# physics

Chapter
13

KINETIC THEORY OF GASES

Gas

In gases the intermolecular forces are very weak and its molecule may fly apart in all directions. So the gas is characterized by the following properties.

(i) It has no shape and size and can be obtained in a vessel of any shape or size.

(ii) It expands indefinitely and uniformly to fill the available space.

(iii) It exerts pressure on its surroundings.

(iv) Intermolecular forces in a gas are minimum.

(v) They can easily compressed and expand.

Assumption of Ideal Gases (or Kinetic Theory of Gases)
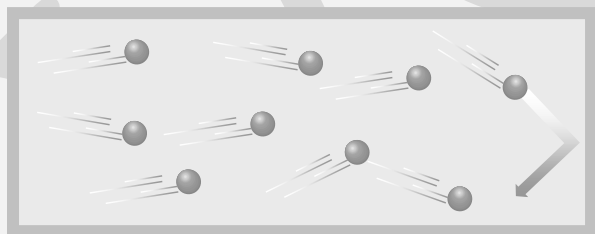
Kinetic theory of gases relates the macroscopic properties of gases (such as pressure, temperature *etc*.) to the microscopic properties of the gas molecules (such as speed, momentum, kinetic energy of molecule *etc*.)

Actually it attempts to develop a model of the molecular behaviour which should result in the observed behaviour of an ideal gas. It is based on following assumptions :

(1) Every gas consists of extremely small particles known as molecules. The molecules of a given gas are all identical but are different than those of another gas.

(2) The molecules of a gas are identical, spherical, rigid and perfectly elastic point masses.

(3) Their size is negligible in comparison to intermolecular distance ($10^{-9}\ m$)

(4) The volume of molecules is negligible in comparison to the volume of gas. (The volume of molecules is only 0.014% of the volume of the gas).

(5) Molecules of a gas keep on moving randomly in all possible direction with all possible velocities.

(6) The speed of gas molecules lie between zero and infinity

(7) The gas molecules keep on colliding among themselves as well as with the walls of containing vessel. These collisions are perfectly elastic.

(8) The time spent in a collision between two molecules is negligible in comparison to time between two successive collisions.

(9) The number of collisions per unit volume in a gas remains constant.

(10) No attractive or repulsive force acts between gas molecules.

(11) Gravitational attraction among the molecules is ineffective due to extremely small masses and very high speed of molecules.

(12) Molecules constantly collide with the walls of container due to which their momentum changes. The change in momentum is transferred to the walls of the container. Consequently pressure is exerted by gas molecules on the walls of container.

(13) The density of gas is constant at all points of the container.

Gas Laws

(1) **Boyle's law :** For a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure.
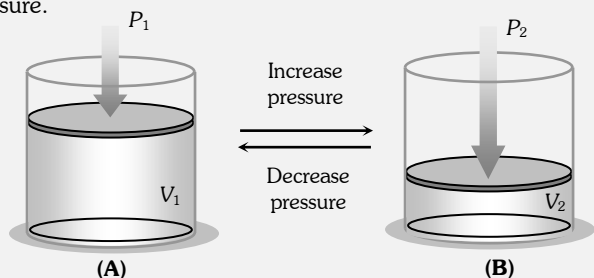

Fig. 13.1

i.e. $V \propto \dfrac{1}{P}$ or $PV = \text{constant} \Rightarrow P_1 V_1 = P_2 V_2$

(i) $PV = P\left(\dfrac{m}{\rho}\right) = \text{constant} \Rightarrow \dfrac{P}{\rho} = \text{constant}$ or $\dfrac{P_1}{\rho_1} = \dfrac{P_2}{\rho_2}$

(As volume $= \dfrac{m}{\rho(\text{Density of the gas})}$ and $m = \text{constant}$)

(ii) $PV = P\left(\dfrac{N}{n}\right) = \text{constant} \Rightarrow \dfrac{P}{n} = \text{constant}$ or $\dfrac{P_1}{n_1} = \dfrac{P_2}{n_2}$

(iii) As number of molecules per unit volume $n = \dfrac{N}{V}$

$\Rightarrow V = \dfrac{N}{n}$ also $N = \text{constant}$

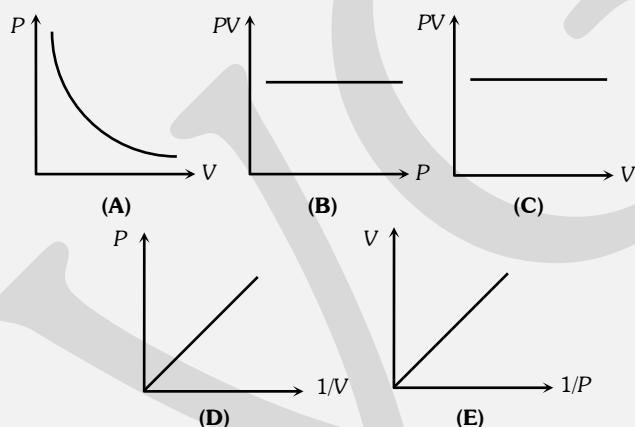(iv) Graphical representation : If m and T are constant

Fig. 13.2

(2) **Charle's law :** If the pressure remaining constant, the volume of the given mass of a gas is directly proportional to its absolute temperature.
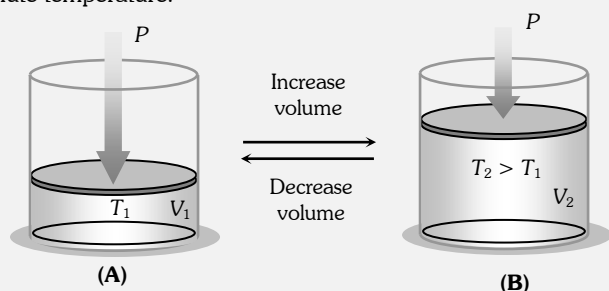

Fig. 13.3

i.e., $V \propto T$ $\Rightarrow \dfrac{V}{T} = \text{constant} \Rightarrow \dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$

(i) $\dfrac{V}{T} = \dfrac{m}{\rho T} = \text{constant}$ (As volume $V = \dfrac{m}{\rho}$)

or $\rho T = \text{constant} \Rightarrow \rho_1 T_1 = \rho_2 T_2$

(ii) If the pressure remains constant, the volume of the given mass of a gas increases or decreases by $\dfrac{1}{273.15}$ of its volume at $0°C$ for each $1°C$ rise or fall in temperature.
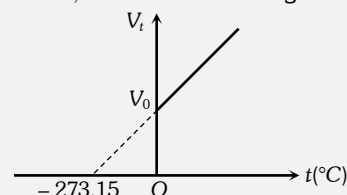
$V_t = V_0\left(1 + \dfrac{1}{273.15} t\right)$.

Fig. 13.4

This is Charle's law for centigrade scale.

(v) Graphical representation: If m and P are constant
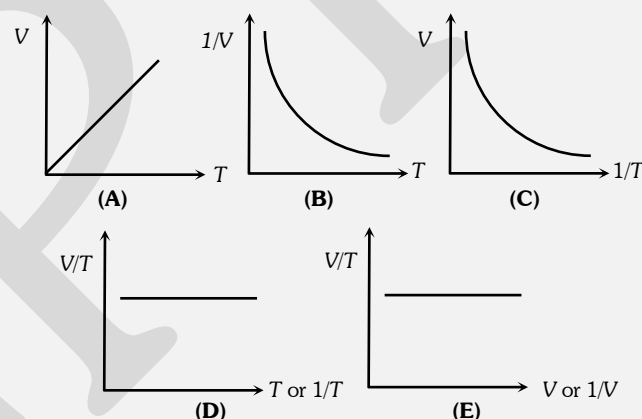
Fig. 13.5

(3) **Gay-Lussac's law or pressure law :** The volume remaining constant, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

$P \propto T$ or $\dfrac{P}{T} = \text{constant} \Rightarrow \dfrac{P_1}{T_1} = \dfrac{P_2}{T_2}$

(i) The volume remaining constant, the pressure of a given mass of a gas increases or decreases by $\dfrac{1}{273.15}$ of its pressure at $0°C$ for each $1°C$ rise or fall in temperature.

$P_t = P_0\left[1 + \dfrac{1}{273.15} t\right]$

Fig. 13.5

This is pressure law for centigrade scale.

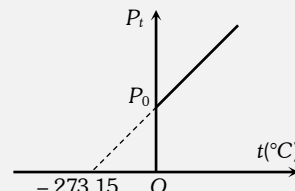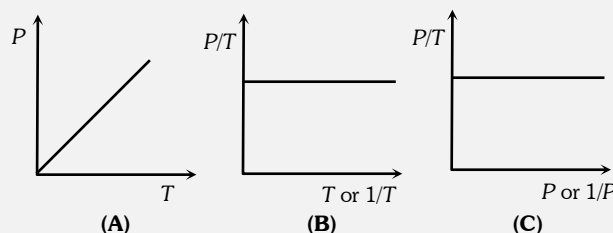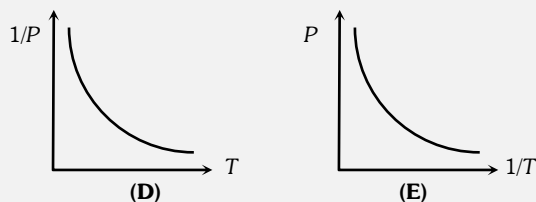(ii) **Graphical representation :** If m and V are constants

Fig. 13.6

(4) **Avogadro's law :** Equal volume of all the gases under similar conditions of temperature and pressure contain equal number of molecules *i.e.* $N_1 = N_2$.

(5) **Grahm's law of diffusion :** When two gases at the same pressure and temperature are allowed to diffuse into each other, the rate of diffusion of each gas is inversely proportional to the square root of the density of the gas *i.e.* $r \propto \dfrac{1}{\sqrt{\rho}} \propto \dfrac{1}{\sqrt{M}}$ (M is the molecular weight of the gas) $\Rightarrow \dfrac{r_1}{r_2} = \sqrt{\dfrac{\rho_2}{\rho_1}} = \sqrt{\dfrac{M_2}{M_1}}$

If V is the volume of gas diffused in t sec then

$$r = \frac{V}{t} \Rightarrow \frac{r_1}{r_2} = \frac{V_1}{V_2} \times \frac{t_2}{t_1}$$

(6) **Dalton's law of partial pressure :** The total pressure exerted by a mixture of non-reacting gases occupying a vessel is equal to the sum of the individual pressures which each gases exert if it alone occupied the same volume at a given temperature.

For n gases $P = P_1 + P_2 + P_3 + \dots P_n$

where P = Pressure exerted by mixture and $P_1, P_2, P_3, \dots P_n$ = Partial pressure of component gases.

Equation of State or Ideal Gas Equation

The equation which relates the pressure (P) volume (V) and temperature (T) of the given state of an ideal gas is known as ideal gas equation or equation of state.

For 1 mole of gas $\dfrac{PV}{T} = R$ (constant) $\Rightarrow PV = RT$

where R = universal gas constant.

Table 13.1 : Different forms of gas equation

Quantity of gas	Equation	Constant
1 mole gas	$PV = RT$	R = universal gas constant
μ mole gas	$PV = \mu RT$	
1 molecule of gas	$PV = \left(\dfrac{R}{N_A}\right)T = kT$	k = Boltzmann's constant
N molecules of gas	$PV = NkT$	
1 gm of gas	$PV = \left(\dfrac{R}{M}\right)T = rT$	r = Specific gas constant
m gm of gas	$PV = mrT$	

(1) **Universal gas constant (R) :** Universal gas constant signifies the work done by (or on) a gas per mole per kelvin.

$$R = \frac{PV}{\mu T} = \frac{\text{Pressure} \times \text{Volume}}{\mu \times \text{Temperature}} = \frac{\text{Work done}}{\mu \times \text{Temperature}}$$

(i) At S.T.P. the value of universal gas constant is same for all gases $R = 8.31 \dfrac{J}{mole \times kelvin} = 1.98 \dfrac{cal}{mole \times kelvin} \simeq 2 \dfrac{cal}{mol \times kelvin}$

$= 0.8221 \dfrac{litre \times atm}{mole \times kelvin}$.

(ii) Dimension : $[ML^2T^{-2}\theta^{-1}]$

(2) **Boltzman's constant (k) :** It is represented by per mole gas constant *i.e.*, $k = \dfrac{R}{N} = \dfrac{8.31}{6.023 \times 10^{23}} = 1.38 \times 10^{-23} J/K$

It's dimension : $[ML^2T^{-2}\theta^{-1}]$

(3) **Specific gas constant (r) :** It is represented by per gram gas constant *i.e.*, $r = \dfrac{R}{M}$. It's unit is $\dfrac{Joule}{gm \times kelvin}$ and dimension $[L^2T^{-2}\theta^{-1}]$

Since the value of M is different for different gases. Hence the value of r is different for different gases. *e.g.* It is maximum for hydrogen $r_{H_2} = \dfrac{R}{2}$

Real Gases

(1) The gases actually found in nature are called real gases.

(2) They do not obeys gas Laws.

(3) For exactly one mole of an ideal gas $\dfrac{PV}{RT} = 1$. Plotting the experimentally determined value of $\dfrac{PV}{RT}$ for exactly one mole of various real gases as a function of pressure P, shows a deviation from identity.

(4) The quantity $\dfrac{PV}{RT}$ is called the compressibility factor and should be unit for an ideal gas.
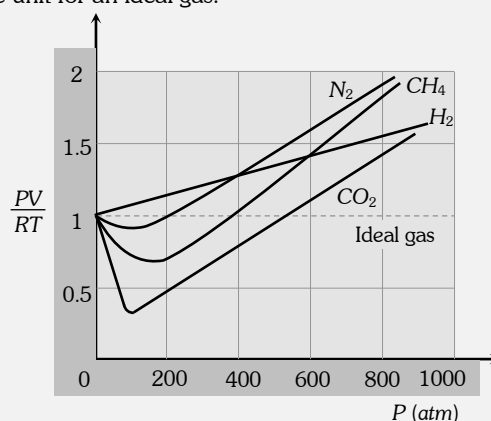

Fig. 13.7

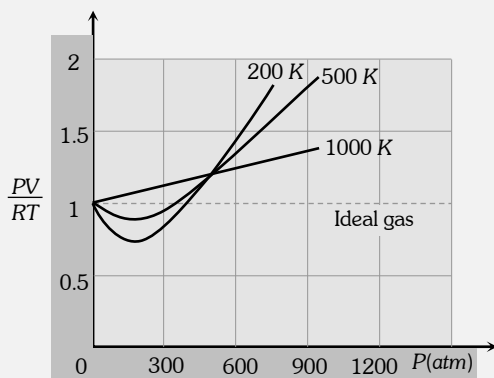(5) Deviation from ideal behaviour as a function of temperature

Fig. 13.8

(6) A real gas behaves as ideal gas most closely at low pressure and high temperature. Also can actual gas can be liquefied most easily which deviates most from ideal gas behaviour at low temperature and high pressure.

(7) **Equation of state for real gases :** It is given by Vander Waal's with two correction in ideal gas equation. The it know as Vander Waal's gas equation.

(i) **Volume correction :** Due to finite size of molecule, a certain portion of volume of a gas is covered by the molecules themselves. Therefore the space available for the free motion of molecules of gas will be slightly less than the volume V of a gas. Hence the effective volume becomes $(V - b)$.

(ii) **Pressure correction :** Due to intermolecular force in real gases, molecule do not exert that force on the wall which they would have exerted in the absence of intermolecular force. Therefore the observed pressure P of the gas will be less than that present in the absence of intermolecular force. Hence the effective pressure becomes $\left(P + \dfrac{a}{V^2} \right)$.

(iii) **Vander Waal's gas equations**

For 1 *mole* of gas $\left(P + \dfrac{a}{V^2} \right)(V - b) = RT$

For μ *moles* of gas $\left(P + \dfrac{a\mu^2}{V^2} \right)(V - \mu b) = \mu RT$

Here a and b are constant called Vander Waal's constant.

Dimension : $[a] = [ML^5 T^{-2}]$ and $[b] = [L^3]$

Units : $a = N \times m^4$ and $b = m^3$.

(8) **Andrews curves :** The pressure (P) versus volume (V) curves for actual gases are called Andrews curves.
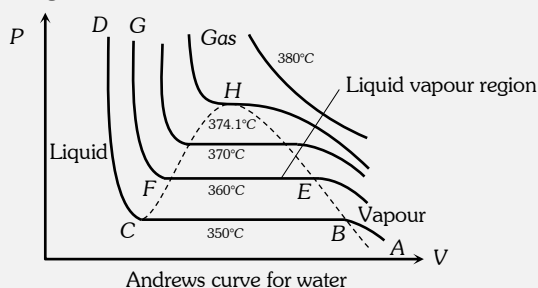

Andrews curve for water

Fig. 13.9

(i) At $350°C$, part AB represents vapour phase of water, in this part Boyle's law is obeyed $\left(P \propto \dfrac{1}{V} \right)$. Part BC represents the co-existence of vapour and liquid phases. At point C, vapours completely change to liquid phase. Part CD is parallel to pressure axis which shows that compressibility of the water is negligible.

(ii) At $360°C$ portion representing the co-existence of liquid vapour phase is shorter.

(iii) At $370°C$ this portion is further decreased.

(iv) At $374.1°C$, it reduces to point (H) called critical point and the temperature $374.1°C$ is called critical temperature (T_c) of water.

(v) The phase of water (at $380°C$) above the critical temperature is called gaseous phase.

(9) **Critical temperature, pressure and volume :** The point on the P-V curve at which the matter gets converted from gaseous state to liquid state is known as critical point. At this point the difference between the liquid and vapour vanishes *i.e.* the densities of liquid and vapour become equal.

(i) **Critical temperature (T_c) :** The maximum temperature below which a gas can be liquefied by pressure alone is called critical temperature and is characteristic of the gas. A gas cannot be liquefied if its temperature is more than critical temperature.

CO_2 $(31.1°C)$, O_2 $(–118°C)$, N_2 $(–147.1°C)$ and H_2O $(374.1°C)$

(ii) **Critical pressure (P_c) :** The minimum pressure necessary to liquify a gas at critical temperature is defined as critical pressure CO_2 $(73.87\ bar)$ and O_2 $(49.7 atm)$

(iii) **Critical volume (V_c) :** The volume of 1 mole of gas at critical pressure and critical temperature is defined as critical volume CO_2 $(95 \times 10^{-6}\ m^3)$

(iv) **Relation between Vander Waal's constants and T_c, P_c, V_c**

$$T_c = \frac{8a}{27Rb}, \ P_c = \frac{a}{27b^2}, \ V_c = 3b,$$

$$a = \frac{27R^2}{64}\frac{T_c^2}{P_c}, \ b = \frac{R}{8}\left(\frac{T_c}{P_c} \right) \ \text{and} \ \frac{P_c V_c}{T_c} = \frac{3}{8}R$$

Pressure of an Ideal Gas

Consider an ideal gas (consisting of N molecules each of mass m) enclosed in a cubical box of side L.
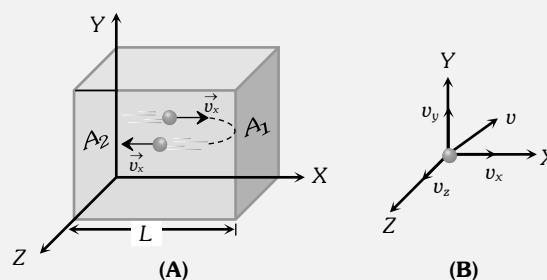

Fig. 13.10

(1) **Instantaneous velocity :** Any molecule of gas moves with velocity $\vec{v}$ in any direction

where $\vec{v} = v_x \hat{i} + v_y \hat{j} + v_z \hat{k} \Rightarrow v = \sqrt{v_x^2 + v_y^2 + v_z^2}$. Due to random motion of molecule $v_x = v_y = v_z \Rightarrow v^2 = 3v_x^2 = 3v_y^2 = 3v_z^2$

(2) **Time during collision :** Time between two successive collision with the wall A_1.

$$\Delta t = \frac{\text{Distance travelled by molecule between two successive collision}}{\text{Velocity of molecule}}$$

$$= \frac{2L}{v_x}$$

(3) **Collision frequency (n) :** It means the number of collision per second. Hence $n = \dfrac{1}{\Delta t} = \dfrac{v_x}{2L}$

(4) **Change in momentum :** This molecule collides with the shaded wall (A_1) with velocity v_x and rebounds with velocity $-v_x$.

The change in momentum of the molecule

$$\Delta p = (-mv_x) - (mv_x) = -2mv_x$$

As the momentum remains conserved in a collision, the change in momentum of the wall A_1 is $\Delta p = 2mv_x$

After rebound this molecule travel toward opposite wall A_2 with velocity $-v_x$, collide to it and again rebound with velocity v_x towards wall A_1.

