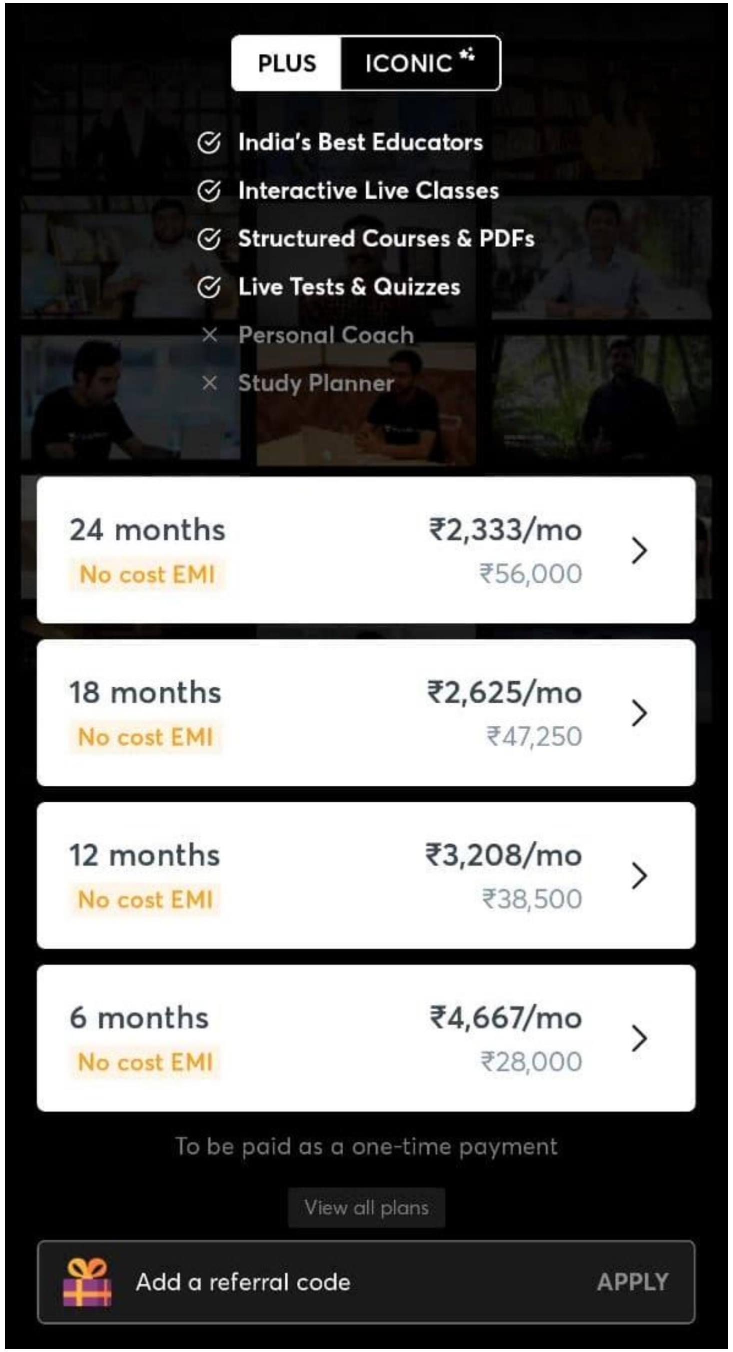
“आज PHYSICS में मचाते हैं।”

SIR PRATEEK JAIN

. Founder @Physicsaholics
. Top Physics Faculty on Unacademy (IIT JEE & NEET)
. 8+ years of teaching experience in top institutes like FIITJEE (Delhi, Indore) , CP (KOTA) etc.
. Produced multiple Top ranks.
. Research work with HC Verma sir at IIT Kanpur
. Interviewed by International media.



