ARJUNA NEET BATCH

States of Matter

LECTURE - 7

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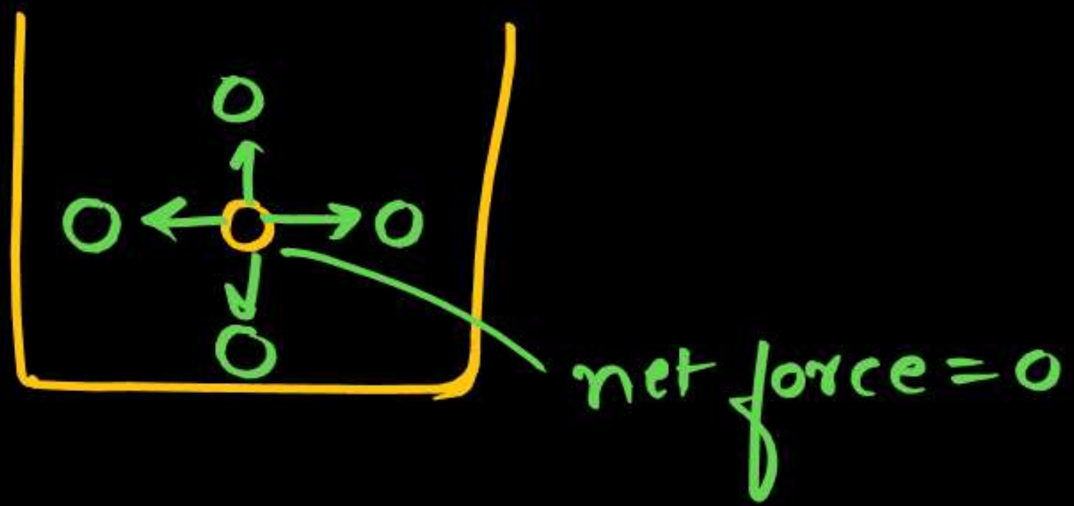
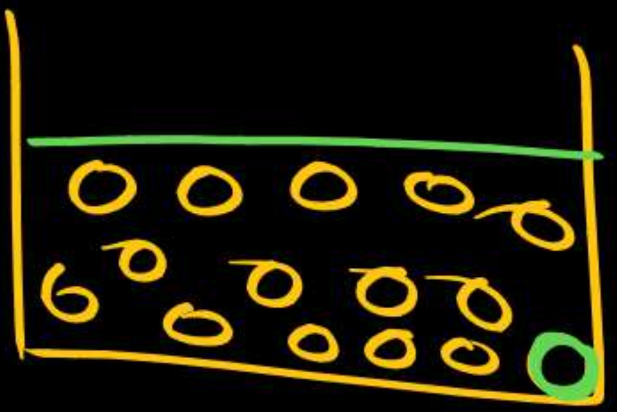
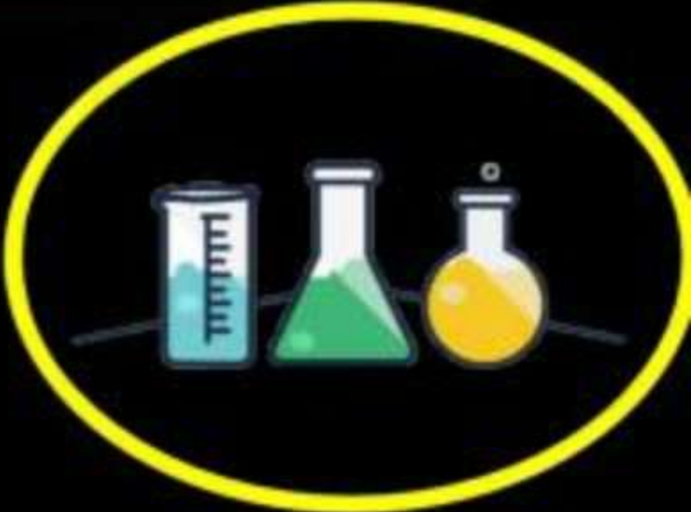




* $K.E. \propto Temp.$

Objective of today's class

MAXWELL BOLTZMANN CURVE AND MOLECULAR SPEEDS



KINETIC ENERGY AND MOLECULAR SPEEDS

According to Kinetic Theory of gases.

P-V Relation :→

$$PV = \frac{1}{3} m \bar{c}^2$$

P → Pressure

V → Volume

m → mass of gas molecules

$\bar{c}^2$ → Root mean square

$\Rightarrow P\cdot V = \frac{1}{3} m\bar{c}^2$

Multiply & divide by 2

$\Rightarrow P\cdot V = \frac{1}{3} \times 2 \times \frac{1}{2} m\bar{c}^2$

$\Rightarrow P\cdot V = \frac{2}{3} \times K.E.$

$\Rightarrow K.E. = \frac{3}{2} P \times V$ — (1)

Acc. to ideal gas Equation.

