

Introduction:

A mixture is defined as a combination of two or more gases or a gas and a liquid or vice versa. For Ex, air is a mixture of nitrogen & O₂ & the fuel oil used in our automobiles is a mixture of CO, CO₂, H₂O, O₂, N₂ etc. May thermodynamic applications involve mixture of several pure substance. These mixtures are classified as follows.

• Non-Reactive mixture.

If the constituents of the mixture do not react chemically with one another & are in a fixed proportion by weight, it is known as non-reactive mixture. As they are homogeneous mixture of different gases, they can be treated as pure substance.

• Reactive mixture.

If the constituents of the mixture reacts chemically with one another & results in combustion it is known as reactive mixture. Here combustion refers to fairly rapid reaction accompanied by a flame, which occurs b/w a fuel & O₂ carriers such as air.

Technology of a gas mixture.

- mole: the amount of substance in a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. It is denoted by 'N'
- molar mass: The mass per kilo mole of any substance. It is denoted by 'M' & is represented as $M = \frac{m}{N}$ where, M = mass of substance
N = No. of moles.
- partial pressure: If a mixture occupies a volume 'V' at a temp 'T', the P_x(P) of any constituent of a mixture when it alone occupied the vol 'V' & temp (T) is known as partial p_x of that constituent.

• Mole fraction: The ratio of no. of moles of a single substance to that of the total no. of moles is called mole fraction & is denoted by ' x '.

• Mass fraction: The ratio of mass of a single substance to the mass of the total mixture is called mass fraction & is denoted by ' y '

→ For Ex:- Let us suppose, a container consists of a mixture of gases A, B, C... existing in equilibrium at pressure 'P' & temp 'T' having vol^m, v as shown in fig.

- Total mass of the mixture, $M_m = M_A + M_B + M_C \dots$

$$= \sum_i m_i$$

- Total No. of moles in mixture, $N_m = N_A + N_B + N_C \dots$

$$= \sum_i N_i$$

- Mass fraction of A = $y_A = \frac{M_A}{M_m}$

- Mass fraction of B = $y_B = \frac{M_B}{M_m} \dots$ and soon.

- Total mass fraction of the mixture = $y_A + y_B + y_C + \dots$

- mole fraction of A = $x_A = \frac{N_A}{N_m}$, $B = x_B = \frac{N_B}{N_m}$, $C = x_C = \frac{N_C}{N_m}$

- Total pressure of mixture, $P_m = P_A + P_B + P_C + \dots = \sum_i P_i$

Analysis of mixture.

Analysis mixtures are classified into two types.

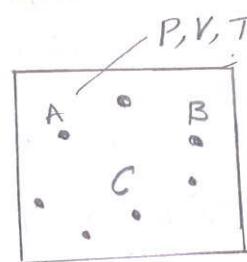
a. Volumetric analysis or mole analysis.

b. Gravimetric analysis or mass analysis.

a. Volumetric analysis: If the analysis of a mixture of gas carried out on the basis of volume measurement, it is treated as volumetric analysis.

mole fraction = $\frac{\text{No. of moles of components}}{\text{Total no. of moles of mixture}} \Rightarrow x_A = \frac{N_A}{N_m}$

$$x_B = \frac{N_B}{N_m} \Rightarrow x_C = \frac{N_C}{N_m}$$



$$\therefore x_A + x_B + x_C + \dots + x_N = \sum_i x_i = 1$$

The sum of mole fraction of all the components present in the mixture is unity.

b. Gravimetric analysis. If the analysis of a mixture is based on the basis of measurement of mass then it is known as gravimetric analysis. Generally, this analysis is not done experimentally.

Consider a mixture of gas, whose total sum of masses i.e.,

$$M_{\text{total}} = M_A + M_B + M_C + \dots + M_n = \sum_i M_i$$

$$\text{Mass fraction} = \frac{M_i}{\sum M_i} = \frac{M_i}{M_{\text{total}}}.$$

$$y_A = \frac{M_A}{M_{\text{total}}}$$

$$y_B = \frac{M_B}{M_{\text{total}}} \dots \text{and so on}$$

$$\therefore y_A + y_B + y_C + \dots + y_N = \sum y_i = 1$$

The sum of mass fraction of all the components in the mixture is unity

Conversion of volumetric analysis into gravimetric analysis and vice-versa.

Generally, for gases, the analysis is made on volumetric basis. To convert this into gravimetric analysis, first the volume fraction of each constituent is obtained. Then the mole fraction of each constituent is multiplied by its molecular weight to get the relative mass of each constituent.

constituent	volumetric Analysis (b)	molecular weight (c)	Relative mass (d) $d = b \times c$	Gravimetric analysis $e = \frac{dx100}{cd}$

constituent	Gravimetric analysis (a)	molecular weight (b)	molecular volume fraction, $c = a/b$	volumetric analysis $d = \frac{c \times 100}{E_c}$

laws of mixture.

