STATES OF MATER

Matter : Anything that occupies, space and has some mass is known as matter. There are three physical states of matter.

(*i*) Gaseous state

(*ii*) Liquid state

(*iii*) Solid state

Gas Laws

(*i*) Boyle's law : For given mass of a gas

$$V \propto \frac{1}{P} \quad \text{or } PV = \text{const.}$$

or $P_1V_1 = P_2V_2$; T constant.

(*ii*) Charles' Law : For given mass of a gas and at constant P.

$$V \propto T \text{ or } \frac{V}{T} = \text{const.}$$

or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

(*iii*) Gay Lussac's Law : For given mass of a gas and at constant V,

$$P \propto T \text{ or } \frac{P}{T} = \text{const.}$$

or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

- t°C = (t + 273)° Abs. or (t + 273)°K
- t°C = T°K – 273 = Abs. – 273
- V ∝ n, where : P and T are const. (Avagadro's law)

Thus for the same P, V and T, $n_1 = n_2 = n_3 = ...$

Equation of state or Ideal gas equation

(*i*) PV = RT for 1 gm mole

(*ii*) PV = nRT for n gm moles or

$$PV = \frac{m(\text{mass})}{M(\text{mol. wt.})} \times RT$$

where R = Gas const. = 0.0821 litres atm $\text{deg}^{-1}\,\text{mol}^{-1}$

$= 8.31 \times 10^7$ ergs $\text{deg}^{-1}\,\text{mole}^{-1}$

$= 8.31$ joule $\text{deg}^{-1}\,\text{mole}^{-1}$

$$\simeq 2 \text{ calories deg}^{-1} \text{ mole}^{-1}$$
$$= (1.987 \text{ calories exactly})$$

- For the same mass of a gas

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

- If mass changes, number of moles also changes in this case,

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

- $\frac{P_1}{d_1T_1} = \frac{P_2}{d_2T_2}$; where d_1 and d_2 stand for densities.
- Rate of diffusion or effusion (r)

$$= \frac{V \text{ (volume)}}{t \text{ (time)}}$$

- $$\frac{r_1}{r_2} = \frac{V_1}{t_1} \Big/ \frac{V_2}{t_2} = \sqrt{\frac{D_2}{D_1}} = \sqrt{\frac{M_2}{M_1}}$$

- Partial pressure of a gas $(P) = \dfrac{nRT}{V}$

where V = volume occupied by the mixture
T = temp. of the mixture and
n = no. moles of the gas.

- Total pressure $(P) = P_1 + P_2 + P_3 + ... + P_n$

$$= \sum n \frac{RT}{V}$$

where $\sum n$ is the total number of moles in the mixture.

- $$\frac{\text{Partial pressure}}{\text{Total pressure}} = \frac{n}{\sum n} = \text{mole fraction}$$

- $$P = \frac{P_1V_1 + P_2V_2 + P_3V_3 + ...}{\text{Total volume}}$$

Symbol Used

P = pressure of gas

C = R.M.S. velocity

V_{av} = mean or average velocity

α = most probable speed

n = no. of molecules of the gas

m = mass of each molecule of the gas

M = mol. wt.

V = volume of one mole of the gas

T = absolute temp.

R = gas const.

λ = mean free path

d = diameter of each molecule

ρ = density of the gas

η = co-efficient of viscosity

K = Boltzman's constant $= \dfrac{R}{N}$

[N = Avogadro's no.]

$V_{av} = 0.9213 \times C$

$$\alpha = 0.816 \times C$$

$$PV = \frac{1}{3}mnC^2 = \frac{1}{3}MC^2$$

$$C = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3KT}{m}}$$

$$V_{av} = \frac{V_1 + V_2 + V_3 + \ldots. + V_n}{n}$$

Crystal System	Lengths of edges	Interfacial angles	Lattice types	Examples
I. Cubic	a = b = c	$\alpha = \beta = \gamma = 90°$	S*, BC, FC	NaCl, KCl, Zinc blende
II. Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$	S, BC	SnO_2, TiO_2, ZnO_2
III. Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	S, BC, FC, EC	$BaSO_4$, KNO_3, $PbCO_3$
IV. Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	S, EC	$CaSO_4 . 2H_2O$, $KClO_3$
V. Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	S	$CuSO_4 . 5H_2O$, $K_2Cr_2O_7$
VI. Rhombohedral or Trigonal	a = b = c	$\alpha = \beta = \gamma \neq 90°$ $< 20°$	S	Al_2O_3, Calcite, $NaNO_3$
VII. Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°$ $\gamma = 120°$	S	Graphites, Ice, CuS, ZnO

* S stands for simple cubic (primitive unit cell)

$$= \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8KT}{\pi m}}$$

$$C = \sqrt{\frac{C_1^2 + C_2^2 + \ldots. + C_n^2}{n}}$$

$$\alpha = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2KT}{m}}$$

Translatory Kinetic energy/mole $= \frac{3}{2}RT = \frac{1}{2}MC^2$

$$\lambda = \eta\sqrt{\frac{3}{P\rho}} \simeq \frac{m}{\pi d^2 \rho} = \frac{m}{\sqrt{2}\pi d^2 \rho}$$

Gas Analysis

1. One mole of all gases occupy 22.4 litres at S.T.P.
2. Equal no. of moles occupy equal volume at the same temperature and pressure.
3. Volume of solid or liquid is considered negligible in comparison to the volume of a gas.