(5) **Force on wall :** Force exerted by a single molecule on shaded wall is equal to rate at which the momentum is transferred to the wall by this molecule.

i.e. $F_{\text{Single molecule}} = \dfrac{\Delta p}{\Delta t} = \dfrac{2mv_x}{(2L/v_x)} = \dfrac{mv_x^2}{L}$

The total force on the wall A_1 due to all the molecules

$$F_x = \frac{m}{L}\sum v_x^2 = \frac{m}{M}(v_{x_1}^2 + v_{x_2}^2 + v_{x_3}^2 + ...) = \frac{mN}{L}\overline{v_x^2}$$

$\overline{v_x^2}$ = mean square of x component of the velocity.

(6) **Pressure :** Now pressure is defined as force per unit area, hence pressure on shaded wall $P_x = \dfrac{F_x}{A} = \dfrac{mN}{AL}\overline{v_x^2} = \dfrac{mN}{V}\overline{v_x^2}$

For any molecule, the mean square velocity $\overline{v^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2}$;

by symmetry $\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2} \Rightarrow \overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2} = \dfrac{\overline{v^2}}{3}$

Total pressure inside the container

$$P = \frac{1}{3}\frac{mN}{V}\overline{v^2} = \frac{1}{3}\frac{mN}{V}v_{rms}^2 \qquad (\text{where } v_{rms} = \sqrt{\overline{v^2}})$$

(7) **Relation between pressure and kinetic energy :** As we know $P = \dfrac{1}{3}\dfrac{mN}{V}v_{rms}^2 = \dfrac{1}{3}\dfrac{M}{V}v_{rms}^2 \Rightarrow P = \dfrac{1}{3}\rho v_{rms}^2$ ... (i)

[As $M = mN$ = Total mass of the gas and $\rho = \dfrac{M}{V}$]

$\therefore$ K.E. per unit volume $E = \dfrac{1}{2}\left(\dfrac{M}{V}\right)v_{rms}^2 = \dfrac{1}{2}\rho v_{rms}^2$ ...(ii)

From (i) and (ii), we get $P = \dfrac{2}{3}E$

i.e. the pressure exerted by an ideal gas is numerically equal to the two third of the mean kinetic energy of translation per unit volume of the gas.

(8) **Effect of mass, volume and temperature on pressure :** $P = \dfrac{1}{3}\dfrac{mN}{V}v_{rms}^2$ or $P \propto \dfrac{(mN)T}{V}$ [As $v_{rms}^2 \propto T$]

(i) If volume and temperature of a gas are constant $P \propto mN$ *i.e.* Pressure $\propto$ (Mass of gas).

i.e. if mass of gas is increased, number of molecules and hence number of collision per second increases *i.e.* pressure will increase.

(ii) If mass and temperature of a gas are constant. $P \propto (1/V)$, *i.e.*, if volume decreases, number of collisions per second will increase due to lesser effective distance between the walls resulting in greater pressure.

(iii) If mass and volume of gas are constant, $P \propto (v_{rms})^2 \propto T$

i.e., if temperature increases, the mean square speed of gas molecules will increase and as gas molecules are moving faster, they will collide with the walls more often with greater momentum resulting in greater pressure.

Various Speeds of Gas Molecules

The motion of molecules in a gas is characterised by any of the following three speeds.

(1) **Root mean square speed :** It is defined as the square root of mean of squares of the speed of different molecules

i.e. $v_{rms} = \sqrt{\dfrac{v_1^2 + v_2^2 + v_3^2 + v_4^2 + ...}{N}} = \sqrt{\overline{v^2}}$

(i) From the expression of pressure $P = \dfrac{1}{3}\rho v_{rms}^2$

$$\Rightarrow v_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3PV}{\text{Mass of gas}}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

where $\rho = \dfrac{\text{Mass of gas}}{V} = $ Density of the gas , $M = \mu \times$ (mass of gas), $pV = \mu RT$, $R = kN_A$, $k = $ Boltzmann's constant,

$m = \dfrac{M}{N_A} = $ mass of each molecule.

(ii) With rise in temperature *rms* speed of gas molecules increases as $v_{rms} \propto \sqrt{T}$.

(iii) With increase in molecular weight *rms* speed of gas molecule decreases as $v_{rms} \propto \dfrac{1}{\sqrt{M}}$. *e.g.*, *rms* speed of hydrogen molecules is four times that of oxygen molecules at the same temperature.

(iv) *rms* speed of gas molecules is of the order of *km/s* *e.g.*, at NTP for hydrogen gas

$$(v_{rms}) = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.31 \times 273}{2 \times 10^3}} = 1840\,m/s .$$

(v) *rms* speed of gas molecules is $\sqrt{\dfrac{3}{\gamma}}$ times that of speed of sound in gas, as $v_{rms} = \sqrt{\dfrac{3RT}{M}}$ and $v_s = \sqrt{\dfrac{\gamma RT}{M}} \Rightarrow v_{rms} = \sqrt{\dfrac{3}{\gamma}} v_s$

(vi) *rms* speed of gas molecules does not depends on the pressure of gas (if temperature remains constant) because $P \propto \rho$ (Boyle's law) if pressure is increased n times then density will also increases by n times but v_{rms} remains constant.

(vii) Moon has no atmosphere because v_{rms} of gas molecules is more than escape velocity (v_e).

A planet or satellite will have atmosphere only if $v_{rms} < v_e$

(viii) At $T = 0$; $v_{rms} = 0$ *i.e.* the *rms* speed of molecules of a gas is zero at $0\ K$. This temperature is called absolute zero.

(2) **Most probable speed :** The particles of a gas have a range of speeds. This is defined as the speed which is possessed by maximum fraction of total number of molecules of the gas. *e.g.*, if speeds of 10 molecules of a gas are 1, 2, 2, 3, 3, 3, 4, 5, 6, 6 *km/s*, then the most probable speed is 3 *km/s*, as maximum fraction of total molecules possess this speed.

Most probable speed $v_{mp} = \sqrt{\dfrac{2P}{\rho}} = \sqrt{\dfrac{2RT}{M}} = \sqrt{\dfrac{2kT}{m}}$

(3) **Average speed :** It is the arithmetic mean of the speeds of molecules in a gas at given temperature.

$$v_{av} = \frac{v_1 + v_2 + v_3 + v_4 + \ldots}{N}$$

and according to kinetic theory of gases

Average speed $v_{av} = \sqrt{\dfrac{8P}{\pi\rho}} = \sqrt{\dfrac{8}{\pi}\dfrac{RT}{M}} = \sqrt{\dfrac{8}{\pi}\dfrac{kT}{m}}$

Maxwell's Law (or the Distribution of Molecular Speeds

(1) The v_{rms} gives us a general idea of molecular speeds in a gas at a given temperature. This doesn't mean that the speed of each molecule is v_{rms}. Many of the molecules have speed less than v_{rms} and many have speeds greater than v_{rms}.

(2) Maxwell derived as equation given the distribution of molecules in different speed as follow

$$dN = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-\frac{mv^2}{2kT}} dv$$

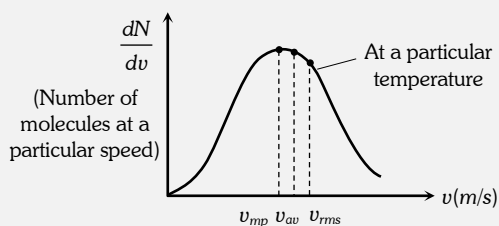where dN = Number of molecules with speeds between v and $v + dv$.

Fig. 13.11

(3) Graph between $\dfrac{dN}{dv}$ (number of molecules at a particular speed) and v (speed of these molecules). From the graph it is seen that $\dfrac{dN}{dv}$ is maximum at most probable speed.

This graph also represent that $v_{rms} > v_{av} > v_{mp}$

(Order remember trick RAM)

$$\Rightarrow \sqrt{\frac{3RT}{M}} > \sqrt{\frac{8RT}{\pi M}} > \sqrt{\frac{2RT}{M}} \Rightarrow 1.77\sqrt{\frac{RT}{M}} > 1.6\sqrt{\frac{RT}{M}} > 1.41\sqrt{\frac{RT}{M}}$$

Area bonded by this curve with speed axis represents the number of molecules corresponds to that velocity range. This curve is asymmetric curve.

Effect of temperature on velocity distribution : With temperature rise the $\dfrac{dN}{dv}$ vs v. Curve shift towards right and becomes broader.
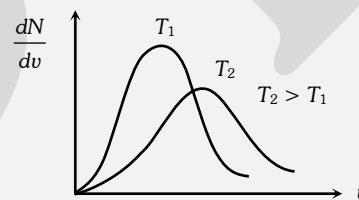
Fig. 13.12

(Because with temperature rise average molecular speed increases).

Mean Free Path

(1) The distance travelled by a gas molecule between two successive collisions is known as free path.

$$\lambda = \frac{\text{Total distance travelled by a gas molecule between successive collisions}}{\text{Total number of collisions}}$$

During two successive collisions, a molecule of a gas moves in a straight line with constant velocity and

Let $\lambda_1, \lambda_2, \lambda_3 \ldots$ be the distance travelled by a gas molecule during n collisions respectively, then the mean free path of a gas molecule is given by

$$\lambda = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \ldots + \lambda_n}{n}$$

(2) $\lambda = \dfrac{1}{\sqrt{2}\pi n d^2}$

where d = Diameter of the molecule,

Fig. 13.13

n = Number of molecules per unit volume

(3) As $PV = \mu RT = \mu NkT \Rightarrow \dfrac{N}{V} = \dfrac{P}{kT} = n = $ Number of molecule per unit volume so $\lambda = \dfrac{1}{\sqrt{2}} \dfrac{kT}{\pi d^2 P}$.
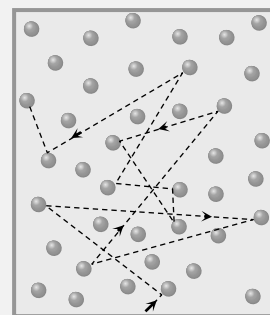
(4) From $\lambda = \dfrac{1}{\sqrt{2}\pi n d^2} = \dfrac{m}{\sqrt{2}\pi (mn)d^2} = \dfrac{m}{\sqrt{2}\pi d^2 \rho}$

[As m = Mass each molecule, mn = Mass per unit volume = Density = ρ]

(5) If average speed of molecule is v then $\lambda = v \times \dfrac{t}{N} = v \times T$

[As N = Number of collision in time t, T = time interval between two collisions].

(i) As $\lambda \propto \dfrac{1}{\rho}$ and $\lambda \propto m$ *i.e.* the mean free path is inversely proportional to the density of a gas and directly proportional to the mass of each molecule.

Fig. 13.14

(ii) As $\lambda = \dfrac{1}{\sqrt{2}} \dfrac{kT}{\pi d^2 P}$. For constant volume and hence constant number density n of gas molecul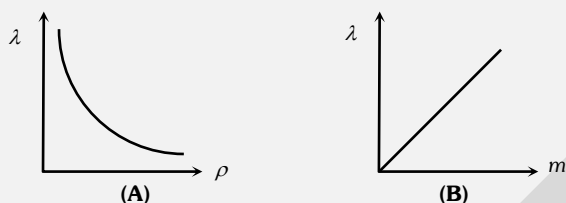es, $\dfrac{P}{T}$ is constant so that λ will not depend on P and T. But if volume of given mass of a gas is allowed to change with P or T then $\lambda \propto T$ at constant pressure and $\lambda \propto \dfrac{1}{P}$ at constant temperature.
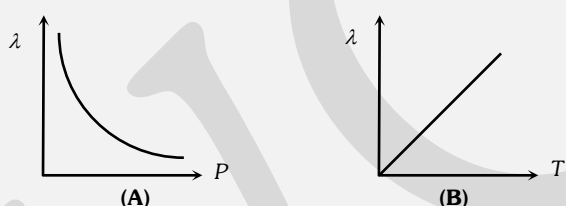

Fig. 13.15

Degree of Freedom

The term degree of freedom of a system refers to the possible independent motions, systems can have.   or

The total number of independent modes (ways) in which a system can possess energy is called the degree of freedom (*f*).

The independent motions can be translational, rotational or vibrational or any combination of these.

So the degree of freedom are of three types :

(i) Translational degree of freedom

(ii) Rotational degree of freedom

(iii) Vibrational degree of freedom

General expression for degree of freedom

$f = 3A - B$;   where A = Number of independent particles,

B = Number of independent restriction

(1) **Monoatomic gas :** Molecule of monoatomic gas can move in any direction in space so it can have three independent motions and hence 3 degrees of freedom (all translational)
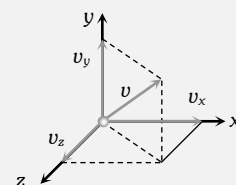
Fig. 13.16

(2) **Diatomic gas :** Molecules of diatomic gas are made up of two atoms joined rigidly to one another through a bond. This cannot only move bodily, but also rotate about one of the three co-ordinate axes. However its moment of inertia about the axis joining the two atoms is negligible compared to that about the other two axes.
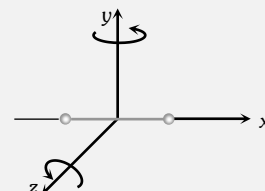
Fig. 13.17

Hence it can have only two rotational motion. Thus a diatomic molecule has 5 degree of freedom : 3 translational and 2 rotational.

(3) **Triatomic gas (Non-linear) :** A non-linear molecule can rotate about any of three co-ordinate axes. Hence it has 6 degrees of freedom : 3 translational and 3 rotational.
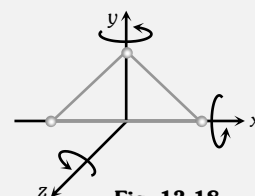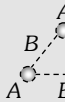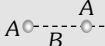
Fig. 13.18

Table 13.2 ; Degree of freedom for different gases

Atomicity of gas	Example	A	B	$f = 3$ $A - B$	Figure
Monoatomic	*He, Ne, Ar*	1	0	$f = 3$	
Diatomic	H_2, O_2, N_2, Cl_2 etc.	2	1	$f = 5$	
Triatomic non linear	H_2O	3	3	$f = 6$	
Triatomic linear	$CO_2, BeCl_2$	3	2	$f = 7$	

The above degrees of freedom are shown at room temperature. Further at high temperature, in case of diatomic or polyatomic molecules, the atoms with in the molecule may also vibrate with respect to each other. In such cases, the molecule will have an additional degrees of freedom, due to vibrational motion.

An object which vibrates in one dimension has two additional degree of freedom. One for the potential energy and one for the kinetic energy of vibration.

A diatomic molecule that is free to vibrate (in addition to translation and rotation) will have $7(2+3+2)$ degrees of freedom.

Kinetic Energy of Ideal Gas

In ideal gases, the molecules are considered as point particles. For point particles, there is no internal excitation, no vibration and no rotation. The point particles can have only translational motion and thus only translational energy. For an ideal gas the internal energy can only be tranlational kinetic energy.

Hence kinetic energy (or internal energy) of 1 mole ideal gas

$$E = \frac{1}{2} M v_{rms}^2 = \frac{1}{2} M \times \frac{3RT}{M} = \frac{3}{2} RT$$

Table 13.3 : Various Translational kinetic energies

Quantity of gas	Kinetic energy
1 mole gas	$\frac{3}{2} RT$; R = Universal gas constant
μ mole gas	$\frac{3}{2} \mu RT$
1 molecule	$\frac{3}{2} kT$; k = Boltzmann's constant
N molecule	$\frac{3}{2} NkT$
1 gm gas	$\frac{3}{2} rT$; r = Specific gas constant
m gm gas	$\frac{3}{2} mrT$

(1) Kinetic energy per molecule of gas does not depends upon the mass of the molecule but only depends upon the temperature of the gas. As $E = \frac{3}{2} kT$ or $E \propto T$ *i.e.* molecules of different gases say He, H_2 and O_2 *etc.* at same temperature will have same translational kinetic energy though their *r.m.s.* speed are different.

(2) For two gases at the same temperature $m_1 (v_{rms})_1^2 = m_2 (v_{rms})_2^2$

(3) Kinetic energy per mole of gas depends only upon the temperature of gas.

(4) Kinetic energy per *gram* of gas depend upon the temperature as well as molecular weight (or mass of one molecule) of the gas. $E_{gram} = \frac{3}{2} \frac{k}{m} T \Rightarrow E_{gram} \propto \frac{T}{m}$

(5) From the above expressions it is clear that higher the temperature of the gas, more will be the average kinetic energy possessed by the gas molecules at $T = 0$, $E = 0$ *i.e.* at absolute zero the molecular motion stops.

Law of Equipartition of Energy

According to this law, for any system in thermal equilibrium, the total energy is equally distributed among its various degree of freedom. And each degree of freedom is associated with energy $\frac{1}{2} kT$ (where $k = 1.38 \times 10^{-23} J/K$, T = absolute temperature of the system).

(1) At a given temperature T, all ideal gas molecules no matter what their mass have the same average translational kinetic energy; namely, $\frac{3}{2} kT$. When measure the temperature of a gas, we are also measuring the average translational kinetic energy of it's molecules.

(2) At same temperature gases with different degrees of freedom (*e.g.*, He and H_2) will have different average energy or internal energy namely $\frac{f}{2} kT$. (f is different for different gases)

(3) Different energies of a system of degree of freedom f are as follows

(i) Total energy associated with each molecule $= \frac{f}{2} kT$

(ii) Total energy associated with N molecules $= \frac{f}{2} NkT$

(iii) Total energy associated with μ mole $= \frac{f}{2} RT$

(iv) Total energy associated with μ molen $= \frac{f}{2} \mu RT$

(v) Total energy associated with each gram $= \frac{f}{2} rT$

(iv) Total energy associated with m gram $= \frac{f}{2} mrT$

Specific Heat (C_P and C_V) of a Gas

The specific heat of gas can have many values, but out of them following two values are very important

(1) **Specific heat at constant volume (C_V) :** The specific heat of a gas at constant volume is defined as the quantity of heat required to raise the temperature of unit mass of gas through $1°C$ or $1 K$ when its volume is kept constant, *i.e.*, $c_V = \frac{(\Delta Q)_V}{m \Delta T}$

If instead of unit mass, 1 mole of gas is considered, the specific heat is called molar specific heat at constant volume and is represented by capital C_v.

$$C_V = M c_V = \frac{M (\Delta Q)_V}{m \Delta T} = \frac{1}{\mu} \frac{(\Delta Q)_V}{\Delta T} \qquad \left[\text{As } \mu = \frac{m}{M} \right]$$

(2) **Specific heat at constant from (C_P) :** The specific heat of a gas at constant pressure is defined as the quantity of heat required to raise the temperature of unit mass of gas through $1 K$ when its pressure is kept constant, *i.e.*, $c_P = \frac{(\Delta Q)_p}{m \Delta T}$

If instead of unit mass, 1 mole of gas is considered, the specific heat is called molar specific heat at constant pressure and is represented by C_p.

$$C_p = M C_p = \frac{M (\Delta Q)_p}{m \Delta T} = \frac{1}{\mu} \frac{(\Delta Q)_p}{\Delta T} \qquad \left[\text{As } \mu = \frac{m}{M} \right]$$

Mayer's Formula

(1) Out of two principle specific heats of a gas, C_P is more than C_V because in case of C_V, volume of gas is kept constant and heat is required only for raising the temperature of one gram mole of the gas through $1°C$ or $1\,K$. Hence no heat, what so ever, is spent in expansion of the gas.

It means that heat supplied to the gas increases its internal energy only *i.e.* $(\Delta Q)_V = \Delta U = \mu C_V \Delta T$ .....(i)

(2) While in case of C_P the heat is used in two ways

(i) In increasing the temperature of the gas by ΔT

(ii) In doing work, due to expansion at constant pressure (ΔW)

So $(\Delta Q)_P = \Delta U + \Delta W = \mu C_P \Delta T$ .....(ii)

From equation (i) and (ii) $\mu C_P \Delta T - \mu C_V \Delta T = \Delta W$

$\Rightarrow \mu \Delta T(C_P - C_V) = P\Delta V \Rightarrow C_P - C_V = \dfrac{P\Delta V}{\mu \Delta T} = R$

[For constant pressure, $\Delta W = P\Delta V$ also from $PV = \mu RT$,

$P\Delta V = \mu R \Delta T$]

This relation is called Mayer's formula and shows that $C_P > C_V$ *i.e.* molar specific heat at constant pressure is greater than that at constant volume.