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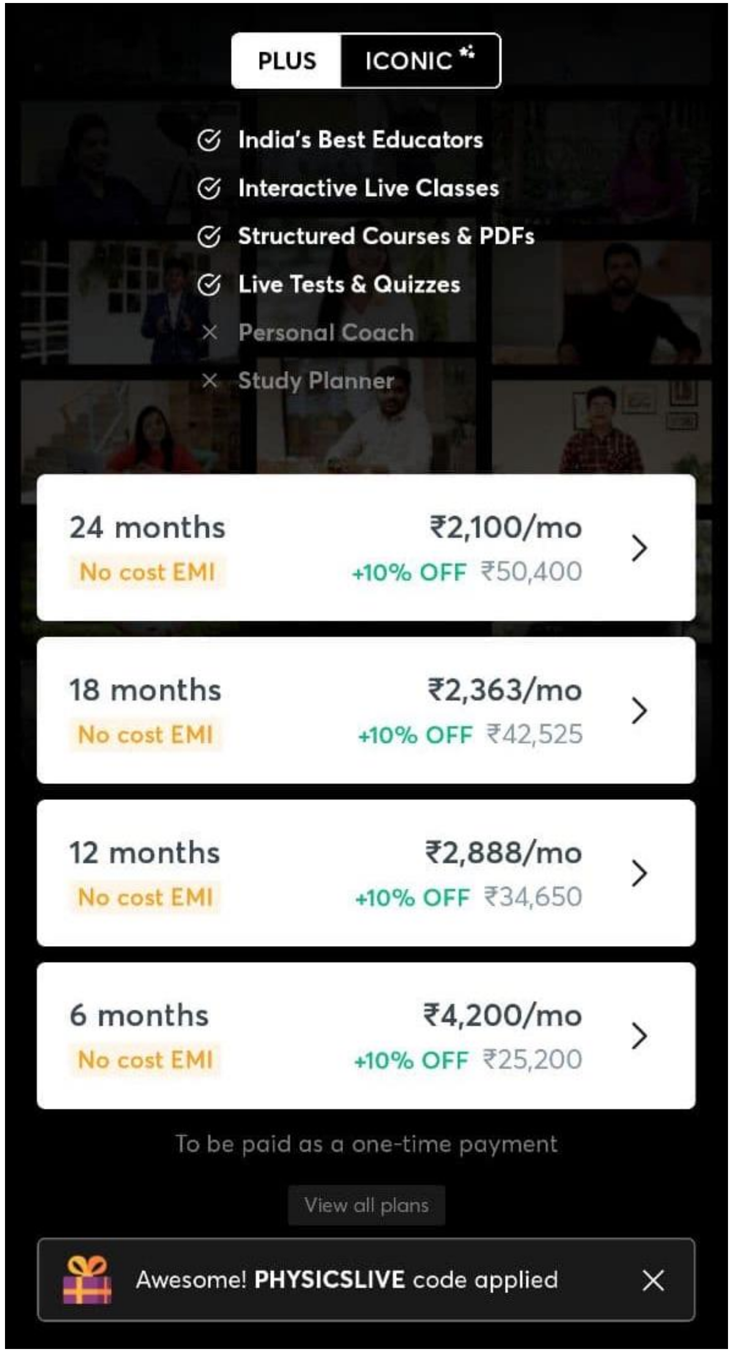

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Physics DPP

DPP-2 KTG: Different type of Velocity and speed of gas molecules

By Physicsaholics Team

Q) Four molecules have speeds 2 km/sec, 3 km/sec, 4 km/sec and 5 km/sec. The root mean square speed of these molecules (in km/sec) is:

(a) $\sqrt{\frac{27}{2}}$ (b) $\sqrt{27}$ (c) 3.5 (d) $3\sqrt{3}$

Ans. a

$$V_{rms} = \sqrt{\frac{V_1^2 + V_2^2 + V_3^2 + \cdots + V_n^2}{n}}$$

$$V_{rms} = \sqrt{\frac{(2)^2 + (3)^2 + (4)^2 + (5)^2}{4}}$$

$$V_{rms} = \sqrt{\frac{4 + 9 + 16 + 25}{4}}$$

$$V_{rms} = \sqrt{\frac{54}{4}}$$

$$\boxed{V_{rms} = \sqrt{\frac{27}{2}} \text{ km/s}}$$

Q) At what temperature will the particles in a sample of helium gas have an rms speed of 1 km/s?

(a) 160°C (b) 222 K (c) 160 K (d) 222°C

Ans. c

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

$M_{He} = 4\,gm$ or 4×10^{-3} kg.

