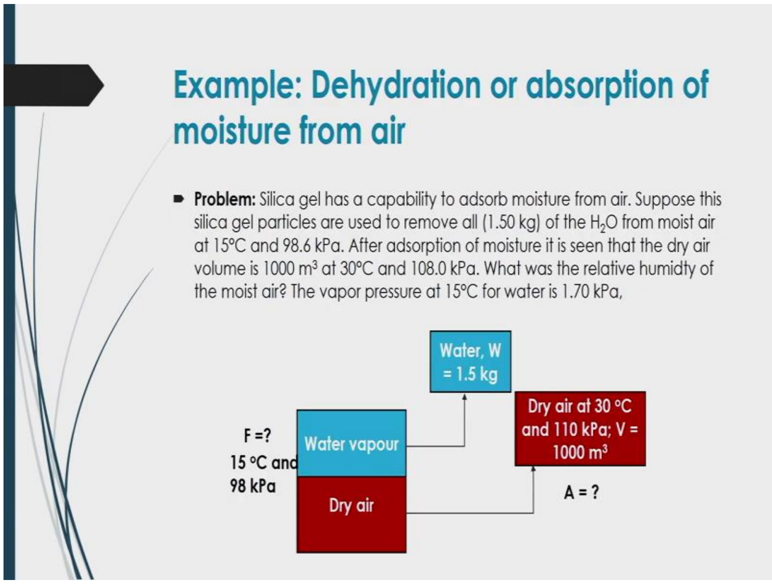

Example: Dehydration or absorption of moisture from air

- **Problem:** Silica gel has a capability to adsorb moisture from air. Suppose this silica gel particles are used to remove all (1.50 kg) of the H_2O from moist air at 15°C and 98.6 kPa. After adsorption of moisture it is seen that the dry air volume is 1000 m^3 at 30°C and 108.0 kPa. What was the relative humidty of the moist air? The vapor pressure at 15°C for water is 1.70 kPa,

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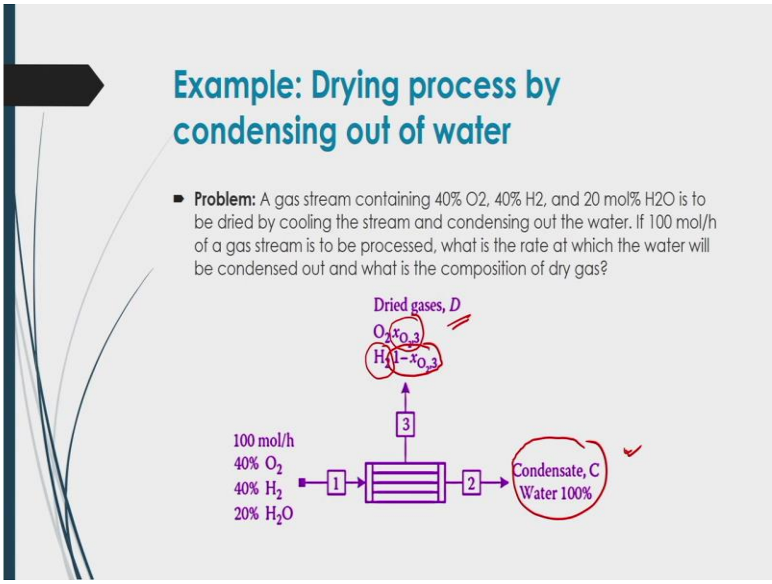

Example: Drying process by condensing out of water

- **Problem:** A gas stream containing 40% O2, 40% H2, and 20 mol% H2O is to be dried by cooling the stream and condensing out the water. If 100 mol/h of a gas stream is to be processed, what is the rate at which the water will be condensed out and what is the composition of dry gas?

Let us do another example here are now drying process by condensing out of water in this case a gas stream containing 40% oxygen 40% you know hydrogen and you know 20% water in mole is to be dried by cooling the stream and condensing out the water if hundred more per hour of a gaseous dream is to be processed, what is the rate at which the water will be condensed out and what is the composition of the dry gas.

So, very simple that you have to you know draw fast that schematic diagram here it is shown on the slide that gases stream of hundred moles per hour is flowing through that, you know You know, dryer, you know in this case here a composition of the gas stream is 40% oxygen 40% hydrogen 20% water vapor. Now, you have to you know, that is to be dried by then is cooling the stream and condensing out the water.

Now, you will see that at this stream 2 this condense it will come out as among C, higher water will be 100% no other competition will be there like oxygen hydrogen will not be there, but the dry gas it will be you know containing oxygen some, you know more fraction that is xo2 and also hydrogen that will be 1 - x o23 So, right gas amount is D it is not known to you. So, based on this problem, you have to find out what is the rate at which that water will be condensed out and what is the composition of the dry gas there.

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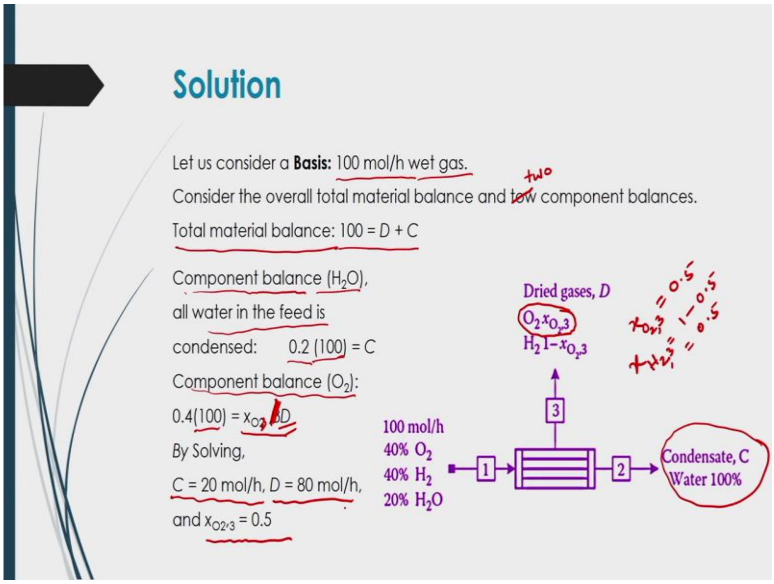

Solution

Let us consider a **Basis:** 100 mol/h wet gas.

Consider the overall total material balance and ~~tow~~ two component balances.

Total material balance: $100 = D + C$

Component balance (H_2O),
all water in the feed is
condensed: $0.2\,(100) = C$

Component balance (O_2):
$0.4(100) = x_{O_2,3}D$

By Solving,
$C = 20$ mol/h, $D = 80$ mol/h,
and $x_{O_2,3} = 0.5$

Now, let us do this example here to solve. Now, let us consider these basic hundred mole per hour that wet gas here the composition of 40% oxygen particles and hydrogen and 20% water and consider the overall total material balance and you know that component balances and also component balances here like your 2 component balances here first of all you have to do that total material balance like 100 will be equal to D plus C yes, this is input these are output.

So, 100 = D + C and component balance for water all water in the heat is here condensed. So, you can see that 0.2 in 200 that will be coming as you know see, and so, we can say that hundred into 0.2 it will be you know that simply you know that 20 moles of water as a condensed. So, C will be = 0.2 into 100 that will go to 20 similarly, if we do the component balance for oxygen then you can see that 40% of oxygen in the feet there in 0.4 into 100 that will be exactly close to the outlet you know oxygen contents that will be here in this stream 3.

That will be you know that then d Xo2 here this 3 will not be here, this is in suffix. So, it will be basically you know that by Xo2 in the stream 3 then it will be coming as you know Xo3 into D. So, by solving we can see that d = 80 mole per hour and Xo23 then to becoming us point 5. So, once you know that Xo2 at 03, then here Xo2 at a stream 3 that is = 0.5 so, similar so, we can say that, at this time hydrogen will be equal to you know x hydrogen at a stream 3, it will be coming as 1 - 0.5 that will go to 0.5.

So, this is your mole fraction of hydrogen in stream 3 dry gas suppose of course, that amount D what is amount 80 mole per hour will contains that 50% you know oxygen and 50% hydrogen there. So, in this way you can you know, do that material balance and in this case total material balance and also component material balance to be done and how much water will be condensed, you can get it from this material balance.