Specific Heat in Terms of Degree of Freedom

(1) C_v : For a gas at temperature T, the internal energy $U = \dfrac{f}{2}\mu RT \Rightarrow$ Change in energy $\Delta U = \dfrac{f}{2}\mu R \Delta T$ ... (i)

Also, as we know for any gas heat supplied at constant volume $(\Delta Q)_V = \mu C_V \Delta T = \Delta U$ ... (ii)

From equation (i) and (ii) $C_V = \dfrac{1}{2}fR$

(2) C_P : From the Mayer's formula $C_p - C_v = R$

$\Rightarrow C_P = C_V + R = \dfrac{f}{2}R + R = \left(\dfrac{f}{2}+1\right)R$

(3) **Ratio of C_p and C_v (γ)** : $\gamma = \dfrac{C_P}{C_V} = \dfrac{\left(\dfrac{f}{2}+1\right)R}{\dfrac{f}{2}R} = 1 + \dfrac{2}{f}$

(i) Value of γ is different for monoatomic, diatomic and triatomic gases. $\gamma_{mono} = \dfrac{5}{3} = 1.6, \gamma_{di} = \dfrac{7}{5} = 1.4, \gamma_{tri} = \dfrac{4}{3} = 1.33$

(ii) Value of γ is always more than 1. So we can say that always $C_P > C_V$.

Gaseous Mixture

If two non-reactive gases are enclosed in a vessel of volume V. In the mixture μ_1 moles of one gas are mixed with μ_2 moles of another gas. If N_A is Avogadro's number then

Number of molecules of first gas $N_1 = \mu_1 N_A$

and number of molecules of second gas $N_2 = \mu_2 N_A$

(1) Total mole fraction $\mu = (\mu_1 + \mu_2)$.

(2) If M_1 is the molecular weight of first gas and M_2 that of second gas.

Then molecular weight of mixture $M = \dfrac{\mu_1 M_1 + \mu_2 M_2}{\mu_1 + \mu_2}$

(3) Specific heat of the mixture at constant volume will be

$$C_{V_{mix}} = \dfrac{\mu_1 C_{V_1} + \mu_2 C_{V_2}}{\mu_1 + \mu_2} = \dfrac{\dfrac{m_1}{M_1}C_{V_1} + \dfrac{m_2}{M_2}C_{V_2}}{\dfrac{m_1}{M_1} + \dfrac{m_2}{M_2}}$$

(4) Specific heat of the mixture at constant pressure will be

$$C_{P_{mix}} = \dfrac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 + \mu_2} = \dfrac{\mu_1\left(\dfrac{\gamma_1}{\gamma_1 - 1}\right)R + \mu_2\left(\dfrac{\gamma_2}{\gamma_2 - 1}\right)R}{\mu_1 + \mu_2}$$

$$= \dfrac{R}{\mu_1 + \mu_2}\left[\mu_1\left(\dfrac{\gamma_1}{\gamma_1 - 1}\right) + \mu_2\left(\dfrac{\gamma_2}{\gamma_2 - 1}\right)\right]$$

$$= \dfrac{R}{\dfrac{m_1}{M_1} + \dfrac{m_2}{M_2}}\left[\dfrac{m_1}{M_1}\left(\dfrac{\gamma_1}{\gamma_1 - 1}\right) + \dfrac{m_2}{M_2}\left(\dfrac{\gamma_2}{\gamma_2 - 1}\right)\right]$$

(5) $\gamma_{mixture} = \dfrac{C_{P_{mix}}}{C_{V_{mix}}} = \dfrac{\dfrac{(\mu_1 C_{P_1} + \mu_2 C_{P_2})}{\mu_1 + \mu_2}}{\dfrac{(\mu_1 C_{V_1} + \mu_2 C_{V_2})}{\mu_1 + \mu_2}}$

$$= \dfrac{\mu_1 C_{P_1} + \mu_2 C_{P_2}}{\mu_1 C_{V_1} + \mu_2 C_{V_2}} = \dfrac{\left\{\mu_1\left(\dfrac{\gamma_1}{\gamma_1 - 1}\right)R + \mu_2\left(\dfrac{\gamma_2}{\gamma_2 - 1}\right)R\right\}}{\left\{\mu_1\left(\dfrac{R}{\gamma_1 - 1}\right) + \mu_2\left(\dfrac{R}{\gamma_2 - 1}\right)\right\}}$$

$\therefore \gamma_{mixture} = \dfrac{\dfrac{\mu_1 \gamma_1}{\gamma_1 - 1} + \dfrac{\mu_2 \gamma_2}{\gamma_2 - 1}}{\dfrac{\mu_1}{\gamma_1 - 1} + \dfrac{\mu_2}{\gamma_2 - 1}} = \dfrac{\mu_1 \gamma_1(\gamma_2 - 1) + \mu_2 \gamma_2(\gamma_1 - 1)}{\mu_1(\gamma_2 - 1) + \mu_2(\gamma_1 - 1)}$

T Tips & Tricks

✍ The cooking gas cylinder contains L.P.G. (Liquid Petroleum gas) which is saturated. And as pressure of saturated vapours is independent of volume (at constant temperature). the pressure of gas coming out of the cylinder remains constant till the cylinder becomes empty.

✍ If the number of molecules in a gas increases, then the temperature, kinetic energy and pressure of the gas increases because $P \propto n$, $T \propto n$ and kinetic energy $\propto T \propto n$.

✍ At constant volume if T increases then $\bar{v}$, v_{rms}, P and collision frequency increases.

✍ If two gases are filled in vessel then nothing can be predicted about the pressure of gases. However their mean molecular energies will be same but their *rms* velocities will be different.

✍ The average distance between two gas molecules at NTP is 10^{-9} m.

✍ The space available for a single gas molecule at NTP is 37.2×10^{-2} m^2.

✍ The molecules of gases will escape out from a planet if the temperature of planet $T \leq \dfrac{Mv_e^2}{3R}$; where v_e = escape velocity from the planet, R = universal, gas constant and M = Molecular mass of the gas.

✍ As f (degree of freedom) increases then $C_P\uparrow$, $C_V\uparrow$ and $\gamma\uparrow$.

✍ The number of molecules present in 1 *gm mole* of a gas is defined as Avogadro number (N_A).

$N_A = 6.023 \times 10^{23}$ per *gm mole* $= 6.023 \times 10^{26}$ per *kg mole*.

At S.T.P. or N.T.P. (T = 273 K and P = 1 *atm*) 22.4 *litre* of each gas has 6.023×10^{23} molecule

✍ One mole of any gas at S.T.P. occupy 22.4 *litre* of volume *e.g.* 32 *gm* oxygen, 28 *gm* nitrogen and 2*gm* hydrogen occupy the same volume at S.T.P.

✍ For any gas 1 *mole* = M *gram* = 22.4 *litre* = 6.023×10^{23} molecule.

✍ $v_{rms} : v_{av} : v_{mp} = \sqrt{3} : \sqrt{\dfrac{8}{\pi}} : \sqrt{2} = \sqrt{3} : \sqrt{2.5} : \sqrt{2}$

✍ For oxygen gas molecules v_{rms} = 461 m/s, v_{av} = 424.7 m/s and v_{rms} = 376.4 m/s

✍ An atom in a solid though has no degree of freedom for translational and rotational motion, due to vibration along 3 axes has $3 \times 2 = 6$ degrees of freedom (and not like an ideal gas molecule). When a diatomic or polyatomic gas dissociates into atoms it behaves as monoatomic gas whose degree of freedom are changed accordingly

✍ In General a polyatmic molecule has 3 translational, 3 rotational degree of freedom and a certain number of vibration mode f_{vib}. Hence $\gamma_{poly} = \dfrac{4 + f_{vib}}{3 + f_{vib}}$.

✍ Only average translational kinetic energy of a gas contributes to its temperature. Two gases with the same average translational kinetic energy have the same temperature even if one has grater rotational energy and thus greater internal energy.

✍ Unsaturated vapours obey gas laws while saturated vapours don't.

✍ For real gases effective volume is considered as ($V - \mu b$) where $b = 4N_A\left(\dfrac{4}{3}\pi r^3\right)$; r = radius of each molecule and N_A = avogrado number.

✍ Variation of degree of freedom of a diatomic gas (H_2) with temperature. At very low temperature only translation is possible. as the temperature increases rotational motion can begin. At still higher temperatures vibratory motion can begin.
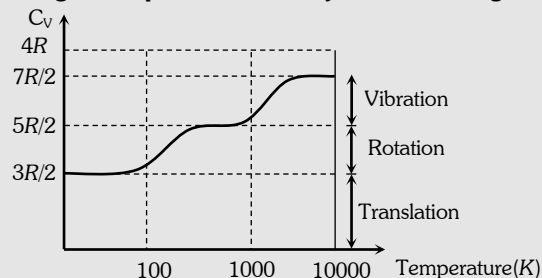
Ordinary Thinking

Objective Questions

Gas Laws

1. The temperature of a gas at pressure P and volume V is $27°C$. Keeping its volume constant if its temperature is raised to $927°C$, then its pressure will be **[MP PMT 1985]**
   (a) 2 P (b) 3 P
   (c) 4 P (d) 6 P

2. 4 moles of an ideal gas is at $0°C$. At constant pressure it is heated to double its volume, then its final temperature will be **[MP PET 1990]**
   (a) $0°C$ (b) $273°C$
   (c) $546°C$ (d) $136.5°C$

3. Every gas (real gas) behaves as an ideal gas **[CPMT 1997; RPMT 2000; MP PET 2001]**
   (a) At high temperature and low pressure
   (b) At low temperature and high pressure
   (c) At normal temperature and pressure
   (d) None of the above

4. Boyle's law holds for an ideal gas during **[AFMC 1994; KCET 1999]**
   (a) Isobaric changes (b) Isothermal changes
   (c) Isochoric changes (d) Isotonic changes

5. S.I. unit of universal gas constant is **[MNR 1988; MP PMT 1994; UPSEAT 1999]**
   (a) $cal/°C$ (b) J/mol
   (c) $J\,mol^{-1}\,K^{-1}$ (d) J/kg

6. Molecules of a gas behave like **[J & K CET 2000]**
   (a) Inelastic rigid sphere
   (b) Perfectly elastic non-rigid sphere
   (c) Perfectly elastic rigid sphere
   (d) Inelastic non-rigid sphere

7. A perfect gas at $27°C$ is heated at constant pressure so as to triple its volume. The temperature of the gas will be

[MP PET 1991]

(a) $81°C$ (b) $900°C$

(c) $627°C$ (d) $450°C$

8. The density of a gas at normal pressure and $27°C$ temperature is 24. Keeping the pressure constant, the density at $127°C$ will be

(a) 6   (b) 12

(c) 18   (d) 24

9. The volume of a gas at $20°C$ is 200 ml. If the temperature is reduced to $-20°C$ at constant pressure, its volume will be

[MP PET 1986]

(a) 172.6 ml (b) 17.26 ml

(c) 192.7 ml (d) 19.27 ml

10. Two gases of equal mass are in thermal equilibrium. If P_a, P_b and V_a and V_b are their respective pressures and volumes, then which relation is true **[AIIMS 1982]**

(a) $P_a \neq P_b ; V_a = V_b$ (b) $P_a = P_b ; V_a \neq V_b$

(c) $\dfrac{P_a}{V_a} = \dfrac{P_b}{V_b}$ (d) $P_a V_a = P_b V_b$

11. At absolute zero temperature, pressure of a gas will be

(a) Zero   (b) One atmospheric pressure

(c) $P_0 \times 273$ (d) $P_0 \times 76$

12. The gas which obeys Boyle's law for maximum range of temperature is

(a) CO_2 (b) O_3

(c) H_2 (d) He

13. The vapour of a substance behaves as a gas **[CPMT 1987]**

(a) Below critical temperature (b) Above critical temperature

(c) At $100°C$ (d) At $1000°C$

14. The temperature below which a gas should be cooled, before it can be liquified by pressure only is termed as

[CPMT 1972]

(a) The dew point   (b) The freezing point

(c) The saturation point   (d) The critical point

15. It is possible for a substance to coexist in all three phases in equilibrium, when the substance is at **[MP PET 1985]**

(a) Boyle temperature   (b) Critical temperature

(c) Triple point   (d) Dew point

16. When air is filled in the balloon, the pressure and volume both increases while temperature does not change. Here Boyle's law is not obeyed because

(a) Mass of air is negligible

(b) Mass of air does not remain constant

(c) Air is not perfect gas

(d) Pressure inside the balloon is less than that of the atmospheric pressure

17. The mean free path of gas molecules depends on (d = molecular diameter)

(a) d (b) d^2

(c) d^{-2} (d) d^{-1}

18. For Boyle's law to hold the gas should be **[CPMT 1978]**

(a) Perfect and of constant mass and temperature

(b) Real and of constant mass and temperature

(c) Perfect and at constant temperature but variable mass

(d) Real and at constant temperature but variable mass

19. If pressure of a gas contained in a closed vessel is increased by 0.4% when heated by $1°C$, the initial temperature must be **[NCERT 1982; EAMCET (Engg.) 1995; RPMT 1996; RPET 1998; MP PET 1999; UPSEAT 1999]**

(a) 250 K (b) $250°C$

(c) 2500 K (d) $25°C$

20. Consider a 1 $c.c.$ sample of air at absolute temperature T_0 at sea level and another 1 cc sample of air at a height where the pressure is one-third atmosphere. The absolute temperature T of the sample at that height is **[NCERT 1980]**

(a) Equal to $T_0 / 3$

(b) Equal to $3 / T_0$

(c) Equal to T_0

(d) Cannot be determined in terms of T_0 from the above data

21. To double the volume of a given mass of an ideal gas at $27°C$ keeping the pressure constant, one must raise the temperature in degree centigrade to

[IIT 1975; MP PMT 1994]

(a) $54°$ (b) $270°$

(c) $327°$ (d) $600°$

22. Which of the following statements about kinetic theory of gases is wrong **[AMU 1995]**

(a) The molecules of a gas are in continuous random motion

(b) The molecules continuously undergo inelastic collisions

(c) The molecules do not interact with each other except during collisions

(d) The collisions amongst the molecules are of short duration

23. If a Vander-Waal's gas expands freely, then final temperature is **[RPMT 1996]**

(a) Less than the initial temperature

(b) Equal to the initial temperature

(c) More than the initial temperature

(d) Less or more than the initial temperature depending on the nature of the gas

24. In Vander Waal's equation $\left[P + \dfrac{a}{V^2}\right](V - b) = RT$, the dimensions of a are **[RPMT 2003]**

(a) $M^1 L^5 T^{-2}$ (b) $M^0 L^2 T^{-3}$

(c) $M^1 L^3 T^{-2}$ (d) $M^1 L^1 T^{-2}$

25. At NTP, sample of equal volume of chlorine and oxygen is taken. Now ratio of No. of molecules **[RPET 2000]**

(a) 1 : 1   (b) 32 : 27

(c) 2 : 1   (d) 16 : 14

26. A gas at the temperature 250 K is contained in a closed vessel. If the gas is heated through 1K, then the percentage increase in its pressure will be

[Pb. PET 1998; KCET 2001, 03]

(a) 0.4%   (b) 0.2%

(c) 0.1%   (d) 0.8%

27. A cylinder of 5 *litre* capacity, filled with air at N.T.P. is connected with another evacuated cylinder of 30 *litres* of capacity. The resultant air pressure in both the cylinders will be **[KCET 2001]**

(a) 38.85 *cm* of *Hg*   (b) 21.85 *cm* of *Hg*

(c) 10.85 *cm* of *Hg*   (d) 14.85 *cm* of *Hg*

28. Volume of gas become four times if **[RPET 2001]**

(a) Temperature become four times at constant pressure

(b) Temperature become one fourth at constant pressure

(c) Temperature becomes two times at constant pressure

(d) Temperature becomes half at constant pressure

29. The relationship between pressure and the density of a gas expressed by Boyle's law, $P = KD$ holds true

[JIPMER 2002]

(a) For any gas under any conditions

(b) For some gases under any conditions

(c) Only if the temperature is kept constant

(d) Only if the density is constant

30. Kinetic theory of gases provide a base for **[AIEEE 2002]**

(a) Charle's law

(b) Boyle's law

(c) Charle's law and Boyle's law

(d) None of these

31. On $0°C$ pressure measured by barometer is 760 *mm*. What will be pressure on $100°C$ **[AFMC 2002]**

(a) 760 *mm*   (b) 730 *mm*

(c) 780 *mm*   (d) None of these

32. A perfect gas at $27°C$ is heated at constant pressure to $327°C$. If original volume of gas (at $27°C$ is V then volume at $327°C$ is **[CPMT 2002]**

(a) V (b) $3V$

(c) $2V$ (d) $V/2$

33. Hydrogen gas is filled in a balloon at 20°C. If temperature is made $40°C$, pressure remaining same, what fraction of Hydrogen will come out **[MP PMT 2002]**

(a) 0.07   (b) 0.25

(c) 0.5   (d) 0.75

34. At constant temperature on increasing the pressure of a gas by 5% will decrease its volume by **[MP PET 2002]**

(a) 5%   (b) 5.26%

(c) 4.26%   (d) 4.76%

35. Which law states that effect of pressure is same for all portion **[AFMC 2003]**

(a) Pascal's law   (b) Gallusac's law

(c) Dalton's law   (d) None of these

36. When the pressure on 1200 *ml* of a gas in increased from 70 *cm* to 120 *cm* of mercury at constant temperature, the new volume of the gas will be **[Pb. PET 2000]**

(a) 700 *ml*   (b) 600 *ml*

(c) 500 *ml*   (d) 400 *ml*

37. The equation for an ideal gas is $PV = RT$, where V represents the volume of **[CPMT 1973, 83; MP PMT 1985]**

(a) 1 *gm* gas   (b) Any mass of the gas

(c) One *gm mol* gas   (d) One *litre* gas

38. The molecular weights of O_2 and N_2 are 32 and 28 respectively. At 15°C, the pressure of 1 *gm* O_2 will be the same as that of 1 *gm* N_2 in the same bottle at the temperature **[MP PMT 1985]**

(a) $-21°C$ (b) $13°C$

(c) $15°C$ (d) $56.4°C$

39. At 100 K and 0.1 atmospheric pressure, the volume of helium gas is 10 *litres*. If volume and pressure are doubled, its temperature will change to **[MP PMT 1986]**

(a) 400 K (b) 127 K

(c) 200 K (d) 25 K

40. Under which of the following conditions is the law $PV = RT$ obeyed most closely by a real gas

[NCERT 1974; EAMCET 1996; MP PMT 1994, 97;
MP PET 1999; AMU 2001; CPMT 2005]

(a) High pressure and high temperature

(b) Low pressure and low temperature

(c) Low pressure and high temperature

(d) High pressure and low temperature

41. The gas equation $\dfrac{PV}{T} = $ constant is true for a constant mass of an ideal gas undergoing **[MP PET 1992]**

(a) Isothermal change   (b) Adiabatic change

(c) Isobaric change   (d) Any type of change

42. That gas cannot be liquified

(a) Which obeys Vander Waal's equation

(b) Which obeys gas equation at every temperature and pressure

(c) The molecules of which are having potential energy

(d) Which is a inert gas

43. At NTP the mass of one litre of air is 1.293 *gm*. The value of specific gas constant will be

(a) 0.29 *J/K-gm*

(b) 4.2 *J/K-gm*

(c) 8.3 *J/K-gm*

(d) 16.5 *J/K-gm*

44. The volume of a gas at $21°C$ temperature and 768 *mm* pressure is 1 *litre*. If the density of the gas is 1.2 *gm/litre* at NTP, then its mass will be

(a) 4 *gm*

(b) 4.21 *gm*

(c) 1.13 *gm*

(d) 10 *gm*

45. For one gram mol of a gas, the value of R in the equation $PV = RT$ is nearly　　　**[CPMT 1974; DPMT 1999]**

(a) 2 *cal/K*

(b) 10 *cal/K*

(c) 0.2 *cal/K*

(d) 200 *cal/K*

46. The number of molecules in a gas at pressure 1.64×10^{-3} atmospheres and temperature 200 *K* having the volume 1 *cc* are

(a) 6.02×10^{16}

(b) 2.63×10^{16}

(c) 3.01×10^{19}

(d) 12.04×10^{19}

47. The pressure P, volume V and temperature T of a gas in the jar A and the other gas in the jar B at pressure $2P$, volume $V/4$ and temperature $2T$, then the ratio of the number of molecules in the jar A and B will be

[AIIMS 1982; MP PMT 1996; Manipal 2003]

(a) 1 : 1

(b) 1 : 2

(c) 2 : 1

(d) 4 : 1

48. We write the relation for Boyle's law in the form $PV = C$ when the temperature remains constant. In this relation, the magnitude of C depends upon　　　**[CPMT 1972]**

(a) The nature of the gas used in the experiment

(b) The magnitude of g in the laboratory

(c) The atmospheric pressure

(d) The quantity of the gas enclosed

49. If a given mass of gas occupies a volume of 10 *cc* at 1 atmospheric pressure and temperature of $100°C$ (373.15 *K*). What will be its volume at 4 atmospheric pressure; the temperature being the same　　　**[NCERT 1977]**

(a) 100 *cc*

(b) 400 *cc*

(c) 2.5 *cc*

(d) 104 *cc*

50. A sample of an ideal gas occupies a volume V at a pressure P and absolute temperature T, the mass of each molecule is m. The expression for the density of gas is (k = Boltzmann's constant)　　　**[EAMCET 1988; MP PMT 1994; UPSEAT 2001]**

