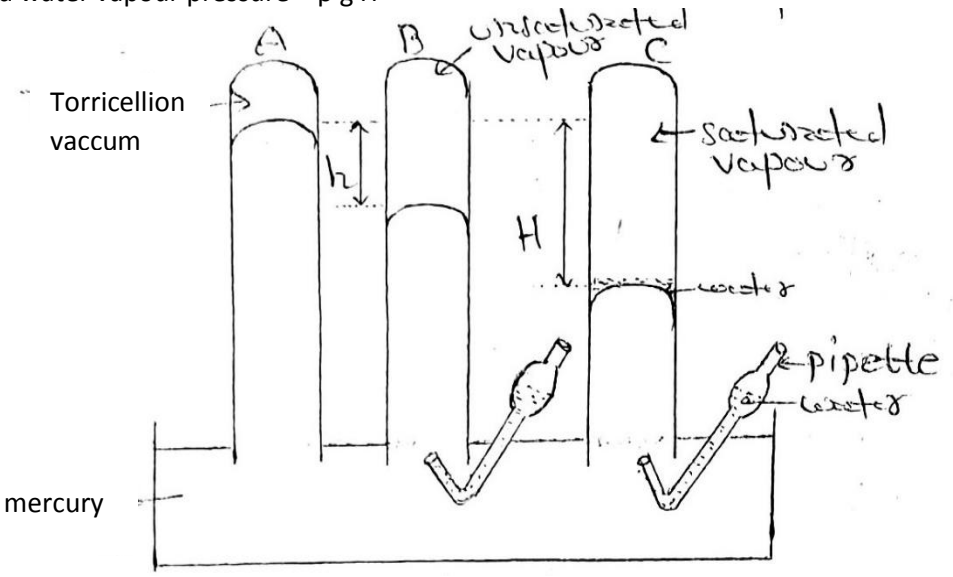
HYGROMETRY

Hygrometry:
The branch of physics which deals with the study and measurement of water vapour present in the atmosphere is called hygrometry.

Saturated and Unsaturated vapour:
An unsaturated water vapour is the vapour which can contain further more water vapour in it and the pressure exerted by such vapour is called unsaturated water vapour pressure.If h is the fall in height of mercury in the tube B ρ is the density of mercury and g is the acceleration due to gravity,then
Unsaturated water vapour pressure= ρ g h
A saturated water vapour is the vapour which cannot contain further more water vapour in it and the pressure exerted by such vapour is called saturated water vapour pressure.If H is the fall in height of mercury in the tube C due to the saturated water vapour pressure present in it, ρ is the density of mercury and g is the acceleration due to gravity, then
Saturated water vapour pressure = ρ g H



Behaviors of saturated vapour:
The saturated vapour pressure of liquid possess the following properties:

1. The saturated vapour pressure is always greater than unsaturated vapour pressure.
2. The saturated vapour pressure of liquid depends upon the nature of the liquid.
3. The saturated vapour pressure of liquid depends upon the temperature of the liquid. It increases with increase in temperature and decreases with decreases in temperature.
4. The saturated vapour pressure of a liquid does not depend upon the volume occupied by the vapour.
5. The saturated vapour pressure of a liquid is independent of the other vapours present.
6. The saturated vapour does not obey gas laws whereas unsaturated vapour obeys the gas laws.
7. The vapour pressure exerted by a vapour of many liquids is equal to the sum of the vapour pressure due to all vapours.
   i.e. $P = P_1 + P_2 + P_3 + \ldots\ldots\ldots$

