



**Discipline Course-I
Semester-II**

Paper No: Thermal Physics : Physics-IIA

Lesson: Root Mean Square Speed And Mean Free Path

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Learning Objectives

After reading the lesson, you should be able to

- 1) understand the concept of Maxwell-Boltzmann Law of Distribution of speeds
- 2) define most probable speed c_m
- 3) develop the concept of Speed Distribution function
- 4) Learn the concept of mean or average speed
- 5) Learn the concept of root mean square speed $\langle c^2 \rangle$
- 6) understand the concept of mean free path.
- 7) develop the theory of distribution of free paths.
- 8) learn how to determine mean free path experimentally



Chapter: Title Root Mean Square Speed And Mean Free Path

2.1 Introduction According to kinetic theory (as we have discussed in chapter 1), a gas consists of a large number of minute discrete particles called molecules and these molecules are continuously colliding with each other. Collisions between these molecules can change individual molecular speeds, but the overall average speed of the system does not get changed. The root mean square speed C_{rms} remains the same at a fixed value of temperature. At any instant, all the molecules are not moving with the same speed. Some of the molecules are having speed greater than C_{rms} and others are moving with a speed lower than this value. But the mean kinetic energy of all the molecules remains constant at a given temperature. Molecules make frequent collisions with each other and change the magnitude and direction of their velocities. As the molecules exert no force on one another except during collision, they travel in straight lines with uniform velocity between two successive collisions, this straight line path being called the free path. The average distance travelled by a molecule between successive collisions is known as mean free path.

2.2 Maxwell-Boltzmann Law of Distribution of speeds

Consider a gas having n number of molecules per c.c. of the gas with all possible velocities from $-\infty$ to $+\infty$. Thus, the number dn of molecules having velocity components lying between u_x and $u_x + du_x$, u_y and $u_y + du_y$, u_z and $u_z + du_z$ is given by

$$dn = n f(u_x) f(u_y) f(u_z) du_x du_y du_z$$

$$dn = n \left(\frac{m}{2\pi k_B T} \right)^{3/2} e^{-m \left(\frac{u_x^2 + u_y^2 + u_z^2}{2k_B T} \right)} du_x du_y du_z \tag{2.1}$$

Let c be the speed of the molecule where u_x, u_y, u_z are its velocity components. Then

$$c^2 = u_x^2 + u_y^2 + u_z^2 \tag{2.2}$$

This is also the equation of a sphere of radius c .

In eq (2.1), $du_x du_y du_z$ represents volume element in the velocity space. Taking into account spherical coordinates, we can express volume element as

$$du_x du_y du_z = c^2 dc \sin \theta d\theta d\phi \tag{2.3}$$

Total volume of the shell between c and $c+dc$ is

$$\int_0^\pi c^2 dc \sin \theta d\theta \int_0^{2\pi} d\phi = 4\pi c^2 dc \tag{2.4}$$

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Now, the number of molecules with speeds in the range c and $c+dc$ is

$$n_{(c)}dc = n \left(\frac{m}{2\pi k_B T} \right)^{3/2} e^{-mc^2/2k_B T} 4\pi c^2 dc \quad (2.5)$$

$$\Rightarrow n_{(c)}dc = 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T} dc \quad (2.6)$$

$$\text{or } n_{(c)} = 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T} \quad (2.7)$$

This is Maxwell Boltzmann's law which explains distribution of speeds.

2.3 Most probable speed c_m

Most probable speed is the speed corresponding to which the number of molecules is maximum i.e. $(= n_{(c)})$ i.e.

$$\text{At } c = c_m, \quad \left| n_{(c)} \right| = \max$$

$$\text{or } \frac{d}{dc} n_{(c)} \Big|_{c=c_m} = 0 \quad (2.8)$$

$$\frac{d}{dc} \left\{ 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T} \right\}_{c=c_m} = 0$$

$$4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} \left\{ 2c e^{-mc^2/2k_B T} + c^2 e^{-mc^2/2k_B T} \left(-\frac{2mc}{2k_B T} \right) \right\}_{c=c_m} = 0$$

$$\left(1 - \frac{mc^2}{2k_B T} \right)_{c=c_m} = 0$$

$$c_m = \sqrt{\frac{2k_B T}{m}} \quad (2.9)$$

2.4 Number of molecules corresponding to maximum probable speed

$$\text{At } c = c_m = \sqrt{\frac{2k_B T}{m}}$$

$$|n_{(c)}|_{\max} = 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} \left(\frac{2k_B T}{m} \right) e^{-2k_B T / 2k_B T}$$

$$(n_{(c)})_{\max} = 4n \sqrt{\frac{m}{2\pi k_B T}} e^{-1} \quad (2.10)$$

As the temperature of gas increases, the maximum probable speed c_m increases, but the number of molecules corresponding to it decreases. The exponential fall of $n_{(c)} = 0$ with c becomes slow. But the area enclosed by the curve (with c -axis) remains the same i.e. the distribution curve spreads.

