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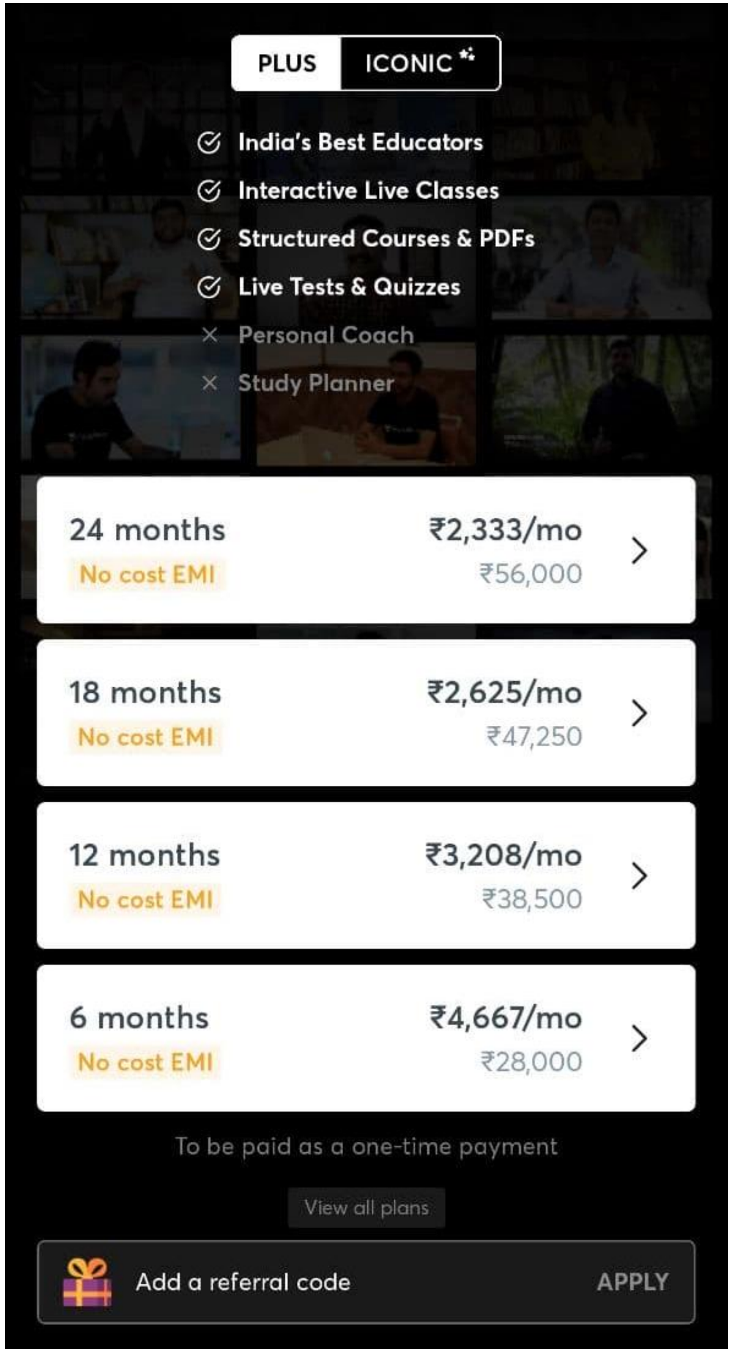