(+) $V_{rms} = 1$ km/s $= 10^3$ m/s

$$(10^3) = \sqrt{\frac{3 \times (8.31) \times T}{4 \times 10^{-3}}}$$

$$10^6 = \frac{3 \times 8.31 \times T}{4 \times 10^{-3}}$$

$$T = \frac{10^6 \times 4 \times 10^{-3}}{3 \times 8.31} \simeq 160\text{ K}$$

$$\boxed{T \simeq 160\text{ K}}$$

Q) The temperature of a gas is increased from 27°C to such an extent that its rms speed be double the speed at 27°C. The final temperature will be

(a) 927°C (b) 250°C (c) 600°C (d) 1200°C

Ans. a

$$V_{rms} \propto \sqrt{T}$$

$$\frac{(V_{rms})_1}{(V_{rms})_2} = \sqrt{\frac{T_1}{T_2}}$$

$$\frac{\cancel{v}}{2\cancel{v}} = \sqrt{\frac{(273+27)}{T_2}}$$

$$\frac{1}{4} = \frac{300}{T_2}$$

$$\boxed{T_2 = 1200\ K}$$

or

$$\boxed{T_2 = 927^\circ C}$$

Q) At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the rms speed of a helium gas atom at $-20°C$? (atomic mass of Ar = 39.9 u, and of He = 4.0 u)

(a) $2.52 \times 10^3 °C$

(b) $2.52 \times 10^3 K$

(c) $25.2 \times 10^3 K$

(d) 25.2×10^3

Ans. b

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

$$V_r \propto \sqrt{\frac{T}{M}}$$

$$\frac{V_{Ar}}{V_{He}} = \left(\sqrt{\frac{T}{M}}\right)_{Ar} \times \left(\sqrt{\frac{M}{T}}\right)_{He}$$

$\because V_{Ar} = V_{He}$ (given)

$$\frac{V_{Ar}}{V_{He}} = 1 = \left(\sqrt{\frac{T_{Ar}}{39.9}}\right) \times \left(\sqrt{\frac{4}{(273-20)}}\right)$$

$$(1)^2 = \frac{T_{Ar}}{39.9} \times \frac{4}{253}$$

$$T_{Ar} = 2523.67 \text{ K}$$

$$\boxed{T_{Ar} = 2.52 \times 10^3 \text{ K}}$$

Q) N (< 100) molecules of a gas have velocities 1, 2, 3,........ N km/s respectively. Then ratio of rms speed and average speed is:

(Given: The sum of squares of the first n natural numbers = $\frac{n(n+1)(2n+1)}{6}$

(a) 1

(b) $\sqrt{\frac{(2N+1)(N+1)}{6N}}$

(c) $\sqrt{\frac{(2N+1)(N+1)}{6}}$

(d) $2\sqrt{\frac{(2N+1)}{6(N+1)}}$

Ans. d

$$V_{avg} = \frac{1+2+3+4+\cdots+N}{N}$$

$$S_n = 1+2+3+\cdots+N$$

$$= \frac{N(N+1)}{2}$$ (Sum of N-natural Numbers)

$$\therefore V_{avg} = \frac{\frac{N(N+1)}{2}}{N}$$

$$\boxed{V_{avg} = \left(\frac{N+1}{2}\right) \text{ km/s}}$$

Now

$$V_{rms} = \sqrt{\frac{1^2+2^2+3^2+4^2+\cdots+N^2}{N}}$$

$$\boxed{V_{rms} = \sqrt{\frac{N(N+1)(2N+1)}{6N}} \text{ km/s}}$$

$$\frac{V_{rms}}{V_{avg}} = \frac{\sqrt{\frac{N(N+1)(2N+1)}{6N}}}{\left(\frac{N+1}{2}\right)}$$

$$= \frac{2}{(N+1)}\sqrt{\frac{(N+1)(2N+1)}{6}}$$

$$\boxed{\frac{V_{rms}}{V_{avg}} = 2\sqrt{\frac{(2N+1)}{6(N+1)}}}$$

Q) Find the ratio of the mean speed of hydrogen molecules to the mean speed of nitrogen molecules in a sample containing a mixture of the two gases

