Basic Principles and Calculations in Chemical Engineering

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Lecture # 15
Humidity, Saturation Psychrometric chart

Welcome to massive open online course on basic principles and calculations in chemical engineering. We are discussing about the basic principles of multi-phase systems as a module 5 and under that module we have discussed in our previous lecture regarding pressure partial pressure, how actually those terms are defined and also how to calculate you know that Dalton's law, even we have discussed how to calculate the vapor pressure at different temperature based on that Clausius-Clapeyron equation and Antoine's equation even how to calculate the vapor pressure.

From that you know vapor pressure of you know substance you know relative to a you know different substances and that you know have a represented it in a you know coxide and based on that coxide how to calculate that vapour pressure that will be that has already been you know discussed and also we have discussed that how, you know do you dew point in saturation point can be defined based on that Vapour pressure and partial pressure under equilibrium condition. So, in this lecture, we will discuss you know more about that saturation condition.

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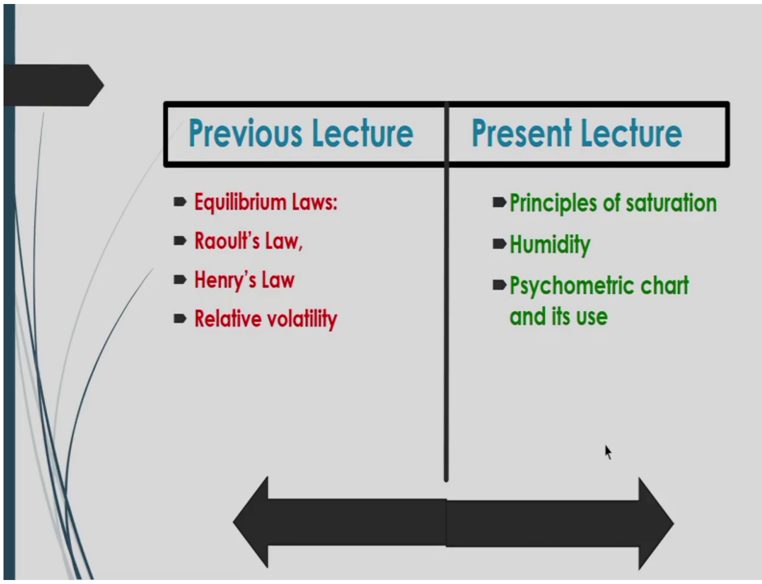

And before actually considering their saturation condition, you have to know some equilibrium laws, that is Raoult's law, and Henry's law and also relative volatility. So, we have discussed in our previous lecture also those laws like a Raoult's law in this law and based on their, you know, laws, how to calculate that, you know, partial pressure and vapour pressure, relative to the constitution of the, you know, components in our liquid phases.

So, based on that, we will discuss more about that, you know, equilibrium condition just by discussing saturation and also how this you know, what vapour will be you know saturated in the air in a mixture of air and water in atmospheric condition to that is represented by you know humidity and that humidity how actually absolute humidity, relative humidity and also the saturation relative saturation or relative humidity how they are actually related and also based on that you know saturation condition.

What should be the, you know that humid volume of that particular amount of air in presence of moisture under equilibrium condition that also to be you know, discussed and those things of course, will be discussed also by using a psychometric chart. This is basically a graphical representation of the you know relation that between you know, absolute humidity, relative humidity, you know saturation and also dew point temperatures are how you know enthalpy are related to those you know that variables there so, those are actually represented in a graphical form that is called psychometric chart. And here in this lecture, we will also discuss how to use that you know, psychometric search to find out those variables there.

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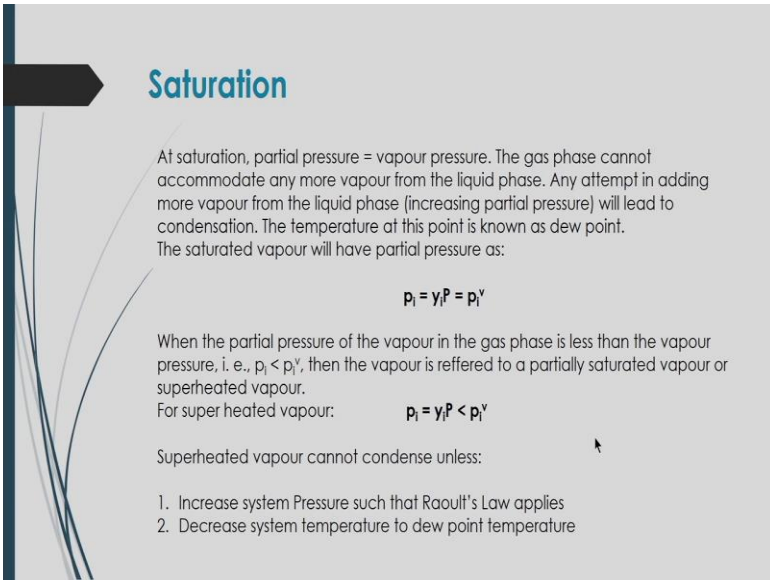

First of all we have to you know, go through again that what is the saturation, so, we know that saturation that partial pressure, of course, will be equal to vapour pressure, already we have discussed that vapour pressure how to calculate at equilibrium condition based on that the Clausius-Clapeyron equation and Antoine's equation. So, if you know that, you know Antoine's equation or Clausius-Clapeyron equation at a particular temperature, you will be able to find out what the vapour pressure.

Now once you know that equilibrium vapor pressure is equilibrium with that partial pressure or you can see that partial pressure will be equal to vapour pressure, then at that condition you will see that if you know a small amount of addition of that vapour under that equilibrium condition from the liquid phase in the liquid phase is done, you will see that the you know system will lead to you know become you know condensed that means, here is called that condensation occur at that particular condition.

And the temperature at which this you know that saturation occurs that means this partial pressure will be able to vapour pressure under which that you know that people will be you know condensing, it is in its first stage, and that point will be regarded as dew point and the saturated vapour will have that partial pressure. And calculated based on this, you know equation or as this partial pressure is defined as the pi is equal yip or pi is called partial pressure of component and yi is called the mole fraction of that component i and here P is called you know total pressure of the system.

So, yi into p that will be your partial pressure and if this partial you know how pressure if it is equals to that vapour pressure which is denoted by Piv that already we have discussed in our previous lecture also so, when this partial pressure of the vapour in the gas phases, you know that will be equal to vapour pressure then you can see that that saturation starts and the temporary respective temperature of that solution will be called as saturated temperature or it is regarded as dew point temperature.

Now, if suppose that a certain condition that vapour pressure is, you know less than the partial pressure, then what will happen? If suppose, the partial pressure will be you know less than that you know vapour pressure then what will happen? Now, this case when the partial pressure of the vapour in the gas phase if it is less than the vapour pressure, then you can see that vapour is report to a partially saturated and vapour or you can see that superheated vapour will be there.

So, for superheated vapor we can see that this partial pressure will be less than equals to vapor pressure and this superheated vapor at this partial saturated condition cannot condensed unless if you know that increase the system pressure says that the Raoult's law applies there and also if you are not actually decreasing the system temperature to the dew point temperature, then you not be able to have that you know that condense it on from the superheated vapour. So, this is regarding that saturation we know that that partial pressure will be equal to vapour pressure and after that.

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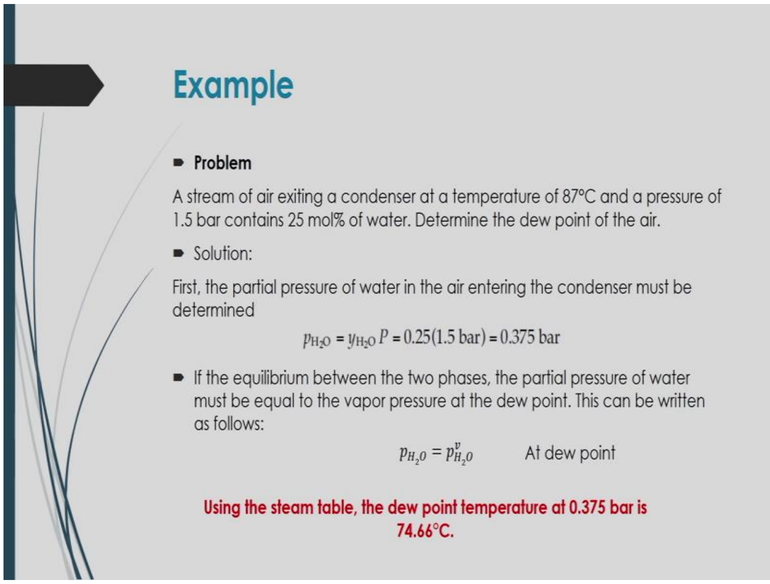

We can see that that the condition of that vapour pressure and you know partial pressure if it is not equal then you have to consider it as a you know partial or you know saturation condition. Now, let us have an example of this you know saturated condition. In this case, suppose a stream of the air that will exit from a condenser at a temperature of 87 degree Celsius and a pressure of 1.5 bar that contains you know 25 moles of water.