The laws associated with the mixture of gases are as follows.

- Dalton's law of partial pressure.
- Amagat's law or law of additive volumes.
- Dalton's law of partial pressure.

Dalton's law of partial pressure states that "the total pr. of mixture of gases is equal to the sum of the partial pr. of each constituent if each constituent exists at the temp & vol^m of the mixture of given gases."

$$\boxed{\frac{M_A P_A}{T_M V_M}} + \boxed{\frac{M_B P_B}{T_M V_M}} + \boxed{\frac{M_C P_C}{T_M V_M}} = \boxed{\frac{M_M P_M}{T_M T_M}}$$

$$\therefore P_M = P_A + P_B + P_C + \dots + P_n = \sum_i^n P_i$$

where P_M is the pr. of mixture & P_A, P_B, P_C, \dots are partial pr. of each constituent.

since by Dalton's law, each constituent occupies the whole volume & the temp is same for each constituent, we can write.

$$T = T_A = T_B = T_C = \dots ; V = V_A = V_B = V_C = \dots$$

\therefore the mass of mixture can be written as, $M_M = M_A + M_B + M_C + \dots + M_n$

$$\therefore P_A V = M_A R_A T = n_A \bar{R} A T ; P_B V = M_B R_B T = n_B \bar{R}_B T ;$$

$$\therefore (P_A + P_B + P_C + \dots) V = (n_A + n_B + n_C + \dots) \bar{R} T .$$

$$\therefore P_M V = n \bar{R} T .$$

- Amagat's law of additive volume.

Total volume of mixture of gases is equal to the sum of the partial volume of each constituent, if each existed along at a pr. temp of the mixture.

$$\boxed{\frac{M_A V_A}{P_M T_M}} + \boxed{\frac{M_B V_B}{P_M T_M}} + \boxed{\frac{M_C V_C}{P_M T_M}} = \boxed{\frac{M_M V_M}{P_M T_M}}$$

From the above definition, we can write.

$$V_M = V_A + V_B + V_C + \dots + V_n = \sum_{i=1}^n V_i$$

Suppose a mixture of gases are in a system at a vol/m³ (V) temp (T) & P. (P) separate the gases such that one constituent occupies a certain part of the volume, the second constituent another part and so on.

The actual volume filled by the mixture is equal to the sum of the partial volume of the constituents.

we know that, $PV_A = n_A RT$; $PV_B = n_B RT$; $PV_C = n_C RT$. (adding)

we get, $\frac{V_A}{V_M} = \frac{n_A}{n_M}$; $\frac{V_B}{V_M} = \frac{n_B}{n_M}$; $\frac{V_C}{V_M} = \frac{n_C}{n_M}$; and so on

$\therefore V_A = x_A V$; $V_B = x_B V$, $V_C = x_C V$; and so on.

The ratio of partial volume of any constituent to the total vol/m³ is equal to the mole fraction of the constituent.

Adiabatic mixing of gases.

M_A		M_B
P_A		P_B
T_A		T_B
V_A		V_B

$M_m = M_A + M_B$
$V = V_A + V_B$
P, T

Consider a closed vessel having two gases A & B separated from each other by a thin wall or diaphragm. When the wall is removed the gases mix with each other & occupies the total volume of the vessel & behave as if the other gases are not present. This process is irreversible.

It can be simplified by assuming the process to be adiabatic as the vessel is perfectly thermal insulated & therefore, there will be an increase in entropy of the system.

In the free expansion process, the internal energy before expansion is equal to the internal energy after expansion.

$$\therefore U_1 = U_2 \Rightarrow U_1 = n_A C_{VA} T_A + n_B C_{VB} T_B$$

$$U_2 = (n_A C_{VA} + n_B C_{VB}) T.$$

$$\therefore n_A C_{VA} T_A + n_B C_{VB} T_B = n_A (C_{VA} + n_B C_{VB}) T$$

$$T = \frac{n_A C_{VA} T_A + n_B C_{VB} T_B}{n_A C_{VA} + n_B C_{VB}}$$

Properties of Ideal Gas mixtures.

The various properties of ideal gas mixture are as follows.