$PV = nRT$ — (2)

from (1) & (2)

$\Rightarrow \boxed{K.E. = \frac{3}{2} nRT}$

if $n = 1$

$\boxed{K.E._{\text{permole}} = \frac{3}{2} RT}$

K.E. per molecule

$\Rightarrow n = \frac{N_0}{N_A} \Rightarrow N_0 = N_A$

$\Rightarrow (K.E.)_{\text{permolecule}} = \frac{3}{2} R \times \frac{1}{N_A} \times T$

$$(K.E.)_{\text{per molecule}} = \frac{3}{2} \times \frac{R}{N_A} \times T$$

$R \rightarrow$ gas constant (8.314)

$T \rightarrow$ Temp.

$N_A \rightarrow 6.02 \times 10^{23}$

$$\boxed{(K.E.)_{\text{per molecule}} = \frac{3}{2} KT}$$

$$\Rightarrow \frac{8.314}{6.02 \times 10^{23}} \left(\frac{R}{N_A}\right) = K$$

$$\Rightarrow 1.38 \times 10^{-23}\ J/K$$

$\boxed{K \rightarrow \text{Boltzmann Constans}}$

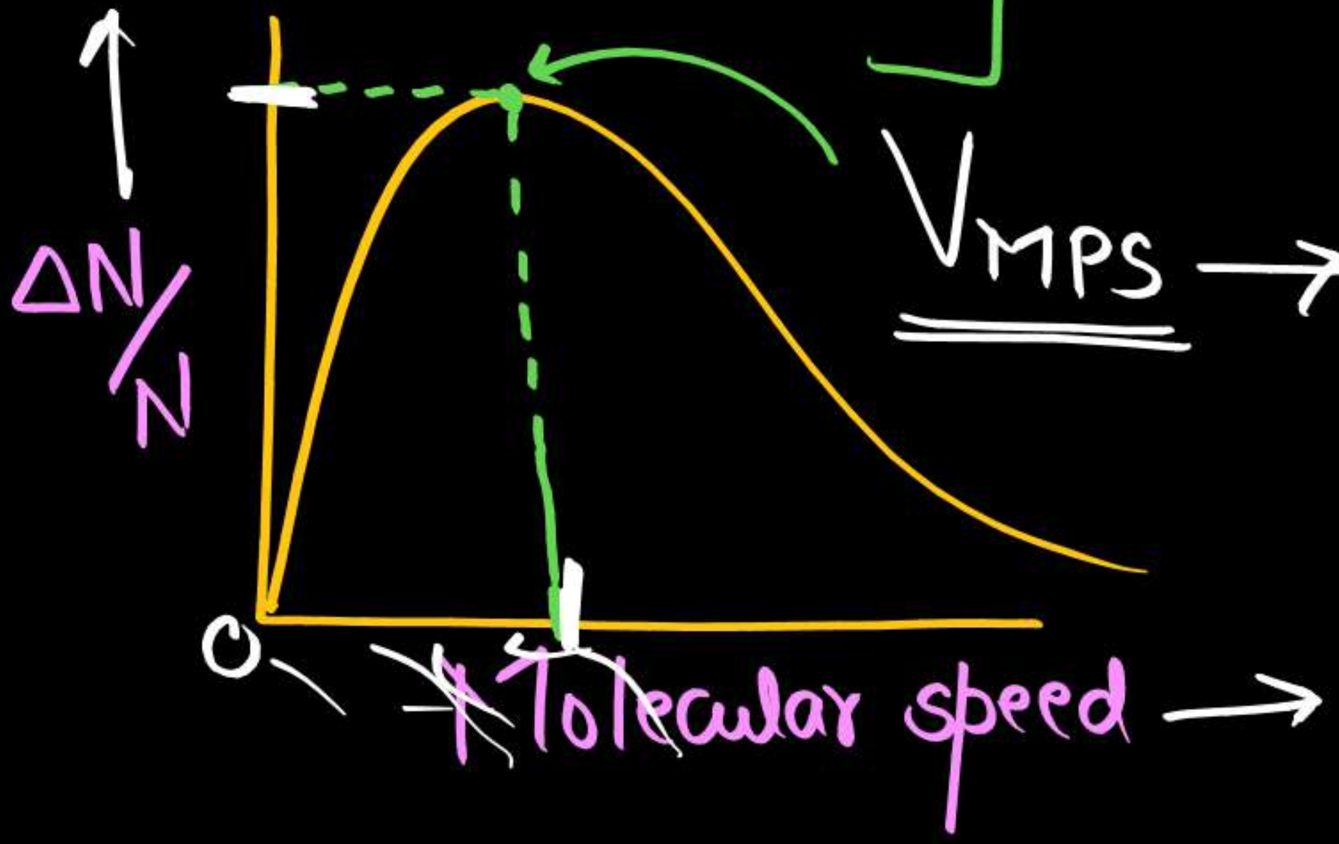
$K = 1.38 \times 10^{-23}$ Joule/K

$\boxed{\text{Average K.E of gas molecules} \propto \text{Temperature}}$

180 Marks → 175 → Most Probable Marks

180 Marks → 160 → Average Marks

180 Marks → ? ? ? → mean → root mean square marks



V_{MPS} → Most Probable Speed

Types of Molecular Speeds

V_{MPS}

(Most probable speed)

⇒ Speed shown by max. no. of molecules present in the sample.