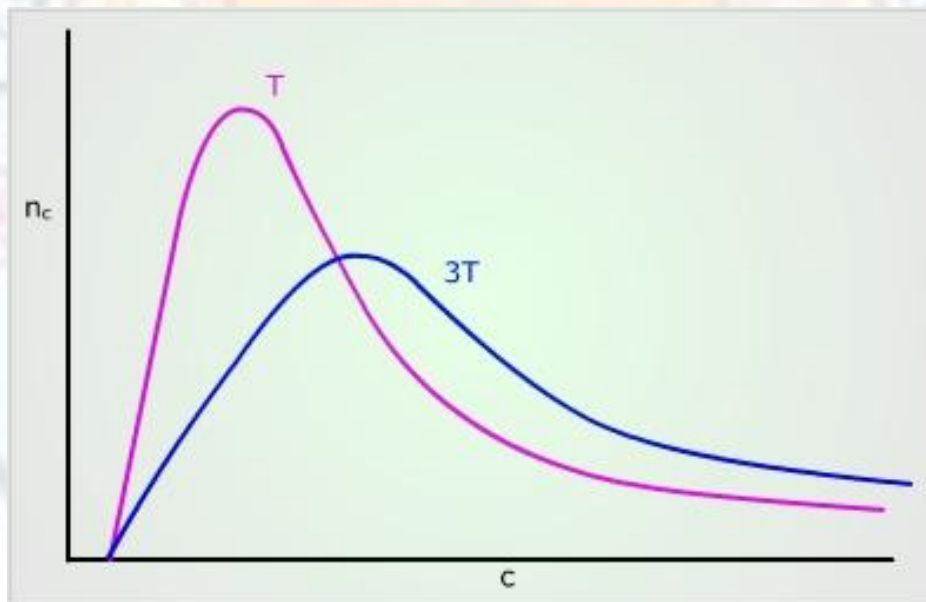


Fig 2.1

2.5 Speed Distribution function

When $c = 0$, $n_c = 0$, i.e. no molecule has the zero speed. For lower values of c , the term c^2 is more effective than $e^{-mc^2/2k_B T}$, therefore as c increases, the number of molecules

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corresponding to it increases and for $c = c_m$, the number of molecules is maximum. If c is further increased, the exponential term $e^{-mc^2/2k_B T}$ becomes more pronounced, and therefore the number of molecules $n_{(c)}$ then decreases exponentially with c . At $c = \infty$, number of molecules vanishes and becomes zero.

2.6 Mean or average speed

$$\langle c \rangle = \frac{\int_0^{\infty} c n_{(c)} dc}{n} \quad (2.11)$$

where number of molecules is given by $n_{(c)} = 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T}$

Substituting its value in eq(2.11), we get

$$\langle c \rangle = \frac{1}{n} \int_0^{\infty} c \times 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T} dc = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} \int_0^{\infty} c^3 e^{-mc^2/2k_B T} dc \quad (2.12)$$

Using a standard formula of a integral, $\int_0^{\infty} x^3 e^{-\beta x^2} dx = \frac{1}{2\beta^2}$

we can calculate the value of $\int_0^{\infty} c^3 e^{-mc^2/2k_B T} dc$.

