

#### **BEHAVIOUR OF GASES**

**Ideal gas :** In an ideal gas, we assume that molecules are point masses and there is no mutual attraction between them. The ideal gas obeys following laws :

(i) **Boyle's law :** According to Boyle's law for a given mass of ideal gas, the pressure of a ideal gas is inveresly proportional to the volume at constant temperature

i.e., 
$$P \propto \frac{1}{V} \Rightarrow PV = \text{constant}$$

(ii) **Charle's law :** For a given mass, the volume of a ideal gas is proportional to temperature at a constant pressure

i.e., 
$$V \propto T \Rightarrow \frac{V}{T} = \text{constant}$$

(iii) **Gay-Lussac's law :** For a given mass of ideal gas, the pressure is proportional to temperature at constant volume

i.e.,  $P \propto T \frac{P}{T} = \text{constant}$ 

(iv) **Avogadro's law :** According to Avogadro's law, the number of molecules of all gases are same at same temperature, pressure and volume

i.e., 
$$N_{A_1} = N_{A_2}$$
 for same P, V and T.

The value of Avagadro number is  $6.02 \times 10^{23}$  molecules.

(v) **Graham's law :** 

(a) At constant temperature and pressure, the rms speed of diffusion of two gases is inversely proportional to the square root of the relative density

i.e., 
$$v_{rms} \alpha \frac{1}{\sqrt{d}} \Rightarrow \frac{(v_{rms})_1}{(v_{rms})_2} = \sqrt{\frac{d_2}{d_1}}$$

(b) According to Graham's law, the rate of diffusion of a gas is inversely proportional to the square root of its density, provided pressure and temperature are constant

$$r$$
(rate of diffusion)  $\propto \frac{1}{\sqrt{\rho}}$ 

(vi) **Dalton's law:** The pressure exerted by a gaseous mixture is equal to sum of partial pressure of each component gases present in the mixture,

i.e., 
$$P = P_1 + P_2 + P_3 + \dots P_n$$

A relation connecting macroscopic properties P, V and T of a gas describing the state of the system is called **equation** of state.

The equation of state for an ideal gas of n mole is

$$\frac{PV}{T} = nR$$

where R is universal gas constant whose value is R = 8.31 J/mol K and  $R = N_A k$ , where k is Boltzmann's constant ( $N_A$  is Avagadro number). *n* is the number of moles of a gas and

$$n = \frac{m}{M} = \frac{N}{N_A}$$
,  $N_A$  is Avagadro's number

where *m* is the mass of a gas, N is the number of molecules and M is the molecular weight of a gas.

#### **Equation of Real Gas :**

The real gas follows Vander Wall's law. According to this:

$$\left(p+\frac{n^2a}{V^2}\right)(V-nb)=nRT;$$

here a and b are Vander Wall's constant

#### **Critical Temperature, Volume and Pressure :**

(a) The temperature at or below which a gas can be liquefied by applying pressure alone is called **critical temperature**.

is given by 
$$T_c = \frac{8a}{27 Rb}$$

- (b) The volume of gas at a critical temperature  $T_C$  is called critical volume  $V_C$ , where  $V_C = 3b$
- (c) The pressure of gas at a critical temperature  $T_C$  is called

critical pressure 
$$P_C$$
, where  $P_C = \frac{a}{27b^2}$ 

#### **Gas Equation**

It

- (i) The gases found in nature are real gases.
- (ii) The real gas do not obey ideal gas equation but they obey vander wall's gas equation

$$\left(\mathbf{P} + \frac{a}{\mathbf{V}^2}\right) \left(\mathbf{V} - b\right) = \mathbf{RT}$$

- (a) 'a' depends upon the intermolecular force and the nature of gas.
- (b) 'b' depends upon the size of the gas molecules and represents the volume occupied by the molecules of the gas.
- (iii) The molecules of real gas have potential energy as well as kinetic energy.
- (iv) The real gas can be liquefied and solidified.
- (v) The real gases like  $CO_2$ ,  $NH_3$ ,  $SO_2$  etc. obey Vander Wall's equ<sup>n</sup> at high pressure and low temperature.