→ It is least presise & smallest among all the molecular

$V_{AVERAGE}$

(Average Speed)

$$V_{Average} = \frac{n_1V_1 + n_2V_2 + n_3V_3 + \cdots}{n_1 + n_2 + n_3}$$

∴ is algebric mean of all the molecules present in the sample.

V_{RMS}

Root mean square Velocity

$$V_{rms} = \sqrt{\frac{n_1V_1^2 + n_2V_2^2 + n_3V_3^2}{n_1 + n_2 + n_3}}$$

V_{MPS}

$$\boxed{V_{MPS} = \sqrt{\frac{2RT}{M}}}$$

ideal gas Eq^n

$PV = nRT$

if $n = 1$

$$\boxed{V_{MPS} = \sqrt{\frac{2PV}{M}}}$$

$$\boxed{V_{MPS} = \sqrt{\frac{2P}{d}}}$$

$V_{AVERAGE}$

$$\boxed{V_{Average} = \sqrt{\frac{8RT}{\pi M}}}$$

ideal gas Eq^n

$PV = nRT$

$$\boxed{V_{Average} = \sqrt{\frac{8PV}{\pi M}}}$$

$$\boxed{V_{Average} = \sqrt{\frac{8P}{\pi d}}}$$

V_{RMS}

$$\boxed{V_{RMS} = \sqrt{\frac{3RT}{M}}}$$

ideal gas Eq^n

$PV = nRT$

$n = 1$

$$\boxed{V_{RMS} = \sqrt{\frac{3PV}{M}}}$$

$$\boxed{V_{RMS} = \sqrt{\frac{3P}{d}}}$$

$n_1 \rightarrow$ no. of gas molecules

$V_1 \rightarrow$ Velocity (speed) of n_1 molecules

$n_2 \rightarrow$ Second gas molecules (Total)

$V_2 \rightarrow$ Velocity (speed) of n_2 gas molecules)

$O_2 \rightarrow V_1, n_1$

$CH_4 \rightarrow V_2, n_2$

$P \rightarrow$ Pressure

$V \rightarrow$ Volume

$M \rightarrow$ Molecular weight

$T \rightarrow$ Temp.

$R \rightarrow$ gas constant

$d \rightarrow$ density

$\pi = 3.14$

Temperature

Q. At what Temperature V_{rms} of He will be same as average speed of Hydrogen at 100 K.

$$(V_{rms})_{He} = (V_{Average})_{H_2} \qquad T = 100\,K$$

$$\sqrt{\frac{3RT}{M}} = \sqrt{\frac{8RT}{\pi M}}$$

Squaring both side

$$\frac{3\cancel{R}T}{M} = \frac{8\cancel{R}T}{\pi M}$$

$$\Rightarrow \frac{3 \times T_{He}}{\cancel{4}\,2} = \frac{8 \times 100}{3.14 \times \cancel{2}}$$

$$T_{He} = \frac{8 \times 100 \times 2}{3.14 \times 3}$$

$$\boxed{T_{He} = \frac{1600}{3 \times 3.14} \Rightarrow 172.7\,K}$$

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Q. **Find rms of He at 100 K (R = 8.314)**

$$(V_{rms})_{He} = \sqrt{\frac{3RT}{M}}$$

$T = 100\,K$

$$\Rightarrow \sqrt{\frac{3 \times 8.314 \times 100}{4}}$$

$$\Rightarrow \underline{\underline{\qquad}}$$

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Q. At what temp. V_{rms} of O_2 gas will be same as that of methane at 27°C.

$T = ?$ $\quad (V_{rms})_{O_2} = (V_{rms})_{CH_4}$ $\qquad T = 27°C \Rightarrow 27 + 273 \Rightarrow 300\,K$

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

On Squaring both side

$$\frac{\cancel{3}\cancel{R}T}{M} = \frac{\cancel{3}\cancel{R}T}{M}$$

$$\frac{T_{O_2}}{\cancel{32}\,2} = \frac{300\,K}{\cancel{16}}$$

$$\boxed{T_{O_2} = 600\,K}$$

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Q. The rate of diffusion of gas having molecular weight just double of H_2 gas is 30 ml/s. The rate of diffusion of H_2 gas.

gas → x → Mol. wt of x = 2 × M wt of H_2 $\left(R \propto \frac{1}{\sqrt{M}}\right)$

$r_x \Rightarrow 30$ ml/s

$$\Rightarrow \frac{r_x}{r_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{x\,gas}}}$$

$$\frac{30\text{ ml/s}}{r_{H_2}} = \sqrt{\frac{2}{\cancel{4}\,2}}$$

$$r_{H_2} = 30\sqrt{2}$$

$$= 30 \times 1.414$$

$$\approx 42.42\text{ ml/s}$$

Q. Two gases A & B having same volume diffuses through porous position in 20 s & 10 s respectively. The molar mass of A is 49 mol. Wt. of B will be-