Here, value of β is $\frac{m}{2k_B T}$, so

$$\int_0^{\infty} c^3 e^{-mc^2/2k_B T} dc = \frac{1}{2 \left(\frac{m}{2k_B T} \right)^2}$$

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Substituting this value of integral, average speed $\langle c \rangle$ becomes

$$\langle c \rangle = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} \frac{1}{2 \left(\frac{m}{2k_B T} \right)^2} = \sqrt{\frac{8k_B T}{\pi m}} \quad (2.13)$$

2.7 Root mean square speed $\langle c^2 \rangle$

$$\langle c^2 \rangle = \frac{\int_0^{\infty} c^2 n_{(c)} dc}{n}$$

$$= \frac{1}{n} \int_0^{\infty} c^2 \times 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T} dc = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} \int_0^{\infty} c^4 e^{-mc^2/2k_B T} dc$$

Using a standard integral $\int_0^{\infty} x^4 e^{-\beta x^2} dx = \frac{3}{8\beta^2} \sqrt{\frac{\pi}{\beta}}$

$$\int_0^{\infty} c^4 e^{-mc^2/2k_B T} dc = \frac{3}{8 \left(\frac{m}{2k_B T} \right)^2} \sqrt{\frac{\pi}{\left(\frac{m}{2k_B T} \right)}} = \frac{3}{8 \left(\frac{m}{2k_B T} \right)^2} \sqrt{\frac{2\pi k_B T}{m}}$$

$$\langle c^2 \rangle = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} \times \frac{3}{8 \left(\frac{m}{2k_B T} \right)^2} \sqrt{\frac{2\pi k_B T}{m}} = 4\pi \left(\frac{m}{2\pi k_B T} \right) \times \frac{3}{8 \left(\frac{m}{2k_B T} \right)^2} = \frac{3k_B T}{m}$$

$$c_{rms} = \sqrt{\langle c^2 \rangle} = \sqrt{\frac{3k_B T}{m}} \quad (2.14)$$

2.8 Expression for Mean Free path

Say a particular molecule shown by the solid circle has been singled out. Each segment of the path between two successive collisions is called a free path. Here we have to find out mean free path, represented by λ .

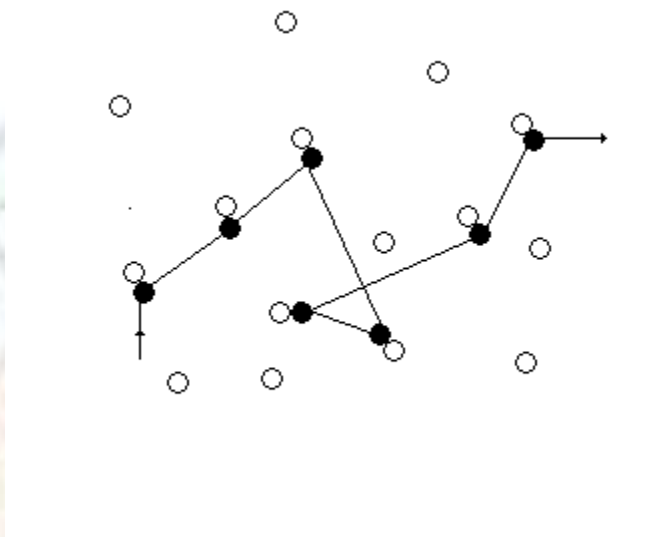


Fig 2.2

10.swf

Say, at a particular time, all of the molecules of a gas except one, are frozen in position. Rest of the molecules continue to move among the others with a speed equal to the average speed (as we have discussed in previous chapter). Let us consider molecules to be perfectly elastic spheres having radius r . At the instant of a collision, the center-to-center distance of the colliding molecules is $2r$ as shown in Fig 2.3.

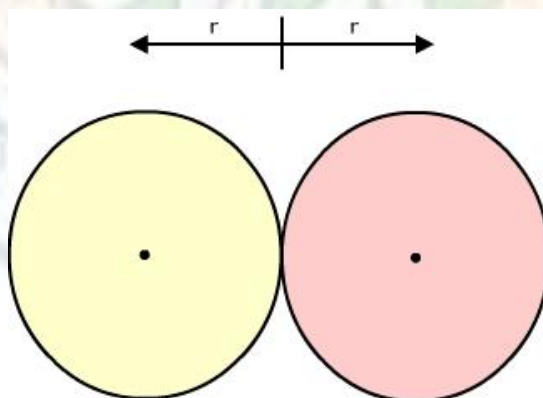


Fig 2.3

Root Mean Square Speed And Mean Free Path

The center-to-center distance would not get changed in case the radius of the moving molecule were increased to $2r$, while the stationary molecules were shrunk to geometrical points, as in Fig 2.4.