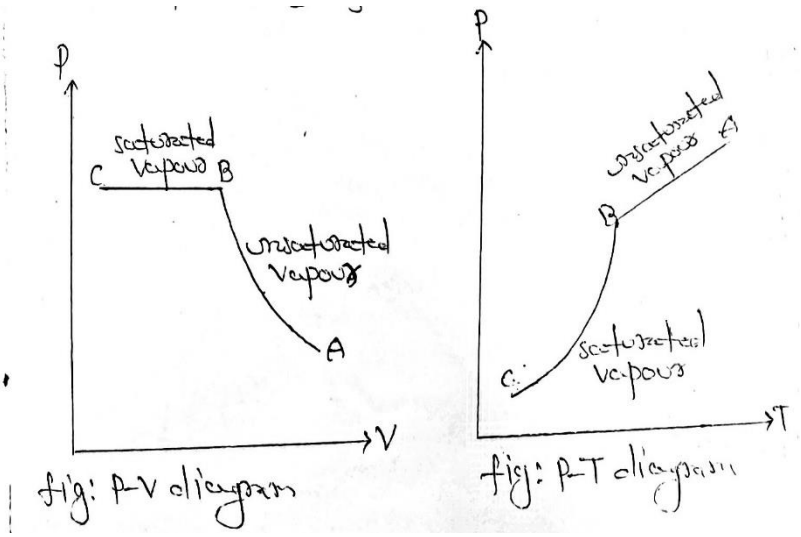


fig: P-V diagram fig: P-T diagram

Distinguish between saturated and unsaturated vapour pressure:

Unsaturated vapour	Saturated vapour
If a space contains less than the maximum amount of vapour that it can hold at that temperature, the vapour in the space is unsaturated vapour.	If a space contains maximum amount of vapour that it can hold at that temperature, the vapour in the space is saturated vapour.
Unsaturated vapour obeys gas laws.	Saturated vapour does not obey gas laws.
Unsaturated vapour changes into saturated by decreasing volume or temperature.	Saturated vapour is independent of volume but increase with increase in temperature.
Vapour in closed space but not in contact with liquid is unsaturated.	Vapour in closed space but in contact with liquid is saturated vapour.

Phase diagram:

The P-T diagram to study the phases of matter is called phase diagram.

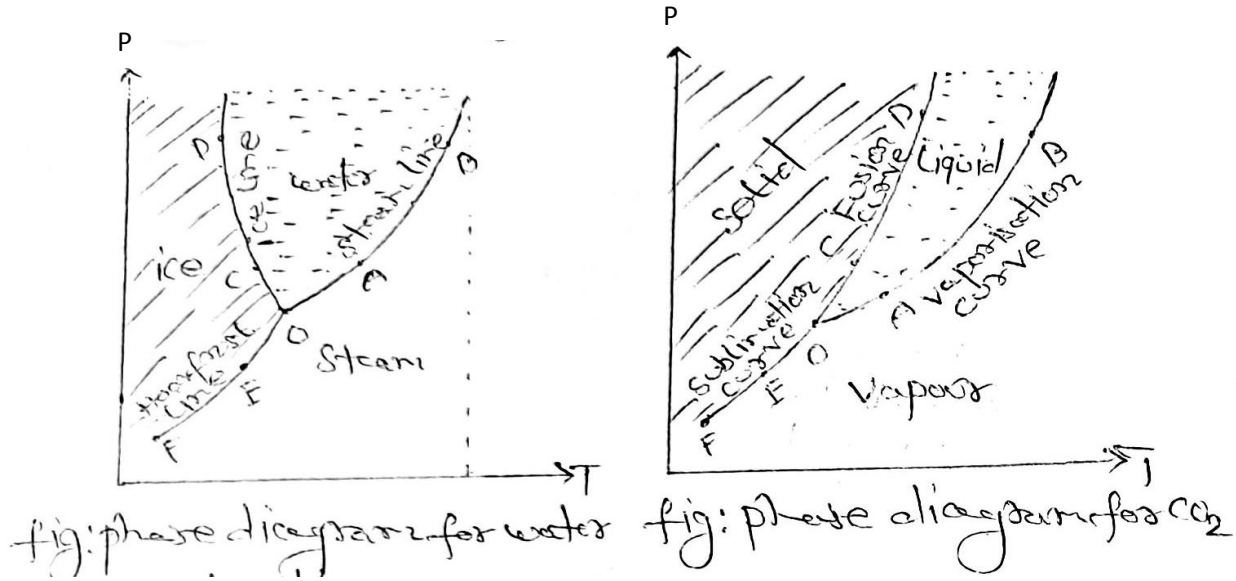


fig: phase diagram for water fig: phase diagram for CO_2

i) vaporization curve

It is a graph between pressure and boiling point of the substance in the liquid state.