(a) mkT

(b) P/kT

(c) P/kTV

(d) Pm/kT

51. The product of the pressure and volume of an ideal gas is

[Manipal MEE 1995]

(a) A constant

(b) Approx. equal to the universal gas constant

(c) Directly proportional to its temperature

(d) Inversely proportional to its temperature

52. A balloon contains $500 m^3$ of helium at $27°C$ and 1 atmosphere pressure. The volume of the helium at $-3°C$ temperature and 0.5 atmosphere pressure will be

[MP PMT/PET 1998; JIPMER 2001, 02]

(a) $500 m^3$

(b) $700 m^3$

(c) $900 m^3$

(d) $1000 m^3$

53. A vessel contains 1 mole of O_2 gas (molar mass 32) at a temperature T. The pressure of the gas is P. An identical vessel containing one mole of He gas (molar mass 4) at temperature $2T$ has a pressure of　　　**[IIT 1997 Re-Exam]**

(a) $P/8$

(b) P

(c) $2P$

(d) $8P$

54. 1 mole of gas occupies a volume of 100 *ml* at 50 *mm* pressure. What is the volume occupied by two moles of gas at 100 *mm* pressure and at same temperature

[EAMCET (Engg.) 1995]

(a) 50 *ml*

(b) 100 *ml*

(c) 200 *ml*

(d) 500 *ml*

55. For ideal gas, which statement is not true　　　**[RPMT 1997]**

(a) It obeys Boyle's law

(b) It follows $PV = RT$

(c) Internal energy depends on temperature only

(d) It follows Vander-Waal's equation

56. A given mass of a gas is allowed to expand freely until its volume becomes double. If C_b and C_a are the velocities of sound in this gas before and after expansion respectively, then C_a is equal to　　　**[SCRA 1998]**

(a) $2C_b$

(b) $\sqrt{2}\,C_b$

(c) C_b

(d) $\dfrac{1}{\sqrt{2}}C_b$

57. Kinetic theory of gases was put forward by　　　**[RPMT 1999]**

(a) Einstein

(b) Newton

(c) Maxwell

(d) Raman

58. One *litre* of Helium gas at a pressure 76 *cm* of *Hg* and temperature $27°$ is heated till its pressure and volume are doubled. The final temperature attained by the gas is

[CPMT 2000]

(a) $927°C$

(b) $900°C$

(c) $627°C$

(d) $327°C$

59. A flask is filled with 13 gm of an ideal gas at 27°C and its temperature is raised to 52°C. The mass of the gas that has to be released to maintain the temperature of the gas in the flask at 52°C and the pressure remaining the same is

[EAMCET (Engg.) 2000]

(a) 2.5 g   (b) 2.0 g

(c) 1.5 g   (d) 1.0 g

60. The molecular weight of a gas is 44. The volume occupied by 2.2 g of this gas at 0°C and 2 atm. pressure will be

[CPMT 2001]

(a) 0.56 litre   (b) 1.2 litres

(c) 2.4 litres   (d) 5.6 litres

61. A gas at 27°C temperature and 30 atmospheric pressure is allowed to expand to the atmospheric pressure. If the volume becomes 10 times its initial volume, then the final temperature becomes **[CBSE PMT 2001]**

(a) 100°C   (b) 173°C

(c) 273°C   (d) − 173°C

62. When volume of system is increased two times and temperature is decreased half of its initial temperature, then pressure becomes **[AIEEE 2002]**

(a) 2 times   (b) 4 times

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

63. A balloon contains 1500 m^3 of helium at 27°C and 4 atmospheric pressure. The value of helium at −3°C temperature and 2 atmospheric pressure will be **[BHU 2002]**

(a) 1500 m^3 (b) 1700 m^3

(c) 1900 m^3 (d) 2700 m^3

64. In the relation $n = \frac{PV}{RT}, n =$ **[RPET 2003]**

(a) Number of molecules   (b) Atomic number

(c) Mass number   (d) Number of moles

65. A gas at 27°C has a volume V and pressure P. On heating its pressure is doubled and volume becomes three times. The resulting temperature of the gas will be **[MP PET 2003]**

(a) 1800°C   (b) 162°C

(c) 1527°C   (d) 600°C

66. The equation of state corresponding to 8 g of O_2 is

[CBSE PMT 1994; DPMT 2000]

(a) $PV = 8RT$ (b) $PV = RT/4$

(c) $PV = RT$ (d) $PV = RT/2$

67. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be

[CBSE PMT 2004]

(a) $PV = (5/32)RT$ (b) $PV = 5RT$

(c) $PV = (5/2)RT$ (d) $PV = (5/16)RT$

(Where R is the gas constant)

68. O_2 gas is filled in a vessel. If pressure is doubled, temperature becomes four times. How many times its density will become **[RPMT 2003]**

(a) 2   (b) 4

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

69. The volume of a gas will be double of what it is at 0°C (pressure remaining constant) at **[JIPMER 1997]**

(a) 1092 K   (b) 273 K

(c) 546°C   (d) 273°C

70. The pressure and temperature of two different gases is P and T having the volume V for each. They are mixed keeping the same volume and temperature, the pressure of the mixture will be **[NCERT 1978;**

Pb. PMT 1997, 98; DPMT 1999; MH CET 2003]

(a) P / 2   (b) P

(c) 2P   (d) 4P

71. Three containers of the same volume contain three different gases. The masses of the molecules are m_1, m_2 and m_3 and the number of molecules in their respective containers are N_1, N_2 and N_3. The gas pressure in the containers are P_1, P_2 and P_3 respectively. All the gases are now mixed and put in one of the containers. The pressure P of mixture will be **[CBSE PMT 1992]**

(a) $P < (P_1 + P_2 + P_3)$ (b) $P = \frac{P_1 + P_2 + P_3}{3}$

(c) $P = P_1 + P_2 + P_3$ (d) $P > (P_1 + P_2 + P_3)$

72. At a given volume and temperature, the pressure of a gas

[SCRA 1994]

(a) Varies inversely as its mass

(b) Varies inversely as the square of its mass

(c) Varies linearly as its mass

(d) Is independent of its mass

73. The rate of diffusion is **[AIIMS 1998]**

(a) Faster in solids than in liquids and gases

(b) Faster in liquids than in solids and gases

(c) Equal to solids, liquids and gases

(d) Faster in gases than in liquids and solids

74. A vessel is filled with an ideal gas at a pressure of 10 atmospheres and temperature 27°C. Half of the mass of the gas is removed from the vessel and temperature of the remaining gas is increased to 87°C. Then the pressure of the gas in the vessel will be **[EAMCET (Engg.)2000]**

(a) 5 atm   (b) 6 atm

(c) 7 atm   (d) 8 atm

75. When a gas in a closed vessel was heated so as to increase its temperature by $5^{o}C$, there occurred an increase of 1% in its pressure. The original temperature of the gas was

[MP PMT 1994, 2000]

(a) $500^{o}C$ (b) $273^{o}C$

(c) $227^{o}C$ (d) $50^{o}C$

76. Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T_1, T_2), volume (V_1, V_2) and pressure (P_1, P_2) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be **[AIEEE 2004]**

(a) $T_1 + T_2$ (b) $(T_1 + T_2)/2$

(c) $\dfrac{T_1 T_2 (P_1 V_1 + P_2 V_2)}{P_1 V_1 T_2 + P_2 V_2 T_1}$ (d) $\dfrac{T_1 T_2 (P_1 V_1 + P_2 V_2)}{P_1 V_1 T_1 + P_2 V_2 T_2}$

77. For matter to exist simultaneously in gas and liquid phases

(a) The temperature must be $0\,K$

(b) The temperature must be less than $0^{o}C$

(c) The temperature must be less than the critical temperature

(d) The temperature must be less than the reduced temperature

78. The value of critical temperature in terms of Vander Waal's constant a and b is **[MP PET 2003]**

(a) $T_c = \dfrac{8a}{27Rb}$ (b) $T_c = \dfrac{a}{2Rb}$

(c) $T_c = \dfrac{8}{27Rb}$ (d) $T_c = \dfrac{27a}{8Rb}$

79. In Vander Waal's equation a and b represent

$$\left(P + \dfrac{a}{V^2}\right)(v - b) = RT$$ **[RPMT 2001]**

(a) Both a and b represent correction in volume

(b) Both a and b represent adhesive force between molecules

(c) a represents adhesive force between molecules and b correction in volume

(d) a represents correction in volume and b represents adhesive force between molecules

80. The gas in vessel is subjected to a pressure of 20 atmosphere at a temperature $27°C$. The pressure of the gas in a vessel after one half of the gas is released from the vessel and the temperature of the remainder is raised by $50°C$ is **[CBSE 1994]**

(a) $8.5\ atm$ (b) $10.8\ atm$

(c) $11.7\ atm$ (d) $17\ atm$

81. At $0°C$ the density of a fixed mass of a gas divided by pressure is x. At $100°C$, the ratio will be **[DCE 1997]**

(a) x (b) $\dfrac{273}{373}x$

(c) $\dfrac{373}{273}x$ (d) $\dfrac{100}{273}x$

82. $2\ gm$ of O_2 gas is taken at $27°C$ and pressure $76\ cm$. Of Hg. Then find out volume of gas (in litre) **[RPMT 2001]**

(a) 1.53 (b) 2.44

(c) 3.08 (d) 44.2

83. An electron tube was sealed off during manufacture at a pressure of $1.2 \times 10^{-7}\ mm$ of mercury at $27°C$. Its volume is $100\ cm^3$. The number of molecules that remain in the tube is **[Kerala (Engg.) 2002]**

(a) 2×10^{16} (b) 3×10^{15}

(c) 3.86×10^{11} (d) 5×10^{11}

84. If the pressure of an ideal gas contained in a closed vessel is increased by 0.5%, the increase in temperature is $2K$. The initial temperature of the gas is **[EAMCET (Med.) 2003]**

(a) $27°C$ (b) $127°C$

(c) $300°C$ (d) $400°C$

85. Air is filled in a bottle at atmospheric pressure and it is corked at $35°C$. If the cork can come out at 3 atmospheric pressure than upto what temperature should the bottle be heated in order to remove the cork **[BHU 1997]**

(a) $325.5°C$ (b) $851°C$

(c) $651°C$ (d) None of these

86. A gas is collected over the water at $25°C$. The total pressure of moist gas was $735\ mm$ of mercury. If the aqueous vapour pressure at $25°C$ is $23.8\ mm$. Then the pressure of dry gas is **[UPSEAT 1999]**

(a) $760\ mm$ (b) $758.8\ mm$

(c) $710.8\ mm$ (d) $711.2\ mm$

87. $125\ ml$ of gas A at 0.60 atmosphere and $150\ ml$ of gas B at 0.80 atmosphere pressure at same temperature is filled in a vessel of 1 $litre$ volume. What will be the total pressure of mixture at the same temperature **[UPSEAT 1999]**

(a) 0.140 atmosphere   (b) 0.120 atmosphere

(c) 0.195 atmosphere   (d) 0.212 atmosphere

88. Saturated vapour is compressed to half its volume without any change in temperature, then the pressure will be

[UPSEAT 2001]

(a) Doubled   (b) Halved

(c) The same   (d) Zero

89. Air is pumped into an automobile tube upto a pressure of $200\ kPa$ in the morning when the air temperature is $22°C$. During the day, temperature rises to $42°C$ and the tube expands by 2%. The pressure of the air in the tube at this temperature, will be approximately **[UPSEAT 2002]**

(a) $212\ kPa$ (b) $209\ kPa$

(c) $206\ kPa$ (d) $200\ kPa$

90. At what temperature volume of an ideal gas at $0°C$ becomes triple **[CPMT 2003]**

(a) $546°C$ (b) $182°C$

(c) $819°C$ (d) $646°C$

91. If an ideal gas has volume V at $27°C$ and it is heated at a constant pressure so that its volume becomes $1.5V$. Then the value of final temperature will be **[DPMT 1995, 2002, 03]**

(a) $600°C$ (b) $177°C$

(c) $817°C$ (d) None of these

92. The temperature of an ideal gas at atmospheric pressure is $300K$ and volume $1m^3$. If temperature and volume become double, then pressure will be **[RPMT 2004]**

(a) $10^5 N/m^2$ (b) $2 \times 10^5 N/m^2$

(c) $0.5 \times 10^5 N/m^2$ (d) $4 \times 10^5 N/m^2$

93. What is the mass of 2 *litres* of nitrogen at 22.4 atmospheric pressure and $273K$ **[J & K CET 2005]**

(a) $28g$ (b) $14 \times 22.4\ g$

(c) $56\ g$ (d) None of these

94. The value of PV/T for one mole of an ideal gas is nearly equal to **[Kerala (Engg.) 2005]**

(a) $2\ J\ mol^{-1}K^{-1}$ (b) $8.3\ cal\ mol^{-1}K^{-1}$

(c) $4.2\ J\ mol^{-1}K^{-1}$ (d) $2\ cal\ mol^{-1}K^{-1}$

95. A tyre kept outside in sunlight bursts off after sometime because of **[AFMC 2005]**

(a) Increase in pressure   (b) Increases in volume

(c) Both (a) and (b)   (d) None of these

96. If the volume of the gas containing n number of molecules is V, then the pressure will decrease due to force of intermolecular attraction in the proportion

(a) n/v (b) n/V^2

(c) $(n/V)^2$ (d) $1/V^2$

97. In Boyle's law what remains constant **[CPMT 2005]**

(a) PV (b) TV

(c) $\dfrac{V}{T}$ (d) $\dfrac{P}{T}$

98. Equation of gas in terms of pressure (P), absolute temperature (T) and density (d) is **[EAMCET 2005]**

(a) $\dfrac{P_1}{T_1 d_1} = \dfrac{P_2}{T_2 d_2}$ (b) $\dfrac{P_1 T_1}{d_1} = \dfrac{P_2 T_2}{d_2}$

(c) $\dfrac{P_1 d_2}{T_1} = \dfrac{P_2 d_1}{T_1}$ (d) $\dfrac{P_1 d_1}{T_1} = \dfrac{P_2 d_2}{T_2}$

99. At constant pressure, the ratio of increase in volume of an ideal gas per degree raise in kelvin temperature to it's original volume is (T = absolute temperature of the gas) **[EAMCET 2004]**

(a) T^2 (b) T

(c) $\dfrac{1}{T}$ (d) $\dfrac{1}{T^2}$

100. Figure shows two flasks connected to each other. The volume of the flask 1 is twice that of flask 2. The system is filled with an ideal gas at temperature 100 K and 200 K respectively. If the mass of the gas in 1 be m then what is the mass of the gas in flask 2 **[CBSE PMT 2000]**
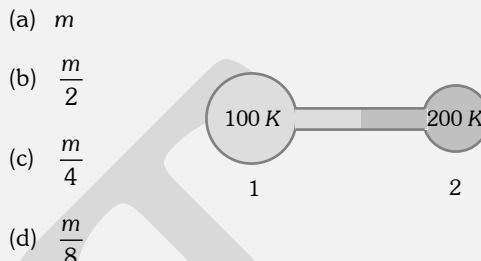
(a) m

(b) $\dfrac{m}{2}$

(c) $\dfrac{m}{4}$

(d) $\dfrac{m}{8}$

Speed of Gas

1. If the molecular weight of two gases are M_1 and M_1, then at a temperature the ratio of root mean square velocity v_1 and v_2 will be **[MP PMT 1989, 96; CPMT 2000; DPMT 2001]**

(a) $\sqrt{\dfrac{M_1}{M_2}}$ (b) $\sqrt{\dfrac{M_2}{M_1}}$

(c) $\sqrt{\dfrac{M_1 + M_2}{M_1 - M_2}}$ (d) $\sqrt{\dfrac{M_1 - M_2}{M_1 + M_2}}$

2. To what temperature should the hydrogen at $327°C$ be cooled at constant pressure, so that the root mean square velocity of its molecules become half of its previous value **[MP PET/PMT 1988]**

(a) $-123°C$ (b) $123°C$

(c) $-100°C$ (d) $0°C$

3. At a certain temperature, the *r.m.s.* velocity for O_2 is 400 *m/sec*. At the same temperature, the *r.m.s.* velocity for H_2 molecules will be

(a) $100\ m/sec$ (b) $25\ m/sec$

(c) $1600\ m/sec$ (d) $6400\ m/sec$

4. At a pressure of $24 \times 10^5\ dyne/cm^2$, the volume of O_2 is 10 *litre* and mass is 20 *gm*. The *r.m.s.* velocity will be

(a) $800\ m/sec$ (b) $400\ m/sec$

(c) $600\ m/sec$ (d) Data is incomplete

5. The *r.m.s.* velocity will be greater for

(a) Hydrogen   (b) Oxygen

(c) Equal for both   (d) Nothing is definite

6. In thermal equilibrium, the average velocity of gas molecules is **[NCERT 1974; RPET 1999]**

(a) Proportional to $\sqrt{T}$ (b) Proportional to T^2

(c) Proportional to T^3 (d) Zero

7. At what temperature will the oxygen molecules have the same root mean square speed as hydrogen molecules at $200\ K$

[MP PMT 1992]

(a) $800\ K$ (b) $1600\ K$

(c) $2400\ K$ (d) $3200\ K$

8. The absolute temperature of a gas is determined by

[NCERT 1974; AFMC 1994; MH CET (Med.) 2001]

(a) The average momentum of the molecules

(b) The velocity of sound in the gas

(c) The number of molecules in the gas

(d) The mean square velocity of the molecules

9. The root mean square velocity of the molecules in a sample of helium is 5/7th that of the molecules in a sample of hydrogen. If the temperature of hydrogen sample is $0°C$, then the temperature of the helium sample is about

[NCERT 1980; BHU 2004; MP PMT 2002]

(a) $0°C$ (b) $0\ K$

(c) $273°C$ (d) $100°C$

10. At what temperature is the root mean square velocity of gaseous hydrogen molecules is equal to that of oxygen molecules at $47°C$

[CPMT 1985; MP PET 1997; RPET 1999; AIEEE 2002]

(a) $20\ K$ (b) $80\ K$

(c) $-73\ K$ (d) $3\ K$

11. For a gas, the *r.m.s.* speed at $800\ K$ is   **[MP PMT 1990]**

(a) Four times the value at $200\ K$

(b) Half the value at $200\ K$

(c) Twice the value at $200\ K$

(d) Same as at $200\ K$

12. The root mean square velocity of a gas molecule of mass m at a given temperature is proportional to

[AFMC 1995; CBSE PMT 1990]

(a) m^0 (b) m

(c) $\sqrt{m}$ (d) $\dfrac{1}{\sqrt{m}}$

13. A sample of gas is at $0°C$. To what temperature it must be raised in order to double the *r.m.s.* speed of the molecule

[MP PET 1991, 92, 95]

(a) $270°C$ (b) $819°C$

(c) $1090°C$ (d) $100°C$

14. A gas is allowed to expand isothermally. The root mean square velocity of the molecules   **[MP PMT 1986]**

(a) Will increase

(b) Will decrease

(c) Will remain unchanged

(d) Depends on the other factors

15. The temperature at which the root mean square velocity of a molecule will be doubled than at $100°C$ **[MP PET 1989]**

(a) $1219°C$ (b) $1492°C$

(c) $400°C$ (d) $400\ K$

16. At room temperature, the *r.m.s.* speed of the molecules of certain diatomic gas is found to be 1930 m/s. The gas is

[IIT 1984; CPMT 1996; MP PET 2000; UPSEAT 2001; BCECE 2003]

(a) H_2 (b) F_2

(c) O_2 (d) Cl_2

17. Moon has no atmosphere because

(a) The *r.m.s.* velocity of all gases is more than the escape velocity from moon's surface

(b) Its surface is not smooth

(c) It is quite far away from the earth

(d) It does not have population and plants

18. Speed of sound in a gas is v and *r.m.s.* velocity of the gas molecules is c. The ratio of v to c is

[CPMT 1983; Bihar CMEET 1995; MP PMT 2001]

(a) $\dfrac{3}{\gamma}$ (b) $\dfrac{\gamma}{3}$

(c) $\sqrt{\dfrac{3}{\gamma}}$ (d) $\sqrt{\dfrac{\gamma}{3}}$

19. The molecules of a given mass of a gas have a *r.m.s.* velocity of $200\ m/sec$ at $27°C$ and $1.0 \times 10^5\ N/m^2$ pressure. When the temperature is $127°C$ and pressure is $0.5 \times 10^5\ N/m^2$, the *r.m.s.* velocity in m/sec will be

[AIIMS 1985; MP PET 1992]

(a) $\dfrac{100\sqrt{2}}{3}$ (b) $100\sqrt{2}$

(c) $\dfrac{400}{\sqrt{3}}$ (d) None of the above

20. Which of the following statement is true   **[IIT 1981]**

(a) Absolute zero degree temperature is not zero energy temperature

(b) Two different gases at the same temperature pressure have equal root mean square velocities