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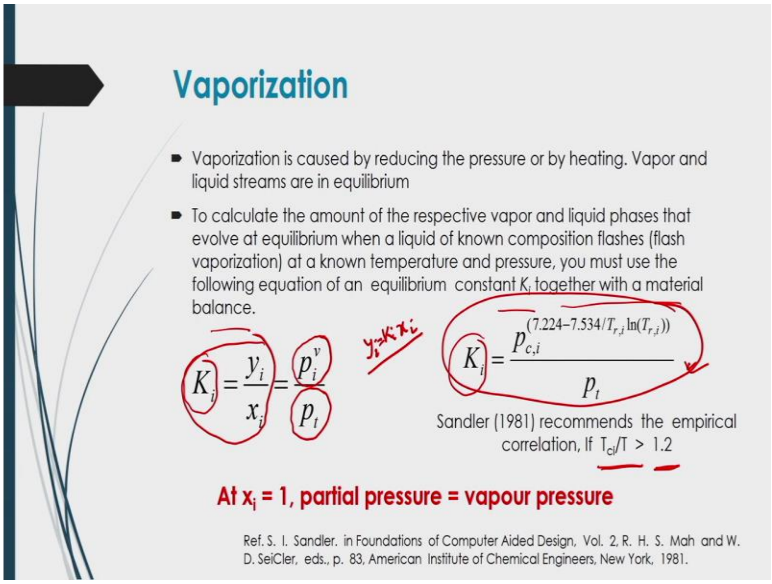

Vaporization

- Vaporization is caused by reducing the pressure or by heating. Vapor and liquid streams are in equilibrium
- To calculate the amount of the respective vapor and liquid phases that evolve at equilibrium when a liquid of known composition flashes (flash vaporization) at a known temperature and pressure, you must use the following equation of an equilibrium constant K_i together with a material balance.

$$K_i = \frac{y_i}{x_i} = \frac{p_i^v}{p_t}$$

$y_i = K_i x_i$

$$K_i = \frac{p_{c,i}^{(7.224-7.534/T_{r,i}\ln(T_{r,i}))}}{p_t}$$

Sandler (1981) recommends the empirical correlation, If $T_{ci}/T > 1.2$

At $x_i = 1$, partial pressure = vapour pressure

Ref. S. I. Sandler. in Foundations of Computer Aided Design, Vol. 2, R. H. S. Mah and W. D. SeiCler, eds., p. 83, American Institute of Chemical Engineers, New York, 1981.

Next we will go for you know that vaporization process what is that vaporization this vaporization basically caused by that reducing the pressure or by heating vapor and liquid streams are in equilibrium there. Now, to calculate that amount of the respective vapor and liquid phases that evolve at equilibrium condition, when a liquid of known composition flashes in a flash operator of flash vaporizer it is called flash vaporization at a known temperature and pressure.

You must use that you know use the following equation of an equilibrium constant of K you know i together with a material balance. So, in this case at equilibrium condition of that you know vaporization condition, you will see that vapor and liquid will be in you know that equilibrium condition at this vaporization condition and at this plus vaporization you will see that at equilibrium condition, some amount of you know vapor will be there from the top of that vaporizer and from the bottom there will be equilibrium.

Now, at that condition vapor and liquid will be in equilibrium and the composition there will be that in the vapor. Let it be considered as yi for that component and you know that in liquid phase 2 competition will be X i. So, at equilibrium condition, you will see that this competition in why i that is in vapor that will be you know equal to that you know mole fraction of you know liquid just by you know that just adjusting with some equilibrium constant.

So, here we can say that that if suppose, yi the mole fraction of component i in the vapor phase and add that equilibrium condition with the mole fraction of i if it is equilibrium in condition then we can write yi will be equal to some Ki into Xi. So, in this case this yi = k i Xi from these we can right here Ki it will be equal to yi by Xi this Ki called that equilibrium constant for the component i and this seems it is mole fraction at that equilibrium condition. So, in the vapor phase that you know, pressure will be of that component it will be vapor pressure at that equilibrium condition.

And you know that what will be that you know total pressure of the system from which you can calculate what from the equilibrium condition or equilibrium constant. Now, in this case, this Ki are you can calculate also from you know that, if you know that reduced temperature and also you know that critical pressure there and from that you can calculate this equilibrium constant from this correlation suggested by Sandler.

You know, this empirical equation in this case, this empirical equation will be valid only if you are you know that ratio of critical temporary set to the you know total pressure. So, the critical temperature to the temperature of the system is greater than 1.2. So, you can directly use this correlation to find out this equilibrium constant. Otherwise, the equilibrium constant you can you know find out from the you know, table that is given in your textbook in the appendix you can find it out what the equilibrium constant there.

Now, you have to remember that at Xi = 1 they are that means that your partial pressure will be equal to vapor pressure there. So, you have to that remember for 100% top 5 new molecules of that component i in the liquid phase then there will be partial pressure of that vapor pressure will be equal there.

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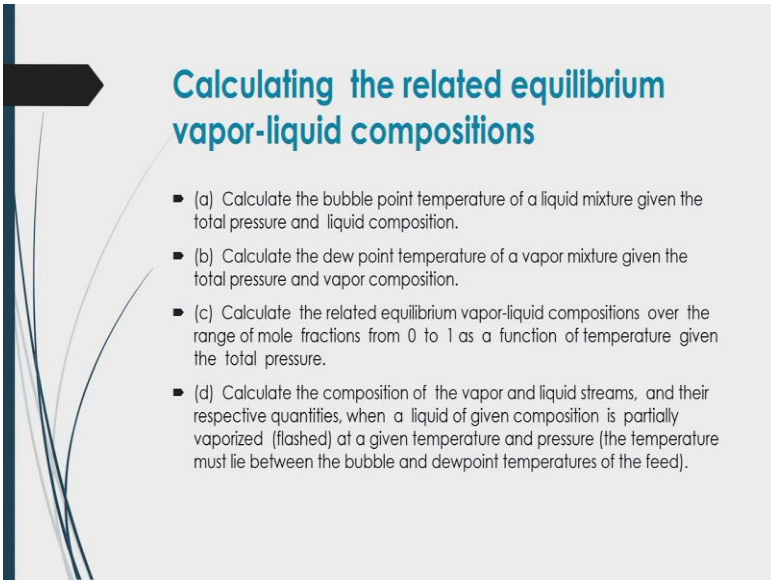

Calculating the related equilibrium vapor-liquid compositions

- (a) Calculate the bubble point temperature of a liquid mixture given the total pressure and liquid composition.
- (b) Calculate the dew point temperature of a vapor mixture given the total pressure and vapor composition.
- (c) Calculate the related equilibrium vapor-liquid compositions over the range of mole fractions from 0 to 1 as a function of temperature given the total pressure.
- (d) Calculate the composition of the vapor and liquid streams, and their respective quantities, when a liquid of given composition is partially vaporized (flashed) at a given temperature and pressure (the temperature must lie between the bubble and dewpoint temperatures of the feed).

Now, calculating that related equilibrium vapor liquid composition, what you have to do first of all you have to calculate the bubble point temperature of the liquid mixture that is given at the total pressure and liquid composition. So, you have to know first that you know bubble point temperature at which temperature this you know that mixture is a exist and also it is supplied for the processing that can be considered as the bubble point temperature.

And also add that bubble point temperature what is the pressure and the liquid composition there. Now, calculate that dew point temperature of a vapor mixture given that total pressure and vapor composition also you have to calculate the relative equilibrium vapor liquid composition. So, what the range of mole fractions of you know 0 to 1 as a function of temperature that is given at that particular total pressure.

Then you have to calculate the composition of the vapor and liquid streams and the respective quantities when a liquid of you know given composition is partly vaporized that is called past vaporization at a given temperature and pressure in this case the temperature must a between the bubble and dew point temperature of the feed.

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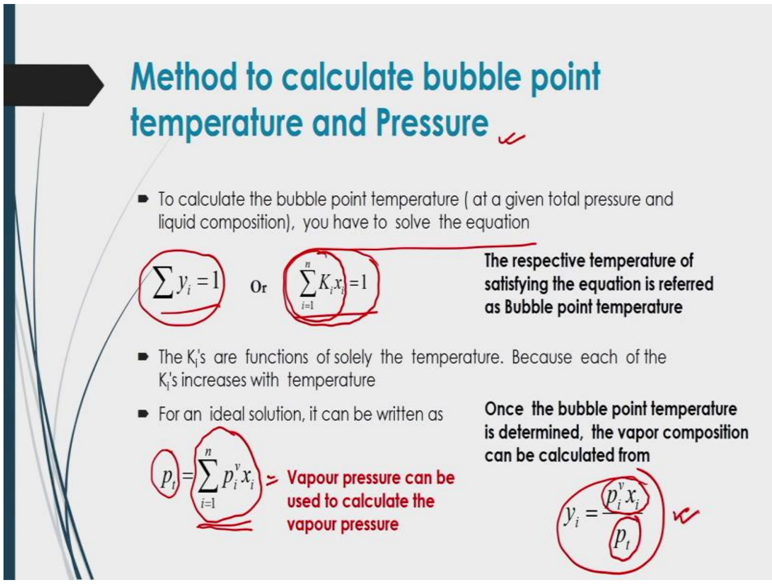

Method to calculate bubble point temperature and Pressure

- To calculate the bubble point temperature (at a given total pressure and liquid composition), you have to solve the equation

$\sum y_i = 1$ Or $\sum_{i=1}^{n} K_i x_i = 1$

The respective temperature of satisfying the equation is referred as Bubble point temperature

- The K_i's are functions of solely the temperature. Because each of the K_i's increases with temperature
- For an ideal solution, it can be written as

$p_t = \sum_{i=1}^{n} p_i^v x_i$ **Vapour pressure can be used to calculate the vapour pressure**

Once the bubble point temperature is determined, the vapor composition can be calculated from

$$y_i = \frac{p_i^v x_i}{p_t}$$

Now, method to calculate the bubble point temperature and pressure, how to calculate that bubble point temperature here will describe that here to calculate the bubble point temperature at a given total pressure and liquid composition, you have to solve this equation like this, all you have to do that at that equilibrium condition in the vapor composition and you know that liquid composition you will see that summation of that you know composition will be equal to 1.

