# Module-4

Pure substance:- A substance that has a fixed chemical composition throughout.

Air is a mixture of several gases, but it is considered to be a pure substance.

$N_2$, air are pure substances. A mixture of liquid and gaseous water is pure substance but mixture of liq & gaseous air is not.

A phase is defined as having a distinct molecular arrangement that is homogeneous throughout and separated from others by easily identifiable boundary surfaces. The various phase transformations taking place are:-

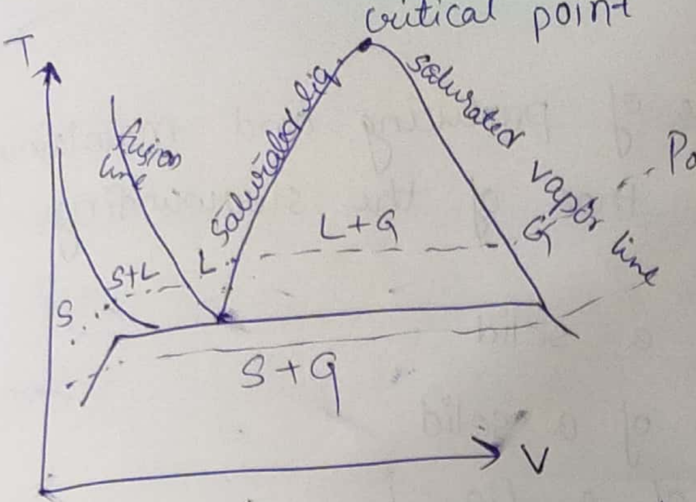
(1) Solid

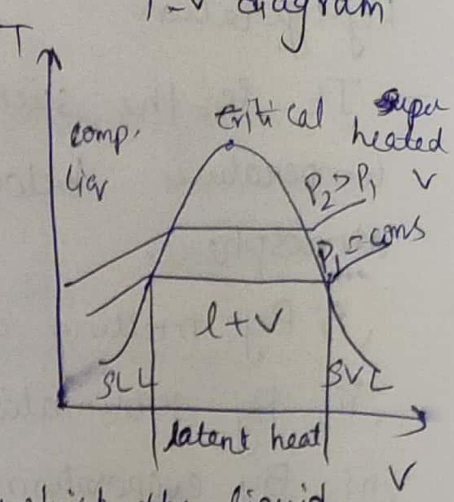
(2) Mixed phase of liquid and solid

(3) Sub-cooled or compressed liquid

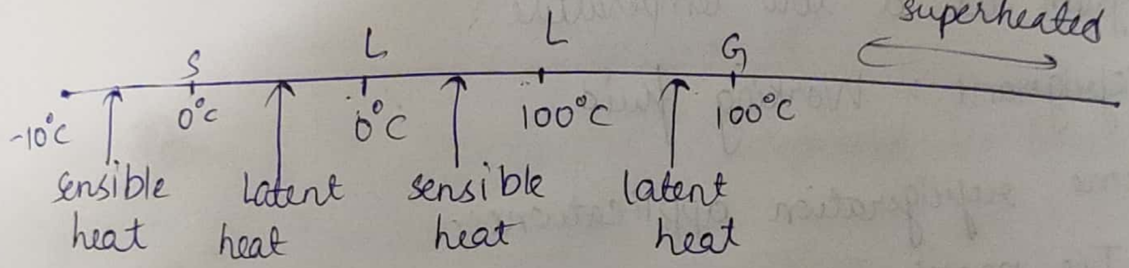
(4) Wet vapour or saturated liquid-vapor mix, the temperature will stop rising until the liquid is completely vapourized.

(5) Superheated vapour.




Critical point is the point at which the liquid, solid and vapor phases can exist together.




Saturation Temp. & Saturation Pressure

1 atm → 100°C (BP of $H_2O$)