So, at this condition of this temperature of 87 degrees Celsius and pressure of 1.5 bar, you have to find out what should be the you know dew point of the air at this particular condition. Now, in this case what you have to do, first of all you have to calculate what should be the partial pressure of water in the air that is entering the condenser. So, that can be calculated based on that equation given by Daltons that is partial pressure will be equal to y for that component water into total pressure that will be equal to what that it will be simply that he had a 0.25 into 1.5 the 0.25 is basically the more fraction of the water in the air and system pressure is 1.5.

But, so, this coming 0.375 bar now, if the equilibrium between the 2 phases, that the saturated condition, the partial pressure of water Of course, must be equal to the vapour pressure of the dew point then this condition the mathematical form can be expressed as like this partial pressure of water will be equal to vapor pressure of water and this will happen only the condition of saturated condition and the temperature at that saturated condition will be regarded as you know dew point.

So, at this point you can see that simply partial pressure will be equal to vapour pressure. Now, you can find out that what should be the dew point temperature from the steam double once you know this, you know pressure and temperature. So, from the steam table that will be actually shown later on that bar from the steam table how to you know find out that dew point temperature once you know that pressure and the respective temperatures are there, so, the dew point of the temperature at that 0.75 bar will be equal to you know 74.66 degree Celsius at this particular this condition of saturation.

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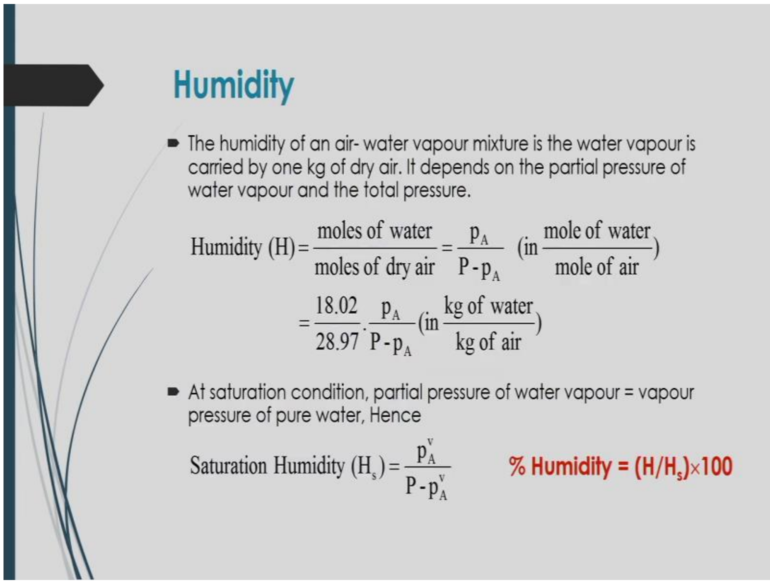

We will discuss about the humidity now, what is that humidity basically that sometimes we are saying in atmosphere that how I you know it is you know that atmosphere or weather is very humid or you can say that today's you know that today's highly here, you know, humid here. So, what is that basically that humidity of that air water vapor mixture in the atmosphere? So, the humidity of an air water weapon mixture is basically the water vapor is carried by 1 kg of a dry air.

That means per kg dry air is how much water is being carried that will be regarded as humidity, it depends on the partial pressure of the water vapor and the total pressures what the total pressure the atmosphere that is one atmosphere you can see. Now, this you will see that the amount of water vapour per kg of dry air which is actually carrying by the dry air at that particular temperature will be represented by humidity and this humidity this amount will be changing with respect to temperature.

So, if there is if you know temperature is you know very high then what will be the humidity at low temperature what will be the humidity that depends on also usually the partial pressure of that, you know, components that is water in that you know air water mixture at that particular temperature. So, humidity basically defined as that ratio of moles of water by what is that moles of you know that dry air.

So, this humidity basically, you know, expressed by this H are denoted by H and it is defined by this equation here, this moles of water by moles of the dry air, now, this since it is a you know, mole percentage or mole ratio you can see, you have to remember this true that in an ideal mixture you will see that in a system mixture of gaseous always this truth to be you know that remember that mole ratio will be equal to pressure ratio that will be equal to volume ratio.

Now, if I say that that there is a mole ratio of water vapor to you know mole ratio of the dry air. So, that is this is the mixture we can say that this is ideal mixture in that case we can see that since it is a molar ratio of these 2 components, so, you can express this as you know, pressure issue now, what pressure issue will be represented here it should be actually partial pressure issue. Now, what should be the partial pressure of that what are you know in the air it will be represented by partial pressure of water.

And it is denoted by PA here you can you know donate you can you can denote this water as w instead of here and also what should be the partial pressure of you know dry air if you know the partial pressure of water as PA and total pressure of P of the system, then you can easily say that partial pressure of the dry air will be equal to total pressure minus partial pressure for that water. So, it would be P - PA. So, in this case you can represent this humidity as the PA divided by 1 - PA as given here in the slide.

So, it will be basically unit as you know molar ratio that means, you are moles of water by moles of air you can represent this humidity in terms of you know mass ratio also so, that will be in case you have water by kg of air. So, in that case you have to you know multiply this moles of water by each molecular weight and also moles of air by its molecular weight. So, in this case if we multiply this partial pressure by it is you know, molecular weight of water then you will see that it will be asked is kg of water.

Similarly, here multiply by molecular weight of air that is 28.97 then you can have this you know, weight of you know that, so, in this way you can represent this humidity in terms of master ratio. So, it will be coming as this as shown here in the slide. And saturation condition the partial pressure of what our vapour will be equal to vapour pressure up your water. So, in that sense at saturation condition we can you know called this you know humidity as saturation humidity.

So, in that case that saturated humidity will be defined by this you know just simply by you know in terms of that vapour pressure, so, what is the vapor pressure of water that will be PAv here and remaining is P – Pav. So, they are mixture partial pressure is p so remaining pressure that will be equal to P – Pav. So, here the saturation humidity would be defined by this PAv divided by P - PAv and what should be the percent is unity similarly, what will be you know absolute humidity that means Hs is saturated humidity into 100. So, this will be you know referred as percentage humidity here.

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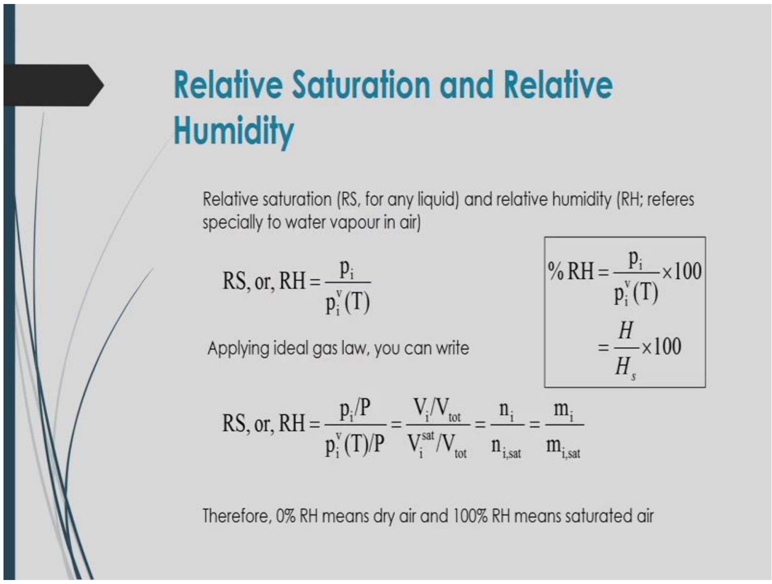

And you can also represent that humidity in terms of you know that relative saturation or relative humidity. So, relative saturation that is denoted by RS or you know relative humidity that is denoted by RH. So, in this case, relative saturation for any liquid and relative humidity, especially, to water vapour in air will be represented by this ratio of that, you know partial pressure divided by you know vapour pressure of that you know component attic temperature t.

So, this is called relative saturation. So, very interesting that here relative saturation basically represented for any liquid, whereas, relative humidity basically represented for the system of water vapor in air and applying the ideal gas law, you can write this relative saturation or relative humidity as Pi by P divided by PiVT by p. That means, here we are dividing this equation by total pressure on its both, you know numerator and denominator.