That means here summation of yi will be = 1. So, at least condition at what temperature you will see that this summation of this, you know, mole fraction of the components in the vapor page will be = 1. So, at that condition, it will be given it will be their respective temperature of that you know bubble point temperature. So, here if I substitute here yi as Ki, so, we can say that summation of Ki will be = 1 here also in this way you can calculate that at for whose condition you can get the summation of Ki into Xi will be = 1.

So, respective temperature will be called as you know that bubble point in person. Now, this Ki air function of solely that temperature and you know, because each of the Ki increases with a temporary said there for an ideal solution, it can be written as that this total pressure will be equal to what summation of this you know that Piv into Xi that means, partial pressure of that you know component you know in mixture. So, summation of that partial pressure can be you know calculated from the vapor pressure at that equilibrium condition.

That is why the submission of this stop before pressure into more fraction at that particular equilibrium condition will be equals to you know total pressure. So, that if you are getting that total pressure will be equal to the submission of vapor pressure into more traction, then you can say that at that particular condition, the you know that temperature will be you know that is called bubble point temperature.

Now, once that bubble point temperature is determined the vapor composition can be calculated from the you know relationship here, Yi will equal to you know that this is you know this is called partial pressure at that equilibrium condition that is Piv into Xi as per hour slots and what will be the temperature there. So, from this equation, you can easily calculate what would be the vapor composition at that particular bubble point temperature.

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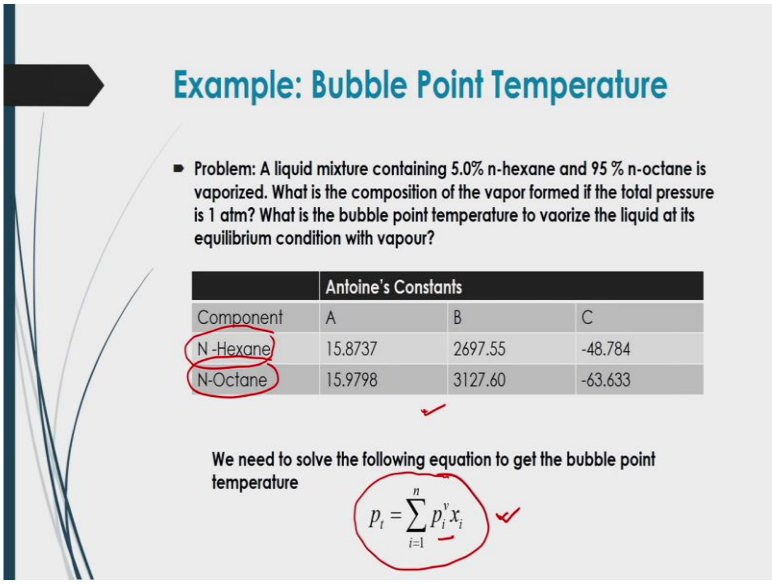

Example: Bubble Point Temperature

- Problem: A liquid mixture containing 5.0% n-hexane and 95 % n-octane is vaporized. What is the composition of the vapor formed if the total pressure is 1 atm? What is the bubble point temperature to vaorize the liquid at its equilibrium condition with vapour?

	Antoine's Constants		
Component	A	B	C
N -Hexane	15.8737	2697.55	-48.784
N-Octane	15.9798	3127.60	-63.633

✓

We need to solve the following equation to get the bubble point temperature

$$p_t = \sum_{i=1}^{n} p_i^v x_i$$ ✓

Now, let us do an example based on this concept. So, in this case, suppose a liquid mixture containing 5% normal hexane and 95% are normal octane is to be vaporized in a flash vaporizer. Now, you have to find out what should be the composition of the vapor formed, if the total pressure will be 1 atmosphere and what is the bubble point temperature said to before is that liquid at its equilibrium condition with the vapor. Now, in this case, you need to calculate the vapor pressure of the component i.

Now for that, you have to use that Antoine's equation but at his temper we said this, you know that vapor pressure to be calculated that is not known to you. So, you have to you know, keep that temperature a certain temperature like you know that if it is denoted by t then keep it as T and that at that temperature you have to find out what should be the vapor pressure by this Antoine's equation. Now, to calculate that vapor pressure by Antoine's equation you need to some equation constant.

So, it is given here for the component for normal hexane this sentence constant is given here and for normal octane also this sentence constants are given in this table as shown here in the slide. Now, we need to solve this following equation to get that bubble point temperature based on this problem. Now, we know that, to get this bubble point temperature, if you equilibrium condition will give you these saw you know equality of that total pressure will be equal to summation of that is Piv into Xi.

So, for all components in the mixture you have to sum up this you know product of this posture pressure of that component into each you know more fraction.

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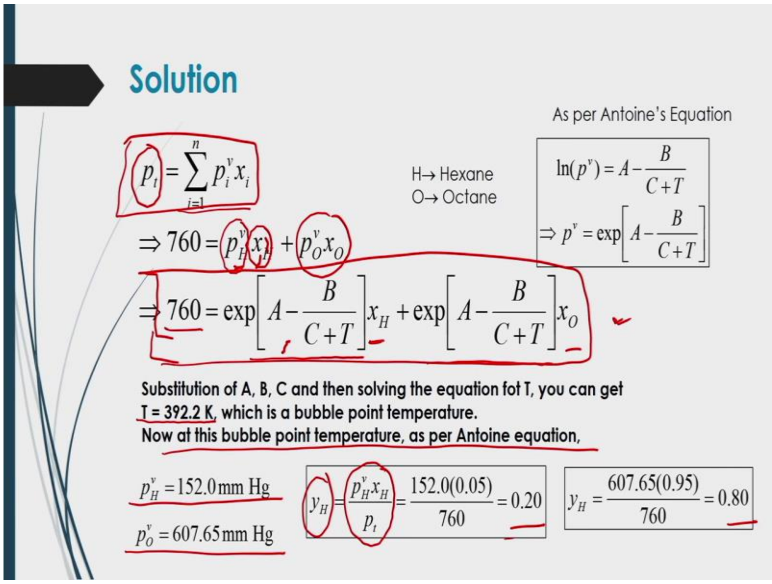

Solution

As per Antoine's Equation

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

$$\Rightarrow p^v = \exp\left[A - \frac{B}{C+T}\right]$$

$$p_t = \sum_{i=1}^{n} p_i^v x_i$$

H→ Hexane
O→ Octane

$$\Rightarrow 760 = p_H^v x_H + p_O^v x_O$$

$$\Rightarrow 760 = \exp\left[A - \frac{B}{C+T}\right] x_H + \exp\left[A - \frac{B}{C+T}\right] x_O$$

Substitution of A, B, C and then solving the equation fot T, you can get T = 392.2 K, which is a bubble point temperature.
Now at this bubble point temperature, as per Antoine equation,

$$p_H^v = 152.0 \text{ mm Hg}$$

$$p_O^v = 607.65 \text{ mm Hg}$$

$$y_H = \frac{p_H^v x_H}{p_t} = \frac{152.0(0.05)}{760} = 0.20$$

$$y_H = \frac{607.65(0.95)}{760} = 0.80$$

So, after that what will happen? Now, let us see here since total pressure is given to 1 atmosphere that is 760 millimeter mercury and here in this case this vapor pressure of you know that components will be there considered. So, we first of all these i component i = 0 here it is 2 components because only you know hexane and octane out there. So, for hexane we use these rotation A, so here are 760 = then Pihv for hexane into Xi, you know, A is for hexane.

