Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 34
Non-Reacting Mixture and Psychrometry

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So let us start this lecture with a thought process.

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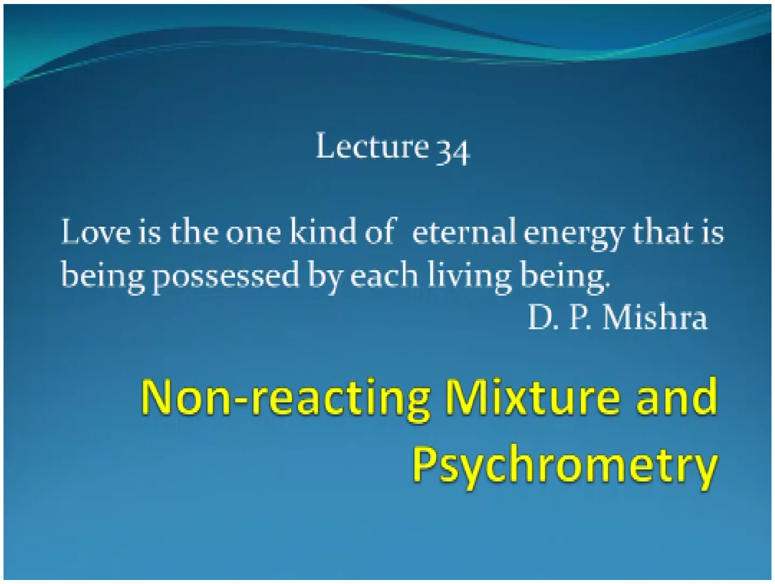

Lecture 34

Love is the one kind of eternal energy that is being possessed by each living being.
D. P. Mishra

Non-reacting Mixture and Psychrometry

Love is the one kind of eternal energy that is being caused by each living being I call it basically is the internal energy of a human being. So let us recall that in the last lecture we are talking about basically you know mixtures which are not reacting and we will be discussing about the Psychometry the Psychometry is basically processed by which we can analyze the moisture content in the air right you know and also find out how we can make it you know analyze that that process is psychometry first we will be taking up non reacting mixtures right because if some mixture of gases are there then it is not reacting, so how will handle it.

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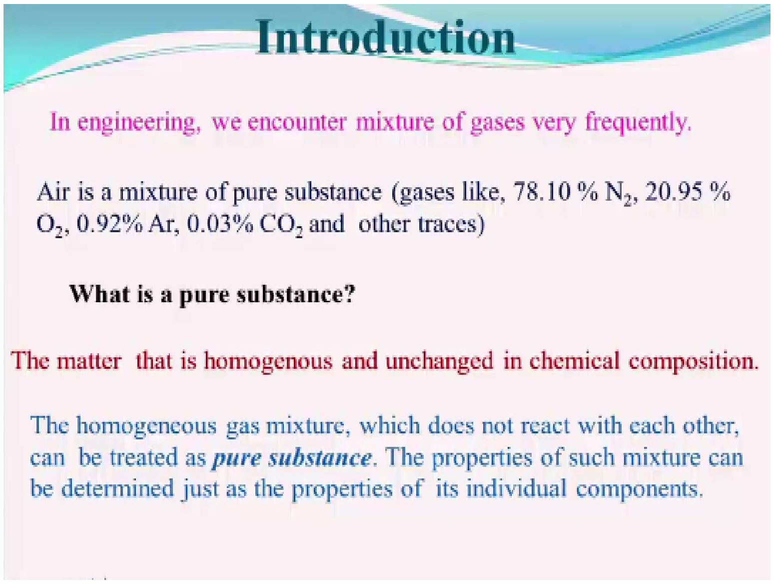

Introduction

In engineering, we encounter mixture of gases very frequently.

Air is a mixture of pure substance (gases like, 78.10 % N_2, 20.95 % O_2, 0.92% Ar, 0.03% CO_2 and other traces)

What is a pure substance?

The matter that is homogenous and unchanged in chemical composition.

The homogeneous gas mixture, which does not react with each other, can be treated as ***pure substance***. The properties of such mixture can be determined just as the properties of its individual components.

So in engineering we can we encounter mixture of gases very frequently we have seen not only you know we are surrounded by the air which is a mixture of gases like oxygen, nitrogen, argon you know like and when we are producing carbon dioxide kind of things but we also handle several mixture of gases right in engineering applications we have seen the heat engines and other things you know like there are several gases particularly gas power cycle we have seen, so as I told that air is a mixture of pure substances like nitrogen 78.1 % and you know oxygen is 20.95% and then argon and carbon dioxide are a very less.

And other trace elements will be there so if you recall what is the pure substance we have already discussed earlier it is basically the matter which is homogeneous in nature and remain unchanged you know with his chemical composition right that we call it as a pure substance and the homogeneous gas mixture basically which will be undergoing right reaction we cannot call it as a pure substance right can we cannot really call it but if it is there is no reactions right or after the reaction before the reaction we can also consider the pure substance and properties of such mixture can be determined just as the properties of the individual components.

If we know the properties of individual gases then we can find out and then we will have to find out mixture therefore we need to you know learn how to handle the mixture properties right.

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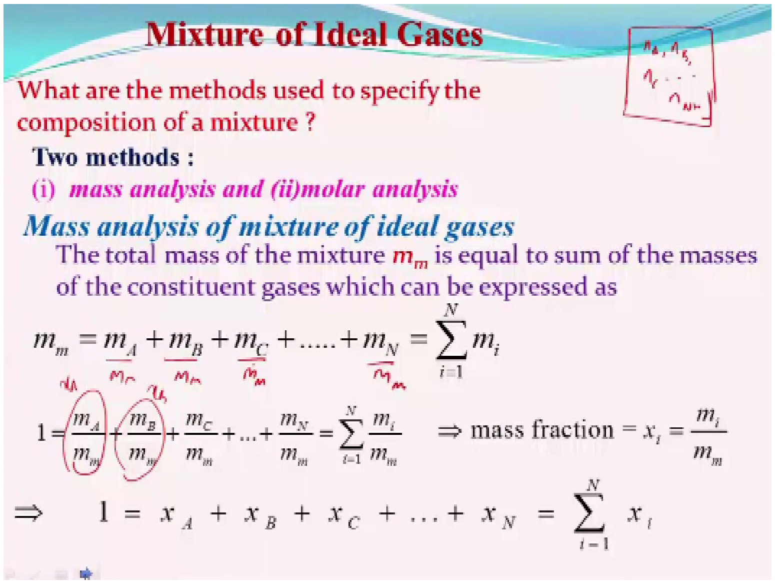

Mixture of Ideal Gases

$n_A, n_B,$
$n_C \cdots$
n_{NH}

What are the methods used to specify the composition of a mixture ?