So, we can have this simply the pressure ratio that we represented by you know that volume ratio as per ideal gas law and also we can then represented by you know molar ratio that means, saw moles of component i to its you know moles at its saturated condition. So, we can represented by ni by n a saturated and similarly, you can represent it by mass ratio, just you know that in terms of you know you know mass ratio just by multiplying each molecular weight of that particular component.

So, in this way this relative saturation or relative humidity can be you know obtain if suppose, there is zero percent relative humidity. That means, you can say that that air should be completely dry whereas 100 percent relative humidity that will mean that here will be saturated they are with each you know vapour pressure and percentage relativity will be you know defined as what is the you know partial pressure of that component i and double pressure of the component i and their ratio.

And if you multiply it by 100 then it will be you know called as percent is relative humidity or you can simply calculate it as if you have the absolute humidity and the humidity at each saturation condition and if you multiply it by 100, then you can obtain that percentage relative humidity.

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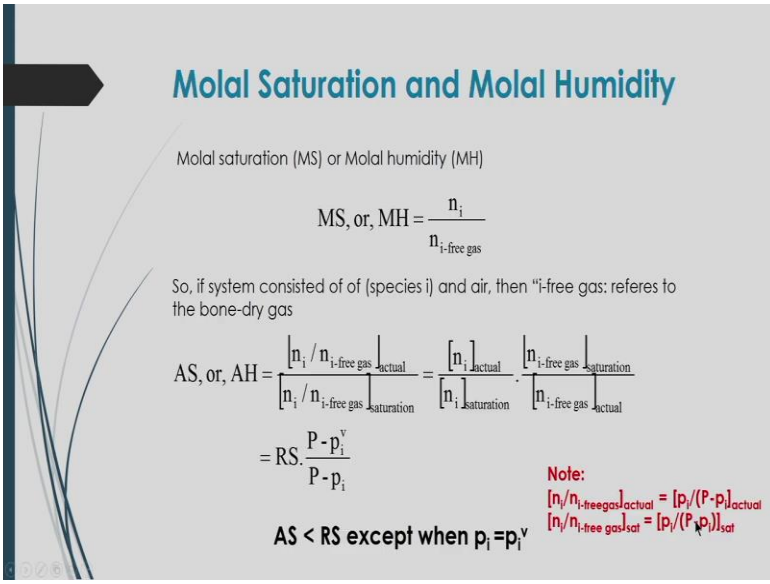

Now, this humidity also can be represented by molal humidity or the saturation can be regarded as molal saturation. In this case this molal saturation or molal humidity can be you know defined as given here in the slides that equation here that image or image will be given by ni free gas in free gas simply we can see that only you know or dry air here. Here in this case i-free gas refers to the bone-dry gas suppose there is a water vapor and you know dry air mixture.

So, in that case if i represented as water vapor, so, i-free gas will be simply you know that dry gas and it will be represented as bone dry gas. So, if the system consisted of a species i and air, then i-free gas refers to the bone-dry gas and according to that, we can represent that absolute you know, saturation or absolute humidity that is in terms of bone-dry gas properties. That means here we can define it as you know, what will be the actual mole fraction of that 2 components of i and bone dry gas in actual condition.

And what should be the mole ratio of that component i and that bone dry gas at saturation condition and from you can simply you know, rearrange heat and you can represented by it is you know ratio of moles of that component i that is that extra and saturation condition and also this you know mole fraction of you know i-free gas that means bone dry gas in saturation and actual condition. So, based on who is you can say that, this absolute you know saturation or absolute humidity can be you know defined as here RS into P minus PiV by P minus Pi.

So, here RS is relative saturation has this you know this ratio of this you know fresh air at each you know saturation condition and it is actual condition to be you know multiplied here. So, in this way, we can define that absolute saturation and absolute humidity. And you will see that here, since absolute saturation is equals to relative saturation into this pressure ratio, we can say from this you know mathematical expression that AS always should be less than you know RS that means absolute saturation will be always less than you know relative saturation.

But there is an exceptional condition, if you are having this condition at you know, saturation condition that means, partial pressure will be equal to vapour pressure. Then in that case you can see that you will not get this you know that absolute saturation will be equal to relative saturation. They are of course will not be inequality, but there will be simply you know that absolute saturation and really relative saturation will be equals to you know each other. So, in that case at you know saturation condition that absolute saturation and relative saturation both will be same.

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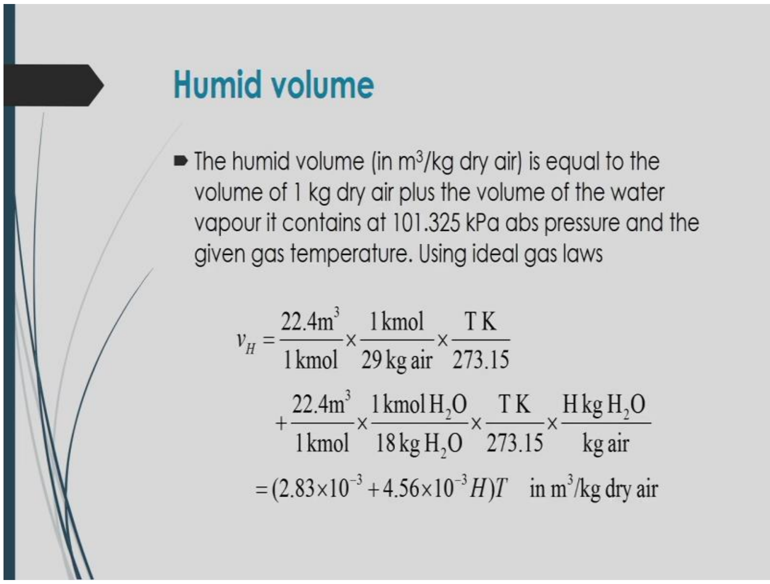

Now, another term in this case humid volume now, the humid volume is basically equals to the volume of one kg of dry air plus volume of the water vapor that it contains at you know what one atmospheric pressure that is absolute pressure and the given temperature there now, if you use that ideal gas laws there the humid volume can be represented as here basically what will be the you know volume of, you know one case you have dry air that can be represented by this you know equation and also what is the volume of that what are we part at that atmospheric condition and temperature given to that can be expressed by this you know term here.

So, if you add these 2 you know volume at that particular atmospheric pressure and given temperature, you can have this final form of equation as given in the slide that will be equal to 2.83 to 10 to the power minus 3 plus 4.56 into 10 to power minus 3 into H into T. Here H humidity, so, humidity it is required because, you know humidity means what is the water the amount of water vapour per kg of your dry air.

So, once you do that amount of vapour per kg of you know, dry air. You have to convert it to mole and once you know, the mole of that what you will be able to calculate for to the volume of that whatever vapour they are based on that you know that one mole of molecule exhibit that 22.4 meter cube volume. So, based on that, you will be able to calculate what the volume of that you know a particular amount of water vapor in the air.

Similarly, same amount of you know air will exhibit how much volume that also to be calculated. So, if you add up these two you know volume then it will be regarded as the humid volume. So, it is simply from this concept of humid volume, we can have this equation for that humid volume in terms of humidity and at a particular given temperature by this equation, but this will be of course, will be represented by, you know our volume per kg of dry air.

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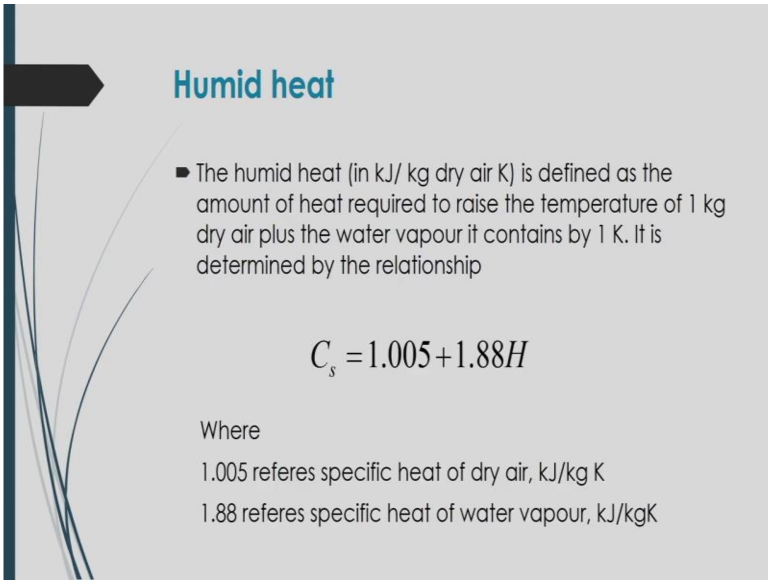

Another important you know terms off for this you know, representation of these you know moisture content in the atmosphere at a particular you know temperature and how much energy will be you know, released as an energy of heat that also to be considered. So, in that case it is regarded as humid heat, this is basically the amount of heat that is required to raise the temperature of 1 kg dry air to get its equilibrium you know, water vapor or that contains by 1 kelvin.