And similarly for you know that octane also we can write here POB and you know that hexane here will follow 10 is for hexane. So, here if you substitute this value for vapor pressure for hexane and octane, what is the vapor pressure of you know, hexane here as per Antoine’s equation exponent of you know a - b by C + D, this is your know Antonio's equation for the publisher of that component, you know that for hexane.

And similarly component topics and easy access and again if you substitute that you know equation for the vapor pressure for octane and then if you multiply 8 composition x as x 0, you can simply express by this equation based on that, you know total pressure and vapor pressure. Now, substitution of this A, B and C and then solving the equation 4042 will come, you can get that you will musical 239 2.2 Calvin who says a bubble point temperature.

So, from this equation you can easily calculate the mobile point in person. So, here you need to know that only that in Antoine’s equation and also be vapor pressure at that particular temperature that solving this you know equality of this total pressure with this you know that submission of this vapor pusher into its components then you can get easily what will be the bubble point temperature.

Now, at this bubble point temperature as for Antoine’s equation, you have to find out past what will be the vapor pressure of hexane and what was the vapor pressure of octane and it is coming as 150.0 millimeter mercury for hexane and 607.65 millimeter mercury for octane at that bubble point temperature up 392.2 Kelvin after that you have to find out what the you know vapor phase competition of you know here hexane.

so hexane why hexane can be calculated from this you know, equation here Psv access by PT, then you can easily calculate what should be the composition here it is coming 0.2 there is 20% of action and remaining will be your you know opt in that will be 80% there. So, in this way you can solve for you know bubble point temperature and also vapor composition when a liquid mixture will be you know partially vaporized in a you know partial vaporized.

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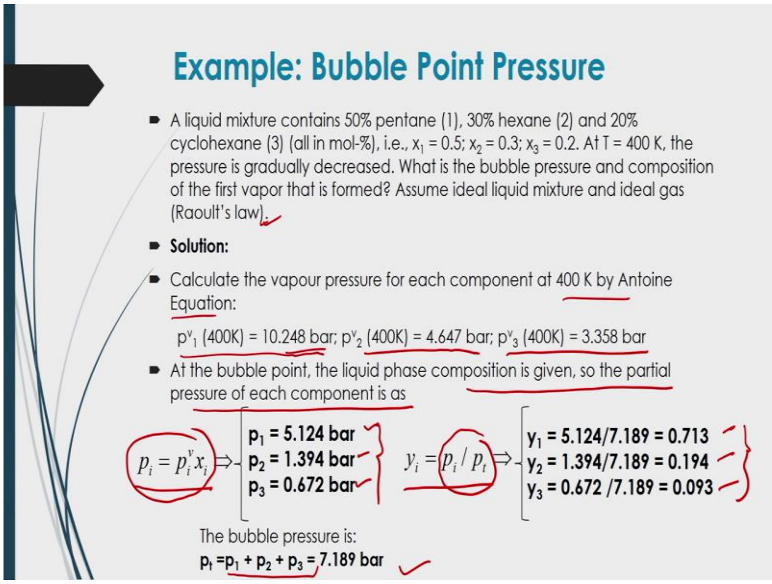

Example: Bubble Point Pressure

- A liquid mixture contains 50% pentane (1), 30% hexane (2) and 20% cyclohexane (3) (all in mol-%), i.e., $x_1 = 0.5$; $x_2 = 0.3$; $x_3 = 0.2$. At T = 400 K, the pressure is gradually decreased. What is the bubble pressure and composition of the first vapor that is formed? Assume ideal liquid mixture and ideal gas (Raoult's law).
- **Solution:**
- Calculate the vapour pressure for each component at 400 K by Antoine Equation:

  p^v_1 (400K) = 10.248 bar; p^v_2 (400K) = 4.647 bar; p^v_3 (400K) = 3.358 bar
- At the bubble point, the liquid phase composition is given, so the partial pressure of each component is as

$$p_i = p_i^v x_i \Rightarrow \begin{cases} p_1 = 5.124 \text{ bar} \\ p_2 = 1.394 \text{ bar} \\ p_3 = 0.672 \text{ bar} \end{cases} \qquad y_i = p_i / p_t \Rightarrow \begin{cases} y_1 = 5.124/7.189 = 0.713 \\ y_2 = 1.394/7.189 = 0.194 \\ y_3 = 0.672/7.189 = 0.093 \end{cases}$$

The bubble pressure is:

$p_t = p_1 + p_2 + p_3 = 7.189$ bar

Similarly, you can you know calculate that what is with the bubble point pressure also. Now, in this case, you will see that a liquid mixture that contains 50% pentane and 30% hexane and remaining that is 20% you know cyclohexane all in mole percent that is x 1 = 0.5; x 2 = 0.3 and x 3 = 0.2 now at this temperature of 400 k you know the pressure is gradually decreased, what is the bubble pressure and composition of the past vapor that is formed there.

Now, assume that idea liquid mixture and ideal gas there and it will follow that Raoult's Law. So, here in this case instead of bubble point temperature you have to find out what is the bubble point pressure. Now, in this case first of all you have to calculate vapor pressure of each component at 400 k by Antoine's equation. So, this will be your you know that here it is given the 4 component 1 this vapor pressure is here and for component 2 it is given and for component 3is given.

Now, at the bubble point the liquid phase competition is given so, that partial pressure of each component is as like this. So, partial pressure will be calculated based on this you know equation you know that you know vapor pressure of his components by the Antoine's equation then you can get that partial pressure of peace component p 1 p 2 p 3 respectively. So, from which you can easily calculate what should be the mole fraction of in the vapor based on this unit of partial pressure.

Then you can get this mole fraction of each component as y 2 y 3 he are shown in the slide. So, the bubble pressure will be able to hear what is the total pressure will be there the that will be able to you know summation of all partial pressure of that components 1 2 and 3, so, to becoming a 7.189 So, it will be called as bubble pressure. So, in this example, you practice it and the you can you know that have idea how to calculate that bubble point pressure.

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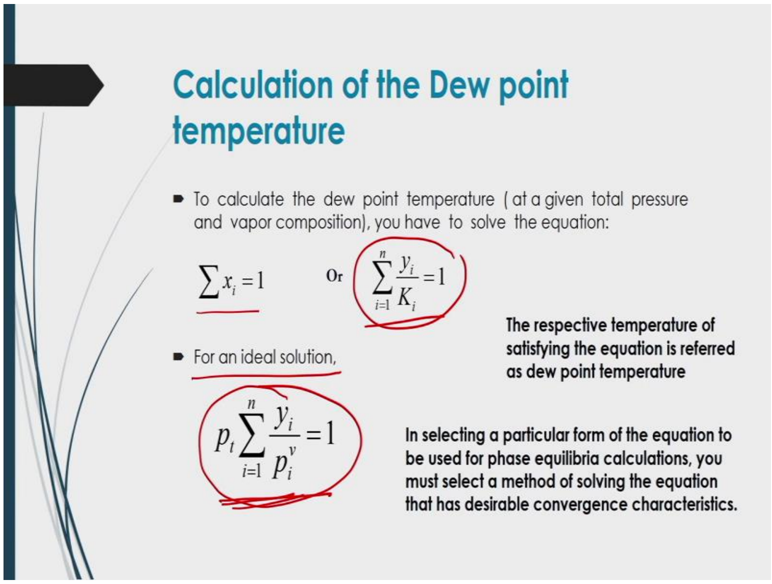

Calculation of the Dew point temperature

- To calculate the dew point temperature (at a given total pressure and vapor composition), you have to solve the equation:

$\sum x_i = 1$ Or $\sum_{i=1}^{n} \frac{y_i}{K_i} = 1$

The respective temperature of satisfying the equation is referred as dew point temperature

- For an ideal solution,

$$P_t \sum_{i=1}^{n} \frac{y_i}{p_i^v} = 1$$

In selecting a particular form of the equation to be used for phase equilibria calculations, you must select a method of solving the equation that has desirable convergence characteristics.

Similarly, how to calculate that dew point temperature here, this is also reverse that you know vaporization to the you know condensation. So, in this case to calculate that dew point temperature at a given total pressure and vapor composition equilibrium condition you know you have to solve the equation here the summation of Xi = 1 and also you can see that from that relationship of equilibrium y is equal to yi = Ki Xi from that you can write after simplification as summation of y by Ki it will be = 1.

Now, for an ideal solution, we can say that this summation of this will be equal to 1. So, from this here we can say that respective temporaries are at which this you know equality satisfied will be called as dew point temperature. So, in selecting a particular form of the equation to be used for phase equilibrium calculations, you must select a method of solving that equation that has desirable convergence characteristics to there.