Two methods :

(i) ***mass analysis and (ii)molar analysis***

Mass analysis of mixture of ideal gases

The total mass of the mixture m_m is equal to sum of the masses of the constituent gases which can be expressed as

$$m_m = \underset{m_m}{\underline{m_A}} + \underset{m_m}{\underline{m_B}} + \underset{m_m}{\underline{m_C}} + \ldots.. + \underset{m_m}{\underline{m_N}} = \sum_{i=1}^{N} m_i$$

$$1 = \overset{x_A}{\frac{m_A}{m_m}} + \overset{x_B}{\frac{m_B}{m_m}} + \frac{m_C}{m_m} + \ldots + \frac{m_N}{m_m} = \sum_{i=1}^{N} \frac{m_i}{m_m} \qquad \Rightarrow \text{mass fraction} = x_i = \frac{m_i}{m_m}$$

$$\Rightarrow \quad 1 = x_A + x_B + x_C + \ldots + x_N = \sum_{i=1}^{N} x_i$$

And we will be considering the ideal gases right most of the time because of you know we are not very handling a very high pressure and even if we are handling the high pressure we are not handling very low temperature because if you know then only it will be real gases comes into picture but too we will be using ideal gases most of the time because of it is handy to use and also we learn how to use you know ideal gas law and making using the compressibility factor into that for the real gases.

So there are two methods of analyzing this mixture of ideal gases one is mass analysis other is mole analysis or molar analyst right and let us consider that there is a container you know which contains let us say certain amount of gas like if you look at there is a container it contains let us say N_A molecules of gas and then N_B and N_C and then several N number of gases are there you know it contains.

So how we you know basically do that we can do mass analysis of the mixture of ideal gases by considering the total mass of the mixture will be basically equal to the sum of the masses of constituent gases right which we know like basically that is the m_m that is the mixture mass is equal to mass of the a component of gas and plus mass of B plus mass of C and it goes on and then there might be n^{th} types of gases and which is nothing but summation of mass i, i can be 1 to n.

So if I will divide this you know like by mixture mass write m over here m over here, so what is this one what you call this one this basically mass fraction right this I can call it as X_A that is your mass fraction and similarly X_B will be mass fraction of the gas B and X_C will be the mass fraction of the gas C, so therefore if you look at the mass fraction of all gases sum over that is equal to 1.

That is the things what we can see so I mean this is the one which we you people might have learnt earlier I mean I am just repeating for the sense for that you can I mean recapitulate those things and similar way we can look at also the mole fraction right.

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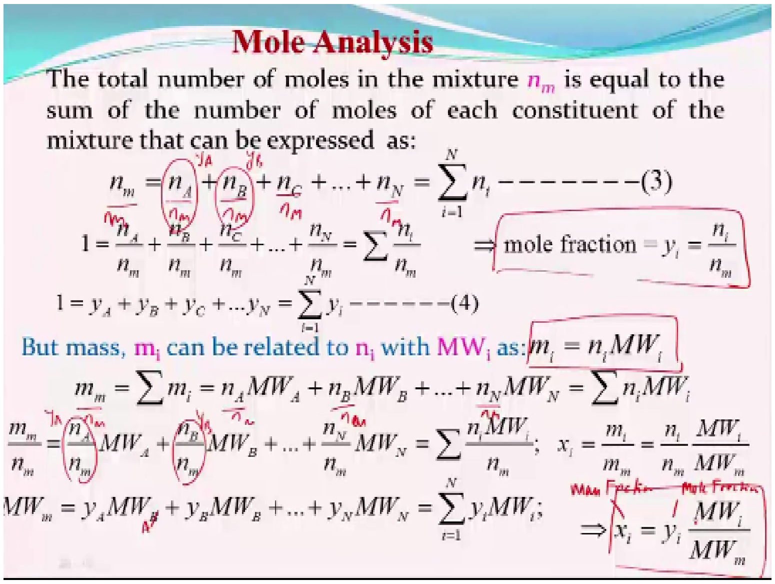

Mole Analysis

The total number of moles in the mixture n_m is equal to the sum of the number of moles of each constituent of the mixture that can be expressed as:

$$n_m = n_A + n_B + n_C + \ldots + n_N = \sum_{i=1}^{N} n_i \text{--------}(3)$$

$$1 = \frac{n_A}{n_m} + \frac{n_B}{n_m} + \frac{n_C}{n_m} + \ldots + \frac{n_N}{n_m} = \sum \frac{n_i}{n_m} \quad \Rightarrow \boxed{\text{mole fraction} = y_i = \frac{n_i}{n_m}}$$

$$1 = y_A + y_B + y_C + \ldots y_N = \sum_{i=1}^{N} y_i \text{------}(4)$$

But mass, m_i can be related to n_i with MW_i as: $\boxed{m_i = n_i MW_i}$

$$m_m = \sum m_i = n_A MW_A + n_B MW_B + \ldots + n_N MW_N = \sum n_i MW_i$$

$$\frac{m_m}{n_m} = \frac{n_A}{n_m} MW_A + \frac{n_B}{n_m} MW_B + \ldots + \frac{n_N}{n_m} MW_N = \sum \frac{n_i MW_i}{n_m}; \quad x_i = \frac{m_i}{m_m} = \frac{n_i}{n_m} \frac{MW_i}{MW_m}$$

$$MW_m = y_A MW_A + y_B MW_B + \ldots + y_N MW_N = \sum_{i=1}^{N} y_i MW_i;$$

Mass Fraction Mole Fraction

$$\Rightarrow \boxed{x_i = y_i \frac{MW_i}{MW_m}}$$

So that is the molar analysis the total number of moles in the mixture n_m is equal to sum of number of moles of each constituent of mixture that can be expressed as basically n_m is equal to n_A + n_B and + n_C goes on till n^{th} 1 I can divide this thing by n_m across right, so that this is nothing but your mass what you call mole fraction that is y_A and similarly this can be y_B and this is you are basically mole fraction of the I's spaces right i, can be anything so what this equation says that the summation of mole fraction of all spaces you know is equal to the 1.

So but the we need to now relate this mass you know to the mole through the of course the molecular weight and that is mi is equal to n_i MW_i MW is the molecular weight of the gas of higher spaces, so we can write down basically this m_m is the summation of all the masses of constituent gases and that is equal to n_i MW_i and if I divide this equation what you call by moles right.

If I divide by this total mixture moles right n_m and m so I will get and if you look at what is this one this is basically the mole fraction of A similarly this will be mole fraction of B and similarly mole fraction of n_H spaces so if you look at the molecular weight of the mixture is basically the mole fraction of the space is A into molecular species a and mole fraction of spaces be and molecular weight of spaces B and it goes on for the N_S spaces that is nothing but summation of the product of molecular weight of the highest spaces into mole fraction of the higher spaces right.

That is the things what you can find out what is the molecular weight of the mixtures very easy and by this way we can also relate the mass fraction with the mole fraction through the molecular weight if you look at this is your mass fraction of higher spaces and this is your mole fraction of higher spaces, so you can relate this you know through the molecular weight of the mixture and higher spaces.