- Internal energy
 - Enthalpy
 - Specific Heat
 - Entropy
1. Internal Energy:

The total internal energy of the system can be found by using Gibb's Dalton's law.

$$U = U_A + U_B + U_C + \dots + U_n = \sum_{i=A}^n u_i \quad \dots \dots \dots (1)$$

The total internal energy of each constituent on mass basis can be expressed as

$$mu = m_A U_A + m_B U_B + m_C U_C + \dots + m_n U_n \quad \dots \dots \dots (2)$$

Here 'u' refers to the specific internal energy deriving eq(2) we get

$$u = y_A U_A + y_B U_B + y_C U_C + \dots + y_n U_n = \sum y_i u_i \text{ kJ/kg} \quad \dots \dots \dots (3)$$

The total internal energy of each constituent on mole basis expressed

$$nU = n_A U_A + n_B U_B + n_C U_C + \dots + n_n U_n \quad \dots \text{--- (1)}$$

By using the above procedure, we get

$$U = \alpha_A U_A + \alpha_B U_B + \alpha_C U_C + \dots + \alpha_n U_n = \sum_i \alpha_i u_i \text{ kJ/kg mole.}$$

2. Enthalpy

The enthalpy of a mixture of ideal gas is the sum of enthalpies of individual constituents. Therefore, $h = h_A + h_B + h_C + \dots + h_n$

$$h = \sum_i h_i. \quad \dots \text{--- (2)}$$

The enthalpy can be found by either mass basis or mole basis. On the basis of mass, eqn(2) can be written as.

$$mh = M_A h_A + M_B h_B + M_C h_C + \dots + M_n h_n \quad \dots \text{--- (2)}$$

Dividing eqn(2) by M , we get

$$h = \frac{M_A}{M} h_A + \frac{M_B}{M} h_B + \frac{M_C}{M} h_C + \dots$$

$$h = Y_A h_A + Y_B h_B + Y_C h_C + \dots$$

$$= \sum_i Y_i h_i \text{ kJ/kg} \quad \dots \text{--- (3)}$$

On the basis of no. of moles eqn(1) we can be written as.

$$nh = n_A h_A + n_B h_B + n_C h_C + \dots$$

Dividing eqn(4) by n we get

$$h = \frac{n_A}{n} h_A + \frac{n_B}{n} h_B + \frac{n_C}{n} h_C + \dots$$

$$h = \alpha_A h_A + \alpha_B h_B + \alpha_C h_C + \dots$$

$$h = \sum_i \alpha_i h_i \text{ kJ/kg mole.}$$

3. Specific heat:

The constant volume specific heat & constant pressure specific heat equations can be obtained by two ways.

i. On the basis of mass.

ii. On the basis of moles.

Equation for constant volume specific heat.

We know that ; $m_u = m_A u_A + m_B u_B + m_C u_C + \dots$

Substituting the value of $u = C_v dT$ in eqn (1), we get

$$m C_v dT = m_A C_v A dT + m_B C_v B dT + m_C C_v C dT + \dots$$

$$\therefore m C_v = m_A C_v A + m_B C_v B + m_C C_v C + \dots$$

Dividing the above eqn by m , we get

$$C_v = \frac{m_A}{m} C_v A + \frac{m_B}{m} C_v B + \frac{m_C}{m} C_v C + \dots$$

$$\therefore C_v = Y_A C_v A + Y_B C_v B + Y_C C_v C + \dots$$

$$C_v = \sum_i Y_i C_{vi} \quad \dots \quad (2)$$

Similarly we get, $n C_v = n_A C_v A + n_B C_v B + n_C C_v C + \dots$

Dividing the above eqn by n we get

$$C_v = \frac{n_A}{n} C_v A + \frac{n_B}{n} C_v B + \frac{n_C}{n} C_v C + \dots$$

$$C_v = \alpha_A C_v A + \alpha_B C_v B + \alpha_C C_v C + \dots$$

$$C_v = \sum_i \alpha_i C_{vi} \text{ kJ/kg mole.} \quad \dots \quad (3)$$

Equation for constant pressure specific heat.

We know that,

$$m' h = m_A h_A + m_B h_B + m_C h_C + \dots \quad (4)$$

$h = C_p dT$ in eqn (4) we get,

$$m C_p dT = m_A C_p A dT + m_B C_p B dT + m_C C_p C dT + \dots$$

$$C_p = m_A C_p A + m_B C_p B + m_C C_p C + \dots$$

Dividing the above eqn by m , we get

$$C_p = \frac{m_A}{m} C_p A + \frac{m_B}{m} C_p B + \frac{m_C}{m} C_p C + \dots$$

$$C_p = Y_A C_p A + Y_B C_p B + Y_C C_p C + \dots$$

$$C_p = \sum_i Y_i C_{pi} \text{ kJ/kg K.}$$

Similarly, we get.

$$nCP = n_A C_{PA} + n_B C_{PB} + n_C C_{PC} + \dots$$

$$CP = x_A C_{PA} + x_B C_{PB} + x_C C_{PC} + \dots$$

$$CP = \sum_i x_i CP_i \text{ kJ/kg cycle.}$$

4. Entropy of Ideal gas mixture.

Here also the entropy of a given mixture of ideal gases can be found out by using Gibb's Dalton's law - the entropy of the mixture of ideal gases is equal to the sum of the entropies of the constituent gases when each ideal gas is at a temp & vol^m of the mixture.