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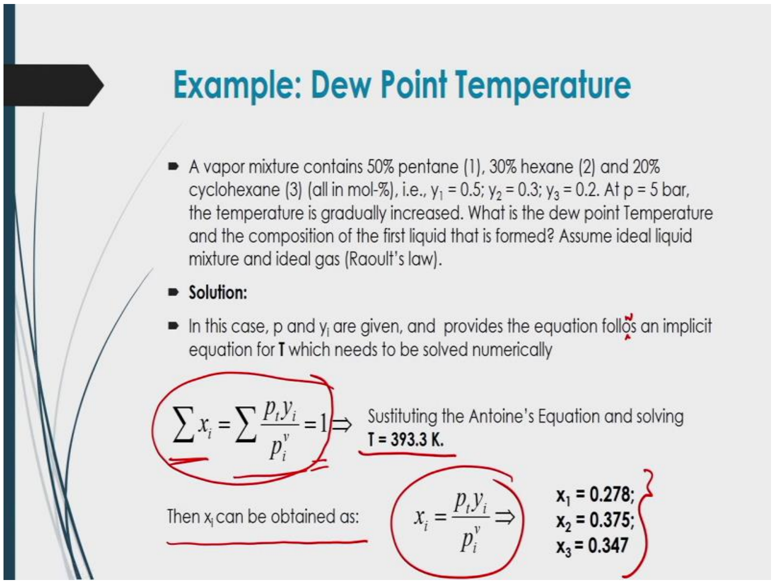

Example: Dew Point Temperature

- A vapor mixture contains 50% pentane (1), 30% hexane (2) and 20% cyclohexane (3) (all in mol-%), i.e., $y_1 = 0.5$; $y_2 = 0.3$; $y_3 = 0.2$. At p = 5 bar, the temperature is gradually increased. What is the dew point Temperature and the composition of the first liquid that is formed? Assume ideal liquid mixture and ideal gas (Raoult's law).
- **Solution:**
- In this case, p and y_i are given, and provides the equation follows an implicit equation for **T** which needs to be solved numerically

$$\sum x_i = \sum \frac{p_t y_i}{p_i^v} = 1 \Rightarrow$$ Sustituting the Antoine's Equation and solving **T = 393.3 K.**

Then x_i can be obtained as: $$x_i = \frac{p_t y_i}{p_i^v} \Rightarrow$$ **$x_1 = 0.278$; $x_2 = 0.375$; $x_3 = 0.347$**

Now, how to calculate that dew point temperature accordingly like, you know, asked the same question problem given in previous example, like a vapor mixture contains 50% painted 30% hexane and 20% cyclohexane or y 1 y 2 y 3 x is given to you and add pressure high bar the temperature is gradually increased and what is the dew point temperature and the composition of the liquid that is formed and assume ideal you know liquid mixture and ideal gas law.

So, in this case also here pressure and composition of that component i are given and also provides the equation that follows an implicit equation for you know that temperature which needs to be solved numerically here. So, in this case summation of Xi that means summation of PT into y by Piv that should be equal to 1. Now in this case when this you know that at which temperature you can get this equality is equal to 1 after substitution of Antonio's equation.

You see that we have to solve for temporary certainty and then it is coming through 93.3 k. So, this is you know that you know that you find comparison. Now, in this case the x i then can be obtained as you know from this relationship and which will give you that respective you know our competition for that our components 1 2 and 3.

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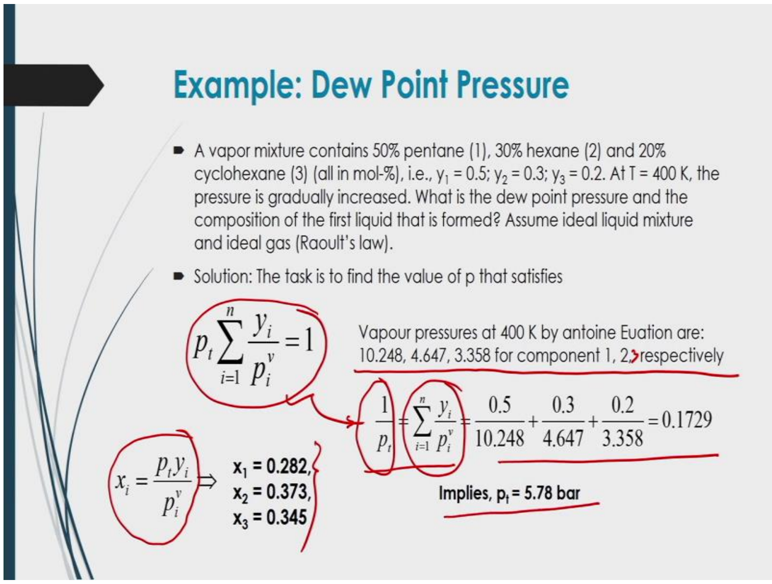

Example: Dew Point Pressure

- A vapor mixture contains 50% pentane (1), 30% hexane (2) and 20% cyclohexane (3) (all in mol-%), i.e., $y_1 = 0.5$; $y_2 = 0.3$; $y_3 = 0.2$. At T = 400 K, the pressure is gradually increased. What is the dew point pressure and the composition of the first liquid that is formed? Assume ideal liquid mixture and ideal gas (Raoult's law).
- Solution: The task is to find the value of p that satisfies

$$p_t \sum_{i=1}^{n} \frac{y_i}{p_i^v} = 1$$

Vapour pressures at 400 K by antoine Euation are: 10.248, 4.647, 3.358 for component 1, 2, 3 respectively

$$\frac{1}{p_t} = \sum_{i=1}^{n} \frac{y_i}{p_i^v} = \frac{0.5}{10.248} + \frac{0.3}{4.647} + \frac{0.2}{3.358} = 0.1729$$

Implies, p_t = 5.78 bar

$$x_i = \frac{p_t y_i}{p_i^v} \Rightarrow$$

x_1 = 0.282,
x_2 = 0.373,
x_3 = 0.345

This way you can calculate this 2 point in process similarly, we can also calculate the dew point pressure in this case the same you know mixture of 50% painting 30% x 10 and 20% cyclohexane. With this composition at 400 you know Kelvin temperature the pressure is gradually increased and what is the dew point pressure and the composition of the form liquid that is formed that you have to find out. So, in this case again this equality to be you know followed that is put into summation of y by P IB that will be equal to 1.

So, in this case vapor pressure at 400 k by Antoine's equation are here calculated as like this for component 1 2 and you know 3 respectively. So, from those you can easily calculate rush with a you know more fraction of those components once you know that, you know vapor pressure. So, from this vapor pressure of components 1 2 and 3, you can you know calculate watch with this value of 1 by PT that will be as part this equation here.

And then this after substitution of this yi and Piv they are then you can easily calculate what should be the you know that total pressure there. So, it is coming here like this 0.1729 and since will imply you that total pressure will be implies 5.78 bar.

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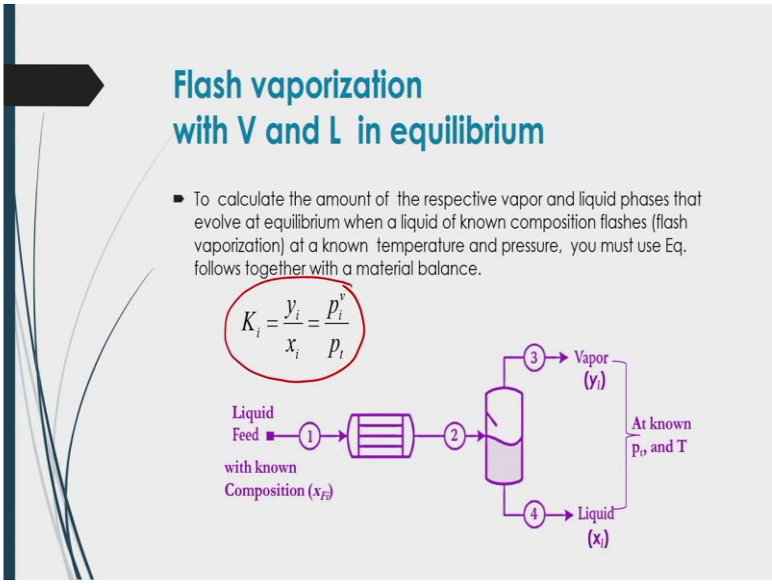

Flash vaporization
with V and L in equilibrium

- To calculate the amount of the respective vapor and liquid phases that evolve at equilibrium when a liquid of known composition flashes (flash vaporization) at a known temperature and pressure, you must use Eq. follows together with a material balance.

$$K_i = \frac{y_i}{x_i} = \frac{p_i^v}{p_t}$$

Flash vaporization with vapor and liquid in equilibrium that we have already discussed that at that flash you know vaporization condition that K i will equal to y i by x i that equal to P i y by p t from which you can calculate that what is the you know partial pressure what would be the total pressure what would be the temperature at which that you know vapor will be condensing or liquid will be you know vaporize to the air.