(a) 14 (b) $\sqrt{14}$ (c) $\frac{1}{28}$ (d) $\frac{1}{\sqrt{14}}$

Ans. b

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

$$V_m \propto \frac{1}{\sqrt{M}}$$

$$\frac{V_{H_2}}{V_{N_2}} = \sqrt{\frac{M_{N_2}}{M_{H_2}}} = \sqrt{\frac{28}{2}}$$

$$\boxed{\frac{V_{H_2}}{V_{N_2}} = \sqrt{14}}$$

Q) The mean speed of the molecules of a hydrogen sample equals the mean speed of the molecules of a helium sample. Calculate the ratio of the temperature of the hydrogen sample to the temperature of the helium sample

(a) $\frac{1}{2}$ (b) 2 (c) $\frac{1}{4}$ (d) 4

Ans. a

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

$$V_{H_2} = V_{He}$$

$$\sqrt{\frac{8RT_{H_2}}{M_{H_2}}} = \sqrt{\frac{8RT_{He}}{M_{He}}} \Rightarrow \left(\frac{8RT_{H_2}}{M_{H_2}}\right) = \left(\frac{8RT_{He}}{M_{He}}\right)$$

$$\frac{T_{H_2}}{T_{He}} = \frac{M_{H_2}}{M_{He}} = \frac{2}{4}$$

$$\boxed{\frac{T_{H_2}}{T_{He}} = \frac{1}{2}}$$

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Q) The ratio of rms speed of an ideal gas molecules at pressure p to that at pressure 2p is

(a) $\frac{1}{2}$

(b) 2

(c) $\frac{1}{\sqrt{2}}$

(d) $\sqrt{2}$

Ans. c

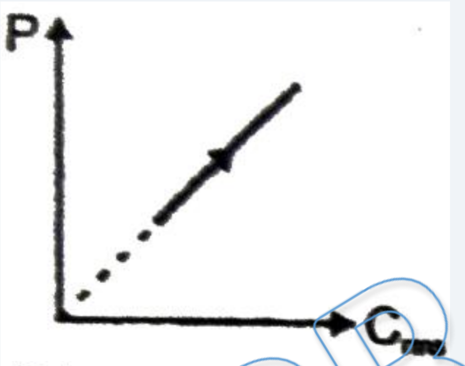
$$v_{rms} = \sqrt{\frac{3P}{\rho}}$$

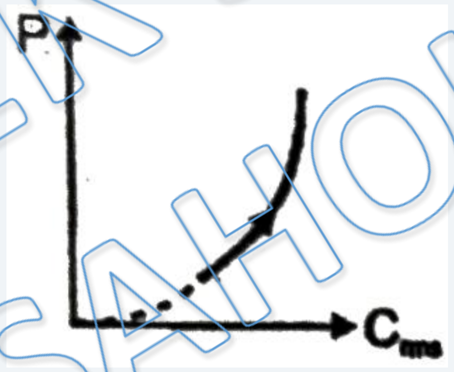
$$v_{rms} \propto \sqrt{P}$$

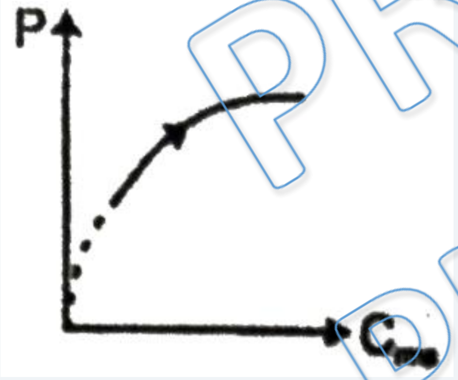
$$\frac{v_P}{v_{2P}} = \frac{\sqrt{P}}{\sqrt{2P}}$$

$$\boxed{\frac{v_P}{v_{2P}} = \frac{1}{\sqrt{2}}}$$

Q) In a closed rigid container an ideal gas is filled. If the gas is heated, the graph of pressure (P) v/s root mean square speed (rms) will be :

(a) 

(b) 

(c) 

(d) None of these

Ans. b

Closed container.