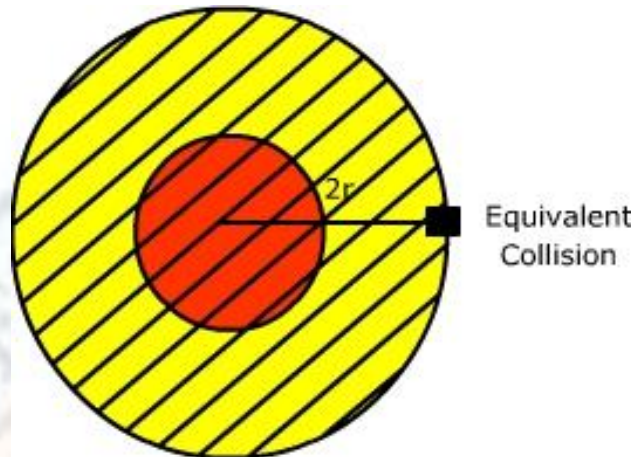


Fig 2.4

Collision cross section of the moving molecule χ , can be expressed as

$$\chi = 4\pi r^2 \quad (2.15)$$

The moving molecule traverses a distance $\bar{u}t$ in a time interval t , along an irregular zigzag path, and sweeps out a cylindrical volume of length l and cross section χ . During this time interval t , this molecule collides with all the other molecules whose centers lie within this cylindrical volume. If there are n molecules per unit volume, the numbers with centers in the cylinder swept out by the moving molecule is $\chi n \bar{u} t$.

We know that mean free path is the average distance travelled by the molecule between collisions, or in other words we can also express it as the total distance covered by the molecule in time t divided by the number of collisions during this time. Hence,

$$\lambda = \frac{\bar{u}t}{\chi n \bar{u} t}$$

$$\Rightarrow \lambda = \frac{1}{\chi n} \quad (2.16)$$

To make it more clear, say $\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_N$ are the successive free paths traversed by the molecule in total time t .

$\lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_N = \bar{u}t$ where \bar{u} is the average speed of a molecule and N the number of collisions suffered i.e. free paths traversed in time t , then

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$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \dots + \lambda_N}{N} = \frac{\bar{u}t}{N} = \frac{D}{N}$$

collisions.

Value Addition: **MEAN FREE PATH**

The following link shows the animation of Mean Free Path

http://physics-animations.com/Physics/English/free_txt.htm

The following animation demonstrates the calculation of mean velocities of the molecules of gas

http://www.myteachingplace.com.au/page.php/resources/view_all?id=p5_stern_gerlach_gas_molecules_velocity_temperature_vessel_kinetic_theory_page_3

2.9 Distribution of free paths

We have to derive the form of distribution function of the free paths.

Say N_A are the large number of molecules at a certain instant. They are colliding with other molecules and in each collision, a molecule gets removed from the group. Consider N as the number that have not yet made a collision after those remaining in the group have travelled a distance s , measured along the free path of each molecule. In the next short distance ds , a certain number of molecules will make collisions and get removed from the group. It is assumed that this number is proportional to the distance ds and the number of molecules N remaining in the group. Since in each collision, a molecule is removed from the group and N decreases,

$$dN = -Z_c N ds \quad (2.17)$$

where Z_c is a proportionality constant called the collision probability. Then

$$\frac{dN}{N} = -Z_c ds$$

$$\ln N = -Z_c s + \text{const}$$

When $s=0$, $N = N_A$

$$N = N_A \exp(-Z_c s) \quad (2.18)$$

The number remaining in the group therefore falls off exponentially with s . Substituting this value for N , dN becomes

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$$dN = -Z_c N_A \exp(-Z_c s) ds \quad (2.19)$$

Here dN (considered with + sign) represents the number of molecules with free paths of length between s and $s+ds$.

$$\lambda = \frac{\int s dN}{N_A} = \frac{\int_0^{\infty} Z_c N_A s \exp(-Z_c s) ds}{N_A} = \frac{1}{Z_c} \quad (2.20)$$

So, mean free path is inversely proportional to the collision probability Z_c .