So, it will be regarded as that humid volume, humid heat. So, it is determined by the relationship like this here this is represented by the symbol here Cs that is humid heat and it will be based on that you know temperature change as well as you know that what will be the humidity will be changing based on that temperature change. According to that, what should be the humid heat that can be calculated by this equation here in this case, you will see that 2 terms are there, 2 numerical values are given in this equation, one is 1.005 and other is 1.88.

Now, in this case 1.005 refers the specific heat of dry air that is in terms of kilojoule per kg kelvin as 1.88 is refers that you know a specific heat of water that contains by that one kg of the dry air in kilojoules per kg kelvin. So, from this equation, you will be able to calculate what should be the humid heat once you know that humidity of that you know, air.

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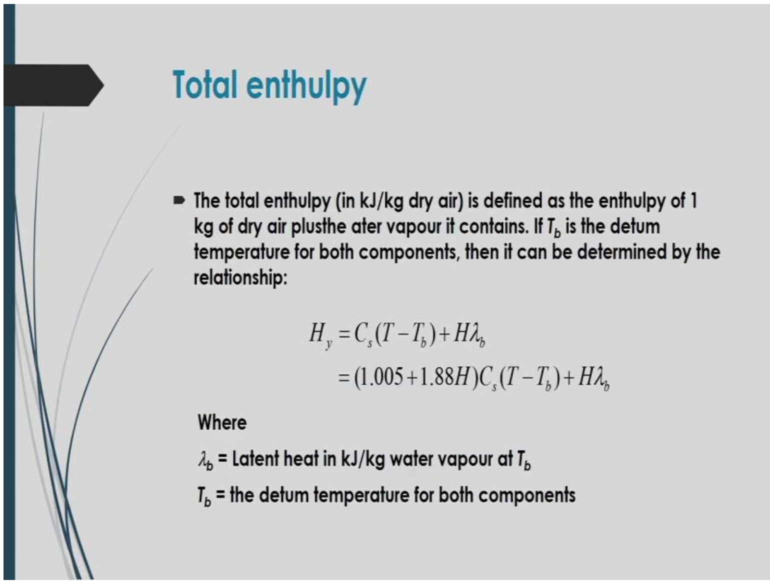

And total enthalpy also one important terms based on which you can say that what should be the enthalpy of 1 kg of dry air plus the enthalpy of water vapor that it contains, if you know bubble point temperature or you can say that you know detum point temperature that is denoted by Tb for both components here suppose water vapour and here dry gas then it can be determined by the relationship here given as like Hy will be equal to Cs into T – T b plus H lambda b.

Here in this case lambda b that latent heat in kilojoules per kg of water vapor at that determines temperature or it is regarded as sometimes bubble point temperature and it can also be represented by humid heat here in this case, this Cs the heat to be, you know defined as 1.005 plus 1.88 H and that also you know that to be written here, in this case the Cs will be you know, cancelled out because Cs we have substitute this value of 1.005 plus 1.88H is here in this slide.

So, please correct it here. So, it will be here 1.005 plus 1.88 H into T minus Tb plus H into lambda b. So, once you do that a latent heat of that vapour in kilojoule per kg at that particular reference temperature and the humidity then at a particular temperature, what should be the total enthalpy you can calculate by this equation.

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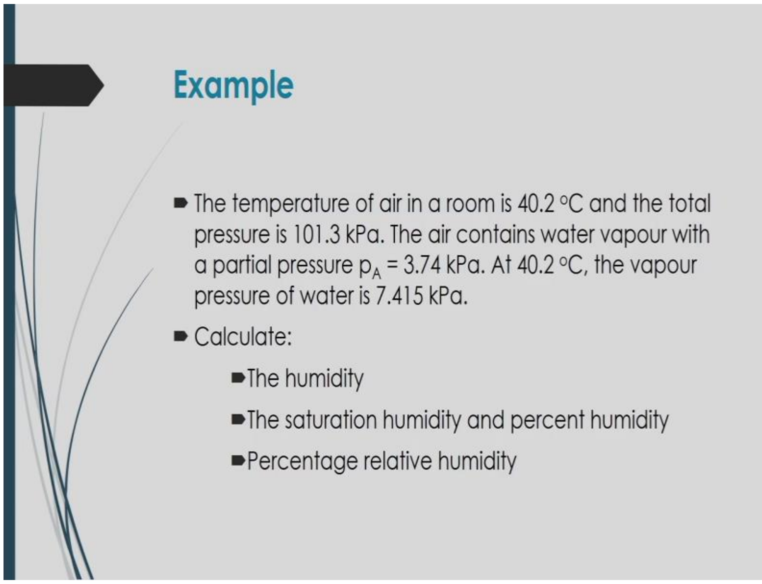

Now, let us do an example based on this theory. In this case, you have given that the temperature of air in a room is 40.2 degrees celsius and under the total pressure is atmospheric pressure that is 101.3 kilo pascal the air contains water vapor with a partial pressure Pa is equal to 3.74 kilo pascal at this temperature of 42.8 degrees Celsius the vapor pressure of water is given us 7.415 kilo pascal. Now, you have to calculate what is the humidity and what is the saturation humidity and percent humidity also you have to calculate for the percentage of humidity.

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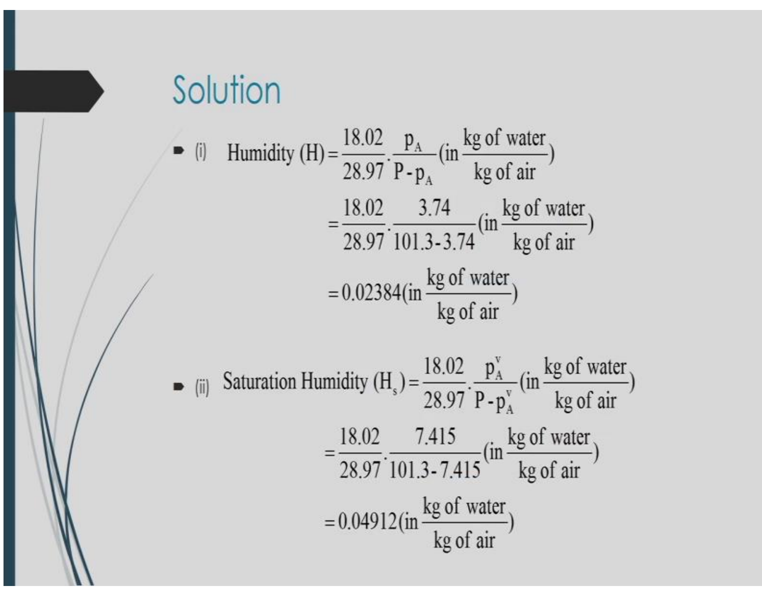

Now, as we know that, humidity is defined as this equation given earlier also in the slide that humidity will be equal to 18.02 by 28.97 into the ratio of this partial pressure of water to the dry gas. So, in kg of what kg is air now, you know these are partial pressure of what vapour and also you know that total pressure of the system. So, if you substitute this value or partial pressure there then you can have this value of 0.0238 in kg of water by kg of air.

So, this is you know that humidity at that particular temperature and what is the saturation humidity that is also know that this partial pressure basically will be you know vapor pressure of the water vapor there so, vapor pressure of the water vapor is given to you that is you know that 7.415 and after that if you substitute that vapor pressure here in this equation, you will get to that saturation humidity will be called 0.04912. That is in kg of water and kg of air.

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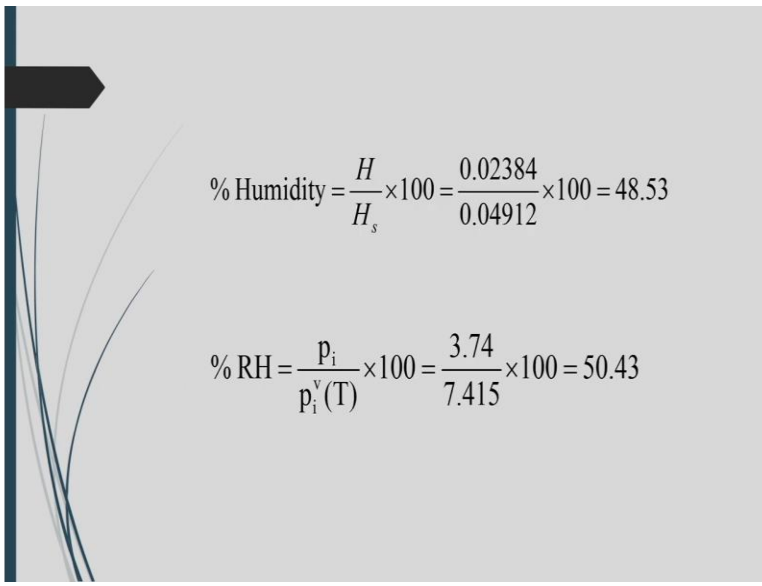

So, this is your saturation humidity and what do ratio of humidity that is you know ratio of that humidity to that at saturation condition into 100. So, it will be basically that divided by this you know 0.0238 by the 0.0492 into 100 it will come as 48.53 there similarly, relative humidity you can calculate for the ratio partial pressure of that component i to the vapor pressure of component i at the particular temperature into 100 that then you can have this value up to the substitution of this you know variables there and it will give you the value of 50.43. So, this is your percentage of relative humidity.