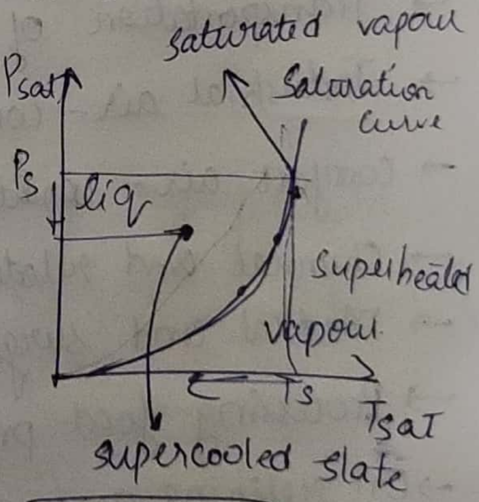
2 atm → ↑

8 atm → ↑

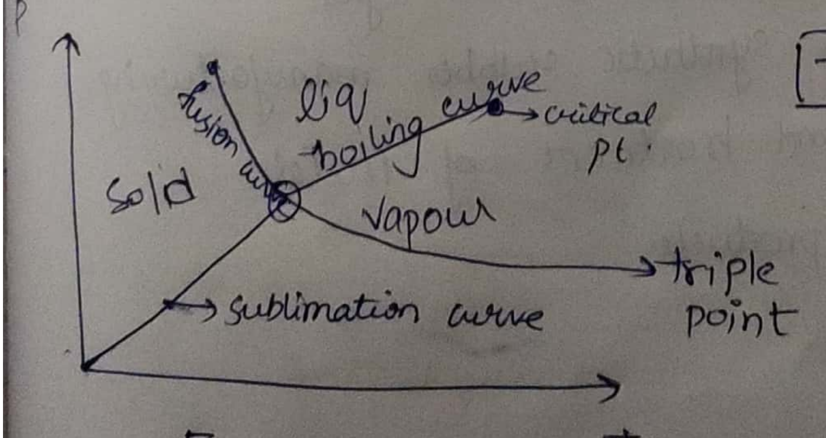
Boiling (or) Condensation → Saturation

⇓

$P_{sat}$




P-T diagram




$\boxed{T_{sat} - T}$

↓

degree of undercooling

For $H_2O$

$T_{tp} = 273.16K$ ; $V_{tp} = 0.611 m^3/kg$

Refrigeration

→ It is the science of producing and maintaining temperatures below that of the surrounding atmosphere.

i) By melting of a solid

ii) By sublimation of a solid

iii) By evaporation of a liquid.

Refrigerator :- The equipment employed to maintain the system at a low Temperature.

Refrigerant :- Working fluid

Some refrigeration applications:-

→ Ice making

→ Transportation of foods above and below freezing

→ Industrial air-conditioning

→ comfort air-conditioning

→ Chemical and related industries

→ Medical and surgical aids

→ Processing food products and beverages.

→ Oil refining and synthetic rubber manufacturing

→ Manufacturing and treatment of metals.

→ Freezing food products.

Various refrigeration systems

1. Ice refrigeration
2. Air refrigeration system
3. Vapour compression refrigeration system
4. Vapour absorption refrigeration system
5. Special refrigeration systems
   (i) Adsorption refrigeration system
   (ii) Cascade refrigeration system
   (iii) Mixed refrigeration system
   (iv) Vortex tube refrigeration

→ The efficiency of refrigerator is expressed in terms of coefficient of performance (COP)

$$COP_R = \frac{Q_L}{W_{in}} \left( \frac{\text{Desired output}}{\text{Req. input}} \right)$$

$$W_{in} = Q_H - Q_L$$

$$COP_R = \frac{Q_L}{Q_H - Q_L}$$

1 tonne of refrigeration

$$= \frac{336 \times 1000}{24} = 14000 \text{ kJ/h}$$

in 24 hrs.