A	B
V ml	V ml
$t = 20\,s$	$t = 10\,s$
$M_A = 49$	$M_B = ?$

$R \propto V$

$\Rightarrow R \propto \frac{1}{\text{time}}$

$\Rightarrow R \propto \frac{1}{\sqrt{M}}$

$$\frac{t_A}{t_B} = \sqrt{\frac{M_A}{M_B}}$$

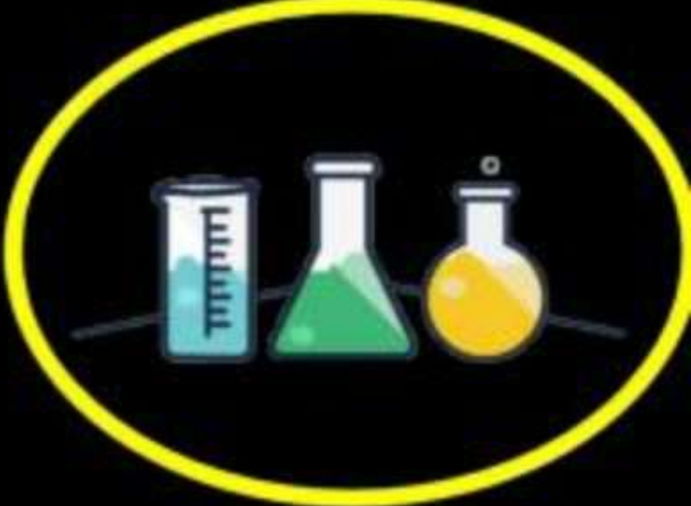
$$\Rightarrow \frac{20}{10} = \sqrt{\frac{49}{M_B}}$$

~~squaring~~ squaring both sid

$$\Rightarrow \frac{\cancel{20} \times \cancel{20}}{\cancel{10} \times \cancel{10}} = \frac{49}{M_B}$$

$$M_B = \frac{49}{4}$$

$$\Rightarrow \underline{\underline{12.25}}$$



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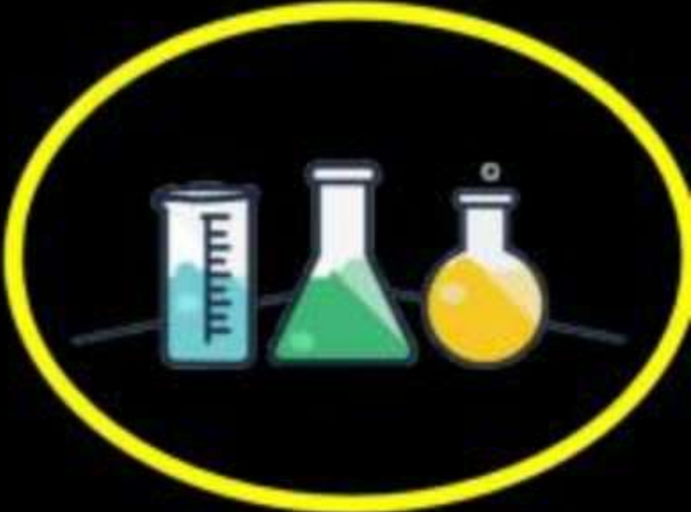
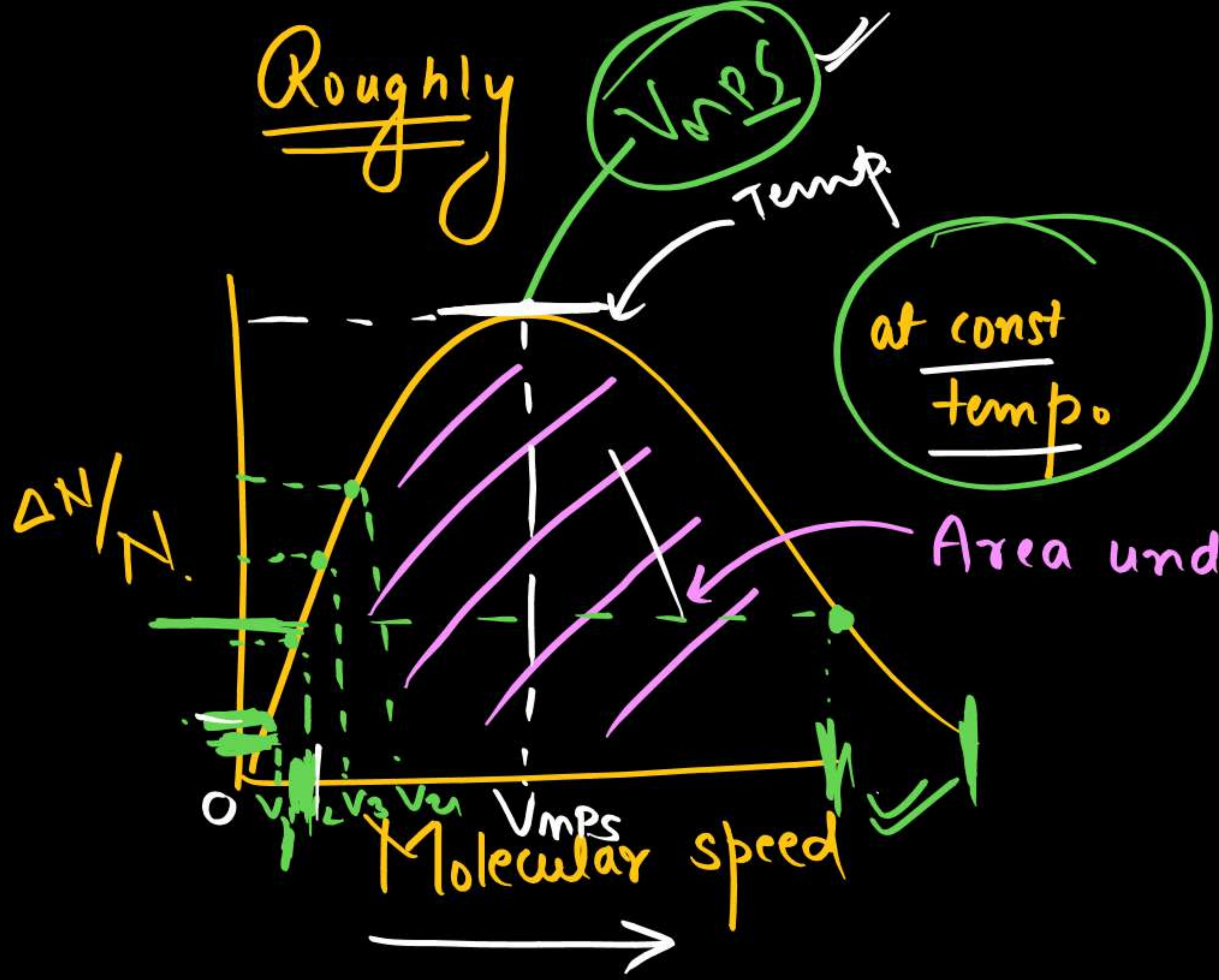
MAXWELL-BOLTZMANN DISTRIBUTION OF MOLECULAR SPEEDS