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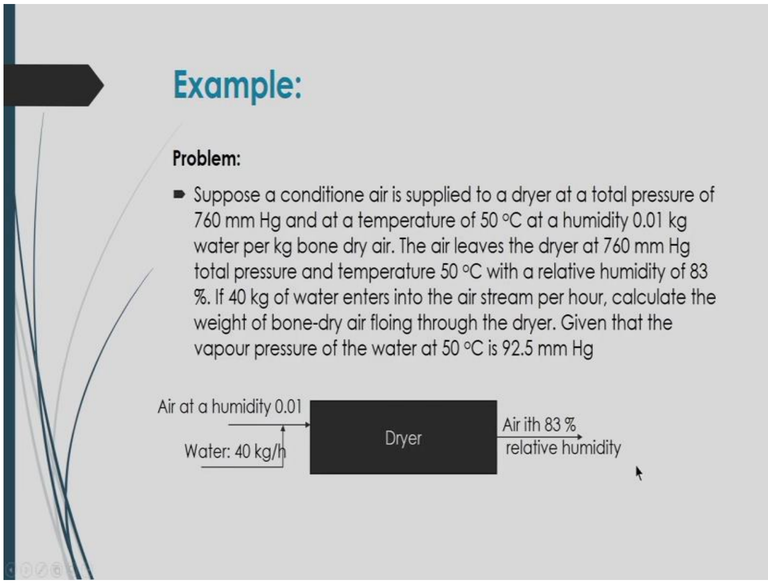

Let us do another example, based on this humidity. Now suppose you know, conditioned air is supplied to a dryer at a total pressure of 760 millimeter mercury and at a temperature of 50 degree celsius at a humidity of 0.01 kg water per kg of bone dry air. Now, this air leaves the dryer at 760 millimeter mercury, total pressure and temperature of 50 degrees Celsius, but here the relative humidity of that, you know, air leaves of 83% of this relative humidity.

If 40 kg of water enters into the air stream per hour, you have to calculate what will be the weight of bone dry air that is flowing through the dry air given that the vapor pressure of the water at 50 degrees Celsius is 92.5 millimeter mercury. Here in this case vapor pressure of the water at 50 degrees Celsius is given to you so, if we draw this you know, schematic diagram of this. Now, let us see that this is your dryer.

Now the airstream at this dryer is coming at a temperature, what is that 50 degree Celsius at a humidity of 0.01 kg of water per kg of bone dry air for us water along air with that 40 kg per hour. So, based on these up to dry of this air will be coming out as you know with 83% of relative humidity. So, in that case, you have to find out what should be that weight of bone dry air that is flowing through the dryer. If the water flow rate is 40 kg with this you know air that is entering into the dry air.

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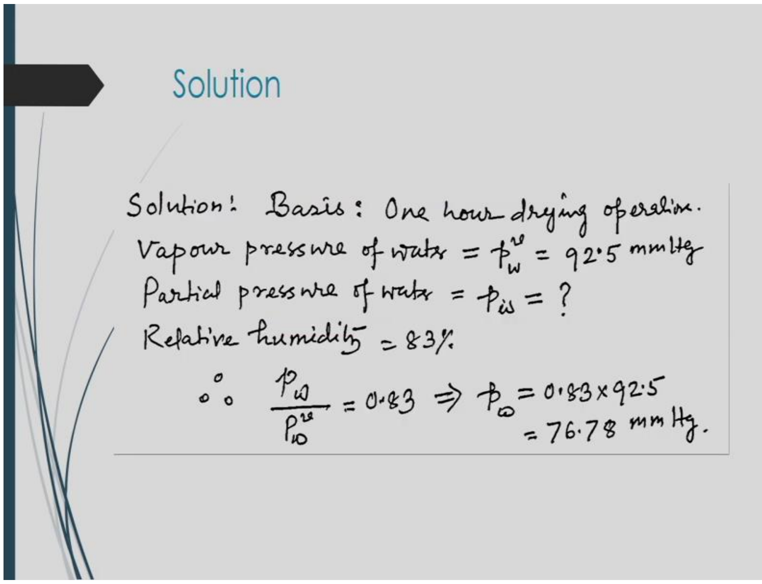

So if I saw this you have to you know consider the basis past now, what should be the basis in this case we can consider the basis as one hour duration of the operation of drying. Now, also you have to calculate what should be the vapor pressure of water at that particular temperature, it is given to you is 92.5 millimeter mercury and also you have to calculate for the partial pressure of the water, but is not given to you have to calculate here anyway is not given to you also you know that at the relative humidity is 83%.

So, if you know that the relative humidity at this air then you can simply say that, since it is defined as a you know ratio of partial pressure to the vapor pressure of water, then you can say that Pw by Pw of v that will be equal to 0.83 from which you can calculate easily. The partial pressure of water.

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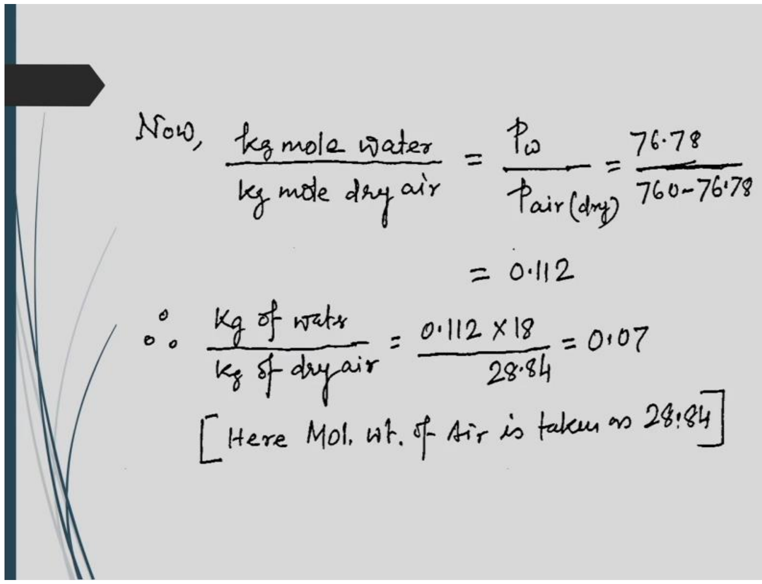

After that, you will see that this kg mole of water per kg mole of dry air that you have to calculate that been thought to be the moles of air is entering per kg of you know that dry air there so, it is basically that you know that partial pressure of water and what to be the partial pressure of air, what is the ratio and from this ratio, you can say this will be equal to 0.112. What does it mean that per kg mole of dry air that will contains you know 0.112 kg mole of water.

Now, in terms of weight you can see per kg mole of water by kg mole of dry air. Simply you have to multiply it by its molecular weight of that water and air then you can get to you know 0.07 here. Now, in this case this 18 and 28.4 basically, they are molecular weights of water and dry air respectively.

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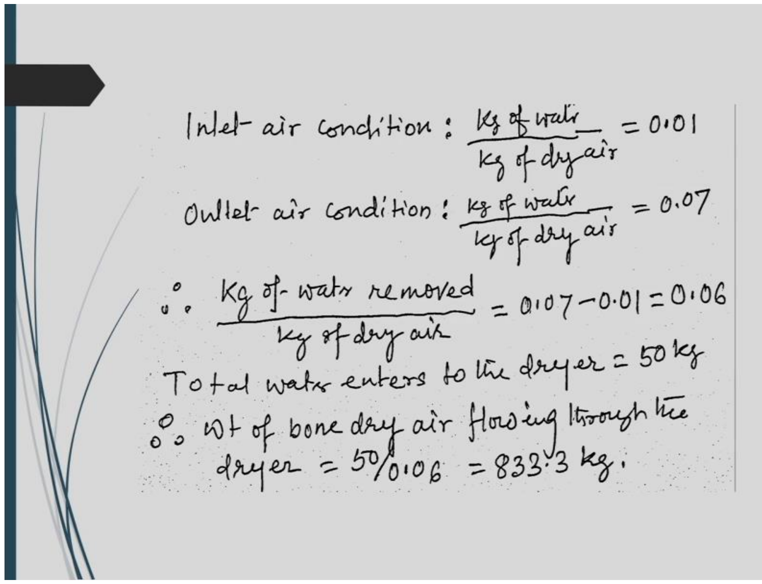

Now, what is the inlet air condition this kg of water by kg of dry air it will be 0.01 it is given since the humidity is 0.01 or us outlet air condition that we have calculated based on the temperature of 50 degrees Celsius and the pressure is 760 millimeter mercury and it is as 0.07. Now, in this case, since dryer is used to you know moisture air or remove the moisture from that object or from the air you know that now, how was amount of actually what air is removed at that particular temperature and pressure in the dry air.

