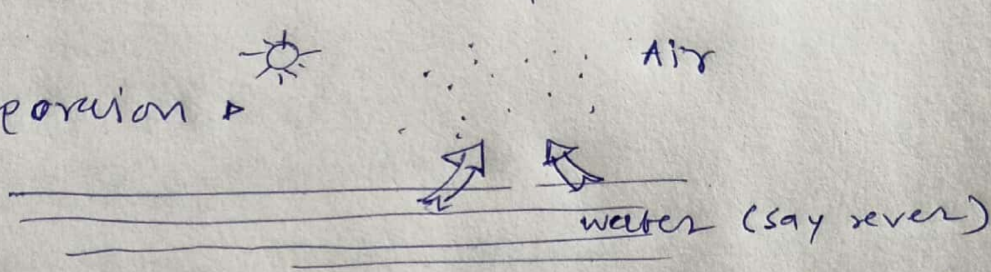
Psychrometric Properties

Atmospheric Air is moist air. The properties of this moist air is called psychrometric properties.

Moist Air = Dry air + Water Vapour

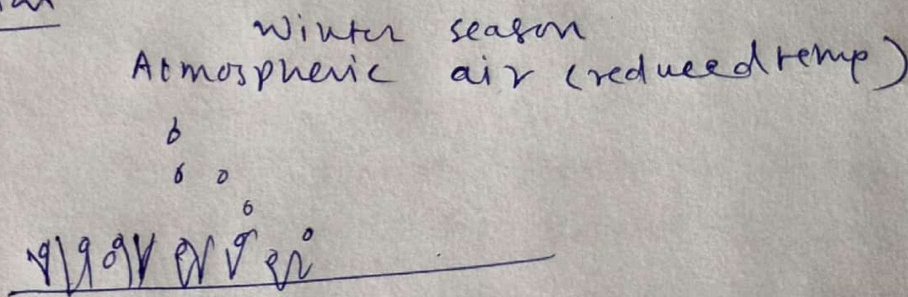
Water vapor in moist air is generally remain present in ~~sat~~ superheated state. The dry air part is assumed constant as water vapour content in moist air continuously changes due to climatic changes (ie. because of condensation or evaporation of water vapor in atmosphere)

exa. Evaporation ▸



Evaporation of water into atmospheric air due to any reason will <u>add</u> water vapour to atmospheric air and hence its humidity will increase.

exa. <u>condensation</u>



Reduced temp in atmosphere will condense the moisture (vapore converted into liquid water droplets) and dew will be formed. The dew is separated from atmospheric air, thus its water vapor content will reduce. Hence humidity of moist atmospheric air will reduce due to condensation let us consider V volume of moist air at temperature t and P. let m be mass of air.

P is now atmospheric pressure and t is called dry bulb temperature (DBT) because our normal thermometer's dry bulb will indicate this temperature.

V — volume
m — mass
P — pressure
t — Temperature

} of moist air

ma → mass of dry air
Pa → Pressure of dry air
t → temp of dry air
$v_a = V/m_a$ sp. volume of d.a.
m_v → mass of w.v.
P_v → Pr of w.v.
t → temp of w.v.
$v_v = V/m_v$ — sp. volume of w.v.

It is imperative that volume of dry air part and volume of water vapour part is same as that of volume of moist air (V). And also temp of dry air, water vapour and its mixture i.e. moist air will be same (t).
The following physical properties of constituents are different

Dry Air →
m_a → mass of dry air
P_a → Partial pressure of d.a.
v_a → V/m_a sp. volume of d.a.

Water vapor →
m_v → mass of water vapor
P_v → Partial pressure of w.v.
$v_v = V/m_v$ sp. volume of w.v.

∴ Total Pressure of moist air $P = P_a + P_v$
and total mass of moist air $m = m_a + m_v$

[As discussed earlier the water vapor part in atmospheric air continuously changes and dry air part remains constant hence, All properties of moist air are measured per unit of dry air.]

① **Absolute or specific humidity or humidity ratio or moisture content (ω)**

It is the ratio of mass of water vapor present in unit mass of dry air.

$$\omega = \frac{m_v}{m_a} \quad \text{(kg of water vapor per kg of dry air)}$$

$$P_v V = m_v \frac{\bar{R}}{M_v} T = m R_v T \quad \text{— (a)}$$

($\bar{R}$ - universal gas const.
$R_v \rightarrow$ Gas constant for water vapor.
$M_v \rightarrow$ molecular weight of water vapour) = 18

$$P_a V = m_a \frac{\bar{R}}{m_a} T = m R_a T \quad \text{— (b)}$$

$m_a \rightarrow$ molecular weight of air $\cong 29$

from (a) & (b)

$$\therefore \omega = \frac{m_v}{m_a} = \frac{M_v}{M_a} \cdot \frac{P_v}{P_a} = \frac{18}{29} \frac{P_v}{P_a}$$

$$\therefore \omega = 0.622 \frac{P_v}{P_a} \quad \text{kg of w.v /kg of d.a.}$$

~~Now~~ or $= 622 \frac{P_v}{P_a}$ gm of w.v / kg of d.a.