$$S = S_A + S_B + S_C + \dots + S_N = \sum_i S_i \text{ (or)}$$

$$CS = C_A S_A + C_B S_B + C_C S_C + \dots$$

Dividing the equation by C , we get

$$S = \frac{C_A}{C} S_A + \frac{C_B}{C} S_B + \frac{C_C}{C} S_C + \dots$$

$$S = Y_A S_A + Y_B S_B + Y_C S_C + \dots$$

$$S = \sum_i y_i S_i \text{ kJ/kg}$$

On the basis of moles,

$$S = x_A S_A + x_B S_B + x_C S_C + \dots$$

$$S = \sum_i x_i S_i \text{ kJ/kg mole.}$$

The change of entropy of an ideal gas mixture in terms of mass basis is

$$S_2 - S_1 = \sum_i Y_i (S_2 - S_1)$$

$$= \sum_i Y_i C_P \cdot \int \frac{dT}{T} - \sum_i Y_i R \ln \frac{P_2}{P_1}$$

$$= C_P \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$\text{Also } S_2 - S_1 = C_V \ln \frac{T_2}{T_1} - R \ln \frac{V_2}{V_1}$$

Similarly, change of entropy in terms of mole basis,

$$S_2 - S_1 = C_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

Combustion Process.

Combustion is a process of burning off fuel in the presence of O_2 or substance containing O_2 such as air. The fuel & the oxidizer used for combustion are called 'reactants' & the constituents resulting from the reaction are called products. The basic combustion reaction for different elements is as follows.

- For carbon, $C + O_2 \rightarrow CO_2$
- For Hydrogen, $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$
- For Sulphur, $S + O_2 \rightarrow SO_2$
- For Methane, $CH_4 + 2O_2 \rightarrow CO_2 + H_2O$

* Theoretical air required for complete combustion

The O_2 required for the combustion of fuel is normally obtained by supplying oxidizers such as air, rather than pure oxygen. The air supplied consists of inert nitrogen which does not enter into the reaction. It is just added to both sides of the equation. Nitrogen & oxygen are the main constituents of air & the % of other gases present are so small that the air can be assumed as a mixture of N_2 & O_2 .

N₂ 79% & O₂ 21% by volume basis & N₂ 77% & O₂ 23% by mass.

If the fuel contains C, H₂, O₂ is then the mass of O₂ required per kg of fuel is given by the relation.

$$\frac{1}{100} \left[\frac{8}{3} (C + 8H + S - O) \right]$$

$$\therefore \text{Air required} = \frac{1}{100} \left[\frac{8}{3} (C + 8H + S - O) \right] \times \frac{100}{23} \text{ kg/l kg of fuel.}$$

Air-fuel ratio

The ratio of mass of air to the mass of the fuel supplied. In terms of volumetric analysis. The ratio of moles of air to moles of fuel supply

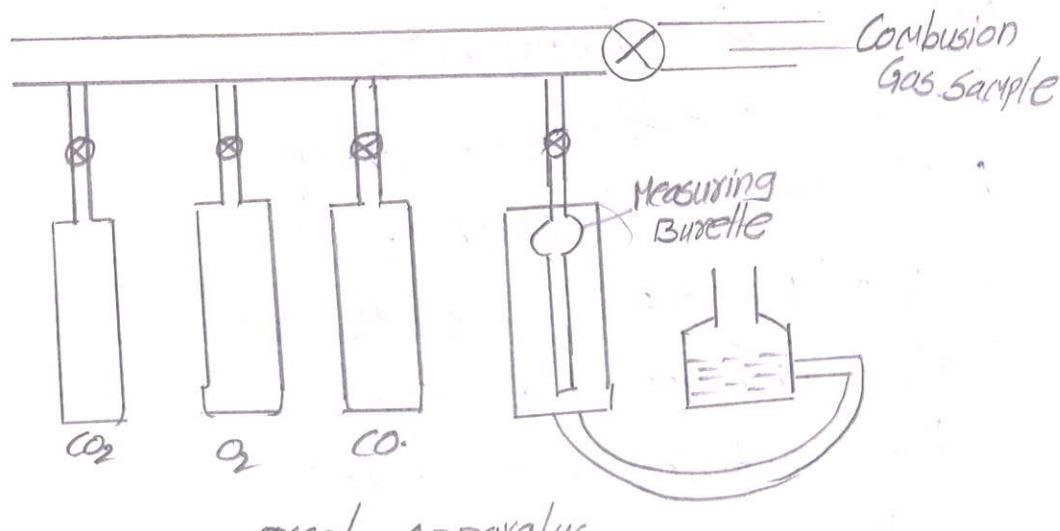
$$\therefore \text{Air-fuel ratio} = \frac{\text{Mass of air}}{\text{Mass of fuel}} \text{ or } \frac{\text{moles of air}}{\text{moles of fuel}}$$

The reciprocal of air fuel ratio is termed as fuel air ratio

$$\therefore \text{A/F ratio} = \frac{1}{\text{F/A ratio}}$$

Analysis of the products of combustion.