#### **KINETIC THEORY OF AN IDEAL GAS**

The basic assumptions of kinetic theory are :

- (i) A gas consist of particles called molecules which move randomly in all directions.
- (ii) The volume of molecule is very small in comparison to the volume occupied by gas i.e., the size of molecule is infinitesimely small.
- (iii) The collision between two molecules or between a molecule and wall are perfectely elastic and collision time (duration of collision) is very small.
- (iv) The molecules exert no force on each other or on the walls of containers except during collision.
- (v) The total number of molecules are large and they obey Newtonian mechanics.

$$pV = \frac{1}{3}mn \overline{C^2} \qquad \dots (i)$$

where  $\overline{C^2}$  is called mean square velocity and  $\sqrt{\overline{C^2}}$  is called

root mean square velocity

i.e, 
$$\overline{C^2} = \frac{C_1^2 + C_2^2 + \dots + C_n^2}{n}$$
 ....(ii)

and  $v_{r.m.s.} = \sqrt{C^2}$ 

where m = mass of one molecule and n = number of molecules

....(iii)

$$\Rightarrow P = \frac{M}{3V}\overline{C^2} = \frac{1}{3}\rho v_{r.m.s}^2 \qquad \dots (iv)$$

or 
$$P = \frac{2}{3} \left[ \frac{1}{2} \rho v_{r.m.s}^2 \right]$$
 (where  $M = m \times n$  and  $\rho = \frac{M}{V}$ 

or 
$$P = \frac{2}{3}E$$
 ....(v)

where E is translational kinetic energy per unit volume of the gas. It is clear that pressure of ideal gas is equal to 2/3 of translational kinetic energy per unit volume.

Kinetic interpretation of temperature : From eq<sup>n</sup>. (iv), we get

$$PV = \frac{1}{3}M\overline{C^2}$$

For 1 mole of a gas at temperature T :

$$PV = RT$$
 so  $\frac{1}{3}m\overline{C^2} = RT$ 

$$\frac{1}{3}m\overline{C^2} = \frac{R}{N}T = kT$$
 (k =  $\frac{R}{N}$  is Boltzmann constant)

$$\frac{1}{2}m\overline{C^2} = \frac{3}{2}kT$$

or

or 
$$\frac{1}{2}mv_{r.m.s}^2 = \frac{3}{2}kT$$

or 
$$v_{r.m.s}^2 = \frac{3kT}{m}$$
 ....(vii)

or 
$$v_{r.m.s} = \sqrt{\frac{3nkT}{nm}} = \sqrt{\frac{3RT}{M}}$$

- (a) It is clear from eq.(vi) that at a given temperature, the average translational kinetic energy of any gas molecules are equal i.e., it depends only on temperature.
- (b) From  $eq^n$ . (vii) It is clear that

(a) 
$$v_{r.m.s} \propto \sqrt{T}$$

(b) 
$$v_{r.m.s} \propto \frac{1}{\sqrt{M}}$$
, where M is moleculer mass of the gas.

#### **DEGREE OF FREEDOM**

The degree of freedom of a particle is the number of independent modes of exchanging energy or the number of idependent motion, which the particle can undergo.

For **monatomic** (such as helium, argon, neon etc.) gas the molecules can have three independent motion i.e., it has *3 degree of freedom, all translational*.



For a **diatomic gas** molecules such as  $H_2$ ,  $O_2$ ,  $N_2$ , etc. it has two independent rotational motion besides of three independent translational motion, so it has 5 *degree of freedom*.



In **polyatomic gas** molecules such as  $CO_2$ , it can rotate about any of three coordinate axes. It has *six degree (three translational* +*three rotational) of freedom*. At high temperature the molecule can vibrate also and degree of freedom due to vibration also arises, but we neglect it.

....(vi)

#### **MEAN FREE PATH**

The distance covered by the molecules between two successive collisions is called the **free path**.