4. For the determination of formula of a hydrocarbon :

$$C_xH_y + \left(x + \frac{1}{4}y\right)O_2 = xCO_2 + \frac{1}{2}yH_2O$$

5. For one cc of hydrocarbon :
   - volume of CO_2 produced = x cc
   - volume of O_2 required = $x + \frac{1}{4}y$ cc
   - Contraction in volume = $1 + \frac{1}{4}$y cc

Absorbant	Gas Absorbed
Conc. H_2SO_4	moisture, NH_3
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NaOH or KOH soln.	CO_2, SO_2, Halogens, NO_2
Ammoniacal cuprous chloride	CO, C_2H_2

Alkaline Pyragallol	O_2
Heated Palladium	H_2
Heated Magnesium	N_2
$FeSO_4$ Soln.	NO
Turpentine	O_3

Differences Between Ideal and Real Gases

Ideal gases	Real gases
I. No intermolecular forces of attraction.	I. Forces of attraction between molecules are significant.
II. Obey all gas laws.	II. Do not obey gas laws at high P and low T.
III. Obey ideal gas equation at all P,T.	III. Obey ideal gas equation at low P, high T and Vander Waals's equation at high P, low T.

IV. Size of molecules negligible as compared to distance between them.	IV. Finite size of molecules.
V. Whole volume of container is available for molecular movement.	V. Actual volume available for free movement of molecules is less than the volume of the container.
VI. Do not exist in nature.	VI. All gases are real.
VII. Volume becomes zero at absolute zero.	VII. Volume is not zero at absolute zero.

Close-packed Crystal Structure

The crystals have the atoms arranged such that minimum volume is left unoccupied. The two types of close-packed structures are:

(*a*) Hexagonal close packing (hcp)

(*b*) Cubic close packing or face-centred cubic close packing (fcc).

I. Hexagonal close packing (hcp)

  (i) It has ABAB .... type of arrangement.

  (ii) Spheres of third layer are placed exactly above the first and of fourth layer above the second.

  (iii) Its coordination number is 12.

  (iv) Its packing fraction is 74%.

II. Face centred cubic close packing (fcc)

  (i) It has ABABC ... type of arrangement.

  (ii) Spheres of third layer are placed on the interstices of the first two layers.

  (iii) Its coordination number is 12.

  (iv) Its packing fraction is 74%.

Differences Between Simple, Body Centred and Face-centred Cubic Systems

sc	*bcc*	*fcc*
I. One atom per unit cell.	I. Two atoms per unit cell.	I. Four atoms per unit cell.
II. Atomic radius, $r = a/2$ where a = cube edge.	II. Atomic radius, $r = \frac{\sqrt{3}}{4}a$	II. Atomic radius, $r = 2\sqrt{2}\ a.$
III. Packing fraction is 52%	III. Packing fraction is 68%	III. Packing fraction is 74%
IV. Coordination number is 6.	IV. Coordination number is 8.	IV. Coordination Number is 12.

Do You Know?

1. All gases are composed entirely of non-metallic elements and have low molecular mass.
2. Pressure, volume and temperature of a gas are related quantities. Any change in one affects the other two.
3. Pressure exerted by a gas on the walls of its container is defined as the force exerted

by the gas per unit area of the walls of the container.

4. Temperature of a gas indicates the kinetic energy of the gas molecules. Higher the temperature, higher is the kinetic energy and vice-versa.
5. Gas laws are independent of the nature of the gas.
6. Real gases do not obey gas laws at very low temperatures and very high pressures as they tend to lightly under such conditions.
7. Boyle's law asserts the compressibility and expansion of gases. At constant T, if pressure is increased, then volume of the gas will decrease i.e., it gets compressed. However, if pressure is released, the volume of the gas will increase, i.e., it expands.
8. According to Charles' law the absolute zero temp. (0K) is the lowest attainable temperature at which volume of an ideal gas would reduce to zero, i.e., it gets liquified at a constant pressure.
9. According to Gay-Lussac's law, the gas exerts no pressure at absolute zero, if volume is constant. This means that the

gas molecules freeze, i.e., molecular movement ceases at 0K.

10. 1 mole of any gas occupies a volume of 22.4 litres at S.T.P.
11. The universal molar gas constant R is independent of the amount or nature of the gas.
12. Air is a mixture of gases and contains about 21 parts oxygen and 79 parts nitrogen by volume, with traces of water.
13. All gases have same average kinetic energy at the same temperature.
14. All gas laws can be derived from the results of kinetic theory of gases.
15. Real gases tend towards ideality as temperature is increased and pressure is reduced.