- The speeds of the individual molecules of a gas do not remain constant. They keep on changing due to intermolecular collisions and due to collisions with the walls of the container. However, at a given temperature, the distribution molecular speeds remains constant. This distribution of molecular speeds is given by Maxwell-Boltzmann distribution law

- For a given gas, at a given temperature, the distribution of Molecular speed is constant.



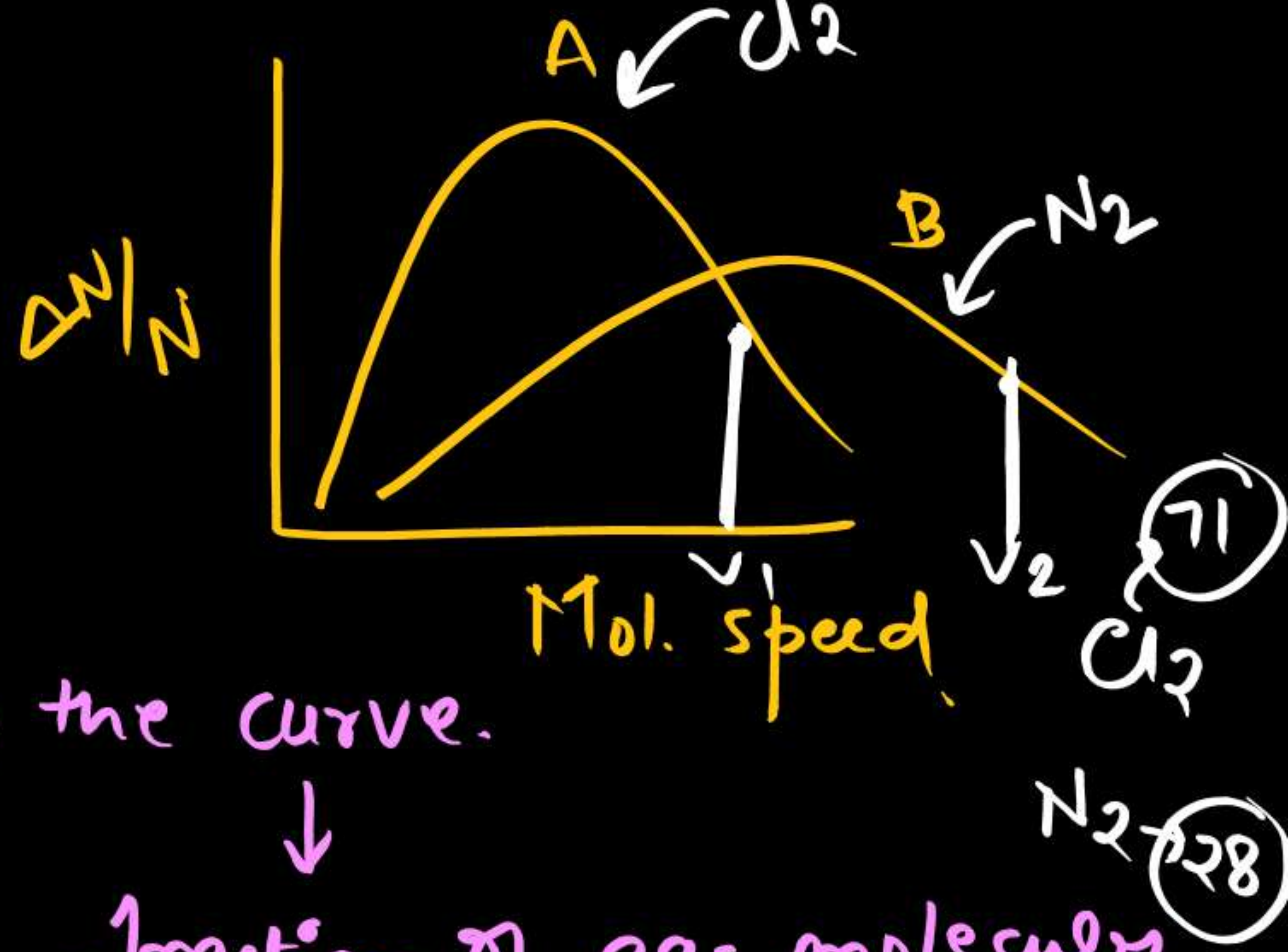
Roughly



Area under the curve.

↓

fraction of gas molecules



$V_4 > V_3 > V_2 > V_1$

Q. Maximum Kinetic Energy at 300 K.

(1) H_2 (2) He (3) U^{238} ~~(4)~~ All have Same.

$$K.E. = \frac{3}{2} KT$$

Q. Kinetic Energy of 6.4 gm of SO_2 at 600 K.

(A) 60 R ~~(B)~~ 90R (C) 20 R (D) 50 R.

$T = 600\,K$

$W_{SO_2} = 6.4\ gm$

$K.E. = \frac{3}{2} nRT$

$n = \frac{W.}{MM}$

$K.E. = \frac{3}{\cancel{2}} \times \frac{\cancel{64}}{\cancel{64} \times 1\cancel{0}} \times R \times \overset{30}{\cancel{600}}$

$\Rightarrow \underline{\underline{90R}}$

Q. Relation between V_{RMS} & $V_{Average}$.

H.W.

MAXWELL BOLTZMANN CURVE

The important features of the distribution curve are:

(a) The fraction of molecules having too low or too high speeds is very small.

(b) There is a certain speed for which the fraction of molecules is maximum. This speed is know as most probable speed.

(c) The most probable speed of a gas, is the speed possessed by the maximum number of molecules of the gas at a given temperature and it corresponds to the peak of the curve.

Since the most probable speed (C^*) is related absolute temperature T by the expression