The average distance covered by the molecules between two successive collisions is called the **mean free path** 

i.e., 
$$\lambda = \frac{1}{\sqrt{2} \cdot \pi nd^2} = \frac{K_B T}{\sqrt{2}\pi d^2 P}$$

where, n = number of molecules per unit volume

d = diameter of each molecule

 $K_B$  = Boltzmann's constant

T = temperature

P = pressure

Mean free path depends on the diameter of molecule (d) and the number of molecules per unit volume n.

At N.T.P.,  $\lambda$  for air molecules is 0.01  $\mu$ m.

#### LAW OF EQUIPARTITION OF ENERGY

If we dealing with a large number of particles in thermal equilibrium to which we can apply Newtonian mechanics, the energy associated with each degree of freedom has the same

average value (i.e.,  $\frac{1}{2}kT$ ), and this average value depends on temperature.

From the kinetic theory of monatomic ideal gas, we have

$$\frac{1}{2}m\overline{C^2} = \frac{3}{2}kT$$
....(i)

or

Energy of molecule

= (number of degree of freedom) 
$$\times \frac{1}{2}$$
kT ....(*ii*)

So it is clear from equation (i) and (ii) that monatomic gas has three degree of freedom and energy associated per degree of

freedom is  $\frac{1}{2}$  kT (where k is Boltzmann's constant)

Since we know that internal energy of an ideal gas depends only on temperature and it is purely kinetic energy. Let us consider an 1 mole ideal gas, which has N molecules and f degree of freedom, then total internal energy

U = (total number of molecules)

- $\times$  (degree of freedom of one molecule)
  - $\times$  (energy associated with each degree of freedom)

$$=(N) (f) \times (\frac{1}{2} kT)$$
$$U = Nf \frac{1}{2} kT \qquad \dots (iii)$$

Differentiating eq.(iii) w.r.t T, at constant volume, we get,

$$\left(\frac{\partial U}{\partial T}\right)_{V} = \frac{NfK}{2} \qquad \dots (iv)$$

Now molar, specific heat at constant volume is defined as

$$C_{V} = \left(\frac{\partial Q}{\partial T}\right)_{V} = \left(\frac{\partial U}{\partial T}\right)_{V} \qquad \dots (v)$$

so  $C_V = \frac{NfK}{2} = \frac{fR}{2}$  ....(vi)

where R is universal gas constant. Now by **Mayer's formula**,

$$C_P - C_V = R \Rightarrow C_P = R\left(1 + \frac{f}{2}\right) \qquad \dots \text{(vii)}$$

So ratio of specific heat  $\gamma = \frac{C_P}{C_V}$  is  $\gamma = 1 + \frac{2}{f} = \frac{C_P}{C_V}$  ...(viii)

where f is degree of freedom of one molecule.

(a) **For monatomic gas,** 
$$f = 3$$
,  $C_v = \frac{3}{2}R$ ,  $C_p = \frac{5}{2}R$ 

so 
$$\gamma = 1 + \frac{2}{3} = 1.67$$

(b) For diatomic gas, 
$$f = 5$$
,  $C_v = \frac{5}{2}R$ ,  $C_p = \frac{7}{2}R$ 

$$\gamma = 1 + \frac{2}{5} = 1.4$$

(c) For Polyatomic gas, f = 6,  $C_v = 3R$ ,  $C_p = 4R$ 

$$\gamma = 1 + \frac{2}{6} = 1.33$$

#### Keep in Memory

 Real gases behave like perfect gas at high temperature and low pressure.
 In real gas, we assume that the molecules have finite size

In real gas, we assume that the molecules have finite size ant intermolecular attraction acts between them.

- 2. Real gases deviate most from the perfect gas at high pressure and low temperature.
- **3.** Gaseous state of matter below critical temperature is called vapours. Below critical temperature gas is vapour and above critical temperature vapour is gas.
- 4. Random motion of the consituents of the system involving exchange of energy due to mutual collisions is called **thermal motion**.
- 5. Total kinetic energy or internal energy or total energy does not depend on the direction of flow of heat. It is determined by the temperature alone.
- 6. The internal energy of a perfect gas consists only of kinetic energy of the molecules. But in case of the real gas it consists of both the kinetic energy and potential energy of inter molecular configuration.