The analysis of product of combustion is usually done by using an apparatus called oxasat apparatus. As shown in fig:



These flasks consists of potassium hydroxide (KOH), pyrogalllic acid in alkali & cuprous chloride for absorbing CO₂, O₂ & CO respectively.

A known volume of a sample of combustion product is drawn into the measuring burette by lowering the levelling bottle. The valve is closed & sample is made to pass through each of the flask

containing reagents that absorb the constituent gases. When the sample is passed through each vessel, it is returned to the vessel.

The analysis is carried out at a temp which is lower than the dew point temp of the coke combustion products, & hence water vapour is not present in the products analyzed by ossat apparatus. Ossat apparatus gives the analysis on the dry basis.

Enthalpy of formation & Enthalpy of Reaction.

• Enthalpy of formation of a compound is generally taken at 25°C & later then, $C + O_2 \rightarrow CO_2$ (i)

Consider a reaction as stated above (neglecting heat loss)

$$\therefore Q = H_P - H_R = h_{CO_2}^{\circ} - h_C^{\circ} - h_{O_2}^{\circ}$$

where, $h_{CO_2}^{\circ}$ = molal enthalpy of CO_2

h_C° = molal enthalpy of carbon

$h_{O_2}^{\circ}$ = molal enthalpy of O_2

We have, $Q = H_P - H_R$ or $Q + H_R = H_P$.

where, H_P = Enthalpy of product

H_R = Enthalpy of reactants.

The heat transfer is actually found to be -393522 kJ/kmole of CO_2 formed

$$\therefore -393522 + H_R = H_P \quad [\text{Then } H_R = 0]$$

$$\therefore H_P = -393522 \text{ kJ/kmole}$$

• Enthalpy of Reaction. Consider a 'steady' state steady flow device undergoing a combustion process as shown in fig. Let us carry out a chemical reaction in the device at a constant P & with no work transfer.

for a steady flow process,

$$\Delta E \cdot K = 0$$

$$\Delta E \cdot P = 0$$

$$\therefore Q = H_P - H_R = \Delta H$$

where, H_P = Enthalpy of products

H_R = Enthalpy of reactions.

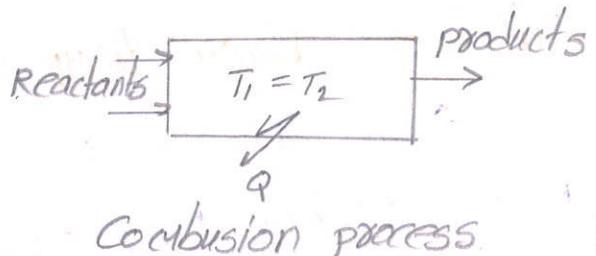
If the temp of both reactants & products are same then the quantity ΔH is called as enthalpy of reaction or heat of reaction.

- If Q is positive then $H_P > H_R$
- If Q is negative then $H_P < H_R$

Heating Values of fuels:

The heat of combustion of fuel at constant P & constant volume are referred to as heating values of the fuels

When a hydrocarbon fuel is burned in a combustion process, water will appear in the products. The water may appear either in liquid or vapour phase. When the water is the products due to combustion is in the liquid state, the energy released will be maximum & the heat of reaction is called as higher heating value (HHV). If all the water in the product due to combustion is in vapour state the heat of reaction is LHV.



$$\therefore HHV = LHV + M_{H_2O} h_{fg}$$

where, M_{H_2O} = amount of water formed kg of water/kg of fuel

h_{fg} = enthalpy of vaporization of water kJ/kg

Adiabatic flame temp. during Combustion of fuel.

Some of the energy released during a combustion process is lost as heat to the surroundings or is used internally to raise the temp. of the combustion product, when work interaction & change in K.E. & P.E is absent

The max. temp. can be achieved only when the fuel is burned with theoretical amount of O_2 . The use of excess O_2 , incomplete combustion & the dissociation of the combustion products also reduces the flame temp.

$$H_R = H_P$$

$$\sum N_P (h_f^{\circ} + \bar{h} - \bar{h}^{\circ})_P = \sum N_O (h_P^{\circ} + \bar{h} - \bar{h}^{\circ}),$$

PSYCHROMETRY

8

Introduction.

Air usually comprises of gases like nitrogen and oxygen with a mixture of water vapour in varying amounts. In atmospheric air, water vapour is always present & its relative weight is less than the weight of atmospherically.

The content of water vapour in air plays an important role in air-conditioning. The art of measuring the moisture content of air is called 'psychometry'. Psychometric properties.