Atmospheric pressure $P = P_a + P_v$

$$\therefore P_a = P - P_v$$

$$\therefore \omega = 0.622 \frac{P_v}{P - P_v}$$

$P_v \ll P$ (Partial Pr of w.v. is very low compared to atmospheric pressure $\therefore P - P_v \cong P$

$$\therefore \omega \cong 0.622 \frac{P_v}{P}$$

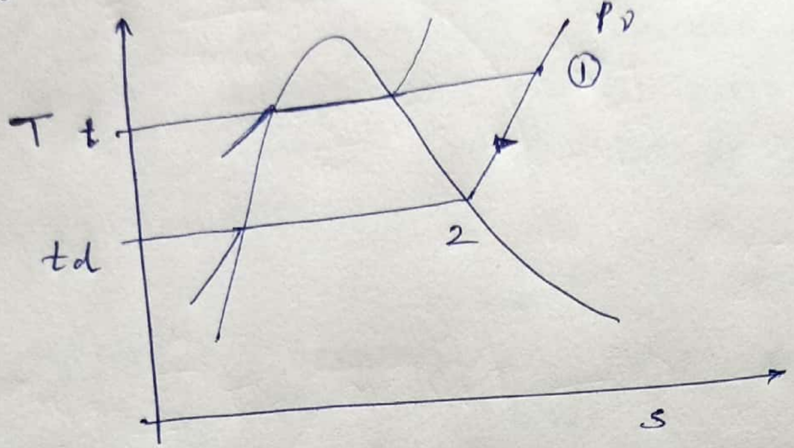
$$\omega = f(P_v)$$

If Humidity increased partial pr of w.v. increases linearly.

(2) Dew point Temperature : (DPT) or td

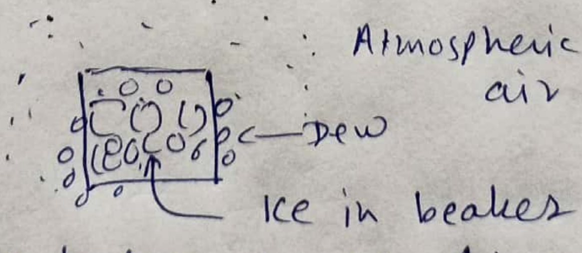
As you know moist air comprises of dry air part and water vapour. Water vapor is mostly in superheated ~~saturated~~ condition and its pressure is (P_v)

~~If~~ we show this w.v. condition on T.S. diagram as point (1), as follows.



The temperature of air (dry bulb temp) and w.v is t and w.v. exists in superheated condition at (1) its partial pressure is P_v. If the air is cooled at constant pressure, its temperature will continuously decrease, and it will reach saturation temp td. At this point 2, w.v. will change phase from vapor to liquid and first drop of water vapor (Dew) will appear. Hence this is called ~~the~~ dew point temp

Exa.



If you keep ice beaker (cold drink bottle) in air, ~~air is~~ surrounding air will get condensed at const pressure (Atmospheric pressure does not change) when condensation starts the dew will appear on bottle) The condensation temp is the saturation temp at this const. pressure P_v.

Defination of Dew point Temperature (DPT or td):

It is the temperature to which the moist air must be cooled at constant pressure till the first drop of dew ~~appeared~~ appears.

or

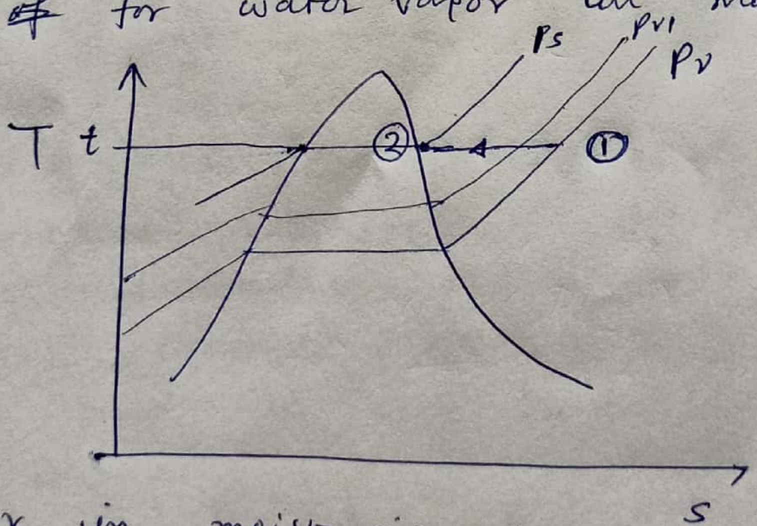
It is the saturation ~~press~~ temperature of water corresponding to partial pressure of water vapor in moist air, ~~to~~ which air is to be cooled so that dew is ~~#~~ separated by condensation