#### **Distribution of Molecular Speeds :**

The speed of all molecules in a gas is not same but speeds of individual molecules vary over a wide range of magnitude.

Maxwell derived the molecular distribution law (by which we can find distribution of molecules in different speeds) for sample

of a gas containing N molecules, which is

$$N(v) = 4\pi N \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/2kT} \qquad ...(1)$$

where N(v)dv is the number of molecules in the gas sample having speeds between v and v + dv.

where T = absolute temperature of the gas

m = mass of molecule

k = Boltzmann's constant

The total number of molecules N in the gas can be find out by integrating equation (1) from  $0 \text{ to } \infty \text{ i.e.}$ ,

$$N = \int_0^\infty N(v) dv \qquad \dots (2)$$



Figure shows Maxwell distribution law for molecules at two different temperature  $T_1$  and  $T_2(T_2 > T_1)$ .

The number of molecules between  $v_1$  and  $v_2$  equals the area under the curve between the vertical lines at  $v_1$  and  $v_2$  and the total number of molecules as given by equation (2) is equal to area under the distribution curve.

The distribution curve is not symmetrical about most probable speed,  $v_p$ ,( $v_p$  is the speed, which is possessed in a gas by a large number of molecules) because the lowest speed must be zero, whereas there is no limit to the upper speed a molecule can attain. It is clear from fig.1 that

 $v_{rms}$ (root mean square) >  $\overline{v}$  (average speed of molecules) > (most probable speed)  $v_P$ 

### AVERAGE, ROOT MEAN SQUARE AND MOST PROBABLE SPEED

#### Average speed

To find the average speed  $\overline{v}$ , we multiply the number of particles in each speed interval by speed v characteristic of that interval. We sum these products over all speed intervals and divide by total number of particles

i.e.,  $\overline{v} = \frac{\int_{0}^{\infty} N(v)vdv}{N}$  (where summation is replaced by

integration because N is large)

$$\bar{hv} = \sqrt{\frac{8kT}{\pi m}} = 1.59\sqrt{\frac{kT}{m}} \qquad \dots (1)$$

#### **Root Mean Square Speed**

In this case we multiply the number of particles in each speed interval by  $v^2$  characteristic of that interval; sum of these products over all speed interval and divide by N

i.e., 
$$\overline{v^2} = \frac{\int_o^\infty N(v)v^2 dv}{N}$$
 ....(2)

Root mean square speed is defined as

$$v_{r.m.s} = \sqrt{v^2} = \sqrt{\frac{3kT}{m}} = 1.73\sqrt{\frac{kT}{m}}$$

#### **Most Probable Speed**

It is the speed at which N(v) has its maximum value (or possessed by large number of molecules), so

$$\frac{\mathrm{d}}{\mathrm{du}}[\mathrm{N}(\mathrm{v})] = 0 \Rightarrow \mathrm{v}_{\mathrm{p}} = \sqrt{\frac{2\mathrm{kT}}{\mathrm{m}}} = 1.41\sqrt{\frac{\mathrm{kT}}{\mathrm{m}}} \qquad \dots (3)$$

It is clear from  $eq^n$ . (1), (2) and (3)

$$v_{r.m.s} > v > v_p$$

The root mean square velocity of a particle in thermal system is given by

$$C_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

where R - universal gas constant

- T temperature of gas
- m mass of the gas
- M molecular weight of gas or mass of one mole of a gas.

The average speed of the gas molecules is given by

$$C_{av} = \sqrt{\frac{8kT}{\pi m}} = \sqrt{\frac{8RT}{\pi M}}$$

where M is the mass of one mole and m is the mass of one particle.