- Dry air: The mixture of O₂ & N₂ without the moisture content & other gases is called dry air. Usually, dry air is not found in nature.
- Saturated air: Moist air is said to be saturated when it exists in equilibrium with an associated moisture. When the air is saturated with water vapour, the partial pressure of water vapour is equal to the saturation pressure.
- Dry Bulb Temp (DBT):- The temp of air which is measured by an ordinary thermometer is known as drybulb temp.
- Wet bulb temp (WBT): The temp of air is measured by a thermometer where its bulb is covered with a wet cloth & is exposed to a current of moving air is called as WBT.
- Dew point temp (DPT): It is the temp at which the moisture present in the atmospheric air begins to condense when the air is cooled.
- Specific humidity (or) Humidity ratio:- The ratio of mass of water vapour to the unit mass of dry air. It is generally expressed as a gms / kg of dry air.

$$\therefore \text{Humidity ratio } (\omega) = \frac{\text{Mass of water vapour}}{\text{Mass of dry air}} = \frac{M_V}{M_d}$$

Let V & T be the volume & Temp of gas mixture.

Applying Dalton's law, we get

$$P_V V = M_V R_V T$$

$$M_V = \frac{P_V V}{R_V T} \quad \& \quad P_a V = M_d R_a T$$

$$M_d = \frac{P_a V}{R_a T}$$

$$\therefore \omega = \frac{M_V}{M_d} = \frac{P_V V / R_V T}{P_a V / R_a T} \Rightarrow \frac{P_V R_a}{P_a R_V}$$

$$\therefore \omega = \frac{0.287}{0.461} \cdot \frac{P_V}{P_a} = 0.622 \frac{P_V}{P_a}$$

But total Pressure.

$$P_t = P_a + P_V$$

$$P_a = P_t - P_V$$

$$\omega = \frac{0.622 P_V}{P_t - P_V} \quad [\text{for saturated air, } P_V = P_{sat}]$$

$$\omega_{sat} = \frac{0.622 P_{sat}}{P_t - P_{sat}}$$

• Relative Humidity (ϕ): it is defined as the ratio of partial P_V of water vapour in the mixture to the saturated partial P_{sat} at dry bulb temp

$$\therefore \phi = \frac{\text{mass of water vapour in given volume}}{\text{mass of saturated water vapour in the same volume}}$$

• Degree of saturation (μ): The ratio of mass of water vapour associated with unit mass of dry air to the mass of saturated water vapour per unit mass of dry air.

$$\mu = \frac{\text{mass of water vapour / unit mass of dry air}}{\text{mass of saturated water / unit mass of dry air}}$$

- Absolute Humidity: The mass of water vapour present in unit volume of dry air. It is also known as vapour density.

We know that, $P_a = P_a R_a T$.

where, $P_a = \frac{P_a}{R_a T}$

Since, $\omega = \frac{M_v}{M_a} = \frac{P_v}{P_a}$,

$$P_v = \omega P_a$$

$$= \omega \times \frac{P_a}{R_a T}$$

$$P_v = \frac{\omega (P_b - P_v)}{R_a T}$$

- Enthalpy of moist air.

It is also called as a mixture of dry air & water vapour.

Enthalpy of moist air = Enthalpy of dry air + Enthalpy of water vapour
+ Enthalpy of water vapour when moisture is super heated.