Each point of the substance in the vaporization curve gives the value of pressure and temperature at which the liquid and gaseous phase can co-exist. In case the pressure is made more than the value of pressure corresponding to a point on this curve will at once condense into liquid. On the other hand, if the pressure is decreased than its value corresponding to a point on the curve, the liquid will evaporate.

Hence all the points above the vaporization curve correspond to the liquid phase and those below the curve correspond to vapour or gaseous state.

In the phase diagram AB represents the vaporization curve or steam line.

ii) Fusion curve

It is a graph between pressure and the melting point of the substance in solid state.

Each point on the fusion curve gives the value of the pressure and the temperature at which the solid and liquid phase can co-exist.

Hence, all points above the fusion curve correspond to liquid phase and those below it correspond to solid phase.

In the phase diagram CD represents the fusion curve or ice line.

iii) Sublimation curve

It is a graph between pressure and the temperature at which the solid directly changes to vapour state.

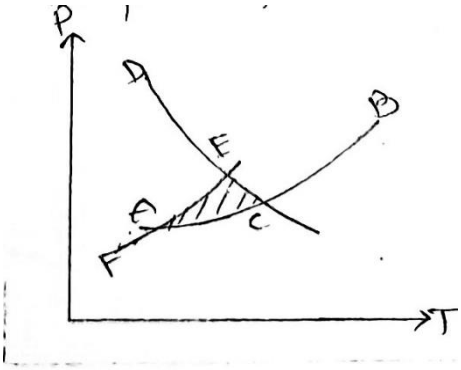
Each point on the sublimation curve gives the value of the pressure and the temperature at which the solid and the vapour state can co-exist.

Hence, all points above the sublimation curve correspond to the solid state and those below it correspond to vapour state.

In the phase diagram EF represent the sublimation curve or Hoarfrost line.

Triple Point:
It is a point in phase diagram representing a particular pressure and temperature at which the solid, liquid and vapor states of the substance can co-exist.
In the phase diagram point O represents the triple point.
For water,triple point(P,T) = (4.58 mm of Hg,0.0075^{0}C)
For CO_2, triple point(P,T)= (5.11 atm,-56.6^{0}C)

To prove that all three curves meet at one point.
The three curves AB, CD and EF come to meet at a single point O. If these curves do not meet at a point, then suppose that they enclose and area ACE as shown in fig.



According to the vaporization curve AB: as the area ACE lies above it, it should correspond to liquid state only.
According to the fusion curve CD as the ACE lies below it, it should correspond to solid only.
Finally, according to the sublimation curve EF as the area ACE lies below it, it should correspond to vapour state only.
It means area AEC is the common region for solid , liquid and gaseous state ,hence the three curves meet at a single point and there exist a single value of triple point.

Atmospheric humidity:
Some amount of water is always present in the atmospheric air. It is due to evaporation of water present on earth's surface in the form of seas, ponds, lakes, damp soil etc.
Absolute humidity:
The absolute humidity of air is defined as the mass of water vapour actually present in one cubic metre volume of air. It is measured in gram per cubic metre(gm^{-3})
Relative Humidity(RH)
The relative humidity of air is defined as the ratio of the mass of water vapour actually present in a certain volume of air at a certain temperature to the mass of water vapour required to saturate the same volume of air at the same temperature.
If m is mass of water vapour actually present and M is the mass of water vapour required to saturate the same volume of air at the same temperature, then relative humidity is given by
R.H.=$\frac{m}{M}$ x100%
The mass of water vapour in a given volume of air and at a given temperature is directly proportional to density. Therefore,
R.H.=$\frac{d}{D}$ x100%
Where d is the density of water vapour actually present and D is the density of water vapour required to saturate the same volume of air at the same temperature.
The unsaturated vapour obey Boyle's law(PV=constant=mrT) up to the point of saturation. Therefore, mass(or density)of the water vapour present in air will be directly proportional to its pressure. Therefore,