(c) The root mean square speed of the molecules of different ideal gases, maintained at the same temperature are the same

(d) Given sample of 1 cc of hydrogen and 1 cc of oxygen both at NTP; oxygen sample has a large number of molecules

21. The average speed v and *r.m.s.* speed $\bar{v}$ of the molecules are related as

(a) $\bar{v} = 0.92v$ (b) $\bar{v}^2 = 0.29v^2$

(c) $\bar{v} = v$ (d) $v = 0.92\bar{v}$

22. The respective speeds of five molecules are 2, 1.5, 1.6, 1.6 and 1.2 km/sec. The most probable speed in km/sec will be

(a) 2   (b) 1.58

(c) 1.6   (d) 1.31

23. At which temperature the velocity of O_2 molecules will be equal to the velocity of N_2 molecules at $0°C$

[CPMT 1985; JIPMER 1997]

(a) $40°C$ (b) $93°C$

(c) $39°C$ (d) Cannot be calculated

24. The respective speeds of the molecules are 1, 2, 3, 4 and 5 km/sec. The ratio of their $r.m.s.$ velocity and the average velocity will be

(a) $\sqrt{11}:3$ (b) $3:\sqrt{11}$

(c) $1:2$ (d) $3:4$

25. Two vessels having equal volume contains molecular hydrogen at one atmosphere and helium at two atmospheres respectively. If both samples are at the same temperature, the mean velocity of hydrogen molecules is

[NCERT 1979]

(a) Equal to that of helium   (b) Twice that of helium

(c) Half that of helium   (d) $\sqrt{2}$ times that of helium

26. The temperature of an ideal gas is increased from $27°C$ to $927°C$. The root mean square speed of its molecules becomes   **[NCERT 1983; CBSE PMT 1994]**

(a) Twice   (b) Half

(c) Four times   (d) One-fourth

27. According to the kinetic theory of gases the $r.m.s.$ velocity of gas molecules is directly proportional to

[CPMT 1983; RPET/PMT 1999]

(a) T (b) $\sqrt{T}$

(c) T^2 (d) $1/\sqrt{T}$

28. At a given temperature the root mean square velocities of oxygen and hydrogen molecules are in the ratio

[ISM Dhanbad 1994; MP PET/ PMT 1994; CPMT 1996; UPSEAT 1998; AMU 1999; RPMT 2000; MH CET 2001]

(a) $16:1$ (b) $1:16$

(c) $4:1$ (d) $1:4$

29. At what temperature the molecules of nitrogen will have the same $r.m.s.$ velocity as the molecules of oxygen at $127°C$

[MP PMT 1994; MH CET 2001; Pb. PET 2000, 02; UPSEAT 2003]

(a) $77°C$ (b) $350°C$

(c) $273°C$ (d) $457°C$

30. $r.m.s.$ velocity of nitrogen molecules at NTP is   **[BHU 1995]**

(a) $492\ m/s$ (b) $517\ m/s$

(c) $546\ m/s$ (d) $33\ m/s$

31. The temperature of the hydrogen at which the average speed of its molecules is equal to that of oxygen molecules at a temperature of $31°C$, is   **[MP PMT 1995]**

(a) $-216°C$ (b) $-235°C$

(c) $-254°C$ (d) $-264°C$

32. The temperature of an ideal gas is increased from $120\ K$ to $480\ K$. If at $120\ K$, the root mean square velocity of the gas molecules is v, at $480\ K$ it becomes   **[IIT 1996]**

(a) $4v$ (b) $2v$

(c) $v/2$ (d) $v/4$

33. Root mean square velocity of a particle is v at pressure P. If pressure is increased two times, then the $r.m.s.$ velocity becomes   **[AFMC 1996; MHCET 1999]**

(a) $2\,v$ (b) $3\,v$

(c) $0.5\,v$ (d) v

34. The root mean square speed of the molecules of a gas is

[Haryana CEE 1996]

(a) Independent of its pressure but directly proportional to its Kelvin temperature

(b) Directly proportional to the square roots of both its pressure and its Kelvin temperature

(c) Independent of its pressure but directly proportional to the square root of its Kelvin temperature

(d) Directly proportional to both its pressure and its Kelvin temperature

35. At temperature T, the $r.m.s.$ speed of helium molecules is the same as $r.m.s.$ speed of hydrogen molecules at normal temperature and pressure. The value of T is

[MP PET 2000; J & K CET 2004]

(a) $273°C$ (b) $546°C$

(c) $0°C$ (d) $136.5°C$

36. The value of densities of two diatomic gases at constant temperature and pressure are d_1 and d_2, then the ratio of speed of sound in these gases will be

[DPMT 1996; CPMT 1995, 1997, 2001; MH CET 2000]

(a) $d_1 d_2$ (b) $\sqrt{d_2/d_1}$

(c) $\sqrt{d_1/d_2}$ (d) $\sqrt{d_1 d_2}$

37. On any planet, the presence of atmosphere implies (C_{rms} = root mean square velocity of molecules and V_e = escape velocity)   **[RPMT 1996; JIPMER 2000]**

(a) $C_{rms} \ll V_e$ (b) $C_{rms} > V_e$

(c) $C_{rms} = V_e$ (d) $C_{rms} = 0$

38. In the two vessels of same volume, atomic hydrogen and helium at pressure 1 *atm* and 2 *atm* are filled. If temperature of both the samples is same, then average speed of hydrogen atoms $<C_H>$ will be related to that of helium $<C_{He}>$ as **[RPMT 1996; JIPMER 2001, 02]**

(a) $<C_H>=\sqrt{2}<C_{He}>$ (b) $<C_H>=<C_{He}>$

(c) $<C_H>=2<C_{He}>$ (d) $<C_H>=\dfrac{<C_{He}>}{2}$

39. At a given temperature the *r.m.s.* velocity of molecules of the gas is **[RPET 1999]**

(a) Same

(b) Proportional to molecular weight

(c) Inversely proportional to molecular weight

(d) Inversely proportional to square root of molecular weight

40. By what factor the *r.m.s.* velocity will change, if the temperature is raised from 27°C to 327°C **[DCE 2000, 03]**

(a) $\sqrt{2}$ (b) 2

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

41. The speeds of 5 molecules of a gas (in arbitrary units) are as follows : 2, 3, 4, 5, 6. The root mean square speed for these molecules is **[MP PMT 2000]**

(a) 2.91   (b) 3.52

(c) 4.00   (d) 4.24

42. At a given temperature the ratio of *r.m.s.* velocities of hydrogen molecule and helium atom will be **[AMU (Engg.) 2000]**

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

(c) $1:2$ (d) $2:1$

43. If the oxygen (O_2) has root mean square velocity of $C\ ms^{-1}$, then root mean square velocity of the hydrogen (H_2) will be **[BHU 2001]**

(a) $C\ ms^{-1}$ (b) $\dfrac{1}{C}ms^{-1}$

(c) $4C\ ms^{-1}$ (d) $\dfrac{C}{4}ms^{-1}$

44. To what temperature should the hydrogen at room temperature (27°C) be heated at constant pressure so that the R.M.S. velocity of its molecules becomes double of its previous value **[MP PMT 2001]**

(a) 1200°C   (b) 927°C

(c) 600°C   (d) 108°C

45. The temperature of an ideal gas is reduced from 927°C to 27°C. The *r.m.s.* velocity of the molecules becomes **[Kerala (Engg.) 2001]**

(a) Double the initial value

(b) Half of the initial value

(c) Four times the initial value

(d) Ten times the initial value

46. The *r.m.s.* speed of the molecules of a gas in a vessel is 400 ms^{-1}. If half of the gas leaks out, at constant temperature, the *r.m.s.* speed of the remaining molecules will be **[Kerala (Engg.) 2002]**

(a) $800\ ms^{-1}$ (b) $400\sqrt{2}\ ms^{-1}$

(c) $400\ ms^{-1}$ (d) $200\ ms^{-1}$

47. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will **[AIEEE 2002]**

(a) Increase

(b) Decrease

(c) Remain same

(d) Decrease for some, while increase for others

48. At a given temperature if V_{rms} is the root mean square velocity of the molecules of a gas and V_s the velocity of sound in it, then these are related as $\left(\gamma=\dfrac{C_P}{C_v}\right)$ **[MP PET 2002]**

(a) $V_{rms}=V_s$ (b) $V_{rms}=\sqrt{\dfrac{3}{\gamma}}\times V_s$

(c) $V_{rms}=\sqrt{\dfrac{\gamma}{3}}\times V_s$ (d) $V_{rms}=\left(\dfrac{3}{\gamma}\right)\times V_s$

49. The root mean square speed of hydrogen molecules at 300 K is 1930 m/s. Then the root mean square speed of oxygen molecules at 900 K will be **[MH CET 2002]**

(a) $1930\sqrt{3}\ m/s$ (b) $836\ m/s$

(c) $643\ m/s$ (d) $\dfrac{1930}{\sqrt{3}}m/s$

50. Let A and B the two gases and given : $\dfrac{T_A}{M_A}=4.\dfrac{T_B}{M_B}$; where T is the temperature and M is molecular mass. If C_A and C_B are the *r.m.s.* speed, then the ratio $\dfrac{C_A}{C_B}$ will be equal to **[BHU 2003]**

(a) 2   (b) 4

(c) 1   (d) 0.5

51. For a gas at a temperature T the root-mean-square velocity v_{rms}, the most probable speed v_{mp}, and the average speed v_{av} obey the relationship **[DCE 1996; MP PET 2003; AIIMS 2004]**

(a) $v_{av}>v_{rms}>v_{mp}$ (b) $v_{rms}>v_{av}>v_{mp}$

(c) $v_{mp}>v_{av}>v_{rms}$ (d) $v_{mp}>v_{rms}>v_{av}$

52. If V_H, V_N and V_O denote the root-mean square velocities of molecules of hydrogen, nitrogen and oxygen respectively at a given temperature, then **[MP PMT 2004]**

(a) $V_N>V_O>V_H$ (b) $V_H>V_N>V_O$

(c) $V_O=V_N=V_H$ (d) $V_O>V_H>V_N$

53. If mass of He atom is 4 times that of hydrogen atom then mean velocity of He is **[BCECE 2004]**

(a) 2 times of H-mean value

(b) 1/2 times of H-mean value

(c) 4 times of H-mean value

(d) Same as H-mean value

54. The *r.m.s.* speed of a group of 7 gas molecules having speeds $(6, 4, 2, 0, -2, -4, -6)$ m/s is **[DPMT 2004]**

(a) 1.5 m/s   (b) 3.4 m/s

(c) 9 m/s   (d) 4 m/s

55. If the ratio of vapour density for hydrogen and oxygen is $\dfrac{1}{16}$, then under constant pressure the ratio of their *rms* velocities will be **[RPMT 2003]**

(a) $\dfrac{4}{1}$ (b) $\dfrac{1}{4}$

(c) $\dfrac{1}{16}$ (d) $\dfrac{16}{1}$

56. Molecular motion shows itself as **[DCE 1999]**

(a) Temperature   (b) Internal Energy

(c) Friction   (d) Viscosity

57. According to the kinetic theory of gases, at absolute temperature **[CBSE PMT 1990; AIIMS 1998; UPSEAT 2000]**

(a) Water freezes   (b) Liquid helium freezes

(c) Molecular motion stops   (d) Liquid hydrogen freezes

58. The *r.m.s.* speed of gas molecules is given by **[MNR 1995; MP PET 2001]**

(a) $2.5\sqrt{\dfrac{RT}{M}}$ (b) $1.73\sqrt{\dfrac{RT}{M}}$

(c) $2.5\sqrt{\dfrac{M}{RT}}$ (d) $1.73\sqrt{\dfrac{M}{RT}}$

59. What is the velocity of wave in monoatomic gas having pressure 1 *kilopascal* and density $2.6\,kg/m^3$ **[CPMT 1996]**

(a) $3.6\,m/s$ (b) $8.9\times10^3\,m/s$

(c) Zero   (d) None of these

60. When temperature of an ideal gas is increased from $27°C$ to $227°C$, its *r.m.s.* speed changed from 400 *metre/sec* to V_s. The V_s is **[BHU 2003; CPMT 2004]**

(a) 516 *metre/sec*   (b) 450 *metre/sec*

(c) 310 *metre*/sec   (d) 746 *metre/sec*

61. The velocity of the molecules of a gas at temperature $120K$ is v. At what temperature will the velocity be $2v$ **[UPSEAT 2003]**

(a) $120\,K$ (b) $240\,K$

(c) $480\,K$ (d) $1120\,K$

62. If the pressure in a closed vessel is reduced by drawing out some gas, the mean free path of the molecules **[CPMT 1973]**

(a) Is decreased

(b) Is increased

(c) Remains unchanged

(d) Increases or decreases according to the nature of the gas

63. At constant volume, temperature is increased. Then **[CBSE PMT 1993; JIPMER 2000]**

(a) Collision on walls will be less

(b) Number of collisions per unit time will increase

(c) Collisions will be in straight lines

(d) Collisions will not change

64. The *r.m.s.* speed of the molecules of a gas at a pressure 10^5 Pa and temperature $0°C$ is $0.5\,km\,sec^{-1}$. If the pressure is kept constant but temperature is raised to $819°C$, the velocity will become **[BHU (Med.) 2000]**

(a) $1.5\,kms^{-1}$ (b) $2\,kms^{-1}$

(c) $5\,kms^{-1}$ (d) $1\,kms^{-1}$

65. At what temperature *r.m.s.* speed of air molecules doubles of that at N.T.P. is **[J & K CET 2002]**

(a) $819°C$ (b) $719°C$

(c) $909°C$ (d) None of these

66. The *r.m.s.* speed of a certain gas is v at $400K$. The temperature at which the *r.m.s.* speed becomes two times, will be **[DPMT 2000]**

(a) $800\,K$ (b) $1600\,K$

(c) $1200\,K$ (d) None of these

67. A cubical box with porous walls containing an equal number of O_2 and H_2 molecules is placed in a large evacuated chamber. The entire system is maintained at constant temperature T. The ratio of v_{rms} of O_2 molecules to that of the v_{rms} of H_2 molecules, found in the chamber outside the box after a short interval is **[DCE 1995, 96]**

(a) $\dfrac{1}{2\sqrt{2}}$ (b) $\dfrac{1}{4}$

(c) $\dfrac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

68. The gas having average speed four times as that of SO_2 (molecular mass 64) is **[DCE 2005]**

(a) He (molecular mass 4)   (b) O_2 (molecular mass 32)

(c) H_2 (molecular mass 2)   (d) CH_4 (molecular mass 16)

Degree of Freedom and Specific Heat

1. A monoatomic gas molecule has **[KCET 1998; DCE 1999]**
   (a) Three degrees of freedom
   (b) Four degrees of freedom
   (c) Five degrees of freedom
   (d) Six degrees of freedom

2. A diatomic molecule has how many degrees of freedom
   [Pb. PET 2000]
   (a) 3 (b) 4
   (c) 5 (d) 6

3. A cylinder rolls without slipping down an inclined plane, the number of degrees of freedom it has, is
   (a) 2 (b) 3
   (c) 5 (d) 1

4. If the degree of freedom of a gas are f, then the ratio of two specific heats C_P / C_V is given by **[MP PET 1995;**
   BHU 1997; MP PMT 1990, 2001; MP PMT 2004]
   (a) $\frac{2}{f} + 1$ (b) $1 - \frac{2}{f}$
   (c) $1 + \frac{1}{f}$ (d) $1 - \frac{1}{f}$

5. The degrees of freedom of a triatomic gas is
   [CBSE PMT 1999]
   (a) 2 (b) 4
   (c) 6 (d) 8

6. A diatomic gas molecule has translational, rotational and vibrational degrees of freedom. The C_P / C_V is
   [EAMCET (Engg.) 1995; Pb. PMT 2002]
   (a) 1.67 (b) 1.4
   (c) 1.29 (d) 1.33

7. For a gas $\frac{R}{C_V} = 0.67$. This gas is made up of molecules which are **[CBSE PMT 1992; JIPMER 2001, 02]**
   (a) Diatomic
   (b) Mixture of diatomic and polyatomic molecules
   (c) Monoatomic
   (d) Polyatomic

8. The value of C_V for one mole of neon gas is **[MP PMT 2000]**
   (a) $\frac{1}{2}R$ (b) $\frac{3}{2}R$
   (c) $\frac{5}{2}R$ (d) $\frac{7}{2}R$

9. For an ideal gas of diatomic molecules
   [UPSEAT 1998; 2002]
   (a) $C_p = \frac{5}{2}R$ (b) $C_v = \frac{3}{2}R$
   (c) $C_P - C_v = 2R$ (d) $C_P = \frac{7}{2}R$

10. At constant volume, for different diatomic gases the molar specific heat is
    (a) Same and 3 $cal/mole/°C$ approximately
    (b) Exactly equal and its value is 4 $cal/mole/°C$
    (c) Will be totally different
    (d) Approximately equal and its value is 5 $cal/mole/°C$

11. At constant volume the specific heat of a gas is $\frac{3R}{2}$, then the value of 'γ' will be **[DPMT 1999]**
    (a) $\frac{3}{2}$ (b) $\frac{5}{2}$
    (c) $\frac{5}{3}$ (d) None of the above

12. The relation between two specific heats of a gas is
    [CPMT 1973, 78; MP PET 1984]
    (a) $C_P - C_V = \frac{R}{J}$ (b) $C_V - C_P = \frac{R}{J}$
    (c) $C_P - C_V = J$ (d) $C_V - C_P = J$

13. The specific heat of a gas at constant volume is 21.2 $J/mole/°C$. If the temperature is increased by $1°C$ keeping the volume constant, the change in its internal energy will be
    (a) 0 (b) 21.2 J
    (c) 42.2 J (d) 10.6 J

14. The specific heat of an ideal gas is
    [RPMT 1999; CPMT 1983, 2002]
    (a) Proportional to T (b) Proportional to T^2
    (c) Proportional to T^3 (d) Independent of T

15. Molar specific heat at constant volume is C_V for a monoatomic gas is **[CPMT 1990; JIPMER 1999]**
    (a) $\frac{3}{2}R$ (b) $\frac{5}{2}R$
    (c) $3R$ (d) $2R$

16. The following sets of values for C_V and C_P of a gas has been reported by different students. The units are cal/gm-$mole$-K. Which of these sets is most reliable
    [NCERT 1974; AFMC 1996]
    (a) $C_V = 3, C_P = 5$ (b) $C_V = 4, C_P = 6$
    (c) $C_V = 3, C_P = 2$ (d) $C_V = 3, C_P = 4.2$

17. The specific heat at constant volume for the monoatomic argon is 0.075 $kcal/kg$-K, whereas its gram molecular specific heat $C_V = 2.98$ $cal/mole/K$. The mass of the argon atom is **[MP PET 1993]**
    (a) 6.60×10^{-23} gm (b) 3.30×10^{-23} gm
    (c) 2.20×10^{-23} gm (d) 13.20×10^{-23} gm

    (Avogadro's number $= 6.02 \times 10^{23}$ $molecules/mole$)

18. Supposing the distance between the atoms of a diatomic gas to be constant, its specific heat at constant volume per mole (gram mole) is [CPMT 1990]

(a) $\frac{5}{2}R$

(b) $\frac{3}{2}R$

(c) R

(d) $\frac{1}{2}R$

19. For a certain gas, the ratio of specific heats is given to be $\gamma = 1.5$. For this gas [CBSE PMT 1990]

(a) $C_V = \frac{3R}{J}$

(b) $C_P = \frac{3R}{J}$

(c) $C_P = \frac{5R}{J}$

(d) $C_V = \frac{5R}{J}$

20. The specific heats at constant pressure is greater than that of the same gas at constant volume because

[DCE 1995; MNR 1987; UPSEAT 2000]

(a) At constant pressure work is done in expanding the gas

(b) At constant volume work is done in expanding the gas

(c) The molecular attraction increases more at constant pressure

(d) The molecular vibration increases more at constant pressure

21. The specific heat of a gas [MP PET 1996; CPMT 1988]

(a) Has only two values C_P and C_V

(b) Has a unique value at a given temperature

(c) Can have any value between 0 and ∞

(d) Depends upon the mass of the gas

22. The molar specific heat at constant pressure for a monoatomic gas is

[UPSEAT 1998; AMU 1999; Pb. PMT 2001]

(a) $\frac{3}{2}R$

(b) $\frac{5}{2}R$

(c) $\frac{7}{2}R$

(d) $4R$

23. For a gas if $\gamma = 1.4$, then atomicity, C_P and C_V of the gas are respectively [MP PET 1997]

(a) Monoatomic, $\frac{5}{2}R, \frac{3}{2}R$ (b) Monoatomic, $\frac{7}{2}R, \frac{5}{2}R$