$$\boxed{C^* = \sqrt{\frac{2RT}{M}}}$$

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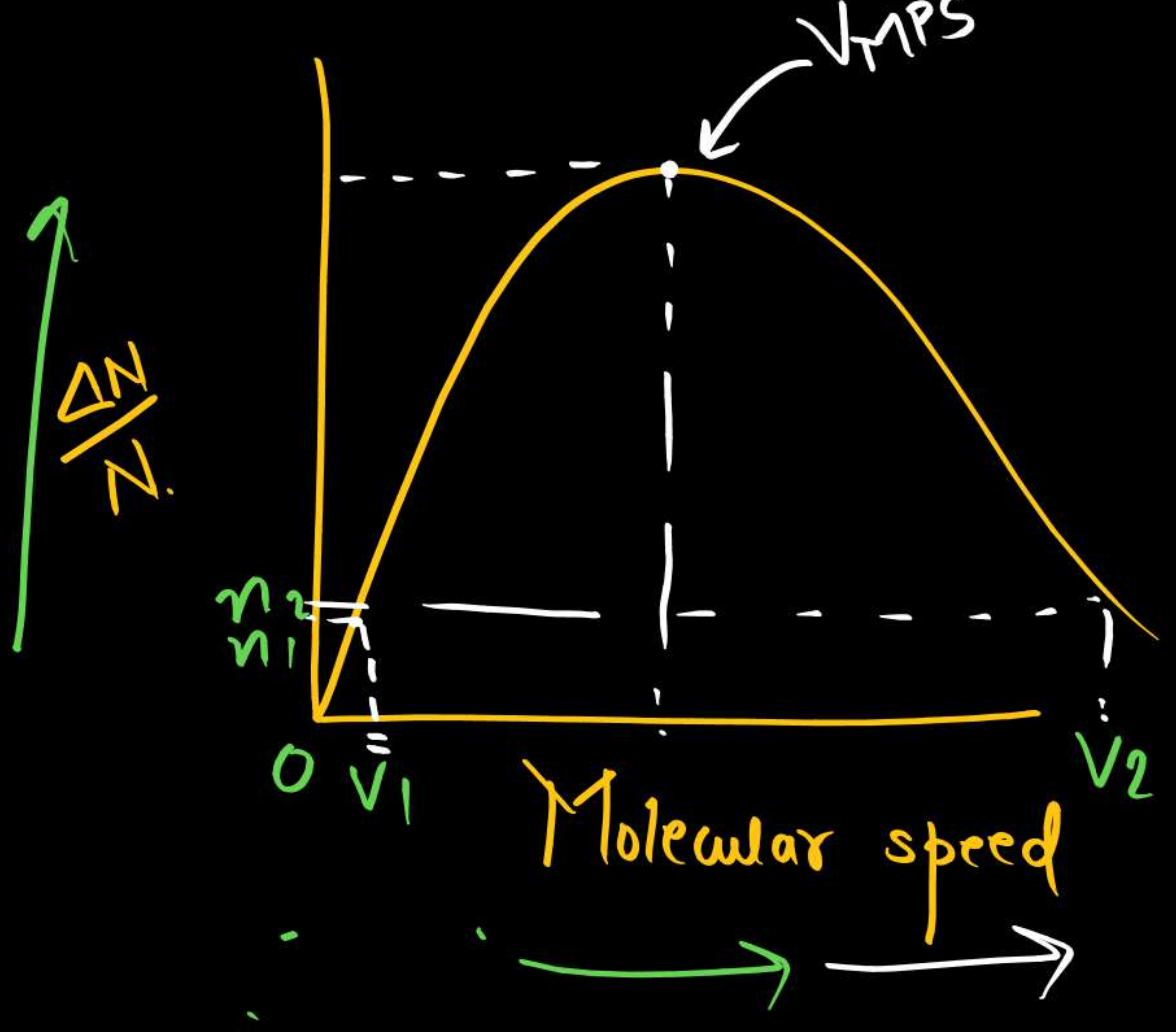
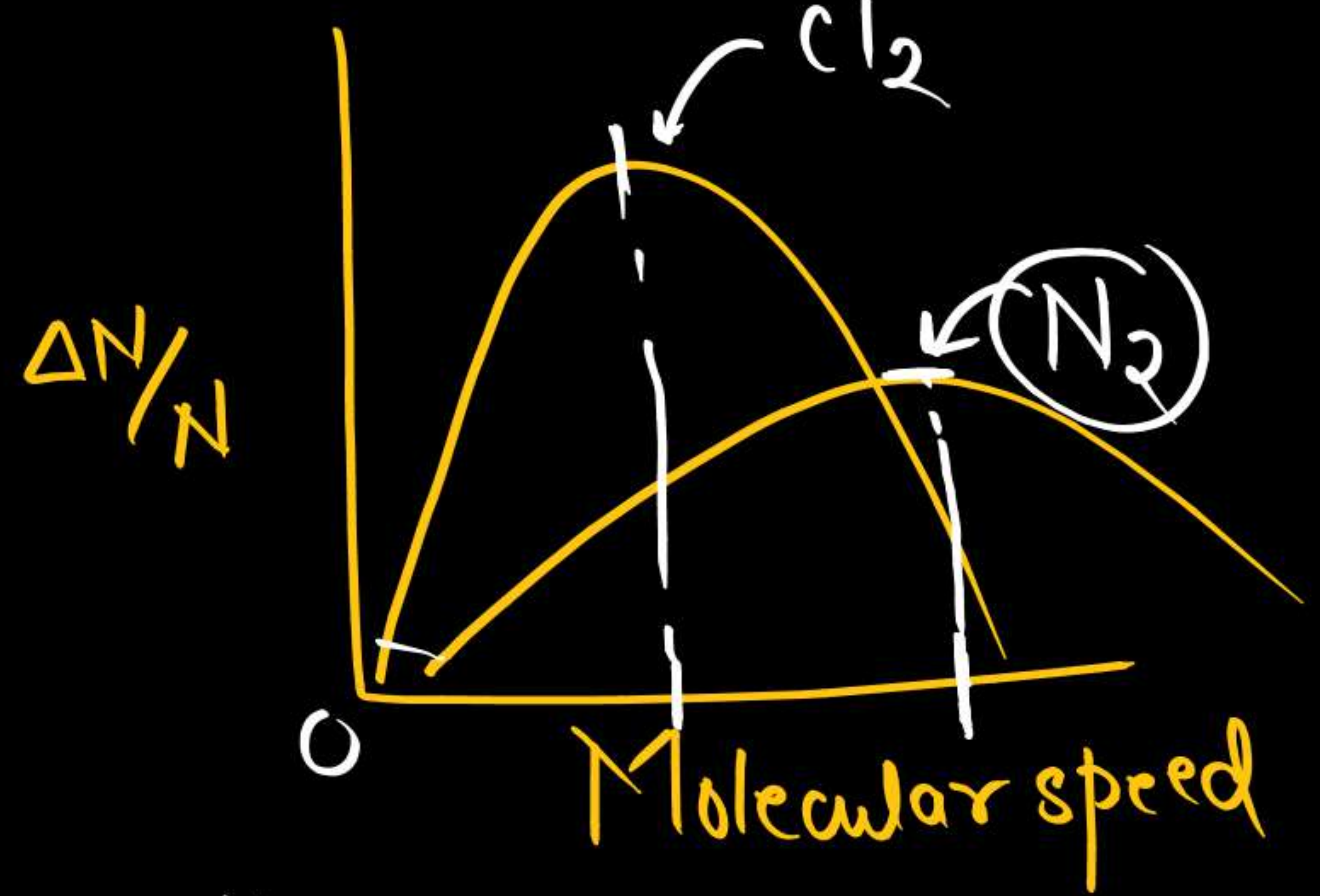


$\frac{\Delta N}{N} \rightarrow$ fraction of molecules

$V_{MPS} \rightarrow$ Most probable speed

It means that at the same temperature, lighter gases shall move faster than heavier gases as is evident from the distribution curves of chlorine and nitrogen gases.