So, kg of water removed per kg of dry air, this is basically then you know, what is the difference of that humidity? So, humidity at outlet is 0.07 and what is the humidity at the inlet that is 0.01 if you subtract it you will get this 0.06 this is basically that amount of water is removed per kg of dry air then what would be the total water interest to the dry air you know that is given 50 kg. Now, this 50 kg of water you know actually removed by that draft.

Now, can you see then, what will be the amount of water then supplied there to remove all these 50 kg of you know, water by this dryer. Now, you know that to remove that 0.0 kg of water it actually requires one kg of dryer per this calculation, so, 50 kg of water to be removed, what would the amount of air to be required. So, simply you just divide this 50 by the 0.06 then you can get this simply this amount of 833.3 kg.

So, that means, here at 833.3 kg of air actually is required to remove this 50 kg of water by this dry air at that particular temperature and pressure. So, this is one example of you know are doing the material balance based on this humidity, the air and of course, you will be doing that you know unknown parameter here in this case here what would be the amount of air is required. Similarly, you can calculate if it is unknown parameter is supposed to be the, what would be the total amount of you know water can be you know remove per you know suppose how kg of air to be supplied there.

Simply you can calculate up to this you have to calculate what do that what a remove and for that for to be the amount of air or amount of water actually remove per 100 kg or 5 kg or whatever amount will be given for air that you can easily calculate. So, these examples will be helpful to you know calculate further that requirement of water requirement of you know that air and also what to be the amount of water to be removed from that you know, device or from that you know that air water mixture by the dry air.

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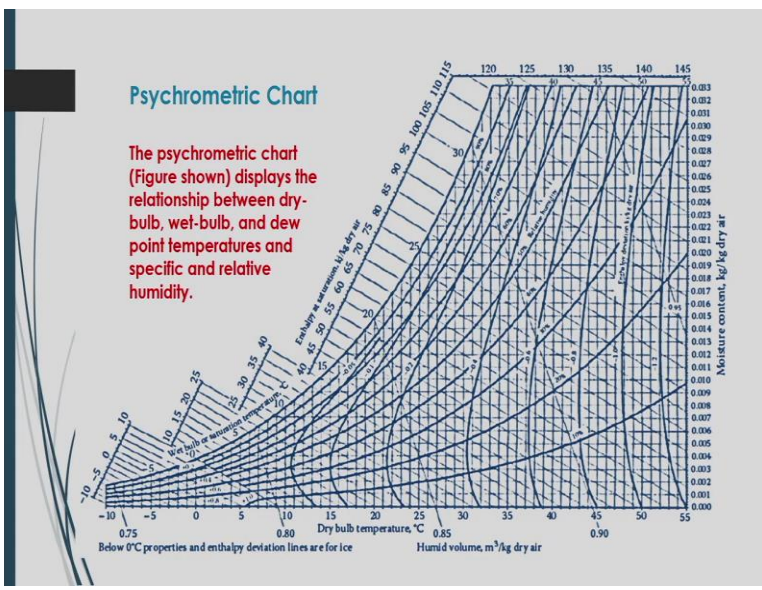

Next we will discuss the psychometric chart, what is that psychometric chart. This is basically that graphical representers graphical representation of moisture content or absolute humidity or you can say that what will be the relative humidity? What should be the wet bulb temperature what our saturation temperatures are how to calculate that enthalpy of the saturation from this you know graphical representation and also watch the humid volume, what is the dry air temperatures are all are related to each other and all those relations and based on their relations profiles are given in this graphical form and this graphical form of representation of those variables based on this humidity and saturation condition will be regarded as psychometric chart.

So, this psychometric chart to displace the relationship between dry bulb, wet bulb and dew point temperature and specific and relative humidity here see these psychometrics chart are shown in you know slides in the x axis you will see that there is no dry air temperature given you know that here, this is minus 10 to you know 55 degree Celsius it is given in the y axis it is given you will see that moisture content per kg dry air even in the y axis is also represented enthalpy at saturation condition.

And that you know that relative humidity and you know enthalpy deviation with saturation temperatures are and also you can say that what will be the humid volume at that particular you know driver compressor all are given here So, from this chart you will get that information of all those parameters provided 2 parameters will be known to you and from those 2 parameters you will be able to you know, you know read that other parameter other you know variables from this psychometric chart.

And let us have an example that how to you know, read this psychometric chart or use the psychometric chart to calculate different, you know, variables or parameters. Now, in this case, one problem is that humid air is considered at 30 degrees Celsius, which has a dew point of 15 degrees Celsius. Now, using this psychometric chart provided to you, have to determine the following like what is the relative humidity? What will be the absolute humidity? What do we the weight bulb temperature? What would the dry bulb temperature what would be the humid volume.

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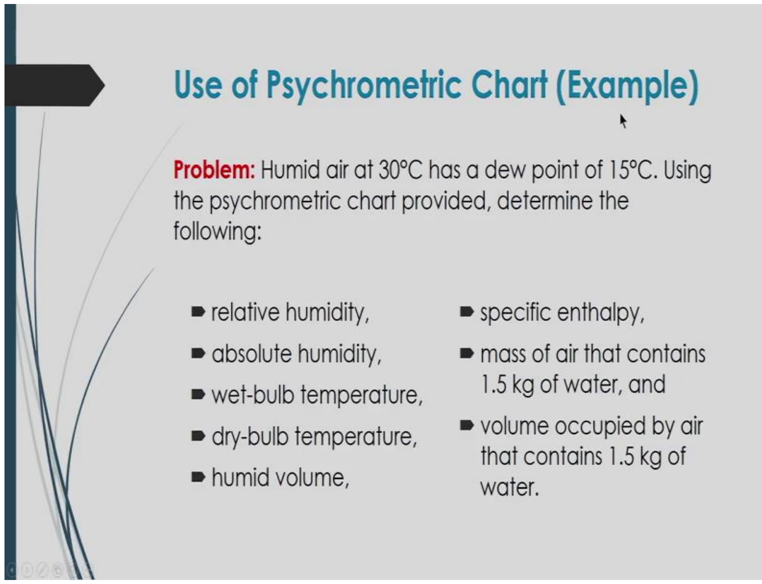

And what would be the specific enthalpy what would be the amount of you know air that contains you know, 1.5 kg of water and also you have to calculate the volume occupied by air that contains 1.5 kg off water there so, all those you know things to be you know calculated based on these psychometrics reading.

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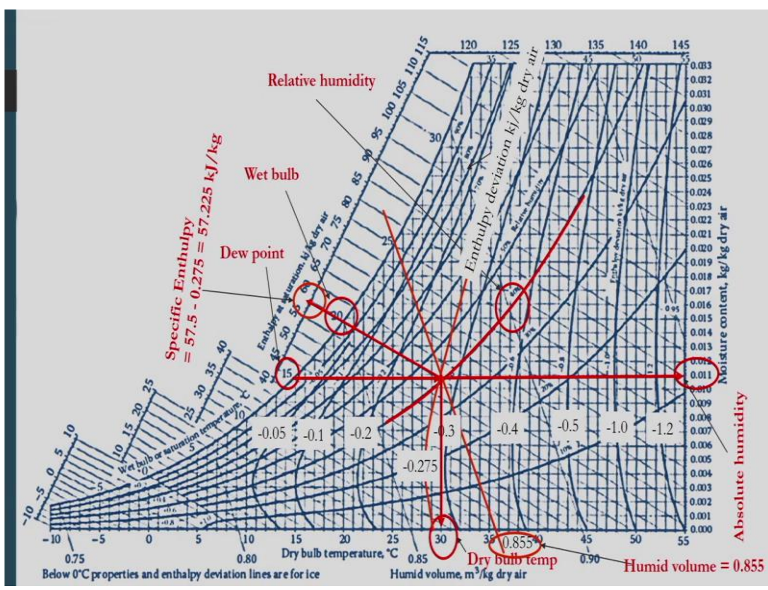

Let us have this past you know relative humidity. Now, how to calculate that or how to read that relative humidity from the psychometric chart, first of all, you know that dry bulb temperature, it is given in your problem that it is 30 degrees Celsius and also it is given to you that they are you know that dew point temperature is 15 degrees Celsius. So, we know that humid air is at 30 degrees Celsius and dew point of 50 degree 15 degrees Celsius.