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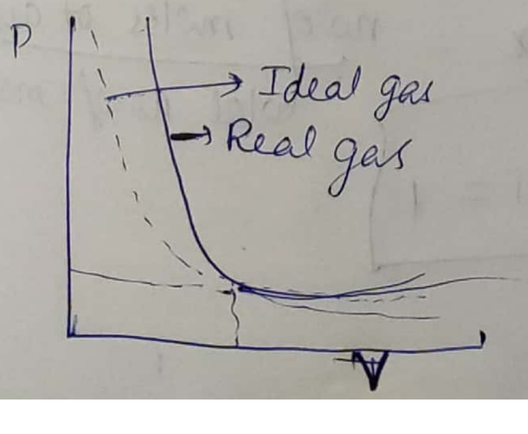
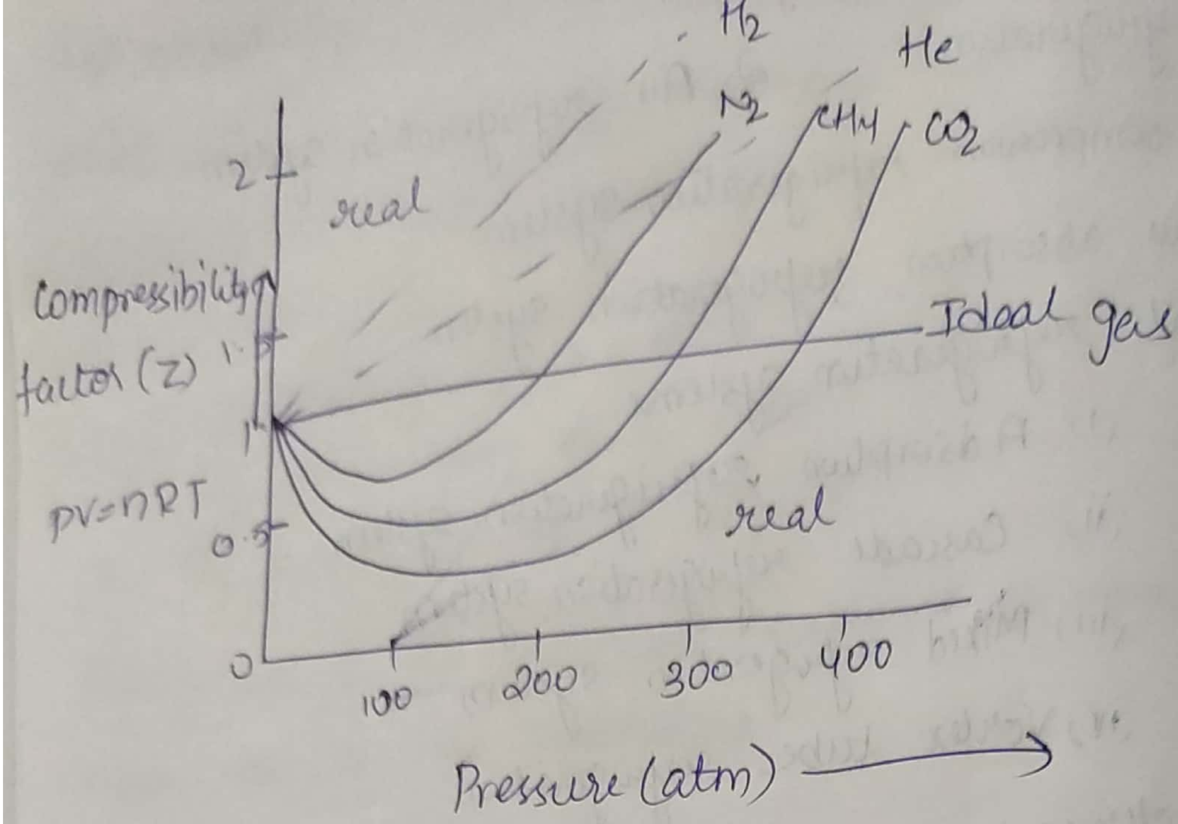
Real gas

$PV \neq mRT$ Behaves as ideal gas when $T\uparrow$ & $P\downarrow$






$PV = nRT$

$\frac{PV}{nRT} = Z$

$Z = 1 \rightarrow$ ideal gas

$Z \neq 1 \rightarrow$ real gas

## Gas mixtures

Mass of mixture

$$m_m = \sum_{i=1}^{k} m_i \qquad (\text{kg})$$

No. of moles $= \sum_{i=1}^{k} N_i \qquad (\text{kmol})$

Mass fraction $= \frac{m_i}{m_m} \quad \left[\sum_{i=1}^{k} mf_i = 1\right]$.

Mole fraction :- $x = \frac{\text{no. of moles of a comp.}}{\text{total no. of moles}}$

$$\boxed{\sum_{i=1}^{k} x_i = 1}$$

Mass = no. of moles × molar mass

$$m = n \times M$$

$$M = \frac{m}{n}$$

Molar mass of a mixture :-

$$M_m = \frac{m_m}{n_m} = \frac{\Sigma m_i}{\cancel{\Sigma A_i} N_m}$$

Dalton's law

| A | B | C | | A+B+C |
|---|---|---|---|---|
| 10 moles | 6 mol | 4 mol | = | 20 moles |
| $P_A = 1$ atm | $P_B = 0.6$ atm | $P_C = 0.4$ atm | | 2 atm |

$$\boxed{P_{total} = P_A + P_B + P_C}$$

Total pressure of a mix of gases = Sum of individual gases.