Most probable speed is that with which the maximum number of molecules move. It is given by

$$V_p = \sqrt{\frac{2}{3}}c_{rms} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2kT}{m}}$$

The most probable speed, the average speed as well as root mean square speed increases with temperature.

#### Example 1.

The root mean square velocity of the molecules in a sample of helium is 5/7th that of the molecules in a samzple of hydrogen. If the temperature of the hydrogen gas is  $0^{\circ}$ c, then find the temperature of helium sample.

#### Solution :

$$\frac{(v_{r.m.s})_{He}}{(v_{r.m.s})_{H}} = \frac{\sqrt{(3KT_{He}/m_{He})}}{\sqrt{3KT_{H}/m_{H}}} = \sqrt{\frac{T_{He}}{T_{H}} \times \frac{m_{H}}{m_{He}}}$$
$$= \sqrt{\frac{T_{He} \times 1}{273 \times 4}} \Rightarrow \frac{5}{7} = \frac{1}{2}\sqrt{\frac{T_{He}}{273}}$$
or  $T_{He} = 557.14^{\circ} \text{K} = 284.14^{\circ} \text{C}$ 

Example 2.

Let  $\overline{v}$ ,  $v_{rms}$  and  $v_P$  respectively denote the mean speed, r.m.s. speed, and most probable speed of the molecules in an ideal monatomic gas at absolute temperature T. The mass of a molecule is m, then which of the following is correct?

- (a) No molecule can have a speed greater than  $\sqrt{2} v_{max}$
- (b) No molecule can have a speed less than  $v_p/\sqrt{2}$
- (c)  $v_p < \overline{v} < v_{r.m.s.}$
- (d) None of these

#### *Solution* : (c)

According to kinetic theory of gases, a molecule of a gas can have speed such that  $0 < v < \infty$ , so the alternatives (a) and (b) can never be correct, Since

$$v_{r.m.s.} = \sqrt{\frac{3kT}{m}}$$
;  $v_{av} = \sqrt{\frac{8kT}{3m}}$ ; and  $v_{mp} = \sqrt{\frac{2kT}{m}}$ 

so  $v_{r.m.s.} > v_{av} > v_p$  i.e.  $v_p < \overline{v} < v_{r.m.s.}$ ;

#### Example 3.

A gas cylinder of 50 litres capacity contained helium at 80 atmospheric pressure. Due to slow leakage it was found after a while that the pressure had dropped to 40 atmosphere. Find the proportion of the gas that has escaped and also the volume the escaped gas would occupy at atmospheric pressure.

#### Solution :

Volume of the remaining gas

= volume of cylinder = 50 *l* at 40 atmospheric pressure The volume of this gas at 80 atmospheric pressure, using Boyle's law  $p_1V_1 = p_2V_2$ 

$$=\frac{40\times50}{80}=25$$

Volume of the gas (at 80 atmospheric pressure) which has escaped = 50 - 25 = 25 l

$$\therefore \frac{\text{Mass of gas escaped}}{\text{Original mass of gas}} = \frac{25}{50} = \frac{1}{2}$$

l

Again using Boyle's law,

 $1 \times V = 80 \times 25$  or V = 2000 litre

#### Example 4.

In Vander Wal's equation the critical pressure  $P_c$  is given by

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

#### Solution : (b)

The Vander Wall's equation of state is

$$\left(P+\frac{a}{V^2}\right)(V-b) = RT$$
; or  $P = \frac{RT}{V-b} - \frac{a}{V^2}$ 

At the critical point,  $P = P_c$ ,  $V = V_c$ , and  $T = T_c$ ;

$$\therefore P_{c} = \frac{RT_{c}}{V_{c} - b} - \frac{a}{V_{c}^{2}} \qquad \dots (i)$$

At the critical point on the isothermal,  $\frac{dP_c}{dV_c} = 0$ 

: 
$$0 = \frac{-RT_c}{(V_c - b)^2} - \frac{2a}{V_c^3}$$
; or  $\frac{RT_c}{(V_c - b)^2} = \frac{2a}{V_c^3}$  ...(ii)