So, to calculate that amount of respect to vapor and liquid phase that evolved at equilibrium. When a liquid of known composition flashes in Flash vaporization at unknown temperature and pressure, you must use that equation that will follows together with a material balance.

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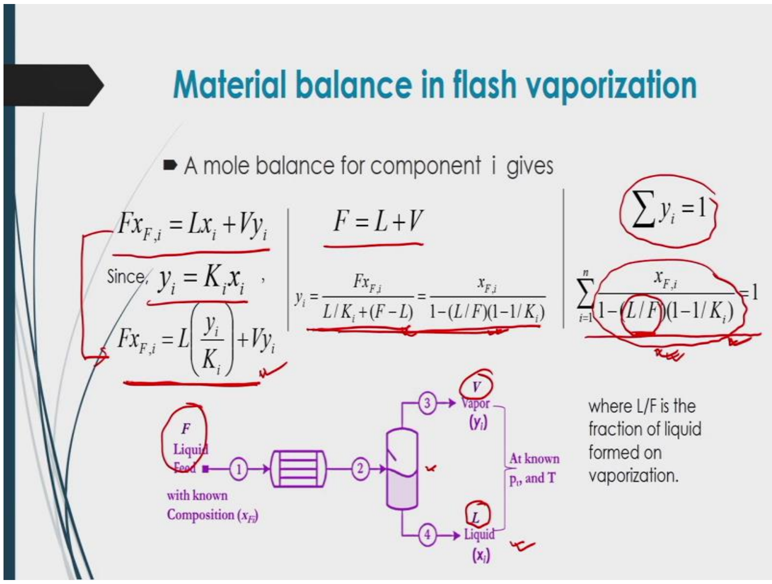

Material balance in flash vaporization

- A mole balance for component i gives

$$Fx_{F,i} = Lx_i + Vy_i$$

Since, $y_i = K_i x_i$,

$$Fx_{F,i} = L\left(\frac{y_i}{K_i}\right) + Vy_i$$

$$F = L + V$$

$$y_i = \frac{Fx_{F,i}}{L/K_i + (F-L)} = \frac{x_{F,i}}{1-(L/F)(1-1/K_i)}$$

$$\sum y_i = 1$$

$$\sum_{i=1}^{n} \frac{x_{F,i}}{1-(L/F)(1-1/K_i)} = 1$$

where L/F is the fraction of liquid formed on vaporization.

Now, material balance in the flash vaporization to be done based on this suppose there is a + h vaporizer and in this soft vaporizer the liquid PDS coming with some composition and at that vaporization power you know process you will see that some amount will be coming out from the top of this unit vaporizer and some amount will be coming you know out from the bottom as a liquid composition at unknown you know total pressure and temperature.

Now in this case what would that feed amount and what was the vapor amount and also you know liquid amount after vaporization then it is if it is not known to you then you have to do the material balance once that is provided at least 1 variables there. So, based on that if we do the total material balance for this vaporization who can write simply equal with regard to L + b. And also if you do the component material balance we can write for component i in this way that if except I that we equal to l xi + b y.

Since we add equilibrium condition we know that y is equal to ki into xi. So, we can you know write this equation of this component material balance of the substitution of this yi are you know equal to ki xi here then finally, you can right here xi if I will, because to L into y by k + b into y at this equation. Now, you will see that from this equation, we can simply you know, express that what will be the why, why I will be able to that is here you know rearrangement.

You can get it or you can express this in terms of here like this except by 1 - l by F into 1 - 1 by Ki. So, in this case, if you are new this xi and also at equilibrium condition under vapor phase all the components are you know, composition will sum up to 1 then you can see the summation of y is equal to 1. So, if you substitute that why from this material balance equation and you can then express like here as shown here in this slide that equation.

And here in this case, we can write the summation of x a pi by 1 - l by F into 1 - 1 by KPI that should be equal to 1. So, here l by F is unknown to you, what would be the amount of liquid and got to be the amount of faith it is not known to you, but if you know that vapor composition, amount of vapor composition, then you can calculate what you know if an L or what without lbf also you can calculate from the material balance or if is given to you what from the B and l that also you can calculate.

So, in this case, very interesting that this equation as shown here, lbf if you keep on changing that l and F value, and also respective, you calculate that summation of this, you know, Antoine is here you see that particular liquid and you know that that is al and if you know value, you will see that the submission. Will you know tends to you know becoming 1. So, at that particular condition you are you know value of liquid and you know feed amount will be known and that condition also you can say that what to be the composition there. So, according to that you can have.

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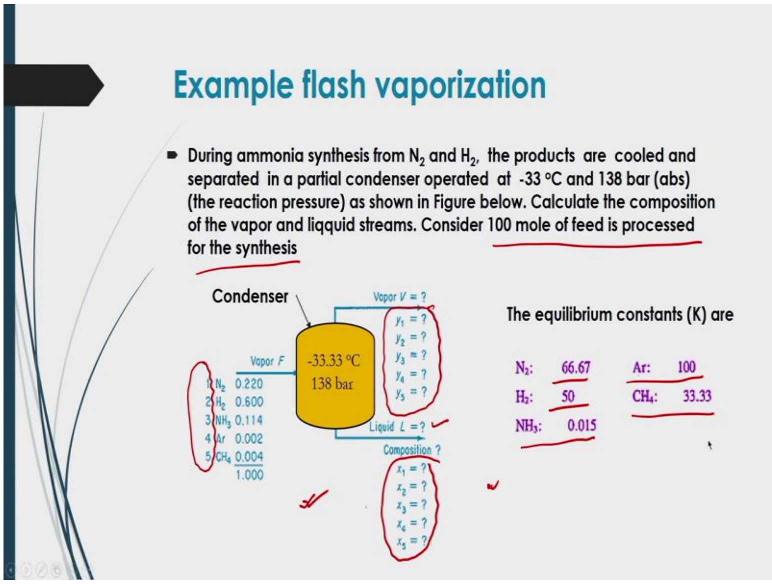

Example flash vaporization

- During ammonia synthesis from N_2 and H_2, the products are cooled and separated in a partial condenser operated at -33 °C and 138 bar (abs) (the reaction pressure) as shown in Figure below. Calculate the composition of the vapor and liqquid streams. Consider 100 mole of feed is processed for the synthesis

The equilibrium constants (K) are

N_2: 66.67
H_2: 50
NH_3: 0.015
Ar: 100
CH_4: 33.33

That you know what will be the you know composition in the vapor phase and liquid phase. So, this is basically depending on that material balance overall. So, let us do an example based on this material balance of this flash vaporizer. Now, you know that during that ammonia synthesis from nitrogen and hydrogen the products are cooled and separated in a partial condenser that is operated - 33.33 degree Celsius and 138 bar absolute as shown in figure below here in the slide.

Now calculate the composition of the vapor and liquid streams in this case considered that hundred mil of feed is processed for the synthesis. Now, here X is given to you and the compositions are nitrogen hydrogen ammonia air methane as for you know figure and in the vapor composition as you know that if we denote that composition as 123 for that respective nitrogen hydrogen ammonia and methane then in the vapor phase what will be the composition.

It is not known to you also want to be the total amount of vapor It is also not known to you that you have to find out similarly in the liquid phase, the amount L is not known to you and also composition That respective components are not known known to you, but equilibrium constants are given to you for nitrogen as like this for hydrogen for ammonia for our you know that our gun and also for methane these are given to you.

So, with these you know that parameters or you know that data you can find out what should be the you know composition of the vapor and liquid streams.

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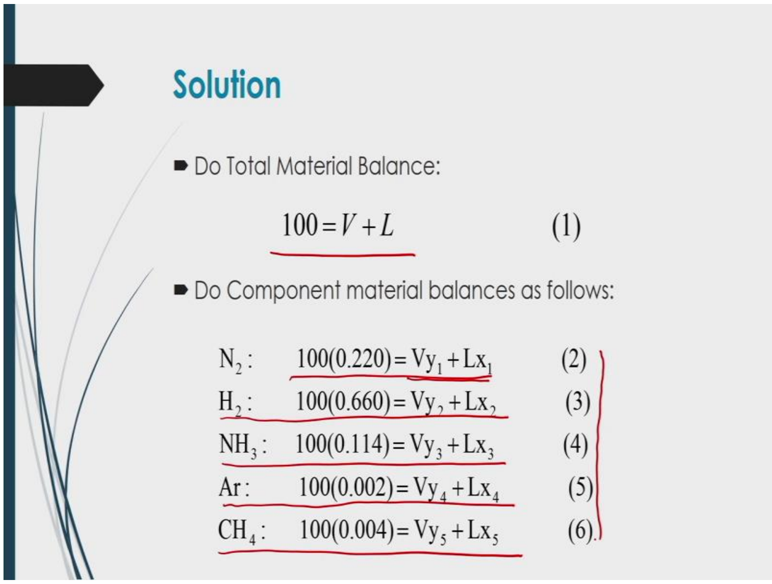

Solution

- Do Total Material Balance:

$$100 = V + L \qquad (1)$$

- Do Component material balances as follows:

$$N_2: \quad 100(0.220) = Vy_1 + Lx_1 \qquad (2)$$
$$H_2: \quad 100(0.660) = Vy_2 + Lx_2 \qquad (3)$$
$$NH_3: \quad 100(0.114) = Vy_3 + Lx_3 \qquad (4)$$
$$Ar: \quad 100(0.002) = Vy_4 + Lx_4 \qquad (5)$$
$$CH_4: \quad 100(0.004) = Vy_5 + Lx_5 \qquad (6).$$

First of all what you have to do you have to do the total material balance. Now, in equation number 1 to assume that this material balance will be as 100 will be = V + l because it will be = V + L that means, your input will be equal to total output that is material balance concept. So, to be coming as hundred that we are going to V + L. Now, after that you have to do the component material balances for each component like this pore nitrogen.