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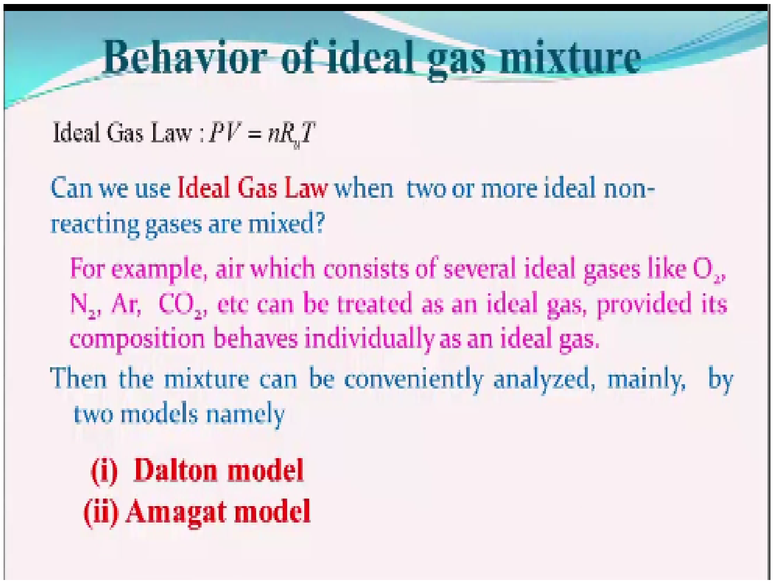

Behavior of ideal gas mixture

Ideal Gas Law : $PV = nR_uT$

Can we use Ideal Gas Law when two or more ideal non-reacting gases are mixed?

For example, air which consists of several ideal gases like O_2, N_2, Ar, CO_2, etc can be treated as an ideal gas, provided its composition behaves individually as an ideal gas.

Then the mixture can be conveniently analyzed, mainly, by two models namely

(i) Dalton model
(ii) Amagat model

So if you look at the behavior of the ideal gas mixture we can use the ideal gas law and by the which is nothing but PV is equal to nR_uT and which we have already discussed extensively and question arises whether we can use the gas ideal gas law when two or more ideal non reacting gases are mixed definitely yes we can do that and for example we will be handling you know several gases of what you call ideal gases and as we know that air which consists of several ideal gases like oxygen, nitrogen and argon carbon dioxide can be easily treated as an ideal gas provided it is composition you know behaves individually as an idea yes then only we can do.
The then we can analyze this mixture very easily by using two models you know like one is basically Dalton model or other is the amateur model that will be discussing.

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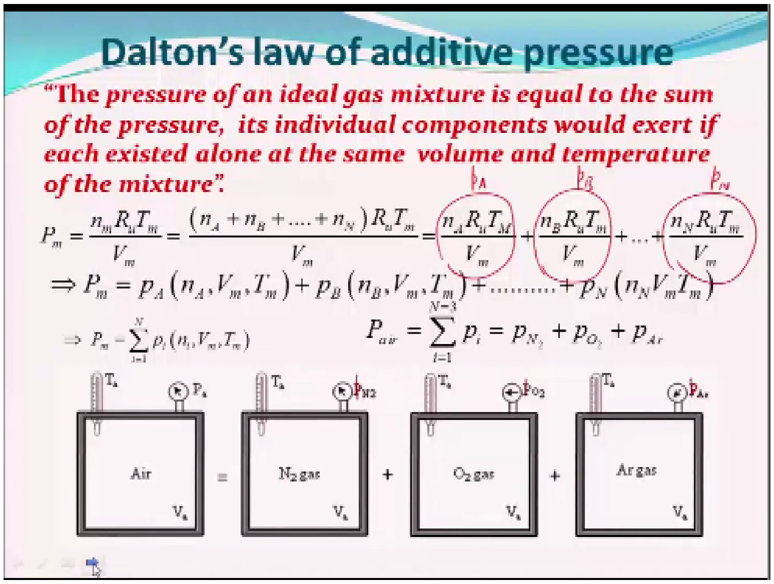

Dalton's law of additive pressure

"The pressure of an ideal gas mixture is equal to the sum of the pressure, its individual components would exert if each existed alone at the same volume and temperature of the mixture".

$$P_m = \frac{n_m R_u T_m}{V_m} = \frac{(n_A + n_B + \ldots + n_N) R_u T_m}{V_m} = \overset{p_A}{\frac{n_A R_u T_M}{V_m}} + \overset{p_B}{\frac{n_B R_u T_m}{V_m}} + \ldots + \overset{p_N}{\frac{n_N R_u T_m}{V_m}}$$

$$\Rightarrow P_m = p_A(n_A, V_m, T_m) + p_B(n_B, V_m, T_m) + \ldots\ldots\ldots + p_N(n_N V_m T_m)$$

$$\Rightarrow P_m = \sum_{i=1}^{N} p_i(n_i, V_m, T_m) \qquad P_{air} = \sum_{i=1}^{N=3} p_i = p_{N_2} + p_{O_2} + p_{Ar}$$

So if you look at the Dalton's law of additive pressure you know very well just for the you know sake of it I am just repeating it the pressure of an ideal gas mixture is equal to the sum of the partial pressure right, what is that partial pressure? Partial pressure is basically pressure exerted by the individual component right when it exists alone at the same volume and temperature the mixture.

For example if I take this air right at certain temperature ambient temperature let us say TA and pressure PA right it is condensing let us say three gases we are considering nitrogen oxygen and argon now if we keep the same volume right and same temperature then it will exert a pressure what we call it as a partial pressure right we generally use a smaller p right for the partial pressure right and similarly for the oxygen if you know like partial pressure it will be when it is maintained at the same volume and the same temperature.

So also the organ so if you look at we can generalize it that is mixture pressure is will be nothing but you what you call like n/m are you TM/VM this is from the ideal gas law and we know that NM is equal to nothing but NA + NB plus you know N^{th} gases and if you just separate it out here so if you look at here in $N_A R_U T_M / V_M$ is nothing but your partial pressure of a and this is partial pressure of B and this is of course the partial pressure of N^{TH} gases.

So and that is we have I have written here and keep in mind this partial pressure A is basically dependent on the number of moles of a universal gas constant and the temperature of the mixture and also the volume of the mixture so similar way basically the we can say that PM is nothing but summation of partial pressure of the number of gases whatever it will be constitutive, so for air what example we had taken PA is basically summation of three partial pressure. In this case we have considered nitrogen, oxygen, argon are the constituent of the air.

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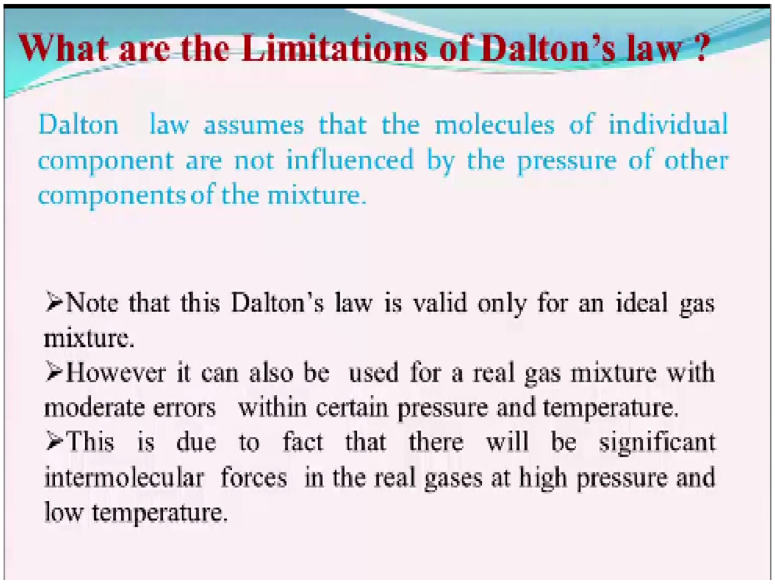

What are the Limitations of Dalton's law ?

Dalton law assumes that the molecules of individual component are not influenced by the pressure of other components of the mixture.