$$\text{R.H.}=\frac{\text{actual vapour pressure at the room temperature}}{\text{saturated vapour pressure at the room temperature}}\ \text{x100\%}$$

or, R.H.=$\frac{p}{P}$ x100%

Dew point:
It is defined as the temperature at which the water vapour actually present in a certain volume of air become just sufficient to saturate it.
Obviously,the actual pressure at room temperature will be equal to saturated vapour pressure at dew point. Hence the relative humidity of air at room temperature may be defined as the ratio of saturated vapour pressure at dew point to the saturated vapour pressure at room temperature. Thus,

$$\text{R.H.}=\frac{\text{saturated vapour pressure at dew point}}{\text{saturated vapour pressure at the room temperature}}\ \text{x 100\%}$$

Hygrometer: A hygrometer is a device to measure the relative humidity of air.

Wet and Dry bulb hygrometer:

Construction**:**It consists of two mercury thermometers A and B. The thermometer B is used to determine the room temperature while the thermometer A is used to measure the dew point.

Action**:**water round the bulb of thermometer A is wet muslin piece evaporates by taking heat form bulb and it gets cooled.Greater the humidity, lesser will be the evaporation. Therefore, the difference in the readings of dry and wet bulb thermometer is a measure of the relative humidity of the air whose value is found by using wet and dry bulb humidity tables.

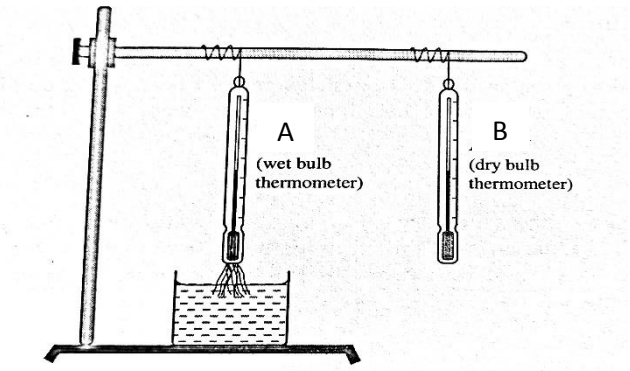


Figure Wet and dry bulb hygrometer.

Critical temperature:A particular temperature of the matter which remarkably separated the gas state and vapour state of the matter is called critical temperature.

Difference between gas and vapour:

vapour	gas
It is the state of the matter below critical temperature.	It is the state of matter above critical temperature.
It can be liquefied by direct application of pressure	It cannot be liquefied by direct application of pressure.

Weather Phenomenon

As said earlier, water vapor is always present in the air. When temperature of air is above the dew point, they are in unsaturated vapor state. At dew point, the vapor become saturated and as the temperature further falls, the air cannot retain the water vapor and they condense on grass blades etc. which provide them as nuclei for condensation. The condensation of water vapor takes place on the ground, near the surface of earth and in air at high altitudes in various ways and accordingly gives rise to different weather phenomenon as explained below:

1. **Dew.** At night, the surface of earth loses heat by radiation and gets cooled faster than atmosphere. Further, the layers of air close to the surface of earth are cooled more than those above. In case the temperature falls below the dew point, the air close to the surface of earth releases the excess water vapour in the form of tiny water drops on grass etc. Dew formation in nature takes place more easily in clear and cloudless nights because the radiation from the earth occurs freely and causes cooling. On a cloudy night, the loss of heat by radiation is much less, the clouds acting as a blanket to the earth surface.
2. **Hoarfrost.** On a day, if the dew point is below 0°C and the layers of air near the surface of earth get cooled below 0°C, the water vapour condense directly into solid white grains, called hoarfrost. It may be noted that in the formation of hoarfrost, water vapour directly pass into the grains without passing through the liquid state.
3. **Mist.** When air gets cooled up to some distance above from the ground to a temperature below the dew point, the water vapour condense on smoke and dust particles floating in the air and it gives rise, what is known as mist.
4. **Fog.** In case, the size of the dust particles and their number present in the air is very large, a very dense mist known as fog is formed.
5. **Cloud.** Due to decrease in pressure, when moisture laden winds are drawn from the sea, these layers after striking the mountains go on rising up in atmosphere and get cooled. When the temperature of the layers at high altitude falls below the dew point, the condensation of water vapour takes place on the dust particles present there. Thus, formation of clouds is the formation of fog at high altitude. However, a fundamental difference between fog and cloud is that in fog, air is at the rest or in slow motion, whereas in the cloud air is in the rapid motion.
6. **Snow.** If the temperature of a cloud falls below 0°C, the moisture deposit occurs directly from the vapour to the solid state and snow is formed. In snow formation, the liquid rain drops are not formed.
7. **Hail.** The hail or hail stones are produced by the freezing of rain. Due to wind and gusts, rain may be carried up to very cold regions and freeze. The hail thus formed may be carried up and down several times and as a result, it grows in size.

SHORT QUESTIONS ANSWERS:

1. What is triple point?

It is a point in phase diagram representing a particular pressure and temperature at which the solid, liquid and vapour states of the substance can co-exist. It can is chosen as standard fix point in modern thermometry as it occurs only at a fixed temperature and fixed pressure.

2. Why is the triple point of water chosen as a standard fixed point in modern thermometry?

The triple point of water is unique. It occurs at a particular pressure and temperature. On the other hand, melting point of ice and boiling point of water change due to pressure or due to the presence of impurities in water. Hence, melting point of ice and boiling point of water cannot be taken as standard fixed points and triple point of water is chosen as standard fixed point in modern thermometry.

3. How are dews formed?

At night, the surface of earth loses heat by radiation and gets cooled faster than atmosphere. Further, the layers of air close to the surface of earth are cooled more than those above. In case the temperature falls below the dew point, the air close to the surface of earth releases the excess water vapour in the form of tiny water drops on grass etc. Dew formation in nature takes place more easily in clear and cloudless nights because the radiation from the earth occurs freely and causes cooling. On a cloudy night, the loss of heat by radiation is much less, the clouds acting as a blanket to the earth surface.

4. Why does dew forms early in the morning?

In the early morning, the earth's surface as well as the atmosphere cools below the dew point. As the temperature falls below the dew point, the air close to the surface of earth releases the excess water vapour in the form of tiny water drops on grass, window pan etc. called dews.

5. Why are dews formed in the clear night but not in the cloudy night? Explain.

In clear night, the earth's surface and atmosphere looses heat by radiation and cool below the temperature of dew point so that dews are formed. But in cloudy night, cloud acts as blankets so that heat radiated by the earth surface cannot escape from the cloud. As a result temperature cannot fall sufficiently to reach the dew point and hence dews cannot be formed.

6. Explain why dew forms more prominently at the blades of grass on cooler night?

Grass blades are good radiators of heat. Besides, this, grass blades also give out water vapours. The space near the blades is rich in water vapour. So the water vapours condense on the grass blades and turn to dew drops

7. What is difference between gas and the vapour**?**

If the matter is above the critical temperature, it is in the gaseous state and when it is below the critical temperature, it is in the vapour state. The matter in the vapour state can be liquefied by the direct application of pressure. However, the matter in the gaseous state cannot be directly converted into liquid even by applying high pressure.

8. What are saturated and unsaturated vapours?

vapour which is in equilibrium with its own liquid is called a saturated vapour. If space contains vapours less than the maximum amount it can hold at the given temperature, it is said to be unsaturated. Saturated vapour pressure is independent of volume but increases with increase in temperature. Unsaturated vapour changes in to saturated by decreasing volume or temperature. Saturated vapour does not obey gas laws [i.e. Boyle's law and Charle's law). But unsaturated vapour obeys Boyle's law and charle's law.