Also since $\lambda = \frac{1}{Z_c}$, it means $Z_c = \chi n$ i.e. the collision probability is directly proportional to χn

the collision cross section and the number of molecules per unit volume. Eq(2.18) can be now written as (using eq(2.20)),

$$N = N_A \exp\left(-\frac{s}{\lambda}\right) \quad (2.21)$$

$$dN = -\frac{N_A}{\lambda} \exp\left(-\frac{s}{\lambda}\right) ds \quad (2.22)$$

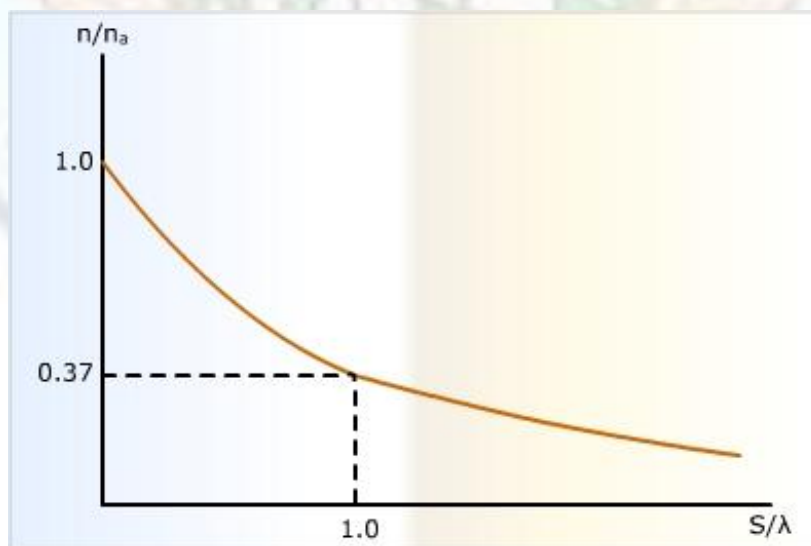


Fig 2.5

2.10 How to determine mean free path experimentally

Max Born developed a technique to determine mean free path experimentally. Q is a tube made of quartz. Four brass discs $D1, D2, D3, D4$ are placed one above the other. These discs are a distance d of 1cm apart from each other. Silver is heated (at the point X) which evaporates and passes through the narrow slit T and then through a circular hole in each of the discs. Each of these discs carries a glass quadrant on which silver atoms get deposited. This deposition is due to the cooling effect of cooling mixture C . The quadrants are arranged in such a way that each quadrant gets one fourth of the incident beam.

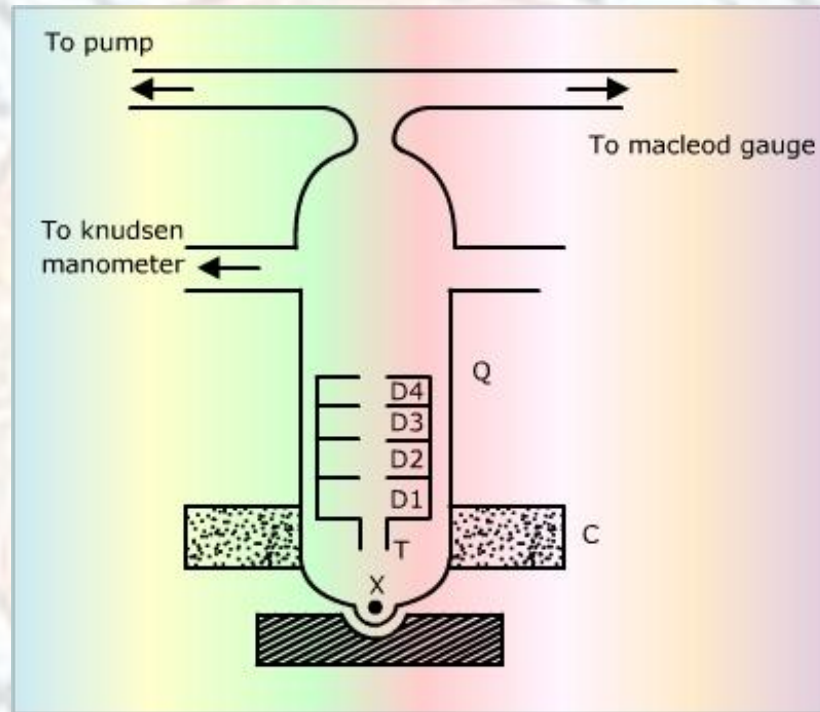


Fig 2.6

Density of deposit ρ_{10} on a quadrant is measured with a microphotometer when all the gas from the tube is pumped out and the free path is equal to the length of the chamber. Then the gas is again pumped giving a free path λ . The density ρ_1 on the same quadrant is again measured. From the law of distribution of free paths,

$$\rho_1 = \rho_{10} e^{-r_1/\lambda} \quad (2.23)$$

where r_1 is the distance of the quadrant from the slit.