What would be the component material balance you can do it under the to 0.22 this composition is given in the you know still phase there. So, and in the you know outlet phase it is not given it is are you know assume that to be y 1 and x 1 similarly for other components also for hydrogen this is your material balance for ammonia this is your material balance for argon this is your material balance and methane also this is your material balance support nitrogen to meet in this material balance equations are given from equation number 2 to 6 here in the slide.

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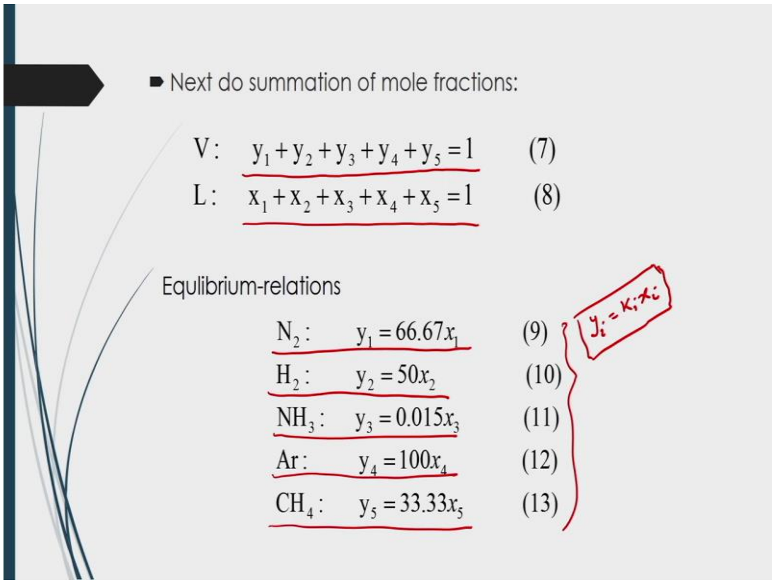

- Next do summation of mole fractions:

$$V: \quad y_1 + y_2 + y_3 + y_4 + y_5 = 1 \qquad (7)$$

$$L: \quad x_1 + x_2 + x_3 + x_4 + x_5 = 1 \qquad (8)$$

Equlibrium-relations

$$N_2: \quad y_1 = 66.67x_1 \qquad (9)$$

$$H_2: \quad y_2 = 50x_2 \qquad (10)$$

$$NH_3: \quad y_3 = 0.015x_3 \qquad (11)$$

$$Ar: \quad y_4 = 100x_4 \qquad (12)$$

$$CH_4: \quad y_5 = 33.33x_5 \qquad (13)$$

$\boxed{y_i = K_i x_i}$

Now, next you have to do the summation of these are mole factions in the vapor phase and liquid phase in the vapor summation of the you know vapor phase competition will be equal to 1 and also summation of the liquid phase composition will be equal to 1. Now, at equilibrium conditions you know that yi will be = Ki Xi we know that y was equal to Ki Xi that is that equilibrium condition. Now, based on this equilibrium equation, you have to express for each component.

What will be the equilibrium equation for nitrogen here it is given why you want that will be to go to 66.67 into x 1, here has 66.67 is the equilibrium constants for this nitrogen. Similarly, for other components you can find out that hydrogen for hydrogen it will be Yi too, because 215 2 x 2 similarly for ammonia similarly for argon similarly, for methane what will be the equilibrium relations or equations there. So, it can be expressed by this equation number 9 to 13 for respective components of nitrogen into the methane as shown in the slides.

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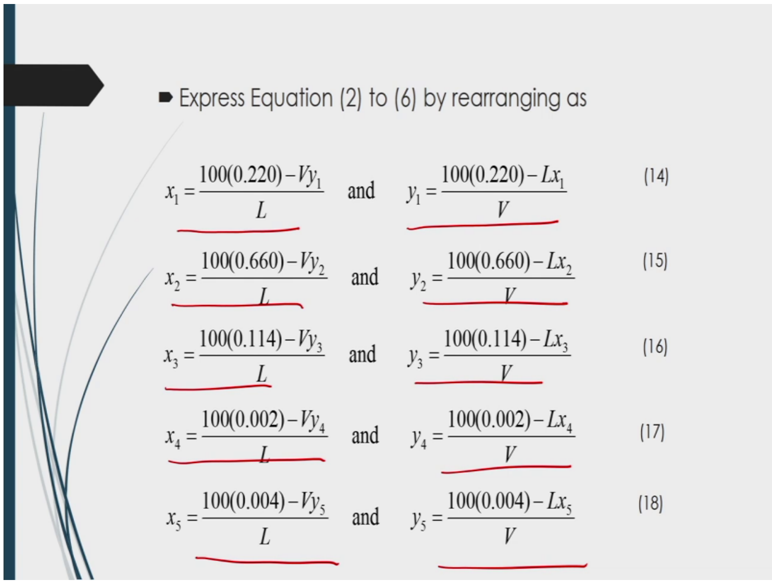

- Express Equation (2) to (6) by rearranging as

$$x_1 = \frac{100(0.220) - Vy_1}{L} \quad \text{and} \quad y_1 = \frac{100(0.220) - Lx_1}{V} \qquad (14)$$

$$x_2 = \frac{100(0.660) - Vy_2}{L} \quad \text{and} \quad y_2 = \frac{100(0.660) - Lx_2}{V} \qquad (15)$$

$$x_3 = \frac{100(0.114) - Vy_3}{L} \quad \text{and} \quad y_3 = \frac{100(0.114) - Lx_3}{V} \qquad (16)$$

$$x_4 = \frac{100(0.002) - Vy_4}{L} \quad \text{and} \quad y_4 = \frac{100(0.002) - Lx_4}{V} \qquad (17)$$

$$x_5 = \frac{100(0.004) - Vy_5}{L} \quad \text{and} \quad y_5 = \frac{100(0.004) - Lx_5}{V} \qquad (18)$$

Next, you have to express this equation 2 to 6 by rearranging it what will be the, you know more fraction of x 1, what would the more fraction of y1 what should they do? What should the y2 simulate x2 y2 similarly, x4 y4 and also x 5 y 5. So, by this equation number 14 to 18 you can express what will be the more fraction of the components based on that material balance by unknown values of liquid composition and vaporization also unknown amount of liquid and vapor there. So, by this perspective you know that equation from 14 to 18.