(c) Diatomic, $\frac{7}{2}R, \frac{5}{2}R$ (d) Triatomic, $\frac{7}{2}R, \frac{5}{2}R$

24. Which of the following formulae is wrong

[MP PMT/PET 1998; JIPMER 2000]

(a) $C_V = \frac{R}{\gamma - 1}$

(b) $C_P = \frac{\gamma R}{\gamma - 1}$

(c) $C_P / C_V = \gamma$

(d) $C_P - C_V = 2R$

25. In gases of diatomic molecules, the ratio of the two specific heats of gases C_P / C_V is [EAMCET (Med.) 1995]

(a) 1.66

(b) 1.40

(c) 1.33

(d) 1.00

26. For hydrogen gas $C_P - C_V = a$ and for oxygen gas $C_P - C_V = b$. So the relation between a and b is given by

[CBSE PMT 1993]

(a) $a = 16b$

(b) $b = 16a$

(c) $a = 4b$

(d) $a = b$

27. For a gas the difference between the two specific heats is 4150 $J/kg\,K$. What is the specific heats at constant volume of gas if the ratio of specific heat is 1.4 [AFMC 1998]

(a) $8475\,J/kg\,K$

(b) $5186\,J/kg\,K$

(c) $1660\,J/kg\,K$

(d) $10375\,J/kg\,K$

28. The quantity of heat required to raise one mole through one degree Kelvin for a monoatomic gas at constant volume is

[JIPMER 1999]

(a) $\frac{3}{2}R$

(b) $\frac{5}{2}R$

(c) $\frac{7}{2}R$

(d) $4R$

29. The specific heat relation for ideal gas is

[RPMT 1999; CPMT 2002; Orissa JEE 2003]

(a) $C_P + C_V = R$

(b) $C_P - C_V = R$

(c) $C_P / C_V = R$

(d) $C_V / C_P = R$

30. The specific heat of 1 mole of an ideal gas at constant pressure (C_P) and at constant volume (C_V) which is correct

[AMU 1999; UPSEAT 2000]

(a) C_P of hydrogen gas is $\frac{5}{2}R$

(b) C_V of hydrogen gas is $\frac{7}{2}R$

(c) H_2 has very small values of C_P and C_V

(d) $C_P - C_V = 1.99$ cal/mole-K for H_2

31. What is the ratio of specific heats of constant pressure and constant volume for NH_3 [RPMT 2003]

(a) 1.33

(b) 1.44

(c) 1.28

(d) 1.67

32. If two moles of diatomic gas and one mole of mono atomic gas are mixed then the ratio of specific heats is

[MP PMT 2003]

(a) $\frac{7}{3}$

(b) $\frac{5}{4}$

(c) $\frac{19}{13}$

(d) $\frac{15}{19}$

33. One mole of ideal monoatomic gas ($\gamma = 5/3$) is mixed with one mole of diatomic gas ($\gamma = 7/5$). What is γ for the mixture? γ denotes the ratio of specific heat at constant pressure, to that at constant volume [IIT 1986; DPMT 1997;

RPMT 1990; UPSEAT 1998; RPET 1998; AIEEE 2002; 04]

(a) 3/2

(b) 23/15

(c) 35/23

(d) 4/3

34. A gaseous mixture contains equal number of hydrogen and nitrogen molecules. Specific heat measurements on this mixture at temperatures below 100 K would indicate that the value of γ (ratio of specific heats) for this mixture is

[SCRA 1998]

(a) 3/2 (b) 4/3

(c) 5/3 (d) 7/5

35. One mole of monoatomic gas and three moles of diatomic gas are put together in a container. The molar specific heat (in $JK^{-1}mol^{-1}$) at constant volume is ($R = 8.3\,JK^{-1}mol^{-1}$)

[DCE 2004]

(a) 18.7 (b) 18.9

(c) 19.2 (d) None of the above

36. The temperature of argon, kept in a vessel, is raised by $1°C$ at a constant volume. The total heat supplied to the gas is a combination of translational and rotational energies. Their respective shares are **[BHU 2000]**

(a) 60% and 40% (b) 40% and 60%

(c) 50% and 50% (d) 100% and 0%

37. On giving equal amount of heat at constant volume to 1 mol of a monoatomic and a diatomic gas the rise in temperature (ΔT) is more for **[RPET 2000]**

(a) Monoatomic (b) Diatomic

(c) Same for both (d) Can not be predicted

38. The kinetic energy, due to translational motion, of most of the molecules of an ideal gas at absolute temperature T is

[Roorkee 1994]

(a) kT (b) k/T

(c) T/k (d) $1/kT$

39. The number of translational degrees of freedom for a diatomic gas is **[CBSE PMT 1993]**

(a) 2 (b) 3

(c) 5 (d) 6

40. The value of the gas constant (R) calculated from the perfect gas equation is 8.32 $joules/gm$ mole K, whereas its value calculated from the knowledge of C_P and C_V of the gas is 1.98 cal/gm mole K. From this data, the value of J is

[MP PET 1993; DPMT 2002]

(a) $4.16\,J/cal$ (b) $4.18\,J/cal$

(c) $4.20\,J/cal$ (d) $4.22\,J/cal$

41. For a gas if ratio of specific heats at constant pressure and volume is γ then value of degrees of freedom is

[CBSE PMT 2000; AFMC 2001; DPMT 2002]

(a) $\dfrac{3\gamma-1}{2\gamma-1}$ (b) $\dfrac{2}{\gamma-1}$

(c) $\dfrac{9}{2}(\gamma-1)$ (d) $\dfrac{25}{2}(\gamma-1)$

42. The ratio of specific heat of a mixture of one mole of helium and one mole of hydrogen gas will be **[RPMT 2002]**

(a) 1 (b) 1.5

(c) 1.53 (d) 1.33

43. For a gas $\gamma = 7/5$. The gas may probably be **[RPMT 2002]**

(a) Helium (b) Hydrogen

(c) Argon (d) Neon

44. If a gas has n degrees of freedom ratio of specific heats of gas is **[DCE 2002]**

(a) $\dfrac{1+n}{2}$ (b) $1+\dfrac{1}{n}$

(c) $1+\dfrac{n}{2}$ (d) $1+\dfrac{2}{n}$

45. 5 moles of oxygen is heated at constant volume from $10°C$ to $20°C$. The change in the internal energy of the gas is (the gram molecular specific heat of oxygen at constant pressure, $C_p = 8\ cal/mole\,°C$ and $R = 8.3\ cal/mole\,°C$) **[BHU 1995]**

(a) $200\ cal$ (b) $300\ cal$

(c) $100\ cal$ (d) None of these

46. What is the value of $\dfrac{R}{C_P}$ for diatomic gas **[Pb. CET 1996]**

(a) 3/4 (b) 3/5

(c) 2/7 (d) 5/7

47. The degrees of freedom of a stationary rigid body about its axis will be **[RPMT 2004]**

(a) One (b) Two

(c) Three (d) Four

48. A gaseous mixture consists of $16g$ of helium and $16g$ of oxygen. The ratio $\dfrac{C_P}{C_V}$ of the mixture is **[AIEEE 2005]**

(a) 1.4 (b) 1.54

(c) 1.59 (d) 1.62

Pressure and Energy

1. The pressure exerted by the gas on the walls of the container because

[CPMT 1972; MP PET 1995; MP PMT 1996]

(a) It loses kinetic energy

(b) It sticks with the walls

(c) On collision with the walls there is a change in momentum

(d) It is accelerated towards the walls

2. Gas at a pressure P_0 in contained is a vessel. If the masses of all the molecules are halved and their speeds are doubled, the resulting pressure P will be equal to

[NCERT 1984; MNR 1995; MP PET 1997; MP PMT 1997; RPET 1999; UPSEAT 1999, 2000; Pb. PET 2003]

(a) $4P_0$ (b) $2P_0$

(c) P_0 (d) $\dfrac{P_0}{2}$

3. A box contains n molecules of a gas. How will the pressure of the gas be effected, if the number of molecules is made $2n$ **[MP PMT/PET 1988]**

(a) Pressure will decrease

(b) Pressure will remain unchanged

(c) Pressure will be doubled

(d) Pressure will become three times

4. The relation between the gas pressure P and average kinetic energy per unit volume E is

[CBSE PMT 1993; UPSEAT 2000; MP PET 1996, 2003; RPMT 2000; RPET 2001]

(a) $P = \frac{1}{2}E$　　　　　　(b) $P = E$

(c) $P = \frac{3}{2}E$　　　　　　(d) $P = \frac{2}{3}E$

5. A cylinder of capacity 20 litres is filled with H_2 gas. The total average kinetic energy of translatory motion of its molecules is $1.5 \times 10^5 \, J$. The pressure of hydrogen in the cylinder is **[MP PET 1993]**

(a) $2 \times 10^6 \, N/m^2$　　　(b) $3 \times 10^6 \, N/m^2$

(c) $4 \times 10^6 \, N/m^2$　　　(d) $5 \times 10^6 \, N/m^2$

6. The root mean square speed of hydrogen molecules of an ideal hydrogen gas kept in a gas chamber at $0°C$ is 3180 metres/second. The pressure on the hydrogen gas is (Density of hydrogen gas is $8.99 \times 10^{-2} \, kg/m^3$, 1 atmosphere $= 1.01 \times 10^5 \, N/m^2$) **[MP PMT 1995]**

(a) $1.0 \, atm$　　　　　　(b) $1.5 \, atm$

(c) $2.0 \, atm$　　　　　　(d) $3.0 \, atm$

7. At a given temperature, the pressure of an ideal gas of density ρ is proportional to **[MP PMT 1999]**

(a) $\dfrac{1}{\rho^2}$　　　　　　(b) $\dfrac{1}{\rho}$

(c) ρ^2　　　　　　　　(d) ρ

8. Consider a gas with density ρ and $\bar{c}$ as the root mean square velocity of its molecules contained in a volume. If the system moves as whole with velocity v, then the pressure exerted by the gas is **[BHU 1994]**

(a) $\dfrac{1}{3}\rho \bar{c}^2$　　　　　(b) $\dfrac{1}{3}\rho(c+v)^2$

(c) $\dfrac{1}{3}\rho(\bar{c}-v)^2$　　　(d) $\dfrac{1}{3}\rho(c^{-2}-v)^2$

9. In kinetic theory of gases, a molecule of mass m of an ideal gas collides with a wall of vessel with velocity V. The change in the linear momentum of the molecule is

[AIIMS 1997; Haryana PMT 2000]

(a) $2mV$　　　　　　(b) mV

(c) $-mV$　　　　　　(d) Zero

10. If the mean free path of atoms is doubled then the pressure of gas will become **[RPMT 2000]**

(a) $P/4$　　　　　　(b) $P/2$

(c) $P/8$　　　　　　(d) P

11. Relationship between $P, V,$ and E for a gas is

[RPMT 2000]

(a) $P = \frac{3}{2}EV$　　　　(b) $V = \frac{2}{3}EP$

(c) $PV = \frac{3}{2}E$　　　　(d) $PV = \frac{2}{3}E$

12. The value of universal gas constant is 8.3 $J/mole/K$, the mean kinetic energy of 32 gm of oxygen at $-73°C$ will be

(a) $480 \, J$

(b) $4980 \, J$

(c) $2490 \, J$

(d) The information is incomplete

13. For a diatomic gas change in internal energy for unit change in temperature for constant pressure and constant volume is U_1 and U_2 respectively. $U_1 : U_2$ is **[MP PMT 1996]**

(a) $5 : 3$　　　　　　(b) $3 : 5$

(c) $1 : 1$　　　　　　(d) $5 : 7$

14. If number of molecules of H_2 are double than that of O_2, then ratio of kinetic energy of hydrogen and that of oxygen at 300 K is **[MP PET 1990]**

(a) $1 : 1$　　　　　　(b) $1 : 2$

(c) $2 : 1$　　　　　　(d) $1 : 16$

15. The average kinetic energy of a gas at $-23°C$ and 75 cm pressure is $5 \times 10^{-14} \, erg$ for H_2. The mean kinetic energy of the O_2 at $227°C$ and 150 cm pressure will be

(a) $80 \times 10^{-14} \, erg$　　　(b) $20 \times 10^{-14} \, erg$

((c) $40 \times 10^{-14} \, erg$　　　(d) $10 \times 10^{-14} \, erg$

16. The ratio of mean kinetic energy of hydrogen and oxygen at a given temperature is **[NCERT 1981; MP PET 1989, 99; MP PMT 1994, 2000, 03; Pb. PMT 2000]**

(a) $1 : 16$　　　　　　(b) $1 : 8$

(c) $1 : 4$　　　　　　(d) $1 : 1$

17. The ratio of mean kinetic energy of hydrogen and nitrogen at temperature 300 K and 450 K respectively is

[MP PET 1990]

(a) $3 : 2$　　　　　　(b) $2 : 3$

(c) $2 : 21$　　　　　　(d) $4 : 9$

18. According to the kinetic theory of gases, total energy of a gas is equal to

(a) Potential energy　　　(b) Kinetic energy

(c) Both (a) and (b)　　　(d) None of the above

19. The average kinetic energy of a gas molecule can be determined by knowing **[MP PMT 1992; RPET 2000]**

(a) The number of molecules in the gas

(b) The pressure of the gas only

(c) The temperature of the gas only

(d) None of the above is enough by itself

20. Mean kinetic energy (or average energy) per *gm* molecule of a monoatomic gas is given by

[CPMT 1978, 90; NCERT 1990; MP PMT 1994]

(a) $\dfrac{3}{2}RT$

(b) $\dfrac{1}{2}KT$

(c) $\dfrac{1}{2}RT$

(d) $\dfrac{3}{2}KT$

21. A sealed container with negligible coefficient of volumetric expansion contains helium (a monoatomic gas). When it is heated from 300 *K* to 600 *K*, the average K.E. of helium atoms is   [NCERT 1980; UPSEAT 1999; DPMT 2002]

(a) Halved

(b) Unchanged

(c) Doubled

(d) Increased by factor $\sqrt{2}$

22. The time average of the kinetic energy of one molecule of a gas taken over a long period of time   [MP PET 1992]

(a) Is proportional to the square root of the absolute temperature of the gas

(b) Is proportional to the absolute temperature of the gas

(c) Is proportional to the square of the absolute temperature of the gas

(d) Does not depend upon the absolute temperature of the gas

23. The kinetic energy per *gm mol* for a diatomic gas at room temperature is   [MP PET 1991]

(a) $3\,RT$

(b) $\dfrac{5}{2}RT$

(c) $\dfrac{3}{2}RT$

(d) $\dfrac{1}{2}RT$

24. At which of the following temperature would the molecules of a gas have twice the average kinetic energy they have at 20°C   [MP PET 1992; BVP 2003]

(a) 40°C

(b) 80°C

(c) 313°C

(d) 586°C

25. The kinetic energy of translation of 20 *gm* of oxygen at 47°C is (molecular wt. of oxygen is 32 *gm/mol* and R = 8.3 J/mol/K)   [MP PET 1991]

(a) 2490 *joules*

(b) 2490 *ergs*

(c) 830 *joules*

(d) 124.5 *joules*

26. The translatory kinetic energy of a gas per gm is

[DPMT 2002]

(a) $\dfrac{3}{2}\dfrac{RT}{N}$

(b) $\dfrac{3}{2}\dfrac{RT}{M}$

(c) $\dfrac{3}{2}RT$

(d) $\dfrac{3}{2}NKT$

27. The kinetic energy of one gram molecule of a gas at normal temperature and pressure is $(R = 8.31\,J/mole-K)$

[DPMT 1997; AFMC 1998;
MH CET 1999; Pb. PMT 1997, 2000, 03]

(a) $0.56\times10^{4}\,J$

(b) $1.3\times10^{2}\,J$

(c) $2.7\times10^{2}\,J$

(d) $3.4\times10^{3}\,J$

28. The mean kinetic energy of a gas at 300 *K* is 100 *J*. The mean energy of the gas at 450 *K* is equal to   [DPMT 2001]

(a) 100 *J*

(b) 3000 *J*

(c) 450 *J*

(d) 150 *J*

29. At what temperature is the kinetic energy of a gas molecule double that of its value of 27°C

[MP PET 1994; BHU 1995; DPMT 2002]

(a) 54°C

(b) 300 *K*

(c) 327°C

(d) 108°C

30. Read the given statements and decide which is/are correct on the basis of kinetic theory of gases   [MP PMT 2003]

(I) Energy of one molecule at absolute temperature is zero

(II) *r.m.s.* speeds of different gases are same at same temperature

(III) For one gram of all ideal gas kinetic energy is same at same temperature

(IV) For one mole of all ideal gases mean kinetic energy is same at same temperature

(a) All are correct

(b) I and IV are correct

(c) IV is correct

(d) None of these

31. The translational kinetic energy of gas molecule for one mole of the gas is equal to

[AFMC 1995; KCET (Engg./Med.) 2001]

(a) $\dfrac{3}{2}RT$

(b) $\dfrac{2}{3}RT$

(c) $\dfrac{1}{2}RT$

(d) $\dfrac{2}{3}KT$

32. At 27°C temperature, the kinetic energy of an ideal gas is E_1. If the temperature is increased to 327°C, then kinetic energy would be   [MP PMT 1996]

(a) $2E_1$

(b) $\dfrac{1}{2}E_1$

(c) $\sqrt{2}E_1$

(d) $\dfrac{1}{\sqrt{2}}E_1$

33. The average kinetic energy of a gas molecule at 27°C is $6.21\times10^{-21}\,J$. Its average kinetic energy at 227°C will be

[MP PMT/PET 1998; AIIMS 1999]

(a) $52.2\times10^{-21}\,J$

(b) $5.22\times10^{-21}\,J$

(c) $10.35\times10^{-21}\,J$

(d) $11.35\times10^{-21}\,J$

34. The average translational kinetic energy of O_2 (molar mass 32) molecules at a particular temperature is 0.048 *eV*. The translational kinetic energy of N_2 (molar mass 28) molecules in *eV* at the same temperature is

[IIT 1997 Re-Exam]

(a) 0.0015

(b) 0.003

(c) 0.048

(d) 0.768

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

[IIT 1997 Cancelled]

(a) $12.42 \times 10^{21} J, 968 m/s$ (b) $8.78 \times 10^{21} J, 684 m/s$

(c) $6.21 \times 10^{21} J, 968 m/s$ (d) $12.42 \times 10^{21} J, 684 m/s$

36. A polyatomic gas with n degrees of freedom has a mean energy per molecule given by **[CBSE PMT 1992]**

(a) $\dfrac{nkT}{N}$ (b) $\dfrac{nkT}{2N}$

(c) $\dfrac{nkT}{2}$ (d) $\dfrac{3kT}{2}$

(N is Avogadro's number)

37. At 0 K which of the following properties of a gas will be zero

[CBSE PMT 1996]

(a) Kinetic energy (b) Potential energy

(c) Vibrational energy (d) Density

38. At the same temperature and pressure and volume of two gases, which of the following quantities is constant

[RPMT 1996]

(a) Total number of molecules

(b) Average kinetic energy

(c) Root mean square velocity

(d) Mean free path

39. A box contains a mixture of H_2 and He gases. Which of the following statements are corrects **[Roorkee 2000]**

(a) The average translational kinetic energies of H_2 molecules and He atoms are same

(b) The average energies of H_2 molecules and He atoms are same

(c) H_2 molecules have greater average energy than that of He atoms

(d) The average speed of H_2 molecules and He atoms are same

40. If temperature of gas increases from 27°C to 927°C the K.E. will be **[RPET 2001]**

(a) Double (b) Half

(c) One fourth (d) Four times

41. Vessel A is filled with hydrogen while vessel B, whose volume is twice that of A, is filled with the same mass of oxygen at the same temperature. The ratio of the mean kinetic energies of hydrogen and oxygen is **[MP PET 2001]**

(a) 16 : 1 (b) 1 : 8

(c) 8 : 1 (d) 1 : 1

42. Energy of all molecules of a monoatomic gas having a volume V and pressure P is $\dfrac{3}{2}PV$. The total translational kinetic energy of all molecules of a diatomic gas as the same volume and pressure is **[UPSEAT 2002]**

(a) $\dfrac{1}{2}PV$ (b) $\dfrac{3}{2}PV$

(c) $\dfrac{5}{2}PV$ (d) $3PV$

43. On absolute temperature, the kinetic energy of the molecules **[RPET 2003]**

(a) Becomes zero (b) Becomes maximum

(c) Becomes minimum (d) Remains constant

44. The temperature of a gas is – 68°C. At what temperature will the average kinetic energy of its molecules be twice that of at – 68°C **[UPSEAT 2003]**

(a) 137°C (b) 127°C

(c) 100°C (d) 105°C

45. The average kinetic energy of a helium atom at $30^o C$ is

[MP PMT 2004]

(a) Less than 1 eV (b) A few keV

(c) 50-60 eV (d) 13.6 eV

46. Two gases are at absolute temperatures 300 K and 350 K respectively. Ratio of average kinetic energy of their molecules is **[DCE 2002]**

(a) 7 : 6 (b) 6 : 7

(c) 36 : 49 (d) 49 : 36

47. A gas mixture consists of molecules of type 1, 2 and 3, with molar masses $m_1 > m_2 > m_3$. V_{rms} and $\overline{K}$ are the r.m.s. speed and average kinetic energy of the gases. Which of the following is true **[AMU (Engg.) 2000]**

(a) $(V_{rms})_1 < (V_{rms})_2 < (V_{rms})_3$ and $(\overline{K})_1 = (\overline{K})_2 = (\overline{K}_3)$

(b) $(V_{rms})_1 = (V_{rms})_2 = (V_{rms})_3$ and $(\overline{K})_1 = (\overline{K})_2 > (\overline{K})_3$

(c) $(V_{rms})_1 > (V_{rms})_2 > (V_{rms})_3$ and $(\overline{K})_1 < (\overline{K})_2 > (\overline{K}_3)$

(d) $(V_{rms})_1 > (V_{rms})_2 > (V_{rms})_3$ and $(\overline{K})_1 < (\overline{K})_2 < (\overline{K})_3$

48. On colliding in a closed container the gas molecules

[RPET 2003]

(a) Transfer momentum to the walls

(b) Momentum becomes zero

(c) Move in opposite directions

(d) Perform Brownian motion

49. The mean kinetic energy of a gas at 300 K is 100 J. The mean energy of the gas at 450 K is equal to **[DPMT 2001]**

(a) 100 J (b) 3000 J

(c) 450 J (d) 150 J

50. The capacity of a vessel is 3 *litres*. It contains 6 *gm* oxygen, 8 *gm* nitrogen and 5 *gm* CO_2 mixture at 27°C. If $R = 8.31$ J/mole × kelvin, then the pressure in the vessel in N/m^2 will be (approx.)