- Note that this Dalton's law is valid only for an ideal gas mixture.
- However it can also be used for a real gas mixture with moderate errors within certain pressure and temperature.
- This is due to fact that there will be significant intermolecular forces in the real gases at high pressure and low temperature.

So we will be looking at basically you know what are the limitation of Dalton's law if you look at the Dalton's law basically assumes that the molecules of individual component are not influenced by the pressure of other component of the mixture which need not to be true but we assume that way and then do that and keep in mind that this Dalton's law is only valid you know for an ideal gas mixtures why it would not be really well you know can be valid for the real gas.

But however we can use it for the real gas mixture in the process of course you know we will have to tolerate some moderate amount of error and within certain pressure and temperature range right and beyond that we cannot really use the Dalton's law for the real gases as a result it will incur you know because of it will be incurring the more amount of error because see why we cannot use this Dalton's law for the real gases at a little higher particularly higher pressure.

And low temperature there will be significant intermolecular forces in real gases at high pressure and low temperature therefore it cannot be used.

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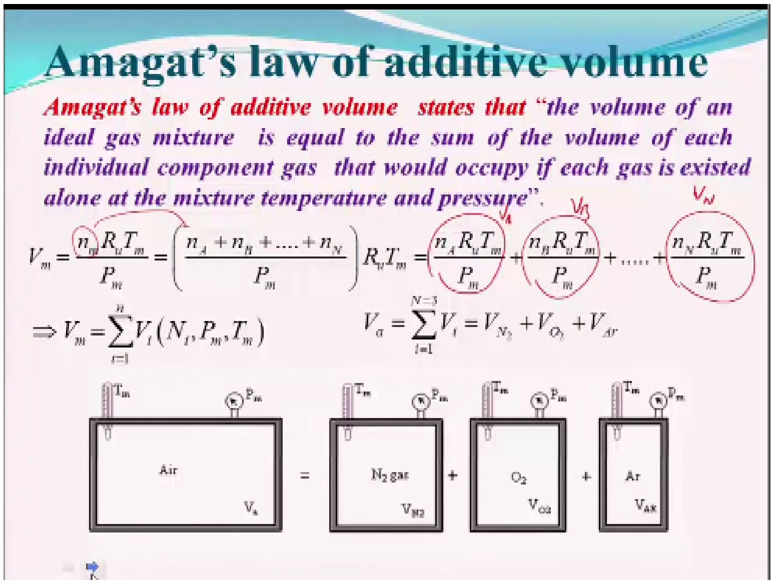

Amagat's law of additive volume

Amagat's law of additive volume states that "the volume of an ideal gas mixture is equal to the sum of the volume of each individual component gas that would occupy if each gas is existed alone at the mixture temperature and pressure".

$$V_m = \frac{n_m R_u T_m}{P_m} = \left(\frac{n_A + n_B + ... + n_N}{P_m}\right) R_u T_m = \overset{V_A}{\frac{n_A R_u T_m}{P_m}} + \overset{V_B}{\frac{n_B R_u T_m}{P_m}} + ... + \overset{V_N}{\frac{n_N R_u T_m}{P_m}}$$

$$\Rightarrow V_m = \sum_{i=1}^{n} V_i (N_i, P_m, T_m) \qquad V_a = \sum_{i=1}^{N=3} V_i = V_{N_2} + V_{O_2} + V_{Ar}$$

And so we look at now Amagat's law of additive volumes and in this case what we do we just put other way around that is you know like we keep this pressure of the mixture constant and also the temperature but however the what you call volume occupied by the individual gases will be different for example if we consider the air you know which is at the mixture temperature and the mixture pressure condensed VA amount of volume right.

And then if you look at the nitrogen and the oxygen and the argon the volume will be different so we can write down the total volume of the mixture of gases in this example is a V air who is equal to summation of the volume of the nitrogen gas oxygen gas and argon gas provided that you know mixture pressure and temperature is remaining constant right and that is nothing but your what you call Amagat's law of additive volume.

We state that the volume of an ideal gas mixture is equal to the sum of the volume of each individual component gas that would occupy if each gas is existed alone at the mixture temperature and pressure in other words what is being said I am just you know like stating again that mixture temperature and pressure will be remaining constant right and in case of Dalton's this thing what is remaining constant is basically the temperature and the volume right.

For the these things and here it is just other way around that is temperature and pressure will be remaining constant for you know same as that of all the individual gases and you can write down that V_M is basically from the ideal gas law $N_M R_U P_M/V_M$ and we can you know take this N_M, N_M is nothing but a summation of $N_A + N_B$ plus you know N^{TH} gases right and if you do expand these gases and then we will get that this is nothing but you from the ideal gas law this is nothing but your V_A volume A and this is volume B right.

Of course this is the volume of inert gases and that says that the summation the mixture volume is basically the summation of all individual gases right.

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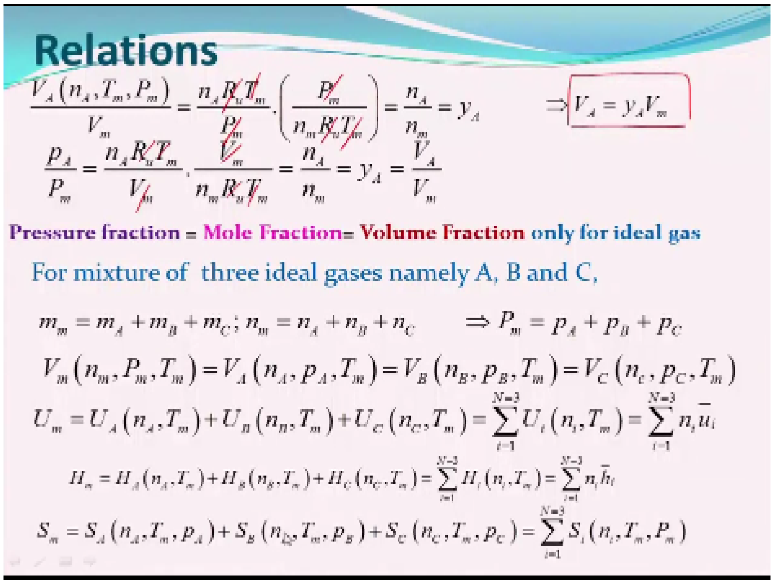

Relations

$$\frac{V_A(n_A, T_m, P_m)}{V_m} = \frac{n_A \cancel{R_u} \cancel{T_m}}{\cancel{P_m}} \cdot \left(\frac{\cancel{P_m}}{n_m \cancel{R_u} \cancel{T_m}} \right) = \frac{n_A}{n_m} = y_A \qquad \Rightarrow \boxed{V_A = y_A V_m}$$

$$\frac{p_A}{P_m} = \frac{n_A \cancel{R_u} T_m}{\cancel{V_m}} \cdot \frac{\cancel{V_m}}{n_m \cancel{R_u} \cancel{T_m}} = \frac{n_A}{n_m} = y_A = \frac{V_A}{V_m}$$