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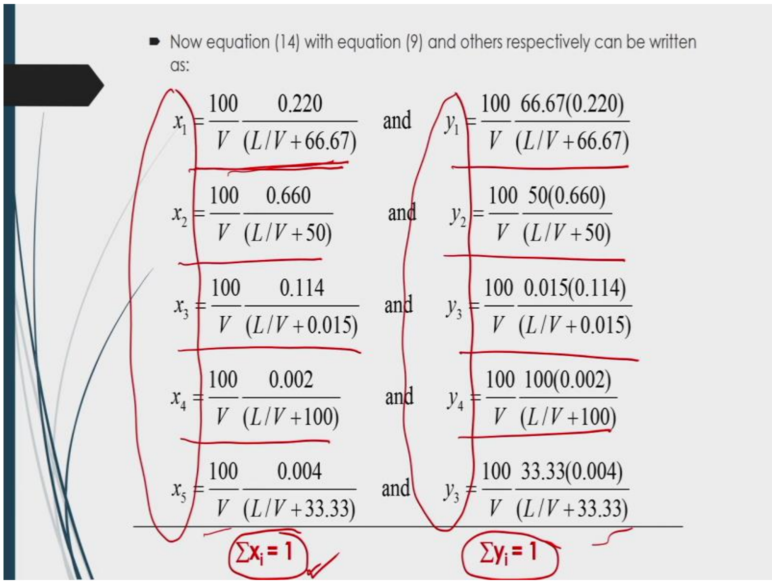

- Now equation (14) with equation (9) and others respectively can be written as:

$$x_1 = \frac{100}{V}\frac{0.220}{(L/V + 66.67)} \quad \text{and} \quad y_1 = \frac{100}{V}\frac{66.67(0.220)}{(L/V + 66.67)}$$

$$x_2 = \frac{100}{V}\frac{0.660}{(L/V + 50)} \quad \text{and} \quad y_2 = \frac{100}{V}\frac{50(0.660)}{(L/V + 50)}$$

$$x_3 = \frac{100}{V}\frac{0.114}{(L/V + 0.015)} \quad \text{and} \quad y_3 = \frac{100}{V}\frac{0.015(0.114)}{(L/V + 0.015)}$$

$$x_4 = \frac{100}{V}\frac{0.002}{(L/V + 100)} \quad \text{and} \quad y_4 = \frac{100}{V}\frac{100(0.002)}{(L/V + 100)}$$

$$x_5 = \frac{100}{V}\frac{0.004}{(L/V + 33.33)} \quad \text{and} \quad y_3 = \frac{100}{V}\frac{33.33(0.004)}{(L/V + 33.33)}$$

$\boxed{\Sigma x_i = 1}$ $\boxed{\Sigma y_i = 1}$

we can you know that, rearrange these things h here like this, with that equation number 9 that equilibrium relations, we can get that to you know equation here for component 1, in the liquid phase and component 1 in the vapor phase similarly for component 2 is it can be retained and similarly for componentry these are can be retained for x component for and component 5 like this, now, we will see that all this you know, liquid phase composition for all components, if you sum it up it will be coming as 1.

And also similarly, if you consider that here before phase composition, then summation of yi will be = 1. So, either 1 you can you know consider at a particular vapor amount and liquid amount then when that ratio of liquid and vapor will give you that summation of this xi = 1 or yi will be = 1 or similarly yi = 1 so, based on this.

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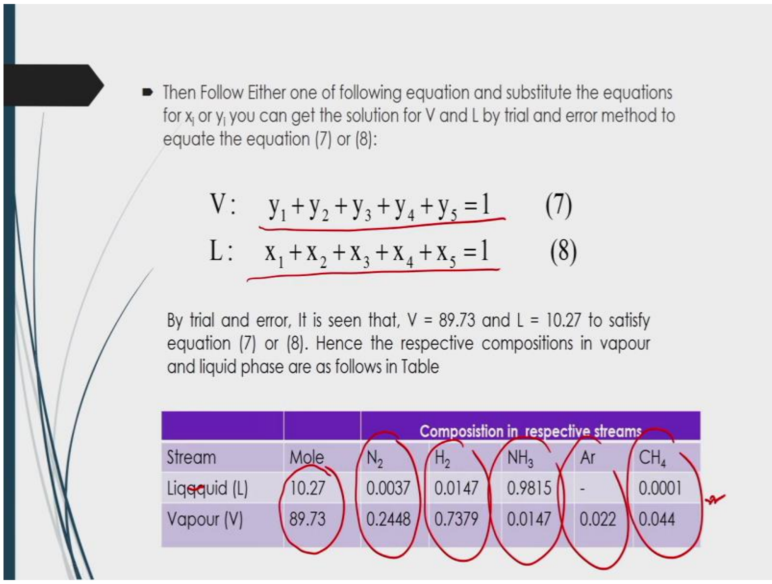

- Then Follow Either one of following equation and substitute the equations for x_i or y_i you can get the solution for V and L by trial and error method to equate the equation (7) or (8):

$$V: \quad \underline{y_1+y_2+y_3+y_4+y_5=1} \qquad (7)$$

$$L: \quad \underline{x_1+x_2+x_3+x_4+x_5=1} \qquad (8)$$

By trial and error, It is seen that, V = 89.73 and L = 10.27 to satisfy equation (7) or (8). Hence the respective compositions in vapour and liquid phase are as follows in Table

		Composistion in respective streams				
Stream	Mole	N_2	H_2	NH_3	Ar	CH_4
Li~~q~~quid (L)	10.27	0.0037	0.0147	0.9815	-	0.0001
Vapour (V)	89.73	0.2448	0.7379	0.0147	0.022	0.044

You can say that at a particular you will see that you know vapor and liquid amount, this summation of this yi summation of x i will be equal to 1 now by trial and error method just by changing up your liquid amount and vapor amount and once you will see that this you know submission will come to you know approximately 1 you cannot say that 100% to 1, but there will be you know very least error to get this you know 1 value that means maybe 1.001 or 0.999 like this.

So, when to come that means a near about to 1 you can say that at that particular vapor and liquid, you know amount, we give you this you know equality of the summation of excite or summation of why you will which you can do 1. Now, once it is finalized for this you know that liquid and vapor amount here, you can see that this at this amount, we can see what should be that, you know, vapor composition and you know that liquid composition for all components here for nitrogen and for hydrogen and for ammonia argon and also methane there.

So, you can find out they are respectively just by putting that value up you know that liquid and vapor amount in the respective equation here in this equation number 14 to you know 18 there. So, in this way you can calculate what should be that you know our liquid and vapor amount by this unit + vaporization you know condition in a vaporizer with this material balance. So, I think you understood that you know how to solve that you know vapor composition and liquid composition to find out at a particular you know that temperature and pressure by this material balance also at an equilibrium condition.

how to calculate the vapor composition liquid composition from each vapor, you know pressure or you know that from the you know the dew point temperature or above Temperature also, you have I think, you know understood that how to find out the dew point temperature how to find out that bubble point temperatures are just by calculating the vapor pressure by Antoine’s equation and substitute needs to the you know.

If you know equality at that equilibrium condition of you know pressure will be due to you know submission of partial pressure of the components and then partial pressure will be related to that you know, vapor pressure there. So, accordingly you can calculate what the new plant or to the vapor you know bubble point temperature based on that vapor pressure. So, I think I should, you know suggest you to you know go partner that some example that is given in your textbook and also more about this you know, flash vaporization you can get it more information from this, you know, takes textbook can also reference books here.

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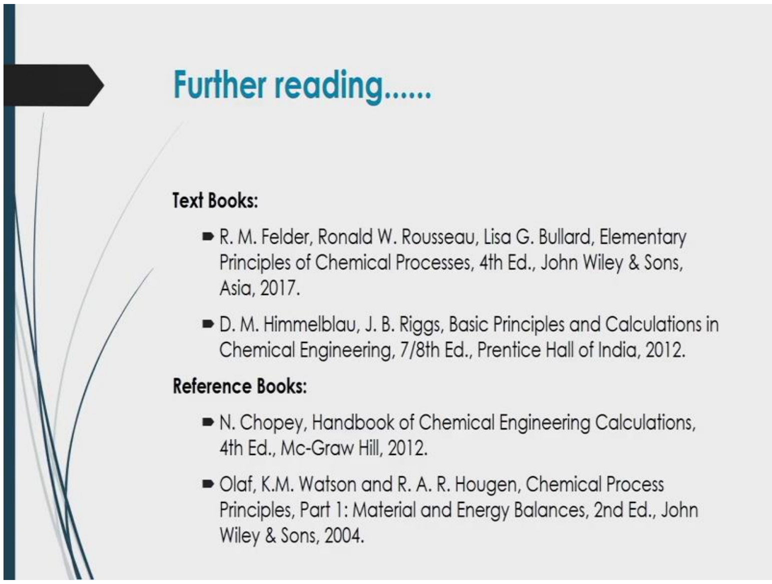

Further reading......

Text Books:

- R. M. Felder, Ronald W. Rousseau, Lisa G. Bullard, Elementary Principles of Chemical Processes, 4th Ed., John Wiley & Sons, Asia, 2017.
- D. M. Himmelblau, J. B. Riggs, Basic Principles and Calculations in Chemical Engineering, 7/8th Ed., Prentice Hall of India, 2012.

Reference Books:

- N. Chopey, Handbook of Chemical Engineering Calculations, 4th Ed., Mc-Graw Hill, 2012.
- Olaf, K.M. Watson and R. A. R. Hougen, Chemical Process Principles, Part 1: Material and Energy Balances, 2nd Ed., John Wiley & Sons, 2004.

In the next class I will, you know, describe, you know, regarding the principles of energy and also we will start that new module there and under that, you know, principles energy, how to do that material balance for energy and also some, you know, that different forms of energy and how it can be, you know, used to calculate that, you know, material balance and or that, you know, this energy balance will be required. We will be discussing the next lecture. So, thank you for your attention.