(a) 5×10^5 (b) 5×10^4

(c) 10^6 (d) 10^5

51. Vapour is injected at a uniform rate in a closed vessel which was initially evacuated. The pressure in the vessel

[UPSEAT 2001]

(a) Increase continuously

(b) Decreases continuously

(c) First increases and then decreases

(d) First increase and then becomes constant

52. In the absence of intermolecular force of attraction, the observed pressure P will be

(a) P (b) $< P$

(c) $> P$ (d) Zero

53. The total momentum of the molecules of 1 *gm mol* of a gas in a container at rest of 300 *K* is

(a) $2 \times \sqrt{3R \times 300}\, gm \times cm/\sec$

(b) $2 \times 3 \times R \times 300\, gm \times cm/\sec$

(c) $1 \times \sqrt{3 \times R \times 300}\, gm \times cm/\sec$

(d) Zero

54. Two ideal gases at absolute temperature T_1 and T_2 are mixed. There is no loss of energy. The masses of the molecules are m_1 and m_2 and the number of molecules in the gases are n_1 and n_2 respectively. The temperature of mixture will be

(a) $\dfrac{T_1 + T_2}{2}$ energy   (b) $\dfrac{T_1 + T_2}{n_1 n_2}$

(c) $\dfrac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$ (d) $(T_1 + T_2)$

55. The molecules of an ideal gas at a certain temperature have

[NCERT 1981]

(a) Only potential energy

(b) Only kinetic energy

(c) Potential and kinetic energy both

(d) None of the above

56. Mean kinetic energy per degree of freedom of gas molecules is   **[MP PET 1995; Haryana CEET 2000; RPET 1999; 2001, 03]**

(a) $\dfrac{3}{2}kT$ (b) kT

(c) $\dfrac{1}{2}kT$ (d) $\dfrac{3}{2}RT$

57. The temperature at which the average translational kinetic energy of a molecule is equal to the energy gained by an electron in accelerating from rest through a potential difference of 1 *volt* is   **[DCE 1997]**

(a) $4.6 \times 10^3 K$ (b) $11.6 \times 10^3 K$

(c) $23.2 \times 10^3 K$ (d) $7.7 \times 10^3 K$

58. The kinetic energy of one gm-mole of a gas at normal temperature and pressure is ($R = 8.31$ J/Mole-K)

[AFMC 1998]

(a) $0.56 \times 10^4 J$ (b) $1.3 \times 10^2 J$

(c) $2.7 \times 10^2 J$ (d) $3.4 \times 10^3 J$

59. The average kinetic energy of hydrogen molecules at 300 *K* is *E*. At the same temperature, the average kinetic energy of oxygen molecules will be   **[JIPMER 2000]**

(a) $E/4$ (b) $E/16$

(c) E (d) $4E$

60. The average translational kinetic energy of a hydrogen gas molecules at NTP will be

[Boltzmann's constant $k_B = 1.38 \times 10^{-23} J/K$]   **[MP PET 2000]**

(a) $0.186 \times 10^{-20} Joule$ (b) $0.372 \times 10^{-20} Joule$

(c) $0.56 \times 10^{-20} Joule$ (d) $5.6 \times 10^{-20} Joule$

61. In kinetic theory of gases, which of the following statements regarding elastic collisions of the molecules is wrong

[RPMT 2002]

(a) Kinetic energy is lost in collisions

(b) Kinetic energy remains constant in collision

(c) Momentum is conserved in collision

(d) Pressure of the gas remains constant in collisions

62. If *r.m.s.* velocity of a gas is $V_{rms} = 1840 m/s$ and its density $\rho = 8.99 \times 10^{-2} kg/m^3$, the pressure of the gas will be

[RPET 2002]

(a) $1.01\ N/m^2$ (b) $1.01 \times 10^3\ N/m^2$

(c) $1.01 \times 10^5\ N/m^2$ (d) $1.01 \times 10^7\ N/m^2$

63. An ideal gas is filled in a vessel, then   **[RPET 2002]**

(a) If it is placed inside a moving train, its temperature increases

(b) Its centre of mass moves randomly

(c) Its temperature remains constant in a moving car

(d) None of these

64. The kinetic energy of one mole gas at 300*K* temperature, is *E*. At 400*K* temperature kinetic energy is *E′*. The value of E'/E is   **[RPMT 2004]**

(a) 1.33 (b) $\sqrt{\left(\dfrac{4}{3}\right)}$

(c) $\dfrac{16}{9}$ (d) 2

Critical Thinking

Objective Questions

1. N molecules each of mass m of gas A and $2N$ molecules each of mass $2m$ of gas B are contained in the same vessel at temperature T. The mean square of the velocity of molecules of gas B is v^2 and the mean square of x component of the velocity of molecules of gas A is w^2. The ratio $\dfrac{w^2}{v^2}$ is   **[NCERT 1984; MP PMT 1990]**

   (a) 1
   (b) 2
   (c) $\dfrac{1}{3}$
   (d) $\dfrac{2}{3}$

2. A gas is filled in a cylinder, its temperature is increased by 20% on Kelvin scale and volume is reduced by 10%. How much percentage of the gas will leak out

   (a) 30%
   (b) 40%
   (c) 15%
   (d) 25%

3. The air density at Mount Everest is less than that at the sea level. It is found by mountaineers that for one trip lasting a few hours, the extra oxygen needed by them corresponds to 30,000 cc at sea level (pressure 1 atmosphere, temperature $27°C$). Assuming that the temperature around Mount Everest is $–73°C$ and that the oxygen cylinder has capacity of 5.2 $litre$, the pressure at which O_2 be filled (at site) in cylinder is   **[MNR 1978; AFMC 2000]**

   (a) 3.86 atm
   (b) 5.00 atm
   (c) 5.77 atm
   (d) 1 atm

4. $\dfrac{1}{2}$ mole of helium gas is contained in a container at S.T.P. The heat energy needed to double the pressure of the gas, keeping the volume constant (specific heat of the gas $= 3\,J\,gm^{-1}K^{-1}$) is   **[MNR 1995]**

   (a) 3276 J
   (b) 1638 J
   (c) 819 J
   (d) 409.5 J

5. The equation of state of a gas is given by $\left(P + \dfrac{aT^2}{V}\right)V^c = (RT + b)$, where a, b, c and R are constants. The isotherms can be represented by $P = AV^m - BV^n$, where A and B depend only on temperature and   **[CBSE PMT 1995]**

   (a) $m = -c$ and $n = -1$
   (b) $m = c$ and $n = 1$
   (c) $m = -c$ and $n = 1$
   (d) $m = c$ and $n = -1$

6. From the following statements, concerning ideal gas at any given temperature T, select the correct one(s)   **[IIT 1995]**

   (a) The coefficient of volume expansion at constant pressure is same for all ideal gases
   (b) The average translational kinetic energy per molecule of oxygen gas is $3KT$ (K being Boltzmann constant)
   (c) In a gaseous mixture, the average translational kinetic energy of the molecules of each component is same
   (d) The mean free path of molecules increases with the decrease in pressure

7. 70 calories of heat are required to raise the temperature of 2 *moles* of an ideal gas at constant pressure from $30°C$ to $35°C$. The amount of heat required to raise the temperature of same gas through the same range ($30°C$ to $35°C$) at constant volume ($R = 2$ $cal/mol/K$)

   [IIT 1985; MP PMT 1997; MP PET 1999, 2001; UPSEAT 1998; 2004]

   (a) 30 cal
   (b) 50 cal
   (c) 70 cal
   (d) 90 cal

8. A closed compartment containing gas is moving with some acceleration in horizontal direction. Neglect effect of gravity. Then the pressure in the compartment is

   [IIT JEE 1999; UPSEAT 2003]

   (a) Same everywhere
   (b) Lower in the front side
   (c) Lower in the rear side
   (d) Lower in the upper side

9. Let $\bar{v}, v_{rms}$ and v_p respectively denote the mean speed, root mean square speed and most probable speed of the molecules in an ideal monoatomic gas at absolute temperature T. The mass of a molecule is m. Then

   [IIT JEE 1998]

   (a) No molecule can have speed greater than $\sqrt{2}\,v_{rms}$
   (b) No molecule can have speed less than $v_p / \sqrt{2}$
   (c) $v_p < \bar{v} < v_{rms}$
   (d) The average kinetic energy of a molecule is $\dfrac{3}{4}mv_p^2$

10. Three closed vessels A, B and C are at the same temperature T and contain gases which obey the Maxwellian distribution of velocities. Vessel A contains only O_2, B only N_2 and C a mixture of equal quantities of O_2 and N_2. If the average speed of the O_2 molecules in vessel A is V_1, that of the N_2 molecules in vessel B is V_2, the average speed of the O_2 molecules in vessel C is   **[IIT 1992]**

    (a) $(V_1 + V_2)/2$
    (b) V_1
    (c) $(V_1 V_2)^{1/2}$
    (d) $\sqrt{3kT/M}$

11. A box containing N molecules of a perfect gas at temperature T_1 and pressure P_1. The number of molecules in the box is doubled keeping the total kinetic energy of the gas same as before. If the new pressure is P_2 and temperature T_2, then **[MP PMT 1992]**

(a) $P_2 = P_1, T_2 = T_1$

(b) $P_2 = P_1, T_2 = \dfrac{T_1}{2}$

(c) $P_2 = 2P_1, T_2 = T_1$

(d) $P_2 = 2P_1, T_2 = \dfrac{T_1}{2}$

12. A gas in container A is in thermal equilibrium with another gas in container B. both contain equal masses of the two gases in the respective containers. Which of the following can be true

(a) $P_A V_A = P_B V_B$

(b) $P_A = P_B, V_A \neq V_B$

(c) $P_A \neq P_B, V_A = V_B$

(d) $\dfrac{P_A}{V_A} = \dfrac{P_B}{V_B}$

13. Two identical glass bulbs are interconnected by a thin glass tube. A gas is filled in these bulbs at N.T.P. If one bulb is placed in ice and another bulb is placed in hot bath, then the pressure of the gas becomes 1.5 times. The temperature of hot bath will be

(a) $100°C$

(b) $182°C$

(c) $256°C$

(d) $546°C$

Ice   Hot bath
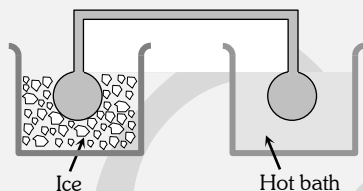
14. Two containers of equal volume contain the same gas at pressures P_1 and P_2 and absolute temperatures T_1 and T_2 respectively. On joining the vessels, the gas reaches a common pressure P and common temperature T. The ratio P/T is equal to

(a) $\dfrac{P_1}{T_1} + \dfrac{P_2}{T_2}$

(b) $\dfrac{P_1 T_1 + P_2 T_2}{(T_1 + T_2)^2}$

(c) $\dfrac{P_1 T_2 + P_2 T_1}{(T_1 + T_2)^2}$

(d) $\dfrac{P_1}{2T_1} + \dfrac{P_2}{2T_2}$

15. At the top of a mountain a thermometer reads $7°C$ and a barometer reads $70\ cm$ of Hg. At the bottom of the mountain these read $27°C$ and $76\ cm$ of Hg respectively. Comparison of density of air at the top with that of bottom is

(a) $75/76$

(b) $70/76$

(c) $76/75$

(d) $76/70$

$7°C, 70\ cm\ of\ Hg$

$27°C, 76\ cm\ of\ Hg$
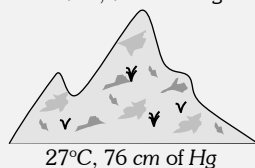
16. The root mean square speed of the molecules of a diatomic gas is v. When the temperature is doubled, the molecules dissociate into two atoms. The new root mean square speed of the atom is **[Roorkee 1996; Pb. PMT 2004]**

(a) $\sqrt{2}v$

(b) v

(c) $2v$

(d) $4v$

17. A vessel is partitioned in two equal halves by a fixed diathermic separator. Two different ideal gases are filled in left (L) and right (R) halves. The rms speed of the molecules in L part is equal to the mean speed of molecules in the R part. Then the ratio of the mass of a molecule in L part to that of a molecule in R part is

(a) $\sqrt{\dfrac{3}{2}}$

(b) $\sqrt{\pi/4}$

(c) $\sqrt{2/3}$

(d) $3\pi/8$

18. A gas is filled in the cylinder shown in the figure. The two pistons are joined by a string. If the gas is heated, the pistons will

(a) Move towards left

(b) Move towards right

(c) Remain stationary

(d) None of these
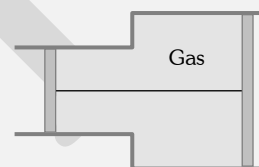
19. A closed vessel contains $8gm$ of oxygen and $7gm$ of nitrogen. The total pressure is 10 atm at a given temperature. If now oxygen is absorbed by introducing a suitable absorbent the pressure of the remaining gas in atm will be

(a) 2

(b) 10

(c) 4

(d) 5

20. $CO_2 (O-C-O)$ is a triatomic gas. Mean kinetic energy of one gram gas will be (If N-Avogadro's number, k-Boltzmann's constant and molecular weight of $CO_2 = 44$)

(a) $(3/88)NkT$

(b) $(5/88)NkT$

(c) $(6/88)NkT$

(d) $(7/88)NkT$

21. 40 $calories$ of heat is needed to raise the temperature of 1 $mole$ of an ideal monoatomic gas from $20°C$ to $30°C$ at a constant pressure. The amount of heat required to raise its temperature over the same interval at a constant volume $(R = 2\ calorie\ mole^{-1}K^{-1})$ is **[UPSEAT 2000]**

(a) 20 $calorie$

(b) 40 $calorie$

(c) 60 $calorie$

(d) 80 $calorie$

22. Find the ratio of specific heat at constant pressure to the specific heat constant volume for NH_3 **[RPMT 2003]**

(a) 1.33

(b) 1.44

(c) 1.28

(d) 1.67

23. The pressure and volume of saturated water vapour are P and V respectively. It is compressed isothermally thereby volume becomes $V/2$, the final pressure will be

[MP PMT 1985]

(a) More than $2P$

(b) P

(c) $2P$

(d) $4P$

24. If the intermolecular forces vanish away, the volume occupied by the molecules contained in 4.5 kg water at standard temperature and pressure will be   **[CPMT 1989]**

(a) $5.6\, m^3$ (b) $4.5\, m^3$

(c) $11.2\ litre$ (d) $11.2 m^3$

25. When an air bubble of radius 'r' rises from the bottom to the surface of a lake, its radius becomes $5r/4$ (the pressure of the atmosphere is equal to the $10\ m$ height of water column). If the temperature is constant and the surface tension is neglected, the depth of the lake is   **[EAMCET (Engg.) 2001]**

(a) $3.53\ m$ (b) $6.53\ m$

(c) $9.53\ m$ (d) $12.53\ m$

26. A horizontal uniform glass tube of $100\ cm$, length sealed at both ends contain $10\ cm$ mercury column in the middle. The temperature and pressure of air on either side of mercury column are respectively $81°C$ and $76\ cm$ of mercury. If the air column at one end is kept at $0°C$ and the other end at $273°C$, the pressure of air which is at $0°C$ is (in cm of Hg)   **[EAMCET (Engg.) 2003]**
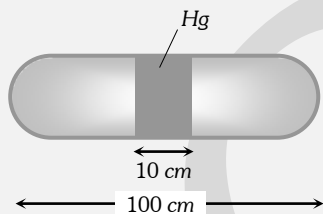
(a) 76   (b) 68.2

(c) 102.4   (d) 122

27. At standard temperature and pressure the density of a gas is $1.3\, kg/m^3$ and the speed of the sound in gas is $330\ m/sec$. Then the degree of freedom of the gas will be

(a) 3   (b) 4

(c) 5   (d) 6

28. The temperature of 5 moles of a gas which was held at constant volume was changed from $100°C$ to $120°C$. The change in internal energy was found to be 80 $Joules$. The total heat capacity of the gas at constant volume will be equal to   **[CPMT 1988; EAMCET 2003]**

(a) 8 J/K (b) 0.8 J/K

(c) 4.0 J/K (d) 0.4 J/K

29. The temperature at which the $r.m.s.$ speed of hydrogen molecules is equal to escape velocity on earth surface, will be   **[RPET 1997]**

(a) $1060\ K$ (b) $5030\ K$

(c) $8270\ K$ (d) $10063\ K$

30. Inside a cylinder having insulating walls and closed at ends is a movable piston, which divides the cylinder into two compartments. On one side of the piston is a mass m of a gas and on the other side a mass $2\,m$ of the same gas. What fraction of volume of the cylinder will be occupied by the larger mass of the gas when the piston is in equilibrium ? Consider that the movable piston is conducting so that the temperature is the same throughout

(a) $\dfrac{1}{4}$ (b) $\dfrac{1}{3}$

(c) $\dfrac{1}{2}$ (d) $\dfrac{2}{3}$

31. The diameter of oxygen molecule is $2.94\times10^{-10}m$. The Vander Waal's gas constant 'b' in m^3/mol will be

(a) 3.2   (b) 16

(c) 32×10^{-4} (d) 32×10^{-6}

32. The temperature of the mixture of one mole of helium and one mole of hydrogen is increased from $0°C$ to $100°C$ at constant pressure. The amount of heat delivered will be

   [RPMT 2002]

(a) 600 cal (b) 1200 cal

(c) 1800 cal (d) 3600 cal

33. A vessel contains a mixture of one mole of oxygen and two moles of nitrogen at $300\ K$. The ratio of the average rotational kinetic energy per O_2 molecule to that per N_2 molecule is   **[IIT 1998; DPMT 2000]**

(a) 1 : 1

(b) 1 : 2

(c) 2 : 1

(d) Depends on the moments of inertia of the two molecules

34. A vessel contains 14 gm (7 moles) of hydrogen and 96 gm (9 moles) of oxygen at STP. Chemical reaction is induced by passing electric spark in the vessel till one of the gases is consumed. The temperature is brought back to it's starting value 273 K. The pressure in the vessel is
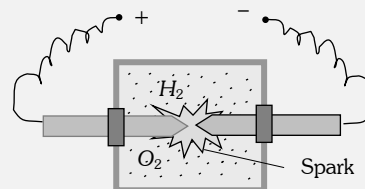
(a) 0.1 atm (b) 0.2 atm

(c) 0.3 atm (d) 0.4 atm

35. A gas mixture consists of 2 mole of oxygen and 4 mole of argon at temperature T. Neglecting all vibrational modes, the total internal energy of the system is

   [IIT-JEE (Screening) 1999; UPSEAT 2003

(a) $4\,RT$ (b) $15\,RT$

(c) $9\,RT$ (d) $11\,RT$

36. A jar contains a gas and few drops of water at T K. The pressure in the jar is 830 mm of mercury. The temperature of jar is reduced by 1%. The saturated vapour pressure of water at the two temperatures are 30 mm and 25 mm of mercury. Then the new pressure in the jar will be

[BHU 1995]