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In the same way, the density ρ_2 and ρ_{20} on the next quadrant at a distance r_2 from the slit T is measured.

$$\rho_2 = \rho_{20} e^{-r_2/\lambda} \quad (2.24)$$

Combining eq(2.23) and eq(2.24), mean free path becomes

$$\lambda = (r_2 - r_1) \log_e \frac{\rho_2 \rho_{10}}{\rho_1 \rho_{20}}$$

Experimentally it was found that mean free path comes out to be 1.7cm, when pressure $P = 5.8 \times 10^{-3} \text{ mm}$.

Thus the product of pressure and mean free path is constant as predicted by theory. This good match between theory and practice verifies the law of distribution of free paths. It helps us in determining mean free path.

Summary

1. Maxwell Boltzmann's speed distribution function is

$$n_{(c)} = 4\pi n \left(\frac{m}{2\pi k_B T} \right)^{3/2} c^2 e^{-mc^2/2k_B T}$$

2. Most probable speed is given by $c_m = \sqrt{\frac{2k_B T}{m}}$

3. Number of molecules corresponding to maximum probable speed $(n_{(c)})_{\max}$

$$(n_{(c)})_{\max} = 4n \sqrt{\frac{m}{2\pi k_B T}} e^{-1}$$

4. Mean or average speed $\langle c \rangle = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} \frac{1}{2 \left(\frac{m}{2k_B T} \right)^2} = \sqrt{\frac{8k_B T}{\pi m}}$

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5. Root mean square speed $c_{rms} = \sqrt{\langle c^2 \rangle} = \sqrt{\frac{3k_B T}{m}}$

6. Mean free path is the average distance which a molecule can travel through a gas without colliding with another molecule.

7. The average distance between collisions, or the mean free path, equals the total distance covered in time t , divided by the number of collisions in this time.

8. $\lambda = \frac{1}{\chi n}$ where collision cross section is χ and n is number of molecules per unit volume. Mean free path is inversely proportional to collision cross section.

9. At a given temperature, the number of molecules per unit volume is directly proportional to the pressure, and the mean free path is inversely proportional to the pressure.

10. The collision probability is equal to reciprocal of mean free path.

Solved Examples

Q1 Calculate root mean square speed at 300K. Given the molar mass M of oxygen as 0.0320 Kg/mol.

Sol. Root mean square speed is given by

$$c_{rms} = \sqrt{\frac{3RT}{M}}$$

Here, $T=300\text{K}$, $M=0.0320\text{ Kg/mol}$, $R=8.314\text{ J/mol K}$, we get

$$c_{rms} = \sqrt{\frac{3 \times 8.314 \times 300}{0.032}} = 483\text{ m/s}$$

Q2 What is the most probable speed at 300K if the molar mass M of oxygen is 0.050Kg/mol.

Sol. Most probable speed is

$$c_m = \sqrt{\frac{2RT}{M}}$$

Substituting values of $T=300\text{K}$, $M=0.050\text{ Kg/mol}$, $R=8.314\text{ J/mol K}$, we get

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$$c_m = \sqrt{\frac{2 \times 8.314 \times 300}{0.050}} = 315.8 \text{ m/s}$$

Q3 Find the mean translational kinetic energy per molecule of a gas at 327°C .

Sol. Mean translational kinetic energy per molecule $K.E._{mean} = \frac{3}{2} k_B T$ where

$$N = 6.023 \times 10^{23}$$

$$T = 327 + 273 = 600 \text{ K}$$

$$R = 8.314 \text{ J/mol-K}$$

$$k_B = \frac{R}{N} = \left(\frac{8.314}{6.023 \times 10^{23}} \right) \text{ J/molecule-K}$$

$$\text{So, } K.E._{mean} = \frac{3}{2} k_B T = \frac{3}{2} \frac{R}{N} T = \frac{3 \times 8.314 \times 600}{2 \times 6.023 \times 10^{23}} = 1.24 \times 10^{-20} \text{ J} = 1.24 \times 10^{-13} \text{ ergs}$$

Q4 Find the total random kinetic energy of 10g of Helium at 1000K?

$$\text{Sol. Energy for 1g of Helium} = \frac{3RT}{2M}$$

$$\text{Energy for 10g of Helium} = 10 \times \frac{3RT}{2M} = \frac{15RT}{M} = \frac{15 \times 8.314 \times 1000}{4} = 31177.5 \text{ J}$$

Q5 Calculate the value of temperature at which will the root mean square speed r.m.s. of a gas be one-third of its value at 0°C when pressure is kept constant?