$$P_A = X_A P_T \qquad X_A = \frac{n_A}{n_T} = \frac{P_A}{P_T}$$

$$\boxed{X_A + X_B + X_C = 1}$$

$$m = m_A + m_B + m_C$$

$m \rightarrow$ mass of a constituent

## Amagat's Law of Partial Volume

The volume of an ideal gas mixture ($V$) is equal to sum of component volumes of each individual component in the gas mixture at the same temperature ($T$) & total pressure ($P$) of the mixture.

| A | B | A + B |
|---|---|---|
| $V_A$ | $V_B$ | $V_A + V_B = V$ |

$P V_A = n_A R T$ $\quad$ $P V_B = n_B R T$ $\quad$ $P V_c = n_c R T$

$$\frac{V_A}{n_A} = \frac{V_B}{n_B} = \frac{V}{n} \Rightarrow \frac{n_A}{n} = \frac{V_A}{V} = y_A \qquad \frac{n_B}{n} = \frac{V_B}{V} = y_B$$

$V$
$T$

$$\boxed{\begin{aligned} m &= m_A + m_B + m_C \\ P &= P_A + P_B + P_C \\ n &= n_A + n_B + n_C \end{aligned}} \quad (a)$$

| $V_A$ | $V_B$ | $V_C$ |
|---|---|---|
| $P$ | $P$ | $P$ |
| $m_A$ | $m_B$ | $m_C$ |
| $n_A$ | $n_B$ | $n_C$ |

$P$
$T$
(b)

$$m_A = \frac{P_A V}{R_A T} \quad (a)$$

$$m_A = \frac{P V_A}{R_A T} \quad (b)$$

$$\frac{P_A V}{R_A T} = \frac{P V_A}{R_A T}$$

$$\Rightarrow P_A V = P V_A$$

$$V_A = \frac{P_A}{P} V$$

$$n = \frac{m}{M}$$

$n \to$ no. of moles

$m \to$ mass of gas

$M \to$ molecul

$$n = n_A + n_B + n_C$$

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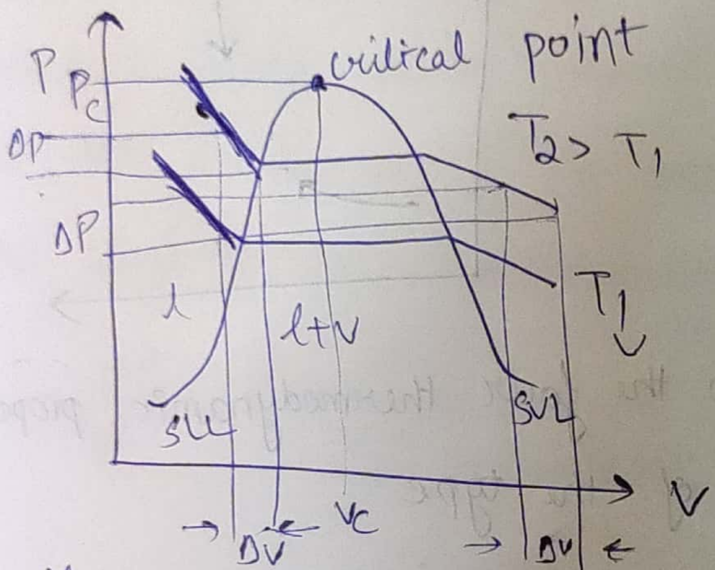
~~Vander Waals eq~~

$$\cancel{\left[P+\frac{a}{v^2}\right](v-b)=RT}$$

$a, b \rightarrow$ Vanderwaal constants

P–V diagram




For $H_2O$

$P_c = 22.09\ MPa$

$T_c = 374.14°C$

$V_c = 0.003155\ m^3/kg$

Vanderwaal's $eq^n$

Real gases have volume, intermolecular force and inelastic collisions

$$a = \frac{27R^2T_c^2}{64P_c} \leftarrow kPa\left(\frac{m^3}{kmol}\right)^2 \qquad b = \frac{RT_c}{8P_c} \rightarrow \frac{m^3}{kmol}$$

$a \rightarrow$ attraction force

$$kPa \leftarrow \left(P+\frac{a}{v^2}\right)(v-b) = RT$$

$v \rightarrow m^3/kmol$

$b \rightarrow$ repulsion effect

$R \rightarrow$ specific gas cons. (not universal)

$$\left(P+\frac{an^2}{V^2}\right)(V-nb) = nRT$$