(a) 917 mm of Hg (b) 717 mm of Hg

(c) 817 mm of Hg (d) None of these

37. Molar specific heat of oxygen at constant pressure $C_p = 7.2\, cal / mol°C$ and $R = 8.3\, joule/mol/K$. At constant volume, 5 mol of oxygen is heated from 10°C to 20°C, the quantity of heat required is approximately   **[MP PMT 1987]**

(a) 25 cal (b) 50 cal

(c) 250 cal (d) 500 cal

38. One mole of an ideal gas requires 207 J heat to raise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same 10 K, the heat required is

[CBSE PMT 1992; DPMT 2000]

(a) 198.7 J (b) 29 J

(c) 215.3 J (d) 124 J

(Given the gas constant $R = 8.3 J / mol$-K)

Graphical Questions

1. The expansion of an ideal gas of mass m at a constant pressure P is given by the straight line D. Then the expansion of the same ideal gas of mass $2m$ at a pressure $P/2$ is given by the straight line

(a) E

(b) C

(c) B

(d) A
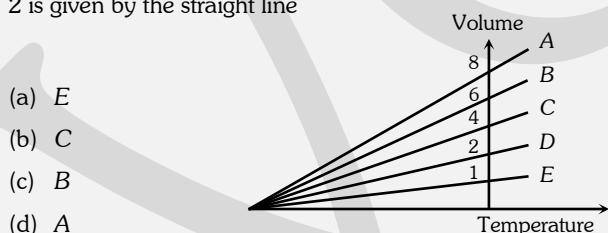
2. An experiment is carried on a fixed amount of gas at different temperatures and at high pressure such that it deviates from the ideal gas behaviour. The variation of $\dfrac{PV}{RT}$ with P is shown in the diagram. The correct variation will correspond to   **[CPMT 1988]**

(a) Curve A

(b) Curve B

(c) Curve C

(d) Curve D
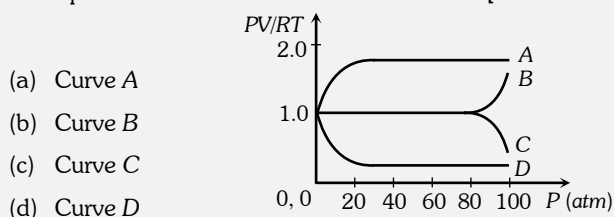
3. The graph which represent the variation of mean kinetic energy of molecules with temperature $t°C$ is
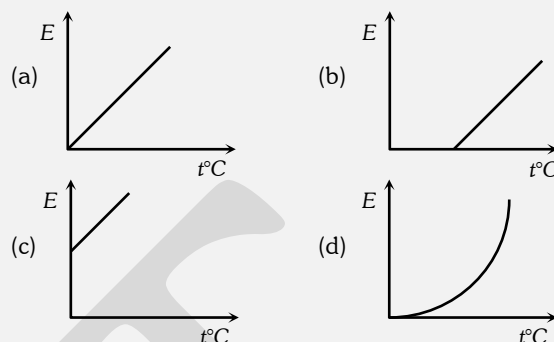
4. The adjoining figure shows graph of pressure and volume of a gas at two temperatures T_1 and T_2. Which of the following interferences is correct

(a) $T_1 > T_2$

(b) $T_1 = T_2$

(c) $T_1 < T_2$

(d) No interference can be drawn
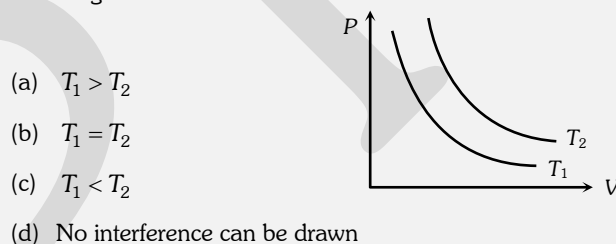
5. The expansion of unit mass of a perfect gas at constant pressure is shown in the diagram. Here
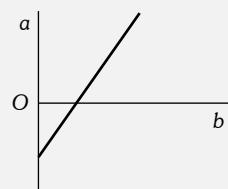
(a) a = volume, b = °C temperature

(b) a = volume, b = K temperature

(c) a = °C temperature, b = volume

(d) a = K temperature, b = volume

6. An ideal gas is initially at temperature T and volume V. Its volume is increased by ΔV due to an increase in temperature ΔT, pressure remaining constant. The quantity $\delta = \Delta V /(V\Delta T)$ varies with temperature as
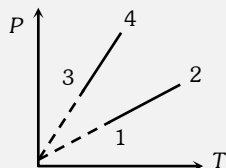
[IIT-JEE (Screening) 2000]
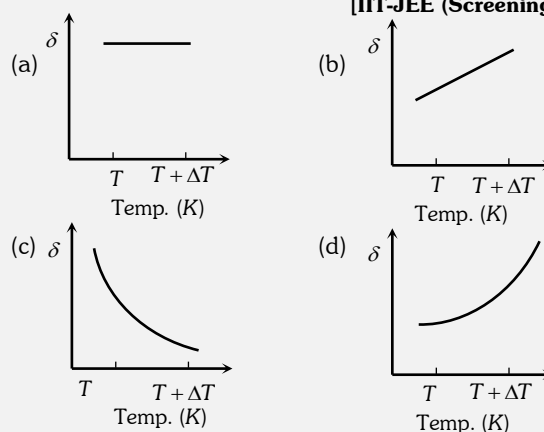
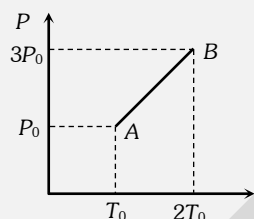**7.** Pressure versus temperature graph of an ideal gas of equal number of moles of different volumes are plotted as shown in figure. Choose the correct alternative

(a) $V_1 = V_2, V_3 = V_4$ and $V_2 > V_3$

(b) $V_1 = V_2, V_3 = V_4$ and $V_2 < V_3$
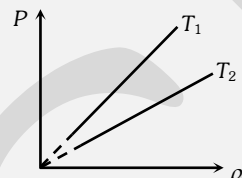
(c) $V_1 = V_2 = V_3 = V_4$

(d) $V_4 > V_3 > V_2 > V_1$

8. Pressure versus temperature graph of an ideal gas is as shown in figure. Density of the gas at point A is ρ_0. Density at B will be

(a) $\dfrac{3}{4}\rho_0$

(b) $\dfrac{3}{2}\rho_0$

(c) $\dfrac{4}{3}\rho_0$

(d) $2\rho_0$

9. The figure shows graphs of pressure versus density for an ideal gas at two temperatures T_1 and T_2

(a) $T_1 > T_2$

(b) $T_1 = T_2$

(c) $T_1 < T_2$

(d) Nothing can be predicted

10. Graph of specific heat at constant volume for a monoatomic gas is **[DPMT 1996]**

(a)

(b)

(c)

(d)
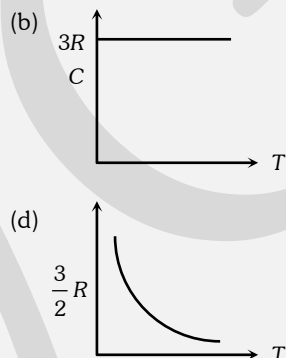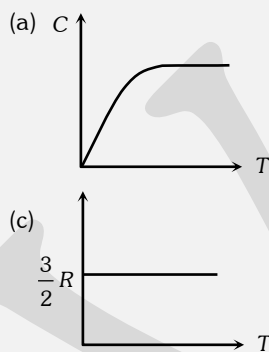
11. A fix amount of nitrogen gas (1 mole) is taken and is subjected to pressure and temperature variation. The experiment is performed at high pressure as well as high temperatures. The results obtained are shown in the figures. The correct variation of PV/RT with P will be exhibited by **[UPSEAT 2001]**
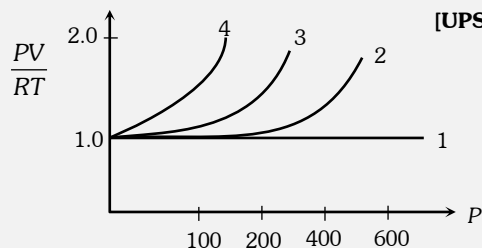
(a) 4

(b) 3

(c) 2

(d) 1

12. A pressure P-absolute temperature T diagram was obtained when a given mass of gas was heated. During the heating process from the state 1 to state 2 the volume

(a) Remained constant

(b) Decreased

(c) Increased

(d) Changed erratically
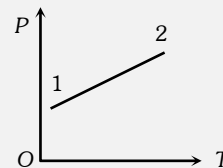
13. A volume V and pressure P diagram was obtained from state 1 to state 2 when a given mass of a gas is subjected to temperature changes. During this process the gas is

(a) Heated continuously

(b) Cooled continuously

(c) Heated in the beginning and cooled towards the end

(d) Cooled in the beginning and heated towards the end
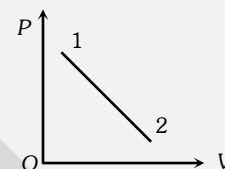
14. The figure shows the volume V versus temperature T graphs for a certain mass of a perfect gas at two constant pressures of P_1 and P_2. What interference can you draw from the graphs **[IIT 1982]**
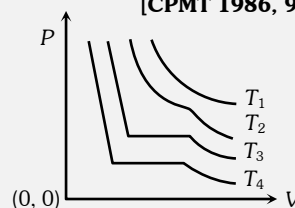
(a) $P_1 > P_2$

(b) $P_1 < P_2$

(c) $P_1 = P_2$
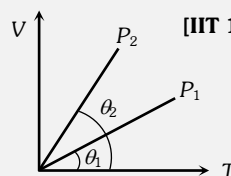
(d) No interference can be drawn due to insufficient information

15. The change in volume V with respect to an increase in pressure P has been shown in the figure for a non-ideal gas at four different temperatures T_1, T_2, T_3 and T_4. The critical temperature of the gas is **[CPMT 1986, 91]**

(a) T_1

(b) T_2
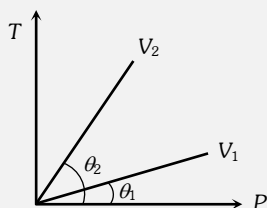
(c) T_3

(d) T_4

16. In the adjoining figure, various isothermals are shown for a real gas. Then **[CPMT 1989]**
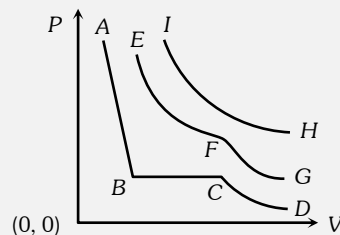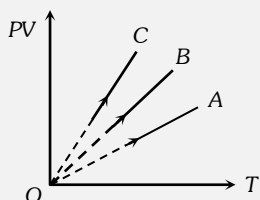
(a) EF represents liquification

(b) CB represents liquification

(c) HI represents the critical temperature

(d) AB represents gas at a high temperature

**17.** From the following P-T graph what interference can be drawn **[SCRA 2000]**

(a) $V_2 > V_1$ (b) $V_2 < V_1$

(c) $V_2 = V_1$ (d) None of the above

18. PV versus T graph of equal masses of H_2, He and O_2 is shown in fig. Choose the correct alternative

(a) C corresponds to H_2, B to He and A to O_2

(b) A corresponds to He, B to H_2 and C to O_2

(c) A corresponds to He, B to H_2 and C to O_2

(d) A corresponds to O_2, B to H_2 and C to H_2

19. Pressure versus temperature graph of an ideal gas at constant volume V of an ideal gas is shown by the straight line A. Now mass of the gas is doubled and the volume is halved, then the corresponding pressure versus temperature graph will be shown by the line
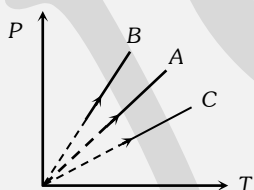

(a) A (b) B

(c) C (d) None of these

20. Two different isotherms representing the relationship between pressure p and volume V at a given temperature of the same ideal gas are shown for masses m_1 and m_2 of the gas respectively in the figure given, then
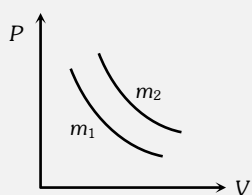

(a) $m_1 > m_2$ (b) $m_1 = m_2$

(c) $m_1 < m_2$ (d) $m_1 \gtrless m_2$

21. Two different masses m and $3m$ of an ideal gas are heated separately in a vessel of constant volume, the pressure P and absolute temperature T, graphs for these two cases are shown in the figure as A and B. The ratio of slopes of curves B to A is
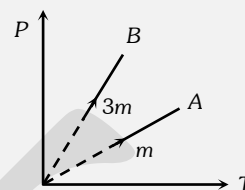
(a) $3 : 1$ (b) $1 : 3$

(c) $9 : 1$ (d) $1 : 9$

22. Under constant temperature, graph between P and $1/V$ is **[CPMT 2002]**

(a) Parabola   (b) Hyperbola

(c) Straight line   (d) Circle

23. Which one the following graphs represents the behaviour of an ideal gas **[KCET 2004]**
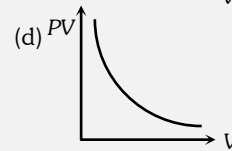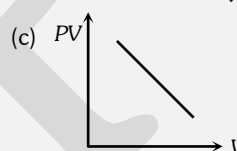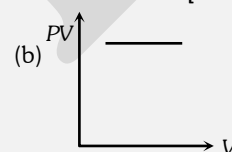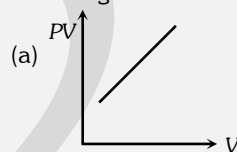
24. The curve between absolute temperature and v^2_{rms} is **[RPMT 2002]**
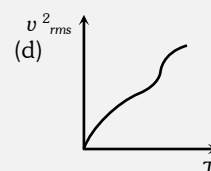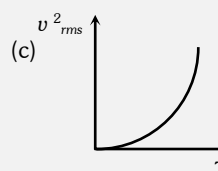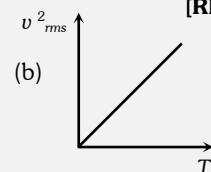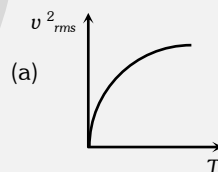
25. Volume-temperature graph at atmospheric pressure for a monoatomic gas (V in m^3, T in $^{\circ}C$) is **[DCE 2005]**
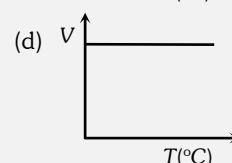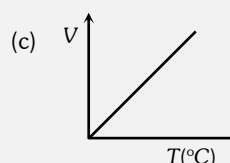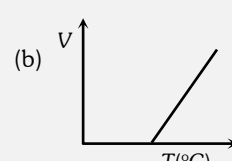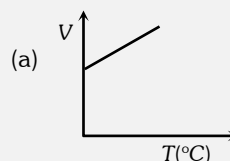
AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : In pressure-temperature (*P-T*) phase diagram of water, the slope of the melting curve is found to be negative.

Reason : Ice contracts on melting to water.

[AIIMS 2005]

2. Assertion : For gas atom the number of degrees of freedom is 3.

Reason : $\dfrac{C_P}{C_V} = \gamma$ **[AIIMS 2000]**

3. Assertion : A gas have a unique value of specific heat.

Reason : Specific heat is defined as the amount of heat required to raise the temperature of unit mass of the substance through unit degree.

4. Assertion : A gas can be liquified at any temperature by increase of pressure alone.

Reason : On increasing pressure the temperature of gas decreases.

5. Assertion : Equal masses of helium and oxygen gases are given equal quantities of heat. There will be a greater rise in the temperature of helium compared to that of oxygen.

Reason : The molecular weight of oxygen is more than the molecular weight of helium.

6. Assertion : Absolute zero is the temperature corresponding to zero energy.

Reason : The temperature at which no molecular motion cease is called absolute zero temperature.

7. Assertion : The ratio of specific heat gas at constant pressure and specific heat at constant volume for a diatomic gas is more than that for a monatomic gas.

Reason : The molecules of a monatomic gas have more degree of freedom than those of a diatomic gas.

8. Assertion : At room temperature, water does not sublimate from water to steam.

Reason : The critical point of water is much above the room temperature.

9. Assertion : Specific heat of a gas at constant pressure (C_P) is greater than its specific heat at constant volume (C_V).

Reason : At constant pressure, some heat is spent in expansion of the gas.

10. Assertion : The internal energy of a real gas is function of both, temperature and volume.

Reason : Internal kinetic energy depends on temperature and internal potential energy depends on volume.

11. Assertion : For an ideal gas, at constant temperature, the product of the pressure and volume is constant.

Reason : The mean square velocity of the molecules is inversely proportional to mass. **[AIIMS 1998]**

12. Assertion : If a gas container in motion is suddenly stopped, the temperature of the gas rises.

Reason : The kinetic energy of ordered mechanical motion is converted in to the kinetic energy of random motion of gas molecules.

13. Assertion : Internal energy of an ideal gas does not depend upon volume of the gas

Reason : Internal energy of ideal gas depends on temperature of gas.

14. Assertion : At low density, variables of gases *P, V* and *T* follows the equation $PV = \mu RT$

Reason : At low density real gases are more closely to ideal gases

15. Assertion : Maxwell speed distribution graph is symmetric about most probable speed

Reason : *rms* speed of ideal gas, depends upon it's type (monoatomic, diatomic and polyatomic)

𝒜nswers

Gas Laws

1	c	2	b	3	a	4	b	5	c
6	c	7	c	8	c	9	a	10	d
11	a	12	d	13	b	14	d	15	c
16	b	17	c	18	a	19	a	20	d
21	c	22	b	23	a	24	a	25	a
26	a	27	c	28	a	29	c	30	c
31	d	32	c	33	a	34	d	35	a
36	a	37	c	38	a	39	a	40	c
41	d	42	b	43	a	44	c	45	a
46	a	47	d	48	d	49	c	50	d
51	c	52	c	53	c	54	b	55	d
56	c	57	c	58	a	59	d	60	a

61	d	62	c	63	d	64	d	65	c
66	b	67	a	68	d	69	d	70	c
71	c	72	c	73	d	74	b	75	c
76	c	77	c	78	a	79	c	80	c
81	b	82	a	83	c	84	b	85	c
86	d	87	c	88	c	89	b	90	a
91	b	92	a	93	a	94	d	95	a
96	c	97	a	98	a	99	c	100	c

Speed of Gas

1	b	2	a	3	c	4	c	5	a
6	a	7	d	8	d	9	a	10	a
11	c	12	d	13	b	14	c	15	a
16	a	17	a	18	d	19	c	20	a
21	d	22	c	23	c	24	a	25	d
26	a	27	b	28	d	29	a	30	b
31	c	32	b	33	d	34	c	35	a
36	b	37	a	38	c	39	d	40	a
41	d	42	a	43	c	44	b	45	b
46	c	47	c	48	b	49	b	50	a
51	b	52	b	53	b	54	d	55	a
56	a	57	c	58	b	59	d	60	a
61	c	62	b	63	b	64	d	65	a
66	b	67	b	68	a				

Degree of Freedom and Specific Heat

1	a	2	c	3	a	4	a	5	c
6	d	7	c	8	b	9	d	10	d
11	c	12	a	13	b	14	d	15	a
16	a	17	a	18	a	19	b	20	a
21	c	22	b	23	c	24	d	25	b
26	d	27	d	28	a	29	b	30	d
31	a	32	c	33	a	34	c	35	a
36	d	37	a	38	a	39	b	40	c
41	b	42	b	43	b	44	d	45	b
46	c	47	c	48	d				

Pressure and Energy

1	c	2	b	3	c	4	d	5	d
6	d	7	d	8	a	9	a	10	b
11	d	12	c	13	c	14	a	15	d
16	d	17	b	18	b	19	c	20	a
21	c	22	b	23	b	24	c	25	a
26	b	27	d	28	d	29	c	30	d
31	a	32	a	33	c	34	c	35	d

36	c	37	a	38	b	39	ac	40	d
41	d	42	b	43	a	44	a	45	a
46	b	47	a	48	a	49	d	50	a
51	c	52	c	53	d	54	c	55	b
56	c	57	d	58	d	59	c	60	c
61	a	62	c	63	c	64	a		

Critical Thinking Questions

1	d	2	d	3	a	4	b	5	a
6	acd	7	b	8	b	9	cd	10	b
11	b	12	bc	13	d	14	d	15	a
16	c	17	d	18	b	19	d	20	d
21	a	22	c	23	b	24	a	25	c
26	c	27	c	28	c	29	d	30	d
31	d	32	b	33	a	34	a	35	d
36	c	37	c	38	d				

Graphical Questions

1	d	2	b	3	c	4	c	5	c
6	c	7	a	8	b	9	a	10	c
11	b	12	c	13	c	14	a	15	b
16	b	17	a	18	a	19	b	20	c
21	a	22	c	23	b	24	b	25	a

Assertion and Reason

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