So, here 30 degrees Celsius to be considered as, you know dry bulb temperature. Now, this dry bulb temperature and if you know that dew point temperature, this is actually that saturation temperature, so, this is 15 degrees Celsius and this is 30 degree Celsius. Now, if you know go forward from this 15 degrees Celsius point here up to these and then also you consider this 30 degree Celsius that is dry bulb temperature.

And what would be the intersection points, you just decided this intersection point you will see you will get a another profile of that, you know here it is given like you know that this type of profile like you know the percent is 40% is 50% is 60% is these are actually relative humidity. Now, at this intersection of this dew point and dry air temperature, what is the percentage you know that is humidity or relative humidity in percentage, you can you know identify so this line this line will give you that 40% relative humidity.

So, very interesting that what will be the relative humidity here, it will be simply 40% here. So, based on these 15 degrees Celsius dew point and 30 degrees Celsius dry bulb, where is the cross intersection point and at that intersection point, what would be the profile of that relative humidity? You have to go through that and you have to read what should what is that relative humidity. So, this will be your 40%. So, you got this what would be the relative humidity at that particular temperature of dry bulb and dew point. Next part of the absolute humidity.

Now, you will see that if you know that go along with that line of dew point from that point here, intersection point and if you go to here the moisture content, you know access and you will see that this will intersect at this point of 0.011. So, this will give you that value of you know, absolute humidity. So, what is your absolute humidity? This is basically 0.011. So, what we did is simply that from that intersection point along with that, you know that dew point line you go up to moisture content per kg dry air access and what is the intersection point there, that value will give you the absolute humidity.

Next, you have to calculate what should be that you have to be what should be the wet bulb temperature. Now, to get this wet bulb temperature, but comparison that what is the intersection point of dew point temperature and wet bulb temperature that is here at this 40% relative humidity. Now, from this, you will see that another lines like this here, this slide this type of lines here at shown this line. So, here if you go just you know following this line up to you know hundred percent you know saturation line.

So, this is you know 100% saturation line. So, from this 100% saturation line or from this intersection point if you go 100% saturation line and what will be the intersection point that will give you wet bulb temperature, so, it is coming 20 degrees Celsius. So, this intersection point is 20 degrees Celsius. So, here you can see that this wet bulb temperature will be equal to 20 degrees Celsius. So, what we did here, this is your intersection point and along this you know wet bulb temperature where it intersects at 100% saturation 100% you know relative humidity or saturation line.

So, that point will be regarded as wet bulb temperature. So, here in this case it is 20 degrees Celsius and then what is the dry bulb temperature is simply that 30 degrees Celsius as given in into a problem.

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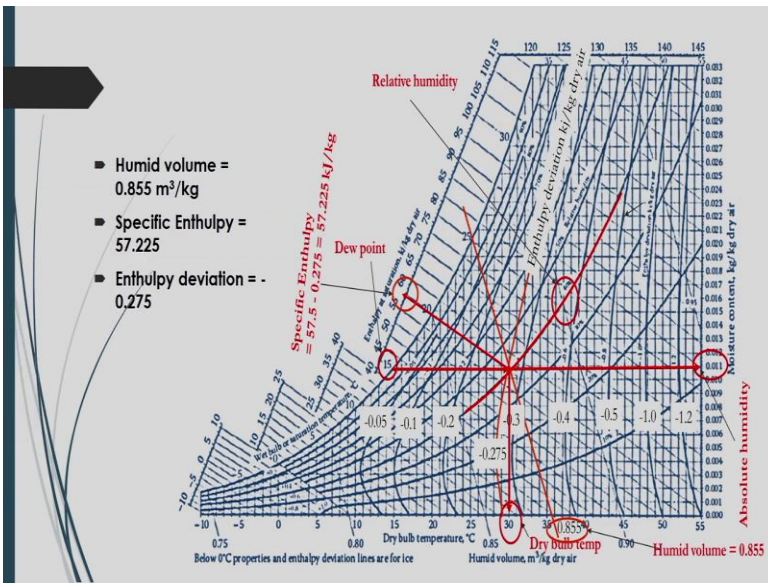

And after that you have to calculate what will be the humid volume. Now, again if you follow that you know the wet bulb temperature line and if you go along that you know wet bulb temperature line up to you know there is a enthalpy line there here it will intersect at this point and you will see that value will be coming as you know at you know certain value and it will be regarded as what is that specific enthalpy there now, this is specific enthalpy will give you that what will be the you know humid volume also and if you go beyond these here at this intersection point.

And this line will intersect this you know that enthalpy deviation line there from that you can calculate the enthalpy deviation of what also you can calculate that humid volume just from this you know line here, this line will give you that humid volume there is some humid volume profile are given in this chart here like this and this is also humid volume. Now in between these humid volume you are getting the intersection point here.

Now, based on this intersection point, where exactly that humid volume will be there and if you know, interpolate or extrapolate of this line or interpolate this line here and you can get this what should be that you know, that humid volume here. So, humid volume to calculate that at that intersection point you have to see that, what should be the, you know humid volume line, it is intersected and that corresponding value will give you that humid volume and a specific enthalpy.

From the intersection of dew point and dry bulb compressor if you go along with that you know, that is you know that wet bulb temperature, and where it is intersected, it will be 20 degrees Celsius at the saturation line. And if you go for that to that enthalpy curve, then you will get that intersection point as a specific enthalpy and also these intersection points. Why are these this slide here you will see that these are some you know line or profile that will that is represented for you know enthalpy deviation.

Now, at this intersection point where this enthalpy deviation curve will come, that also to be you know known by interpolating or extrapolating of this, you know volume of two profiles near about this, then you can get the corresponding value of enthalpy deviation there. So, based on this, you know, psychometric chart we can easily calculate we can easily obtain what will be the you know, that humid volume specific enthalpy, enthalpy deviation, even dew point dependent dry bulb temperature even, you know, wet bulb temperature are also.

You can get the relative humidity and also humid volume there. So, in this way you have to read this psychometric chart.

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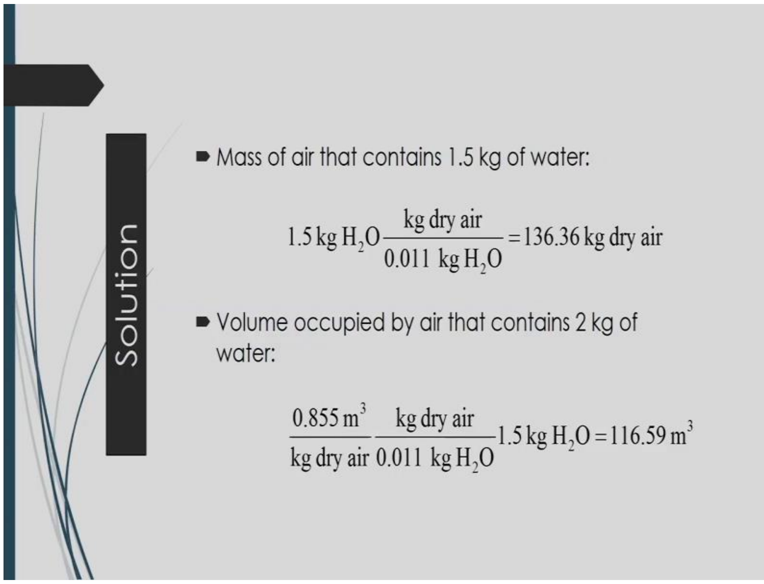

Next is that you have to find out what should be the amount of dry air that contains you know 1.5 kg of water. So, as per this case 1 kg of water that means here will be actually, you know, contained by that air that can be calculated just by you know dividing that humidity of you know, dry air that is here, we know that, absolute humidity is 0.011. So, if you divide this you know that 1.5 kg of water by the humidity you can easily calculate what should be the you know a dry air to you know contain that 1.5 kg of water.

Similarly, what should be the volume occupied by that air that contains 2 kg of water, you can easily calculate it from you know humid volume. That humid volume from the psychometric chart is 0.855 and we know that absolute humidity if you divide this humid volume by these you know that humidity absolute humidity and then multiply by this you know amount of water, then you can get the total volume of you know, here that is they are to contain that 2 kg of water there so, it will be amount 160.59 meter cube.