$$h = h_a + h_{v_g}$$

where $h_a = C_p a t_{dbt}$

$$h_v = \omega \cdot h_s$$

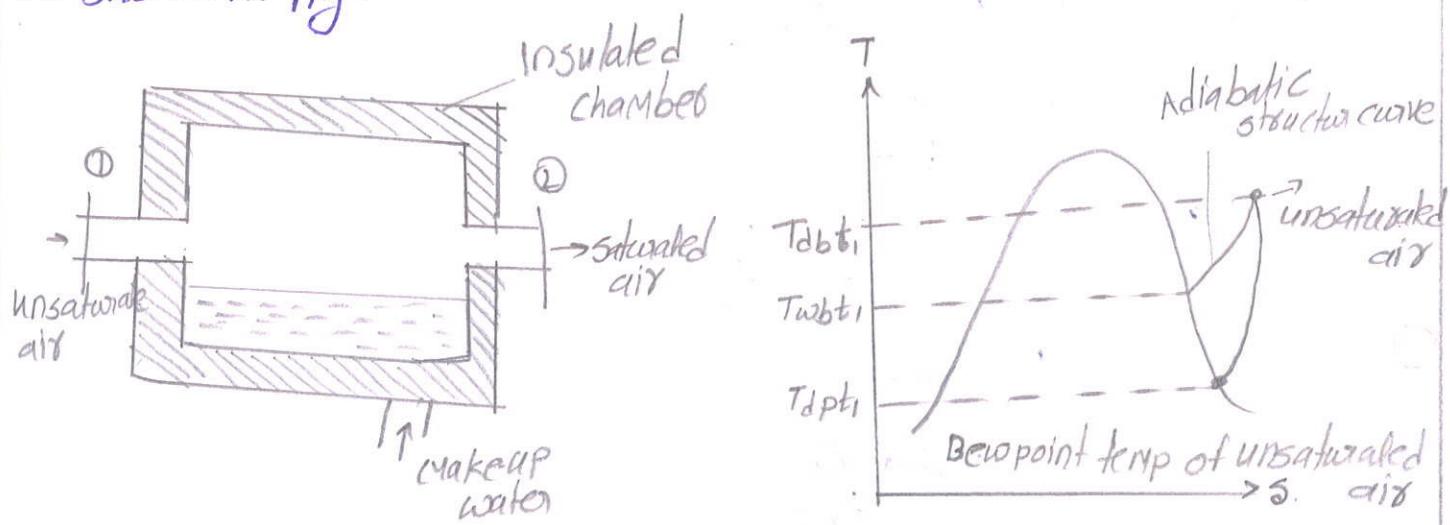
h_s = Enthalpy of water vapour at DPT

$$h_{v_g} = \omega C_p s (t_{dbt} - t_{dpt})$$

$$h = C_p a t_{dbt} + \omega h_s + \omega C_p s (t_{dbt} - t_{dpt})$$

Adiabatic structure.

The temp at which the air is brought to saturated condition by adding water adiabatically to the air in a steady flow. The supply of water is at the final temp of the mixture. This process is shown in fig.



Let h_1 = Enthalpy of saturated air at inlet

h_2 = Enthalpy of saturated air at outlet

w_1 = Specific humidity of air at inlet

w_2 = Specific humidity of air at outlet

h_{fw} = sensible heat of water at adiabatic saturation temp

Since : Enthalpy at inlet = Enthalpy of outlet

$$h_1 + (w_2 - w_1) h_{fw} = h_2$$

$$h_1 + w_2 h_{fw} - w_1 h_{fw} = h_2$$

$$h_1 - w_1 h_{fw} = h_2 - w_2 h_{fw}$$

But, $h_1 = h_{a1} + w_1 h_{s1}$

$$h_2 = h_{a2} + w_2 h_{s2}$$

$$\therefore (h_{a1} + w_1 h_{s1}) - w_1 h_{fw} = (h_{a2} + w_2 h_{s2}) - w_2 h_{fw}$$

$$h_{a1} + w_1 (h_{s1} - h_{fw}) = h_{a2} + w_2 (h_{s2} - h_{fw})$$

$$\omega_1(h_{s1} - h_{f20}) = h_{a2} - h_{a1} + \omega_2(h_{s2} - h_{f20})$$

$$\omega_1 = \frac{h_{a2} - h_{a1} + \omega_2(h_{s2} - h_{f20})}{h_{s1} - h_{f20}}$$

where, h_{a1} = Enthalpy of dry air at t_{db1} ,

h_{s1} = Enthalpy of superheated air at t_{db1} ,

h_{a2} = Enthalpy of air at t_{db2} ,

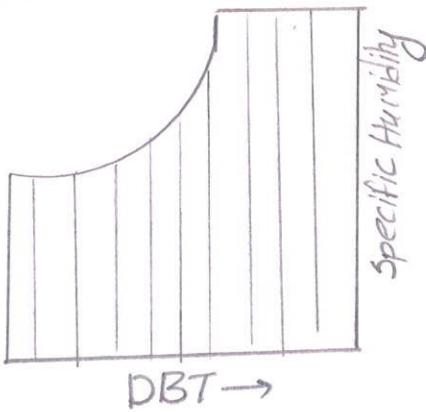
h_{s2} = Enthalpy of saturated vapour at t_{db2}

Psychrometric Lines.

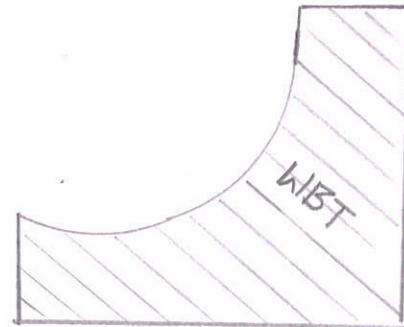
The lines drawn on psychrometric chart areas follows.

• Dry Bulb temp (DBT) lines:

DBT lines are vertical & \perp to abscissa. The DBT is shown on the x-axis. The DBT extends from left to right representing 1° change in temp.



fig(a): DBT lines



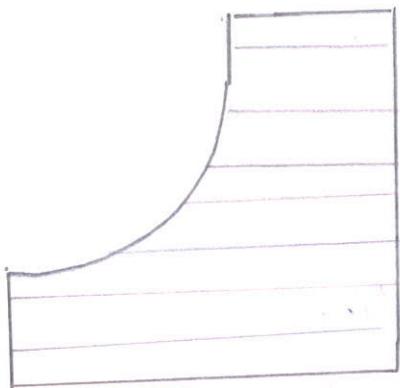
fig(b): WBT lines

Wet Bulb temp (WBT) Lines:

The WBT lines are diagonally downward sloping starting from 1st step as shown in fig(b). Each line represents 1° change in temp.