Pressure fraction = Mole Fraction= Volume Fraction only for ideal gas

For mixture of three ideal gases namely A, B and C,

$$m_m = m_A + m_B + m_C;\ n_m = n_A + n_B + n_C \qquad \Rightarrow P_m = p_A + p_B + p_C$$

$$V_m(n_m, P_m, T_m) = V_A(n_A, p_A, T_m) = V_B(n_B, p_B, T_m) = V_C(n_c, p_C, T_m)$$

$$U_m = U_A(n_A, T_m) + U_B(n_B, T_m) + U_C(n_C, T_m) = \sum_{i=1}^{N=3} U_i(n_i, T_m) = \sum_{i=1}^{N=3} n_i \bar{u}_i$$

$$H_m = H_A(n_A, T_m) + H_B(n_B, T_m) + H_C(n_C, T_m) = \sum_{i=1}^{N=3} H_i(n_i, T_m) = \sum_{i=1}^{N=3} n_i \bar{h}_i$$

$$S_m = S_A(n_A, T_m, p_A) + S_B(n_B, T_m, p_B) + S_C(n_C, T_m, p_C) = \sum_{i=1}^{N=3} S_i(n_i, T_m, P_m)$$

So now if you look at like we can talk that in terms of you know like V_A / V_M and VA we have seen is a function of number of moles of A and TM and pressure is you know we can divide this by the P_M and then multiplied by the these things right and if you look at this V_A from the ideal gas law is equal to $N_M R_U P_M/V_M$ and the V_M we can express in terms of P_M / $N_M R_U P_M$ and this R_U you will cancel it out so also TM and if you look at the P_M will cancel it and what you will get is basically the mole fraction of A right.

And similarly as a result we can find out this volume is nothing but of A is equal to mole fraction of A into mixture volume and similarly we can also find out the pressure ratio that is the partial pressure of a divided by the total pressure of the mixture is you know can be expressed in the sense using ideal gas law the partial pressure of A is nothing but $N_M R_U P_M/V_M$ and the P_M we can write down as a $N_M R_U P_M/V_M$ you can cancel it out the terms and you will also get this you know like that which is the pressure ratio is equal to the mole ratio.

That is N_A / N_M and which is nothing but your mole fraction right why a which is equal to the V_A/V_M from these we can conclude that the pressure fraction is equal to the mole fraction is equal to the volume fraction for an ideal gas it would not be true for real gases right so for mixture of three ideal gases namely ABC we can write down this you know mass balance we can do and so also the most mole balance that we have already done.

And similarly the we can express the mixture pressure in terms of partial pressure of the three gases what we have considered in this example, so as the volume is remaining same for all the three gases and so also the mixture then we can you know calculate very easily the what you call internal energy of the mixture which is nothing but summation of internal energy of A and Band C in this example and that is we can generalize also this for the I^{th} you know spaces and you know of course for this example is a three spaces you can take n number of spaces, and which is nothing but n_I x U_I U_I is the what are called more internal energy or specific internal energy or internal energy per unit mole.

Similarly we can calculate the enthalpy is the summation of India is enthalpy of individual gases and in cancan be expressed in terms of product of summation of other summation of the N_I x $H_{i.}$ Right and similarly we can calculate the call entropy of the mixtures by knowing the entropy of individual gases and you just sum it up and then you can get those values.

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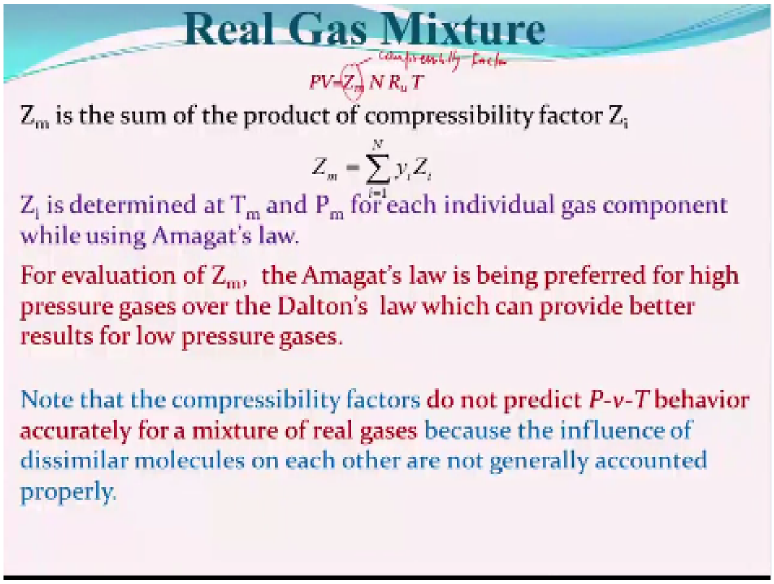

Real Gas Mixture

compressibility factor

$PV = \boxed{Z_m} N R_u T$

Z_m is the sum of the product of compressibility factor Z_i

$$Z_m = \sum_{i=1}^{N} y_i Z_i$$

Z_i is determined at T_m and P_m for each individual gas component while using Amagat's law.

For evaluation of Z_m, the Amagat's law is being preferred for high pressure gases over the Dalton's law which can provide better results for low pressure gases.

Note that the compressibility factors do not predict *P-v-T* behavior accurately for a mixture of real gases because the influence of dissimilar molecules on each other are not generally accounted properly.

So now we will be you know we have till now discussed how to handle the ideal gas mixtures but we will be discussing about how to handle. The deal gas mixtures so we know that the ideal gas law can be utilized for the real gas mixtures are real gas by just you know including a factor. What we call is a compressibility factor in only you look at the Zm is a compressibility to factor. Which we have already discussed earlier for a gas and these Zm is the sum of product of compressibility factor of ji.

You know lake of the all the mixture of the mixture components so Zm means basically ∑ Y_I and Z I is the IH spaces and I can be 12 you know like there might be several number especially in this case I =12 n. Like it maybe three spaces four paces ten spaces whatever it may be but you need to point out individual you know compressibility factor and also the x the mole fraction and sum over all the spaces will give you the mixture what we call compressibility factor.

So keep in mind that Zi has to be determined at the mixture vertical temperature and pressure for each individual components while using the maggots law see that is a very important point you should keep in mind. Right what determining the Z what pressure and temperature will have to take basically the mixture temperature and patient right.

So actually for evaluation of the Zm the Amagats gets law is being preferred for high pressure gases over the Dalton is law. Where you know you keep this basically what we call temperature and volume the same as that of the mixture while calculating and because of you know can it can give a better results. That is the reason why it is being used and whenever you are using the low pressure gases right you can use the Daltons kind of thing but a high-pressure one has to go further Emma gets long.