Also at critical point,  $\frac{d^2 P_c}{dV_c^2} = 0$ 

:. 
$$0 = \frac{2 RT_c}{(V_c - b)^3} - \frac{6a}{V_c^4}$$
; or  $\frac{2 RT_c}{(V_a - b)^3} = \frac{6a}{V_c^4}$  ...(iii)

Dividing eq<sup>n</sup>. (iii) by (ii), we get,

$$\frac{1}{2}(V_c - b) = \frac{1}{3}V_c \text{ or } V_c = 3b$$
 ...(iv)

Putting this value in eq<sup>n</sup>. (ii), we get,

$$\frac{RT}{4b^2} = \frac{2a}{27b^3} \text{ or } T_c = \frac{8a}{27bR} \qquad ...(v)$$

Putting the values of  $V_c$  and  $T_c$  in eq<sup>n</sup>. (i), we get,

$$P_{c} = \frac{R}{2b} \left( \frac{8a}{27bR} \right) - \frac{a}{9b^{2}} = \frac{a}{27b^{2}}$$

#### Keep in Memory

1. Brownian motion, provides a direct evidence for the existance of molecules and their motion. The zig-zag motion of gas molecules is Brownian motion.

2. Average speed 
$$\overline{v} = \sqrt{\frac{8k_BT}{\pi m}} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8PV}{\pi M}}$$

3. Root mean square speed,

$$v_{rms} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3PV}{M}}$$

4. Most probable speed  $V_{mp} = \sqrt{\frac{2k_BT}{m}} = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2PV}{M}}$ 

5. 
$$V_{rms}: \overline{V}: V_{mp} = 1.73: 1.60: 1.41$$
  
 $V_{rms} > \overline{V} > V_{mp}$ .



### EXERCISE - 1 **Conceptual Questions**

- The kinetic theory of gases 1.
  - (a) explains the behaviour of an ideal gas.
  - (b) describes the motion of a single atom or molecule.
  - (c) relates the temperature of the gas with K.E. of atoms of the gas
  - (d) All of the above
- 2. The ratio of principal molar heat capacities of a gas is maximum for
  - (a) a diatomic gas
  - (b) a monatomic gas
  - (c) a polyatomic gas having linear molecules.
  - (d) a polyatomic gas having non-linear molecules.
  - The correct statement of the law of equipartition of energy is
    - (a) the total energy of a gas is equally divided among all the molecules.
    - (b) The gas possess equal energies in all the three directions x, y and z-axis.
    - (c) the total energy of a gas is equally divided between kinetic and potential energies.
    - (d) the total kinetic energy of a gas molecules is equally divided among translational and rotational kinetic energies.
- 4. The internal energy of an ideal gas is
  - (a) the sum of total kinetic and potential energies.
  - (b) the total translational kinetic energy.
  - (c) the total kinetic energy of randomly moving molecules.
  - (d) the total kinetic energy of gas molecules.
- A fixed mass of gas at constant pressure occupies a volume 5. V. The gas undergoes a rise in temperature so that the root mean square velocity of its molecules is doubled. The new volume will be
  - (b)  $V / \sqrt{2}$ (a) V/2
  - (d) 4V (c) 2V
- 6. In kinetic theory of gases, it is assumed that molecules (a) have same mass but can have different volume
  - (b) have same volume but mass can be different
  - (c) have different mass as well as volume
  - (d) have same mass but negligible volume.
- 7. Gases exert pressure on the walls of the container because the gas molecules
  - (a) possess momentum
  - (b) collide with each other
  - (c) have finite volume
  - (d) obey gas laws.
- 8. Let v denote the rms speed of the molecules in an ideal diatomic gas at absolute temperature T.

The mass of a molecule is 'm' Neglecting vibrational energy terms, the false statement is

- a molecule can have a speed greater than  $\sqrt{2}v$ (a)
- (b) v is proportional to  $\sqrt{T}$

- (c) the average rotational K.E. of a molecule is  $\frac{1}{4}mv^2$
- (d) the average K.E. of a molecule is  $\frac{5}{6}mv^2$
- 9. The adjoining figure shows graph of pressure and volume of a gas at two tempertures T<sub>1</sub> and T<sub>2</sub>. Which of the following inferences is correct?