Dew point Temp (DPT) lines

The lines are horizontal lines \parallel to the ordinate & \perp to x-axis on Psych. Saturated curve both DPT & DBT are same.



fig(c): DPT lines



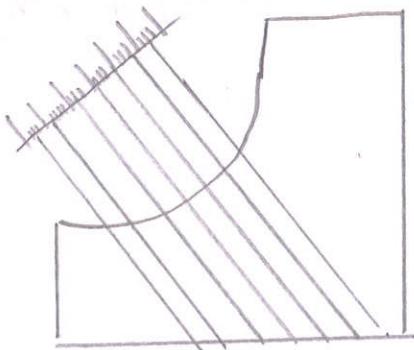
fig(d): Specific Humidity lines $\rightarrow DBT$

- Specific humidity lines

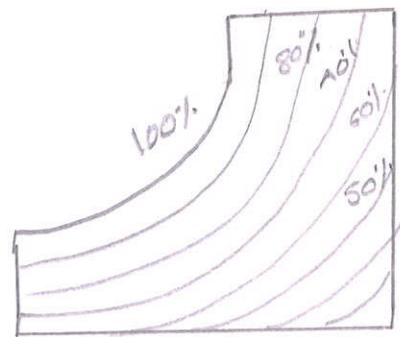
Specific humidity or humidity ratio lines are parallel to x-axis & to y axis these lines are also called as moisture content line.

- Enthalpy lines:

These lines are inclined straight lines as shown in figure(e). The scale on the lines is indicated above the saturation lines.



fig(e): Enthalpy lines



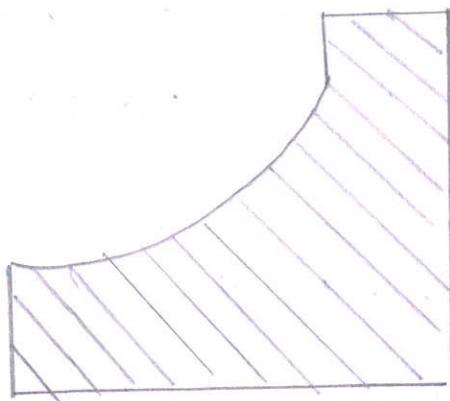
fig(f): Relative Humidity

- Relative Humidity (RH) lines

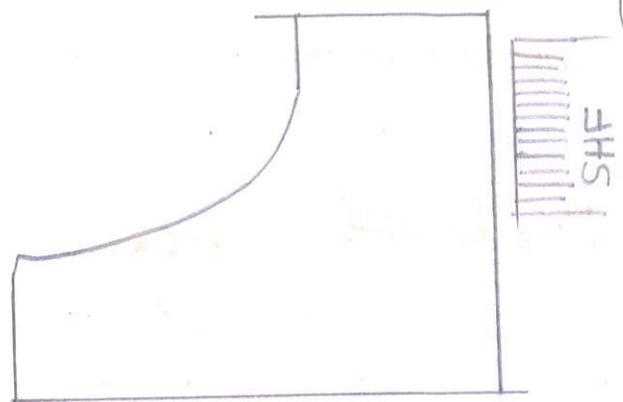
The lines are curved lines & are parallel to each other. Saturation curve shows a relative humidity of 100%. The constant RH lines are shown in fig (f).

- Specific Volume.

These are inclined straight lines & are drawn up to the saturated line or curve.



Fig(g) Specific Volumelines.



Fig(h) SHF scale

- sensible heat factor.

The ratio of sensible heat to the sum of sensible & latent heat.

$$SHF = \frac{S.H}{S.H + L.H}$$

The scale showing SHF is shown on the right side of the chart.

Carrier's Equation.

Dr. Carrier has proposed an equation for calculating the partial pressure of water vapour in the air. This eqn is known as Carrier's eqn.

$$P_v = (P_{vs})_{w.b} = \frac{[P_t - (P_{vs})_{w.b}](t_{db} - t_{w.b})}{1527.4 - 1.3t_{w.b}}$$

where, P_v = Partial pressure of the water vapour

P_{vs} = Partial pressure of water vapour when air is fully saturated

P_t = total pressure of the moist air.

t_{db} = dry bulb temp, °C

$t_{w.b}$ = wet bulb temp, °C

* Vapour pressure: The partial pressure of water vapour calculated by the above formula i.e. by carter's equation is called vapour pr.

Psychometric Chart:

It shows graphically all the necessary air properties used for air conditioning calculations. It shows the relation b/w various properties of air like DBT, WBT, DPT, RH etc. When any two properties stated above are known, then others can be determined directly from the psychometric chart without any mathematical calculation.