So keep in mind that the compressibility factors do not predict the pvt very accurately for a mixture of gases because of the effect of these similar molecules are not taken care by this you know when you use this compressibility factor. So therefore you will be incurring some kind of error even though you are using the compressibility factor for calculation or calculating the real gas mixtures properties. Right but however we will live with that because that error may not be you knows that much for your engineering calculation particularly.
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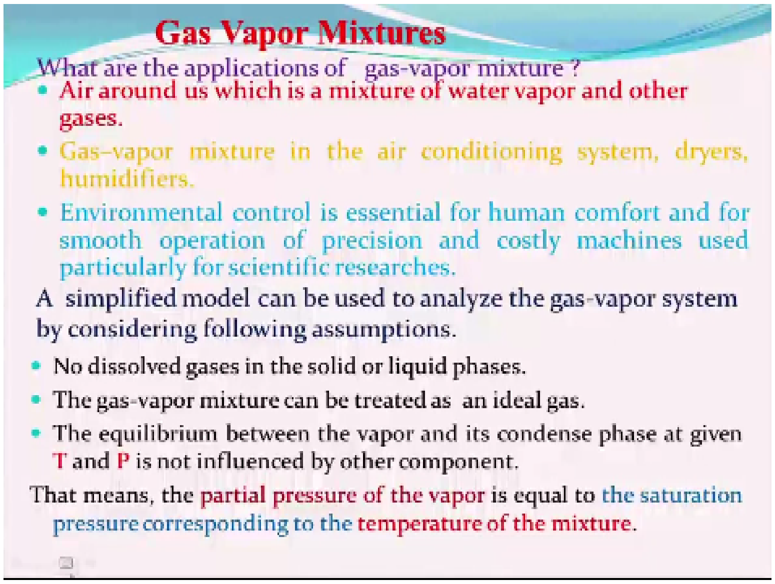

Gas Vapor Mixtures

What are the applications of gas-vapor mixture ?

- Air around us which is a mixture of water vapor and other gases.
- Gas–vapor mixture in the air conditioning system, dryers, humidifiers.
- Environmental control is essential for human comfort and for smooth operation of precision and costly machines used particularly for scientific researches.

A simplified model can be used to analyze the gas-vapor system by considering following assumptions.

- No dissolved gases in the solid or liquid phases.
- The gas-vapor mixture can be treated as an ideal gas.
- The equilibrium between the vapor and its condense phase at given T and P is not influenced by other component.

That means, the partial pressure of the vapor is equal to the saturation pressure corresponding to the temperature of the mixture.

So what we will be discussing is basically you know interested in to look at gas and vapor mixtures right and when we talk about the gas vapor mixture we will be discussing basically the water and it is vapor. You know like kind of things because that is having applications for air conditioner kind of things and because the air around us you know whatever is there is a mixture of water and vapor.

Of course the other gases like nitrogen oxygen a thing because water is a part and parcel of us and then particularly in the rainy season you know like the air will be containing lot of moisture. Right and moisture control is very essential for you know maintaining a comfort and also the several other applications kind of things. So if you look at you know like moisture content of the air is plays a very important role in several food processing industries and then several drying processes kind of things for example if you want to try this mango you know what we keep it or you want to have some let us say potato chips you know like for your this thing.

So you will have to maintain the water content otherwise it will be difficult so therefore we will be looking at it but the gas vapor mixture in air conditioning systems as I told like is essential to be control which in our country we do not do that because the costly FS what air condition we use is basically air cooler. It is not air conditioner and when you talk about air conditioner you hope to not only the control the moisture but also the other obnoxious gases and which will be there that means the quality of the air has to be controlled in case of air conditioning system.

Right so which is a very costly of s but we hear what we will be discussing about the moisture content in air type and as I told it will be very essential for dryer and humidifiers right kind of things so environmental control as I told earlier is very essential for human comfort and also the smooth operation of the appreciation and costly machine use particularly for scientific research. You know like we get a lot of instruments from outside you import it.

But it will not work here because this is the very harsh environment in our country it will be not only the moisture content will be fluctuating and also the dust label and other gases so you know like we spoil the instrument very easy. Now we will have to maintain that so that is also very important aspect of controlling the environment or the conditioning the air and kind of things.

So what we will be doing will be using a very simplified model to analyze the gas paper system by following by considering the following assumptions that is no diesel gases in the solid or liquid phases are there right. That we are considering but however you know like one has to consider those things those are basically you know has to be controlled so far good air conditioning is concerned.

So gasp our mixture can be treated as an ideal gas and we can do that thing because their temperature range what we will be operating is very low rather it is moderate something 52^0 Celsius and the one side which is highest temperature one can think up and also the -10 degrees Celsius we can think of kind of things and therefore we can very easily use that ideal gas and we will be operating will be handling the atmospheric pressure.

So far air conditioning is concerned you know so the equilibrium between the vapors is condensed phase at a given temperature is not influenced by other component. Right that we are assuming but in real situation it will be affected right if other constituents you know are there then their equilibrium condition you know like will be affected and that means if you look at what we are doing we will be using the partial pressure of the vapor.

You know like which is equal to the saturation pressure corresponding to temperature of the mixtures basically we will be using that I mean you will be using that kind of things and then. So that we can handle so before really getting into analyzing this air water vapor mixture let us you know get acquainted with the terminology is what will be using.

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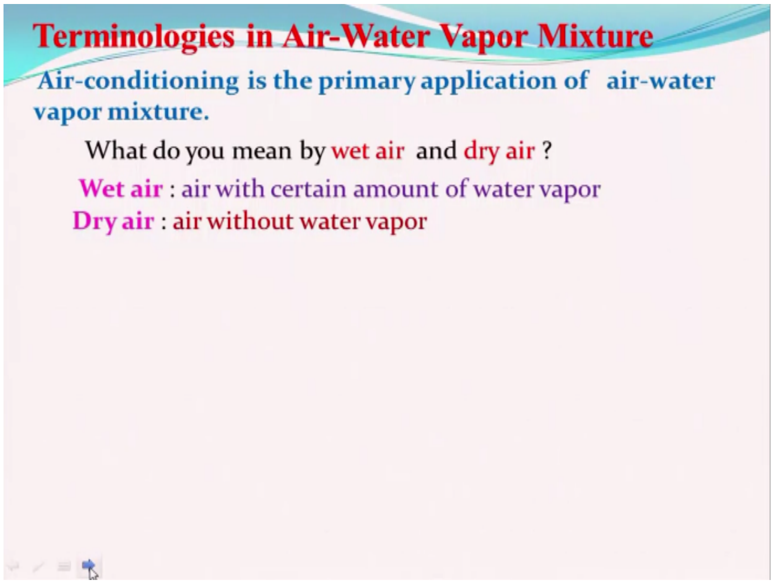

Terminologies in Air-Water Vapor Mixture

Air-conditioning is the primary application of air-water vapor mixture.

What do you mean by wet air and dry air ?

Wet air : air with certain amount of water vapor

Dry air : air without water vapor

So air conditioning as I told earlier that it is basically to handle the air water vapor mixtures and control it right that is the things and because we will be you know controlling the moisture content in the air and then when we talk about this air conditioning we will be looking at basically one is dry air other is the weight air. Of course from the name indicates you know it is very clear that dry air means it will not contain any kind of moisture level will be zero which is very difficult to get in particularly in our country.

Okay and where is the air with a certain amount of water vapor and always will be there if it is not there let us say Yuma is in water vapor will not be there what will happen that means we will get dry skins you know it is very difficult to maintain particularly we fail this dry skin problem in old days and also the in winter season right. So therefore you know we will have to maintain that that we need to understand the dry air and wet air.

So in analyzing the air conditioning system we should basically treat this atmospheric air as a mixture of dry air and water vapor and actually it will be always with you know kind of air you cannot get a 100-percentdry air unless you control it and then produce it right but atmosphere always will be the way to hear of course the label of water moisture will be different depending upon the season depending on temperature depending upon the you know conditions so as a roll earlier the temperature of air in the air conditioning application.