$V =$ constant

$\Rightarrow P \propto T$

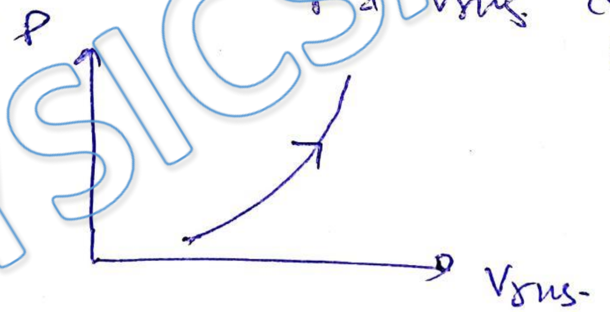
$$V_{rms} = \sqrt{\frac{3P}{\rho}}$$

$V_{rms} \propto \sqrt{P}$

$V_{rms}^2 \propto P$

$\Rightarrow P \propto V_{rms}^2$

↳ parabolic curve between P & V_{rms} (upward open parabola)



Q) A gas is filled in a rigid container at pressure P_0. If the mass of each molecule is halved keeping the total number of molecules same and their r.m.s speed is doubled then find the new pressure

(a) $\sqrt{2}P_0$ (b) $3P_0$ (c) $\sqrt{3}P_0$ (d) $2P_0$

Ans. d

$$V_{rms} = \sqrt{\frac{3P_0}{\rho}}$$

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

when mass of each molecules is halved

then total mass $= m' = \frac{m}{2}$

$$\rho' = \frac{m}{2V} = \frac{\rho}{2}$$

so, $V'_{rms} = \sqrt{\frac{3P'}{\rho'}}$

$\because V'_{rms} = 2\, V_{rms}$ (given)

$$\sqrt{\frac{3P'}{\rho'}} = 2\sqrt{\frac{3P_0}{\rho}}$$

$$\frac{3P'}{\rho'} = 4\left(\frac{3P_0}{\rho}\right)$$

$$\frac{P'}{\left(\frac{\rho}{2}\right)} = 4\frac{P_0}{\rho}$$

$$2P' = 4P_0$$

$$\boxed{P' = \frac{4P_0}{2}}$$

or

$$\boxed{P' = 2P_0}$$

Q) At what temperature most probable speed of SO_2 molecule have the same value as root mean square speed of O_2 molecules at 300 K?

(a) $150K$ (b) $600K$ (c) $750K$ (d) $900K$

Ans. d

Most Probable speed $= \sqrt{\frac{2RT}{M}}$

root Mean square speed $= \sqrt{\frac{3RT}{M}}$

$$\left(\sqrt{\frac{2RT}{M}}\right)_{SO_2} = \left(\sqrt{\frac{3RT}{M}}\right)_{O_2}$$

$$\sqrt{\frac{2R\,T_{SO_2}}{(64)}} = \sqrt{\frac{3R(300)}{32}}$$

$$\frac{\cancel{2}R\,T_{SO_2}}{\cancel{64}\ 2} = \frac{3R(300)}{\cancel{32}}$$

$$T_{SO_2} = 3 \times 300$$

$$\boxed{T_{SO_2} = 900\ K}$$

Q) Most probable velocity, average velocity and root mean square velocity are related as:

(a) 1: 1.128: 1.224

(b) 1: 1.128: 1.424

(c) 1: 2.128: 1.224

(d) 1: 1.428: 1.442

Ans. a

Most Probable speed $= V_m = \sqrt{\frac{2RT}{M}}$

average velocity $= V_a = \sqrt{\frac{8RT}{\pi M}}$

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

$$V_m : V_a : V_{rms} = \sqrt{\frac{2RT}{M}} : \sqrt{\frac{8RT}{\pi M}} : \sqrt{\frac{3RT}{M}}$$

$$= \sqrt{2} : \sqrt{\frac{8}{\pi}} : \sqrt{3}$$

$$= 1 : \frac{1}{\sqrt{2}}\left(\sqrt{\frac{8}{\pi}}\right) : \sqrt{\frac{3}{2}}$$

$$= 1 : \sqrt{\frac{4}{\pi}} : \sqrt{\frac{3}{2}}$$

$$= 1 : 1.128 : 1.224$$

$$\boxed{V_m : V_a : V_{rms} = 1 : 1.128 : 1.224}$$

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Chalo Niklo