Sol. Given initial value of r.m.s. = $C = C_1$

$$C_2 = \frac{C_1}{3}$$

$$\text{Here } \frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$$

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$$\frac{1}{3} = \sqrt{\frac{T_2}{273}}$$

$$\frac{1}{9} = \frac{T_2}{273} \quad \text{or} \quad T_2 = \frac{273}{9} = 30.33 \text{ K}$$

Q6 What will be the root mean square speed of the hydrogen molecules at 327°C ?

Sol. R.M.S. speed of oxygen at N.T.P. = $C_1 = \sqrt{\frac{3P}{\rho}}$

$$P = 76 \times 13.6 \times 980 \text{ dynes / cm}^2$$

$$\rho = .000089 \text{ gm / cc}$$

$$C_1 = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 76 \times 13.6 \times 980}{0.000089}} = 184780 \text{ cm / s}$$

$$\frac{C_2}{C_1} = \sqrt{\frac{T_2}{T_1}}$$

$$C_2 = 184780 \sqrt{\frac{600}{273}} = 184780 \times 1.48 = 273474 \text{ cm / s}$$

Q7 Find the mean free path of a gas molecule, given that the molecular diameter is $3.5 \times 10^{-10} \text{ m}$ and the number of molecules per cc is 2×10^{19} .

Sol. $\lambda = \frac{1}{\pi d^2 n} = \frac{1}{3.14 \times (3.5 \times 10^{-8})^2 \times 2 \times 10^{19}} = 1.29 \times 10^{-5} \text{ cm}$

Q8 Calculate the value of mean free path of the molecules of gas if following parameters are given

$$\eta = 3.4 \times 10^{-2} \text{ dynes / cm}^2$$

$$\rho = .003 \text{ gm / cc}$$

$$C = 3000 \text{ cm / s}$$

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$$\text{Sol. } \lambda = \frac{3\eta}{\rho C} = \frac{3 \times 3.4 \times 10^{-2}}{.003 \times 3000} = 1.13 \times 10^{-2} \text{ cm}$$

Q9 Find the mean free path at NTP if the diameter of the molecule of a gas is 3.5 \AA .

$$\text{Sol. Here } d = 3.5 \text{ \AA} = 3.5 \times 10^{-10} \text{ m}$$

$$k_B = 1.38 \times 10^{-23} \text{ J/K}$$

Let n be the number of molecules per cubic meter.

$$PV = RT$$

$$PV = Nk_B T$$

$$n = \left(\frac{N}{V} \right) = \frac{P}{k_B T}$$

At NTP

$$n = \frac{0.76 \times 13.6 \times 10^3 \times 9.8}{1.38 \times 10^{-23} \times 273} = 2.7 \times 10^{25}$$

Mean free path

$$\lambda = \frac{1}{\pi d^2 n} = \frac{1}{3.14 \times (3.5 \times 10^{-10})^2 \times 2.7 \times 10^{25}} = 9.62 \times 10^{-8} \text{ m}$$

Q10 Find the frequency of collision if given r.m.s. $C = 3000 \text{ cm/s}$ and mean free path $\lambda = 8.5 \times 10^{-5} \text{ cm}$?

$$\text{Sol. Frequency of collision} = n = \frac{C}{\lambda} = \frac{3000}{8.5 \times 10^{-5}} = 352.9 \times 10^5$$

MCQ

Q1 The ratio of Universal gas constant R and Avagadro's number N is called

- a) Stefan constant
- b) Avagadro constant

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- c) Rydberg constant
- d) Boltzmann constant

Q2 At a temperature T , the root mean square velocity, c_{rms} , of a gas molecule having mass m is proportional to

- a) $\frac{1}{m}$
- b) $\frac{1}{\sqrt{m}}$
- c) $\frac{1}{m^2}$
- d) m

Q3 At a given temperature, the average kinetic energy of gaseous nitrogen molecules is

- a) equal to
- b) a little greater than
- c) less than
- d) much larger than the average kinetic energy of gaseous oxygen molecules.