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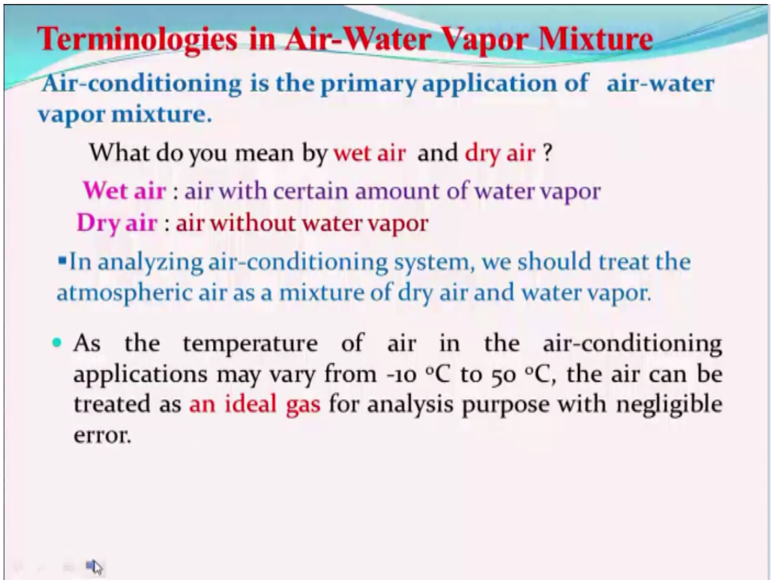

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Air-conditioning is the primary application of air-water vapor mixture.

What do you mean by wet air and dry air ?

Wet air : air with certain amount of water vapor

Dry air : air without water vapor

- In analyzing air-conditioning system, we should treat the atmospheric air as a mixture of dry air and water vapor.

- As the temperature of air in the air-conditioning applications may vary from -10 °C to 50 °C, the air can be treated as an ideal gas for analysis purpose with negligible error.

Generally varies from something minus 10 degree tote 50 degree Celsius so therefore and also atmospheric pressure right so therefore we can consider air as an ideal gas for analysis purpose without incurring much error you know like and water vapor can also be treated conveniently as an ideal gas with of course certain amount of error which is negligibly small that is around point one percent we have seen that whenever there is a two-phase fluid you know like that we cannot treat as an ideal gas law we have discussed enough but in and you know like in air conditioning kind of thing system.

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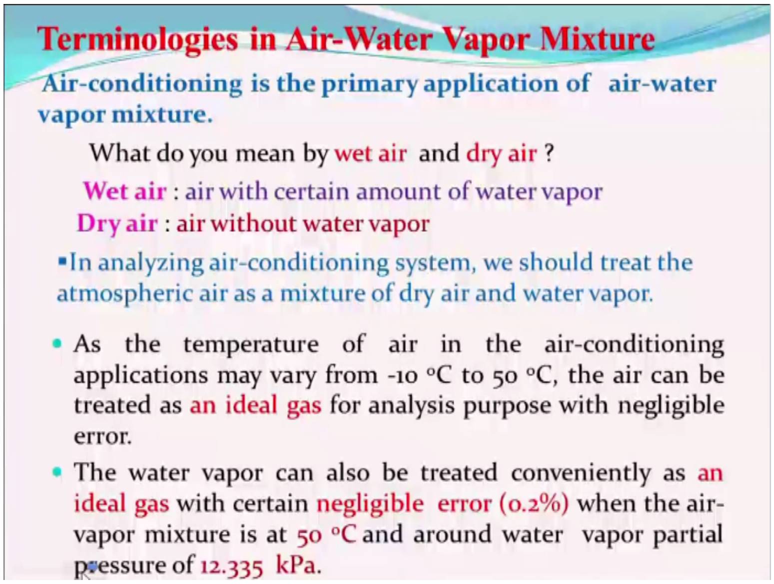

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- In analyzing air-conditioning system, we should treat the atmospheric air as a mixture of dry air and water vapor.

- As the temperature of air in the air-conditioning applications may vary from -10 °C to 50 °C, the air can be treated as an ideal gas for analysis purpose with negligible error.
- The water vapor can also be treated conveniently as an ideal gas with certain negligible error (0.2%) when the air-vapor mixture is at 50 °C and around water vapor partial pressure of 12.335 kPa.

Like air water vapor mixtures is that 50 degree Celsius right and the water vapor partial pressure corresponding to this 50 degree Celsius will be around something 12.33 5 kilopascal’s see how we'll get this partial pressure this basically corresponding tote saturated pressure this is equal tote saturated vapor corresponding to the50 degree Celsius from the steam table you can get you know very easily so the pressure of atmospheric air with water vapor will be equal to what will come the p is equal to p a +p wz this is basically partial pressure of air right.

This is partial pressure of dry air right and this is the partial pressure of water vapor this is partial pressure of partial pressure am just writing of water vapor I have written WG basically the vapor if that is the total pressure and is by the Dalton’s law of partial pressure we are doing that show to characterize the amount of water vapor in the air that we need to look at it so we can talk that thing you know in terms of two quantities one is relative humidity other is the specific humidity right.

And if you look at the specific humidity is basically the ratio of amount of water vapor and the amount of dry air the mass of the dry air it is the basically the ratio of the mass of water vapor and the mass of dry air .

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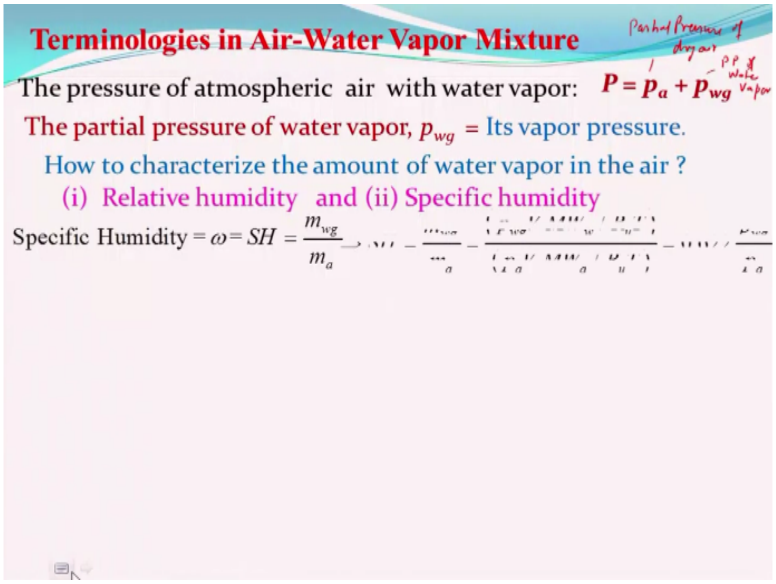

Terminologies in Air-Water Vapor Mixture

Partial Pressure of dry air

The pressure of atmospheric air with water vapor: $P = p_a + p_{wg}$

PP of Water Vapor

The partial pressure of water vapor, p_{wg} = Its vapor pressure.

How to characterize the amount of water vapor in the air ?

(i) Relative humidity and (ii) Specific humidity

Specific Humidity $= \omega = SH = \frac{m_{wg}}{m_a}$ [illegible]

And can write down that as by using the ideal gas law that is p wz into v volume is the same into molecular weight of water into / re 1 t and similarly for air I can write on the using ideal gas law that is PA v molecular weight of air/ r UT if you look at like this the same temperature because the air will be at the weight air will be at same temperature right so therefore this will be cancelled it out right.