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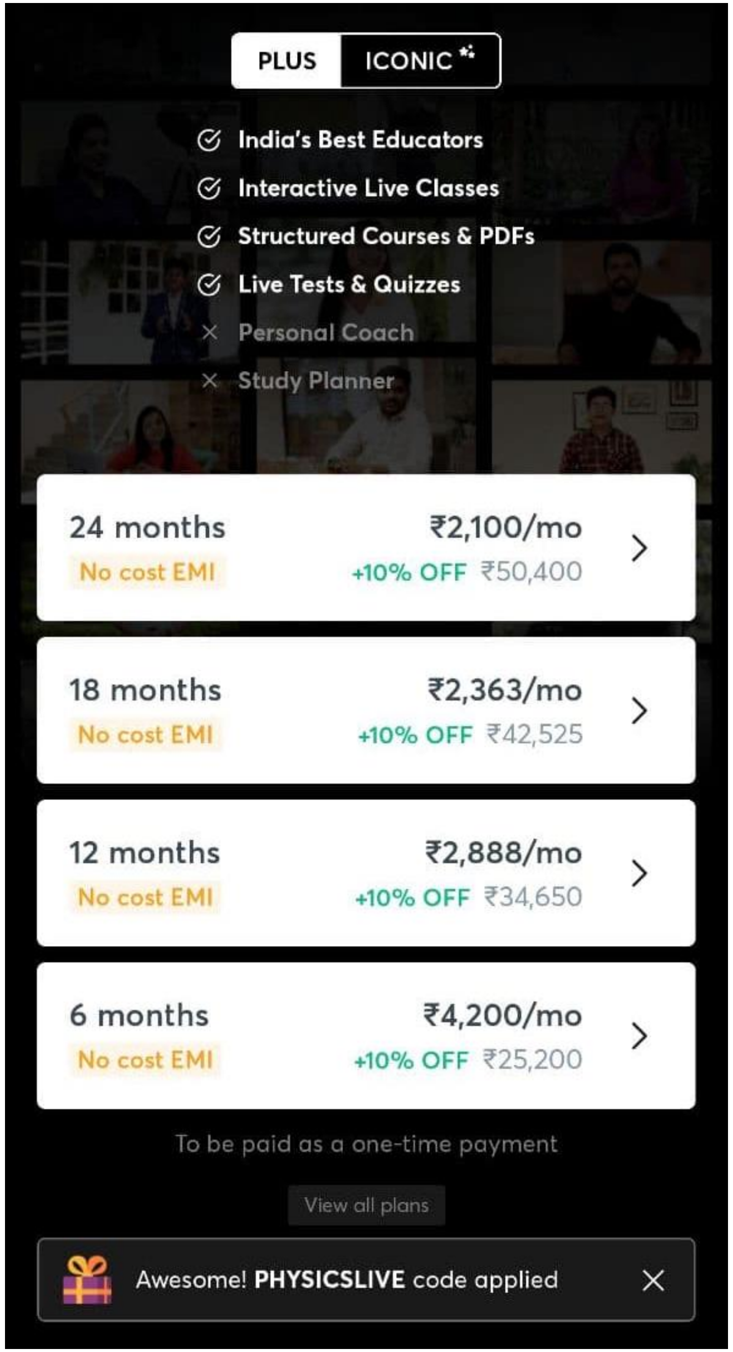

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Physics DPP

DPP-3 KTG: Kinetic Energy of Gas, Degree of freedom of gas molecules

By Physicsaholics Team

Q) The number of degrees of freedom for a rigid diatomic molecule is

(a) 3 (b) 5 (c) 6 (d) 7

Ans. b

Solution:

Rigid diatomic molecules have 3 translational degrees of freedom and 2 rotational degrees of freedom

3 + 2 = 5 degree of freedom

Q) Calculate the total number of degree of freedom for a mole of diatomic gas at STP

(a) 30.10×10^{23} (b) 3.10×10^{23}

(c) 12.24×10^{20} (d) 3.14×10^{17}

Ans. a

Dof for Diatomic gas Molecule $= f = 5$

No. of Molecules in 1 mole $= 6.02 \times 10^{23}$

$\therefore$ Total Dof. $= 5 \times 6.02 \times 10^{23}$

$\boxed{\text{Total D.o.f.} = 30.10 \times 10^{23}}$

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Q) At what temperature, the kinetic energy of a gas molecule is half of the value at 27°C?

(a) 123°C

(b) $123\ K$

(c) $-123\ K$

(d) -123°C

Ans. d

$$KE = \frac{3}{2} k T$$

$$KE \propto T$$

$$\frac{KE_1}{KE_2} = \frac{T_1}{T_2}$$

& $KE_2 = \frac{1}{2} KE_1$

& $T_1 = 27^\circ C = 300\,K$

$$\therefore \frac{KE_1}{\frac{1}{2} KE_1} = \frac{300\,K}{T_2}$$

$$2 = \frac{300\,K}{T_2}$$

$$\boxed{T_2 = 150\,K}$$

or

$$\boxed{T_2 = -123\,^\circ C}$$

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Q) The energy associated with each degree of freedom of a molecule

(a) $\frac{1}{2}RT$ (b) $\frac{1}{2}KT$ (c) $\frac{3}{2}RT$ (d) $\frac{3}{2}KT$

Ans. b

Dof for Diatomic gas Molecule = $f = 5$

No. of Molecules in 1 mole = 6.02×10^{23}

$\therefore$ Total Dof. = $5 \times 6.02 \times 10^{23}$

$$\boxed{\text{Total D.o.f.} = 30.10 \times 10^{23}}$$

When Degree of freedom = f

then $KE = \frac{f}{2} kT$

$\therefore$ KE. associate with each D.of

$$= \boxed{\frac{KE}{f} = \frac{1}{2} kT}$$

Q) A polyatomic gas with (n) degress of freedom has a mean energy per molecule given by

(a) $\frac{n}{2}RT$ (b) $\frac{1}{2}RT$ (c) $\frac{n}{2}kT$ (d) $\frac{1}{2}kT$

Ans. c

$$KE = \frac{f}{2} KT$$

when ; f = degree of freedom,

here, $f = n$ (given)

$$\therefore \boxed{KE = \frac{n}{2} KT}$$

Q) The number of degrees of freedom of molecules of argon gas is

(a) 1 (b) 3 (c) 5 (d) 7

Ans. b

Solution:

Argon gas has monoatomic molecules of Ar.