Q4 In a gas the expression for the average speed of molecule is given by

- a) $\sqrt{\frac{k_B T}{\pi m}}$
- b) $\sqrt{\frac{2k_B T}{\pi m}}$
- c) $\sqrt{\frac{8k_B T}{\pi m}}$
- d) $\sqrt{\frac{3k_B T}{\pi m}}$

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Q5 In a gas the relative magnitudes of the most probable speed v_p , the average speed \bar{v} and root mean square speed v_{rms} of the molecule are

a) $v_{rms} > \bar{v} > v_p$

b) $v_{rms} < \bar{v} < v_p$

c) $v_{rms} < \bar{v} < v_p$

d) $v_{rms} < 3\bar{v} < v_p$

Q6 In a Maxwellian gas, if v_{rms} is the root mean square velocity, then the most probable velocity v_p is

a) $\sqrt{\frac{2}{3}} v_{r.m.s.}$

b) $\sqrt{\frac{3}{2}} v_{r.m.s.}$

c) $\sqrt{\frac{2}{5}} v_{r.m.s.}$

d) $\frac{1}{2} v_{r.m.s.}$

Q7 The root mean square speed, average speed and the most probable speed for a gas are in the ratio

a) $1:2\sqrt{2}:\sqrt{2}$

b) $\sqrt{3}:2\sqrt{2}:\sqrt{2}$

c) $\sqrt{3}:2\sqrt{2}:2$

d) $\sqrt{3}:3:\sqrt{2}$

Q8 If the root-mean-square speed of the molecules of a gas is doubled, then

a) its temperature will decrease by a factor of 3.

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- b) its temperature will increase by a factor of 4.
- c) its pressure will increase by a factor of 4.
- d) its temperature will decrease by a factor of 2.

Q9 The total random kinetic energy of one gm-molecule of nitrogen at 300K is

- a) 3840 J
- b) 6400 J
- c) 3733 J
- d) 3741 J

Q10 "Under the same condition of temperature and pressure, equal volume of all gases has equal number of molecules". This statement corresponds to

- a) Graham Law of diffusion
- b) Charles Law
- c) Avagadro Law
- d) Boyles Law

Q11 An ideal gas is kept in a rigid container. When its temperature is 100K, the mean free path of the gas molecules is λ . What will be the mean free path of the molecules at 400K?

- a) λ
- b) $\frac{\lambda}{2}$
- c) $\frac{\lambda}{4}$
- d) $\frac{1}{\lambda}$

Q12 The distance between molecules at standard conditions is of the order of $3 \times 10^{-9} m$, so the mean free path is of the order of _____ times the molecular distance.

- a) 5
- b) 10
- c) 2

Root Mean Square Speed And Mean Free Path

d) 3

Q13 Collision frequency in oxygen at standard conditions is _____ collisions/sec.

a) 5.5×10^9

b) 4.8×10^9

c) 5.9×10^9

d) 7.5×10^9

Q14 Mean free path of the hydrogen molecules at N.T.P. is _____ cm, when coefficient of viscosity is 8×10^{-5} c.g.s. unit and density of hydrogen at N.T.P. is 9×10^{-5} g/cc.

a) 3.5×10^{-5}

b) 4.8×10^{-5}

c) 5.9×10^{-5}

d) 1.5×10^{-5}

Q15 Mean free path λ and diameter d of the molecule is related by

a) $\lambda \propto \frac{1}{d^2}$

b) $\lambda \propto \frac{1}{d^3}$

c) $\lambda \propto \frac{1}{d}$

d) $\lambda \propto d$

Answers

1. d 2. b 3. c 4. c 5. a 6. a 7. b 8. b 9. d 10. c 11. a 12. b 13. a 14. d 15. a

Fill in the blanks

1. The path covered by a molecule between any two consecutive collisions is called the _____.

Root Mean Square Speed And Mean Free Path

2. It depends upon _____ and _____.
3. Increasing the number of molecules or decreasing the volume will cause the density to _____.
4. Increasing the radius of the molecule will decrease the space between them. So, mean free path will _____.
5. Mean free path is _____ proportional to the pressure.
6. The collision probability is equal to reciprocal of _____.
7. Mean free path is _____ proportional to density of the gas.
8. Transport phenomena are governed by _____ of a molecule.

Answers

1. free path
2. molecular diameter, temperature
3. increase
4. decrease
5. inversely
6. mean free path
7. Inversely
8. Mean free path

References/ Bibliography/ Further Reading References

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