If you look at I can cancel this out and similarly volume will be canceled it out whereas molecular weight and of water /molecular air will give me 0.62 to write into pw z / p a that is nothing but your specific humidity right so if you look at the specific humidity of a dry air what it would be it will be what 0 right dry air means there is no water vapor so therefore it will be 0 because pw n is 0therefore you know then the specific humidity will be 0.

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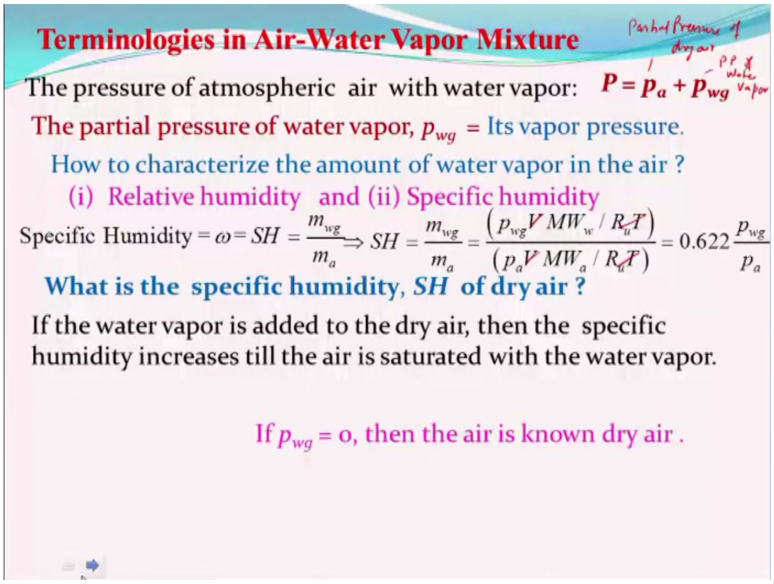

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How to characterize the amount of water vapor in the air ?

(i) Relative humidity and (ii) Specific humidity

$$\text{Specific Humidity} = \omega = SH = \frac{m_{wg}}{m_a} \Rightarrow SH = \frac{m_{wg}}{m_a} = \frac{\left(p_{wg}\cancel{V}\, MW_w / R_u\cancel{T}\right)}{\left(p_a\cancel{V}\, MW_a / R_u\cancel{T}\right)} = 0.622\frac{p_{wg}}{p_a}$$

What is the specific humidity, *SH* of dry air ?

If the water vapor is added to the dry air, then the specific humidity increases till the air is saturated with the water vapor.

If $p_{wg} = 0$, then the air is known dry air .

If water vapor is added to the air then specific humidity of course will increase right till whittle it attains the saturated condition right and once it is saturated you cannot really change that unless you change the temperature right because in atmosphere you cannot really change the pressure that much but temperature can go up so therefore we need to know that what is the relative humidity.

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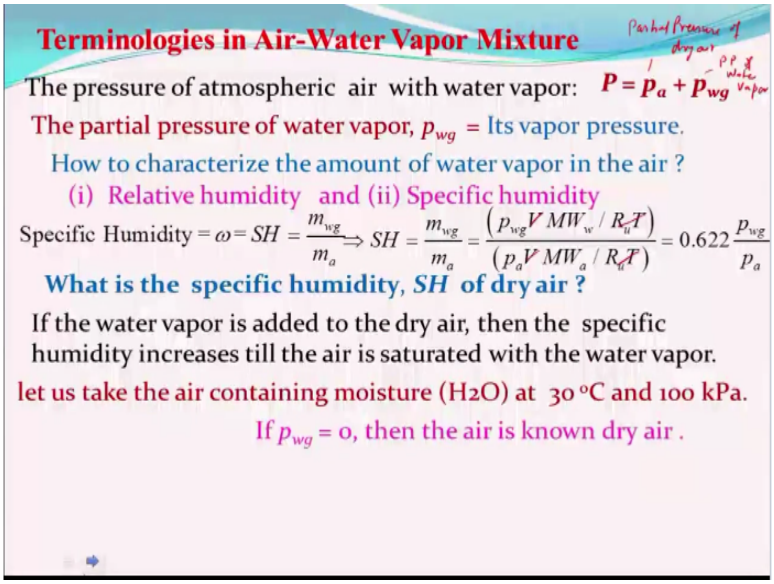

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What is the specific humidity, *SH* of dry air ?

If the water vapor is added to the dry air, then the specific humidity increases till the air is saturated with the water vapor.

let us take the air containing moisture (H2O) at 30 °C and 100 kPa.

If p_{wg} = 0, then the air is known dry air .

And let us you know take an example of air conditioning moisture you know air containing moisture at 30 degree Celsius hundred kilo Pascal's and if you look at PS you know pw that is a partial pressure of the water at saturated condition is basically 0 point 2 4 3 kilo Pascal’s right and this you can get from the way from your saturated steam table corresponding to the 30 degree Celsius okay and if pw in the air or the weight air is less than four point two four three then it will be unsaturated that means it can carry more amount as some amount of air but if it is equal to that.

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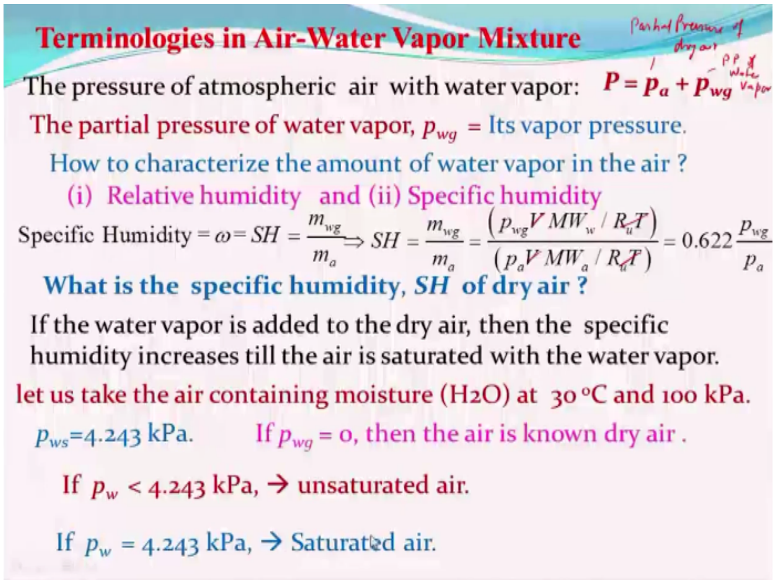

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What is the specific humidity, *SH* of dry air ?

If the water vapor is added to the dry air, then the specific humidity increases till the air is saturated with the water vapor.

let us take the air containing moisture (H2O) at 30 °C and 100 kPa.

p_{ws}=4.243 kPa. If p_{wg} = 0, then the air is known dry air .

If $p_w < 4.243$ kPa, → unsaturated air.

If $p_w = 4.243$ kPa, → Saturated air.

Then it cannot really take and that is the saturated condition but if pw is equal to four point two four three kilopascal then it has saturated a right so therefore we need to look at the you know define a quantity which will tell us how much air can carry in a water moisture corresponding to the particle saturated condition so that will be the relative humidity which will be discussing in the next class more elaborately and we will be trying tolerate the specific humidity with the relative annuity so that we can see how we can you know control and other things thank you very much you.

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