$\therefore$ It has only translational degree of freedom

So, degree of freedom for argon gas is = 3

Q) Helium gas is filled in a closed vessel (having negligible thermal expansion coefficient) when it is heated from 300 K to 600 K, then average kinetic energy of helium atom will be

(a) $\sqrt{2}$ times (b) 2 times (c) unchanged (d)half

Ans. b

for He gas

$$KE = \frac{3}{2} kT$$

$$KE \propto T$$

$T_1 = 300\,K \quad T_2 = 600\,K$

$$\frac{KE_1}{KE_2} = \frac{T_1}{T_2} = \frac{300}{600} = \frac{1}{2}$$

$$\boxed{KE_2 = 2\,KE_1}$$

Q) The average rotational kinetic energy of hydrogen molecule at a temperature T is E. The average translational kinetic energy of helium at same temperature will be:

(a) $\frac{2E}{3}$ (b) $\frac{5E}{3}$ (c) E (d) $\frac{3E}{2}$

Ans. d

rotation degree of freedom

for H_2 molecule = 2

$$\therefore \quad E_R = \frac{f_R}{2} kT = \frac{2}{2} kT$$

$$E_R = kT = E \quad \text{—①}$$

↳ Rotation K.E of H_2 gas molecule.

Also for He gas molecule.

Translational D of = 3

$$E_T = \frac{f_T}{2} kT = \frac{3}{2} kT$$

from eqⁿ ① ; $kT = E$

$$\therefore \quad E_T = \frac{3}{2} kT = \frac{3}{2} E$$

$$\boxed{E_T = \frac{3}{2} E}$$

Q) The average translational energy and the rms speed of molecules in a sample of oxygen gas at 300 K are 6.21×10^{-21}J and 484m/s respectively The corresponding values at 600 K are nearly (assuming ideal gas behavior)

(a) 12.42×10^{-21}J, 928 m/s
(b) 8.78×10^{-21}J, 684 m/s
(c) 6.21×10^{-21}J, 968 m/s
(d) 12.42×10^{-21}J, 684 m/s

Ans. d

$KE = \frac{f}{2} KT$

$KE \propto T$

$\frac{KE_1}{KE_2} = \frac{T_1}{T_2}$

$\frac{6.21 \times 10^{-21}}{KE_2} = \frac{300}{600}$

$KE_2 = 2 \times 6.21 \times 10^{-21}$

$\boxed{KE_2 = 12.42 \times 10^{-21} J}$

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

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

$\frac{V_{rms-1}}{V_{rms-2}} = \sqrt{\frac{T_1}{T_2}}$

$\frac{V_1}{V_2} = \sqrt{\frac{300}{600}}$

$\frac{484}{V_2} = \frac{1}{\sqrt{2}}$

$\boxed{V_2 \simeq 684 m/s}$

Q) One kg of a diatomic gas is at a pressure of $8 \times 10^4\ N/m^2$. The density of the gas is $4\text{kg}/m^3$. What is the energy of the gas due to its thermal motion?

(a) $5 \times 10^4 \text{J}$ (b) $6 \times 10^4 \text{J}$ (c) $7 \times 10^4 \text{J}$ (d) $4 \times 10^4 \text{J}$

Ans. a

$KE = \frac{5}{2} PV$ [Dof = 5 for diatomic gas]

$KE = \frac{5}{2} \times P \times \left(\frac{\text{Mass}}{\text{density}}\right)$

$KE = \frac{5}{2} \times 8 \times 10^4 \times \left(\frac{1\ kg}{4\ kg/m^3}\right)$

$KE = \frac{5}{2} \times \cancel{8}^{2} \times 10^4 \times \frac{1}{\cancel{4}}$

$\boxed{KE = 5 \times 10^4\ J}$

Q) The average kinetic energy of H_2 molecules at 300K is E at the same temperature the average kinetic energy of O_2 molecules is:

(a) E (b) $\frac{E}{4}$ (c) $\frac{E}{16}$ (d) $16E$

Ans. a

Solution:

The mean kinetic energy of a gas depends only on temperature and is independent of molecular weight

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