9. What do you mean by super saturated air?

If the partial pressure of water vapour in air exceeds the saturated vapour pressure of water, the air is said to be super saturated. Hence the relative humidity would be greater than 100% and the super saturated air cannot hold this much water. The excess water condenses and appears as dew; this process is also responsible for formation of fog, clouds and rain.

10. What is relative humidity? Why is its value near sea water?

It is defined as the ratio of the mass of water vapour (m) actually present in a given volume of air to the mass of water vapour required to saturate the same volume of air at the same temperature.

$\therefore$ R.H. $= \frac{m}{M} \times 100\%$ .It has no unit i.e. it is a number.

: The amount of water vapour present in the atmosphere near the sea water is comparatively more because of this, the value of relative humidity is more near sea water.

11. A weather report said relative humidity of 80%.Explain its meaning.
    If m is mass of water vapour actually present and M is the mass of water vapour required to saturate the same volume of air at the same temperature, then relative humidity is given by
    R.H.=$\frac{m}{M}$ x100%

    The relative humidity of 80% means that the mass of water vapour present in air is 80 parts of the mass of water vapour required to saturate the volume of air on that day or time.
12. Why are you feel more uncomfortable on a hot day when the humidity is high than when it is cooled?
    If the humidity is high, evaporation takes place very slowly. At high humidity, body's temperature control mechanism is inhibited so we feel a kind of discomfort in the body. Hence we feel uncomfortable on a high humid day.
13. Why it takes longer time to dry wet clothes in rainy summer than in sunny winter?
    The evaporation depends upon the humidity of air. The process of drying clothes depends upon the evaporation process and hence, humidity of air. In rainy summer, there is more humidity in air than the sunny winter. So, clothes dry faster in sunny winter than rainy summer
14. How does the formation of snow or rain affect the temperature of air?
    The formation of snow or rain from water vapours is accompanied by an increase in atmospheric temperature, water vapour releases energy in transforming to the liquid or solid phase. So it is always a little warmer when it rains or snows than it would be.
15. Explain why we can see our breath in winter but not in summer?
    The exhaled gases consist of water vapour with other wastes. The winter temperature is very less than the summer. When the gases come out form mouth during breath, they are exposed to lower temperature in winter. The vapour condenses to water. So white trace is seen more in winter. In summer less vapour condenses to water and the white trace is not seen during breath.
16. Clothes dry faster when a wind is blowing. Why?
    If the wind blows, clothes dry faster because it increases the rate of evaporation by driving molecules of wet clothes away from it.

NUMERICAL PROBLEM:

1. At certain day the air temperature in a room is 17.7 ^{0} C and the dew point 5.3 ^{0} C. Find the relative humidity (SVP at 5^0,6^0,17^0 and 18^0C are 0.654cm ,0.705cm,1.442cm,1.546 cm respectively. (Ans:44.18%)
   Room temperature= 17.7 ^{0} C
   Dew point =5.3 ^{0} C
   SVP at 5^0 C =0.654cm
   SVP at 6^0 C = 0.705cm
   Difference of vapour pressure for 1^0 C = 0.705-0.654 = 0.051 cm
   Difference of vapour pressure for 0.3^0 C = 0.3x0.051 = 0.0153 cm
   SVP at 5.3 ^{0} C = SVP at 5^0 C+ SVP at 0.3^0 C =0.654+0.0153 =0.6693 cm
   SVP at 17^0 C =1.442cm
   SVP at 18^0 C = 1.546 cm
   Difference of vapour pressure for 1^0 C = 1.546 - 1.442=0.104cm
   Difference of vapour pressure for 0.7^0 C = 0.7x0.104 = 0.0728cm
   SVP at 17.7 ^{0} C = SVP at 17^0 C+ SVP at 0.7^0 C =1.442+0.0728 = 1.5148cm

   Relative Humidity = $\frac{saturated\ vapour\ pressure\ at\ dew\ point}{saturated\ vapour\ pressure\ at\ the\ room\ temperature}$ x100%

   = $\frac{0.6693}{1.5148}$ x100%

   = 44.18%