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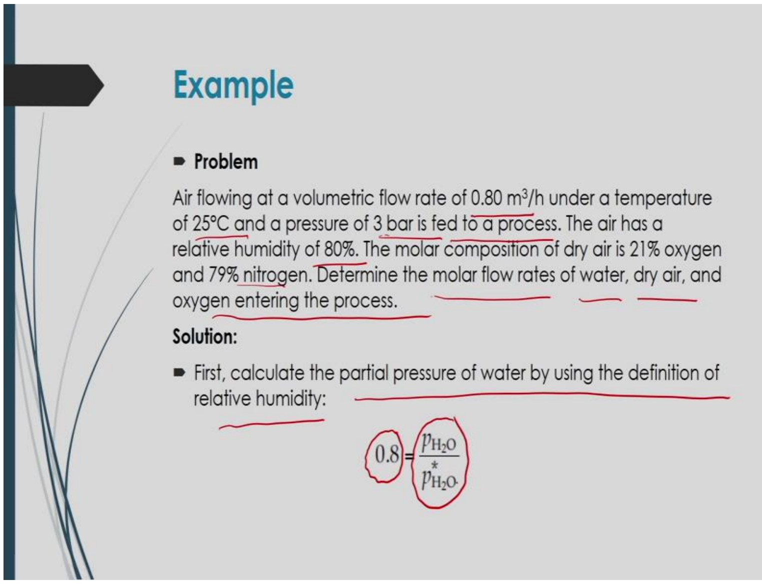

Let us do another example, you know regarding this you know humidity and also what is that partial pressure based on who is let us see that other you know material balance problem. Now, air flowing at a volumetric flow rate of 8.8 meter cube per hour under the temperature of 25 degrees Celsius and a pressure of the bar that is paid to a process here now, the air has a relative humidity of 80% given the molar composition of dry air is 21% oxygen and 79% nitrogen.

Now, in this case you have to find out what should be the molar flow rate of water dry air and oxygen that interrupts the process. Now, in this case you have to you know first calculate the partial pressure of water by using the definition of relative humidity. So, relative humidity is given to you that is 80% that means, 0.8 that is defined basically partial pressure of water by vapor pressure of water. So, it is represented by this equation here.

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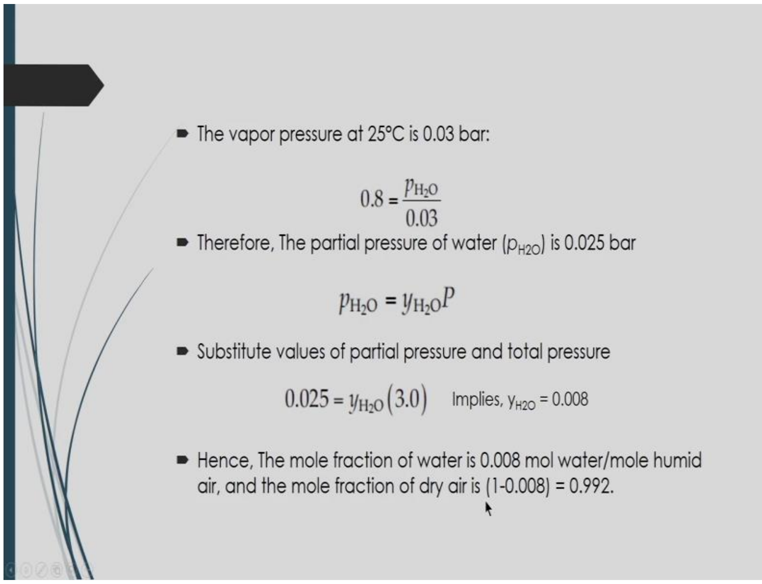

And after that you can calculate the vapour pressure at the 25 degrees Celsius and the pressure of 0.03 as by this equation here 0.8 to, you know, partial pressure of water by 0.03. Vapour pressure is given a 0.03 bar therefore, partial pressure of water will be coming as here from this equation 0.8 into 0.03. And this partial pressure can be represented by this equation here partial pressure of water with regard to y water into pressure now substitute this value here in this equation, you can simply you know get this you know partial pressure of you know that water here.

And then you can represent it as what to be the mole fraction they are based on the two equation and then you can get what will be the mole fraction of water there that will be 0.008. Now, hence in this case, the mole fraction of water will be equal to 0.008 mole of water per mole of humid air and the more fraction of dry air will be able to here zero point you know 0.992 just by you know subtracting that mole fraction of water from the total moles of the mixture. It is there one minus 0.008. So, that will give you this 0.992 moles of you know mole fraction of you know dry air in the mixture.

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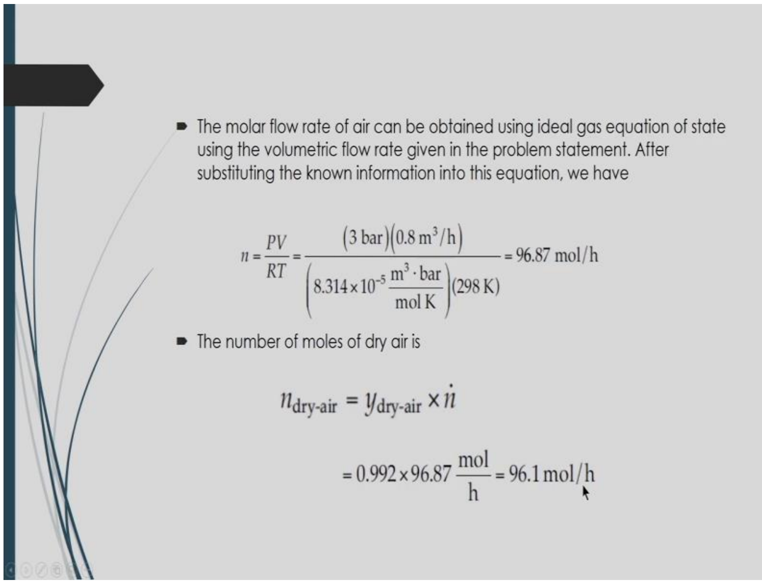

Now, in that case, you have to now follow that molar flow rate of air that can obtain using ideal gas equation of state using the you know volumetric flow rate given in the problem statement, whatever it is after substitute that known information into this equation, we can get that n will be equal to PV by RT. Now, in this case P is given to you and also V is known to you and R value is 8.314 into 10 to the power minus 5.

Of course, you have to remember this unit because this value of our will be different for different units. So, you have to you know, be, careful to use these different values of R value based on the unit and temperature is given to you, and in that case number of moles of dry air, it will be simply that, you know, mole fraction of air into total mold rate is given year 96.87 as per this calculation, and then if you multiply it by that mole fraction, that already we have calculated in the previous slides, that will be the mole fraction of air is coming. So, based on that we can see that total mole of dry air will be equal to 96.1 mole per hour.

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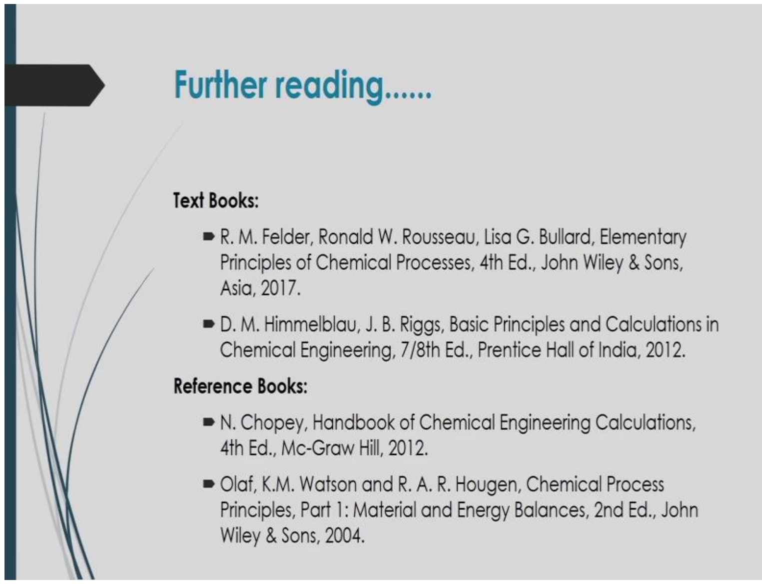

So, we have land here in this lecture, that what is the saturation what is the humidity what is the different definition or different form of humidity and how that humidity can be you know, explained or can be read by that psychometric chart and how to you know obtain that different value of that humidity and also a different uniform of that you from the psychometric chart and also we how we can actually you know, do the material balance based on the value in a particular process.

You need basically for dry air, we have learn I suggest to go further districts book to, you know practice several problems that is given in their examples. And I think it would be helpful for you for your further understanding of doing the material balance based on the humidity and also it will be helpful how to read that psychometric chart and from that psychometric chart, how to use those value for the material balance equation thank you. Next class our next lecture will be discussing about that you know, processes of phase change like you know, condensation process and vaporization process.