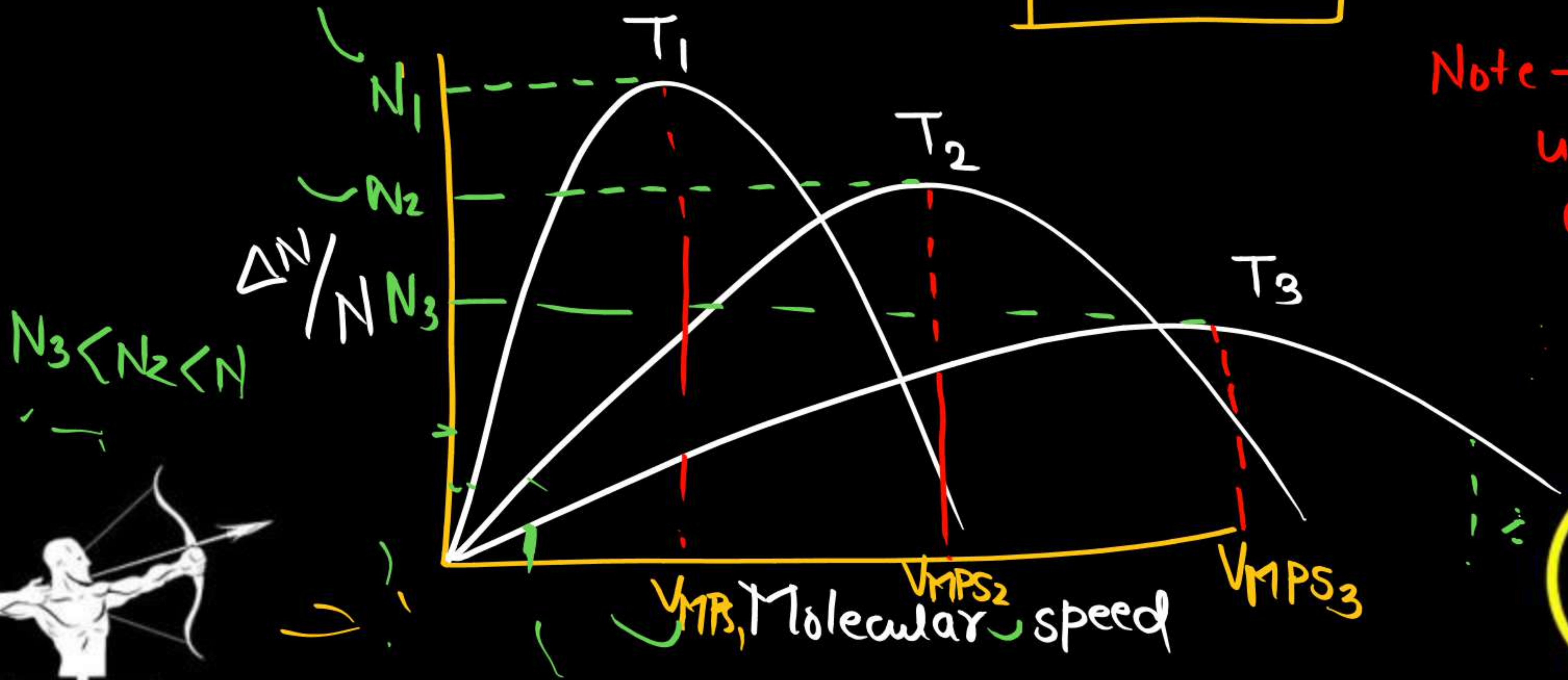


$Cl_2 \rightarrow 71$

$N_2 \rightarrow 28$

EFFECT OF TEMPERATURE

❖ Maxwell Boltzmann distribution curves of a gas at three different temperature T_1, T_2, and T_3 such that $\boxed{T_3 > T_2 > T_1}$.



Note → Area under the curve remains constant.

It can be seen from these distribution curves that as the temperature increases

- The entire curves shift towards right.
- The most probable speed increases. $(V_{MPS_3} > V_{MPS_2} > V_{MPS_1}$
- The fraction of molecules having most probable speed decreases.
- The curve becomes broader in the middle range indicating that more molecules have speeds near to the most probable speed.
- The fraction of molecules having higher speed increases.
- The fraction of molecules having lower speed decreases.

H.W.

Q. At what temperature V_{rms} of N_2 will be $\sqrt{3}$ times of V_{rms} of H_2 at 100 K.

thanks
for watching

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