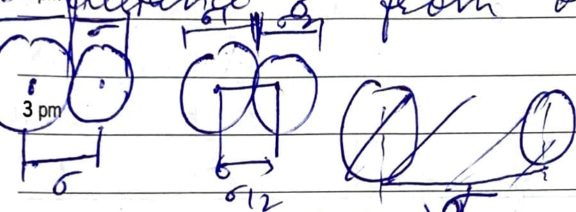
Collision Parameters

9 am
Since molecules of a gas are in random
10 am motion & colliding all the time it is
important to discuss about collision
11 am parameters.

① Collision diameter: (σ)

Noon

1 pm Collision is an event in which the centres
of two identical molecules come within a
2 pm distance σ from one another.



$\sigma_{12} = \frac{1}{2}(\sigma_1 + \sigma_2)$

Collision cross-section $= \pi\sigma^2$
It is cross-sectional area of imaginary sphere surrounding the molecule into which another molecule cannot penetrate.

3 pm
4 pm
σ = distance between centres of the molecules
5 pm at the point of closest approach.
It is called collision diameter

6 pm

② Collision Number: (Z_1)

7 pm
It is the number of molecules with which
a single molecule will collide per unit time
per unit volume of the gas.

NOTES

$Z_1 = \sqrt{2}\pi\sigma^2\bar{c}\rho$ = collision number.
σ = Diameter of the molecule
$c = \bar{c}$ = Average velocity
ρ = Number of molecules per unit volume of a gas.

9 am
10 am
11 am
Noon
1 pm
2 pm
3 pm
4 pm
5 pm
6 pm
7 pm

(3) Collision Frequency (Z_{11} or Z_{12})

It represents the number of molecule collisions occurring per unit time per unit volume of the gas.

$$Z_{11} = \frac{1}{2}\sqrt{2}\,\pi\sigma^2\bar{c}\rho^2 = Z_1 \times \rho$$

$$= \frac{1}{\sqrt{2}}\pi\sigma^2\bar{c}\rho^2$$ (for collisions between molecules of the same type)

$$Z_{12} = \frac{1}{\sqrt{2}}\pi\sigma^2\bar{c}\,\rho_1\rho_2$$

(for collisions between molecules of type 1 & type 2).

ρ_1 & ρ_2 are densities of molecules of type 1 & 2 respectively!

(4) Mean Free Path : (λ)

It represents the mean distance travelled by a gas molecule between two successive collisions.

$$\lambda = \frac{\bar{c}}{Z_1} = \frac{\bar{c}}{\sqrt{2}\pi\sigma^2\bar{c}\rho} = \frac{\text{Average distance travelled per second}}{\text{No. of collisions per second by a molecule}}$$

NOTES

$$PV = nRT = nN_AkT \qquad k = \frac{R}{N_A}$$

$$P = \frac{nN_AkT}{V} = \frac{NkT}{V}$$ $N = N_A n$ = Total number of molecules of a gas.

$\rho = \frac{N}{V}$

$P = \rho k T$. or $\rho = \frac{P}{kT}$

$\therefore \lambda = \frac{\bar{c} \quad kT}{\sqrt{2}\pi\sigma^2 \bar{c} P}$

$$\boxed{\lambda = \frac{kT}{\sqrt{2}\pi\sigma^2 P}}$$

At 1atm, high pressure, λ is very small compared to macroscopic dimensions. Molecules collide with one another far more frequently ~~than~~ than with walls of the container

$\lambda = \eta \sqrt{\frac{3}{Pd}}$

P = Pressure of the gas
d = density of the gas
η = coefficient of viscosity of the gas.

Effect of temperature & pressure of λ & Z_{11} or Z_{12}:

$\lambda = \frac{kT}{\sqrt{2}\pi\sigma^2 P}$ $\quad \therefore \lambda \propto \frac{T}{P}$

At low pressure or vacuum, λ is large & hence molecules collide more with walls: knudsen gas.

$Z_{11} = \frac{1}{\sqrt{2}} \pi\sigma^2 \bar{c} \rho^2$

$Z_{11} \propto \bar{c}$ & hence $Z_{11} \propto \sqrt{T}$
as C_{rms} or $C_{av} \propto \sqrt{T}$

$Z_{11} \propto \rho^2 \quad \therefore Z_{11} \propto P^2$.