—x—

The difference between DBT and DPT is called Dew point Depression: $= t - t_d$

—x—

Degree of Saturation: Again reffering to T–s diagram ~~of~~ for water vapor in moist air as follows



water vapor in moist air is at superheated state ① and its temp is t (dpt) and partial pressure is P_v. If more moisture is added to this moist air keeping temp t ~~constants~~ Constant, its partial pressure will continuosly increase say P_{v1}, P_{v2} etc. until it reaches P_s at point ②. After this point-2 we can not add w.v. (moisture) to air as water vapour can not remain in vapour state beyond this point, i.e. ~~and~~ we have reached saturated state.

Means moist air is saturated with w. vapour

∴ The partial pressure corresponding to this point (Ps) is called saturation pressure. and air at this point is said to be saturated.

__Degree of Saturation__ (μ) is defined as the ratio of absolute humidity (ω) of unsaturated air (at point 1) to absolute humidity (ω_s) of saturated air (at point 2)

$$\therefore \quad \mu = \frac{\omega}{\omega_{sat}} = \frac{0.622\, P_v / P - P_v}{0.622\, P_s / P - P_s}$$

$$= \frac{P_v}{P_s} \frac{(P - P_s)}{(P - P_v)} = \phi \frac{(P - P_s)}{(P - P_v)}$$

__Relative Humidity__ (ϕ) : Again reffering to previous diagram, we can see that at point ①, air is unsaturaded and it will ~~hold~~ have less moisture content. while at ② Air is saturated and it will hold maximum moisture content.

Relative Humidity is defined as

$$\phi = \frac{\text{mass of w.v. in unsaturated air}}{\text{mass of w.v. in saturated air at same temp}}$$

$$\phi = \frac{m_v}{m_s} = \frac{P_v V / R_v T}{P_s V / R_v T} = \frac{P_v}{P_s}$$

[Hence it is simply the ratio of partial pressure of W.V. of unsaturated air to Partial Pr. of Saturated air at same temp]

Enthalpy of moist Air

Enthalpy of moist air = Enthalpy of Dry air + Enthalpy of moist air

$= h_a + \omega h_v$ kJ/kg of d.a.

Enthalpy of dry air at temp t and pressure p, $h_a = C_p \Delta t$

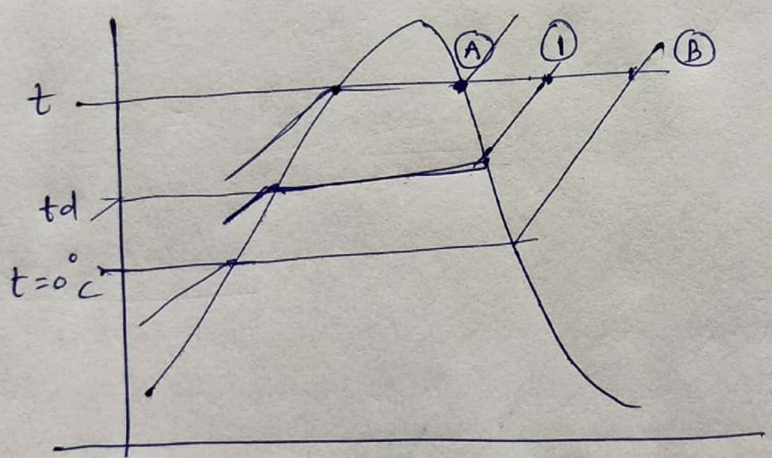
Considering zero enthalpy at 0°C temp.

$h_a = c_p t = 1.005 t$

$c_p = 1.005$ kJ/kgK for air

To calculate Enthalpy of water vapour

Consider following T-s diagram.



At the low partial pressure of w. vapor $h = f(t)$ only. Water vapor exists at point ① and point Ⓐ and point Ⓑ is at same temp

$\therefore h_1 = h_A = h_B$

$\therefore$ We can write enthalpy of moisture in three ways

$h_1 = c_{pw} t_d + h_{fg_{td}} + C_{psup}(t - t_d)$

$h_A = c_{pw} t + h_{fg_t}$

$h_B = (h_{fg})_0 + C_{psup}(t - 0) = h_{fg_0} + C_{psup} t$

The last formula is most simple

$\therefore \quad h_B = (h_{fg})_0 + C_{p\,sup}\, t$

$= 2500 + 1.88\, t$

$\therefore$ Enthalpy of moist air

$h = h_a + \omega (h_v)$

$= 1.005\, t + \omega (2500 + 1.88\, t)$

$= (1.005 + 1.88\, \omega)\, t + 2500\, \omega$

$= C_{p\omega}\, t + 2500\, \omega$

↓

~~Specific~~ humid. specific heat

---x---