(a)  $T_1 > T_2$ (c)  $T_1 < T_2$ At constant pressure, the ratio of increase in volume of an 10. ideal gas per degree rise in kelvin temperature to its original volume is (T = absolute temperature of the gas) is

(a) 
$$T^2$$
 (b)  $T$  (c)  $1/T$  (d)  $1/T^2$ 

11. The K.E. of one mole of an ideal gas is E = (3/2) RT. Then  $C_p$ will be

(a)	0.5 R	(b)	0.1 R
(c)	1.5 R	(d)	2.5 R

The root mean square speed of the molecules of a diatomic 12. gas is v. When the temperature is doubled, the molecules dissociate into two atoms. The new root mean square speed of the atom is

(a) 
$$\sqrt{2}v$$
 (b) v (c) 2v (d) 4v

13. Which of the following formula is wrong?

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

(c) 
$$C_p / C_V = \gamma$$
 (d)  $C_p - C_V = 2R$ 

14. For a gas if ratio of specific heats at constant pressure and volume is  $\gamma$  then value of degrees of freedom is

(a) 
$$\frac{3\gamma - 1}{2\gamma - 1}$$
 (b)  $\frac{2}{\gamma - 1}$  (c)  $\frac{9}{2}(\gamma - 1)$  (d)  $\frac{25}{2}(\gamma - 1)$ 

- In the kinetic theory of gases, which of these statements 15. is/are true?
  - The pressure of a gas is proportional to the mean speed (i) of the molecules.
  - (ii) The root mean square speed of the molecules is proportional to the pressure.
  - (iii) The rate of diffusion is proportional to the mean speed of the molecules.
  - (iv) The mean translational kinetic energy of a gas is proportional to its kelvin temperature.
  - (ii) and (iii) only (b) (i),(ii)and (iv) only (a)
  - (c) (i) and (iii) only (d) (iii) and (iv) only

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3.

16. 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?

(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  $(\overline{K})_1 < (\overline{K})_2 < (\overline{K})_3$
- 17. A sample of an ideal gas occupies a volume of V at a pressure P and absolute temperature. T. The mass of each molecule is m. The equation for density is
  - (a) m k T (b) P/k T
  - (c) P/(kTV) (d) Pm/kT
- **18.** The value of critical temperature in terms of van der Waal's constant a and b is given by

(a) 
$$T_{c} = \frac{8a}{27 R b}$$
 (b)  $T_{c} = \frac{a}{27 b R}$   
(c)  $T_{c} = \frac{a}{2 R b}$  (d)  $T_{c} = \frac{-a}{R b}$ 

- **19.** At room temperature, the rms speed of the molecules of a certain diatomic gas is found to be 1930 m/s. The gas is
  - (a)  $H_2$  (b)  $F_2$
  - (c)  $\overline{O_2}$  (d)  $\overline{Cl_2}$
- **20.** Two gases A and B having the same temperature T, same pressure P and same volume V are mixed. If the mixture is at the same temperature T and occupies a volume V, the pressure of the mixture is

- (a) 2 P (b) P
- (c) P/2 (d) 4 P
- 21. The perfect gas equation for 4 gram of hydrogen gas is(a) PV=RT(b) PV=2RT

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

- 22. Maxwell's laws of distribution of velocities shows that
  - (a) the number of molecules with most probable velocity is very large
  - (b) the number of molecules with most probable velocity is very small
  - (c) the number of molecules with most probable velocity is zero
  - (d) the number of molecules with most probable velocity is exactly equal to 1
- **23.** According to kinetic theory of gases, which one of the following statement(s) is/are correct?
  - (a) Real gas behave as ideal gas at high temperature and low pressure.
  - (b) Liquid state of ideal gas is impossible
  - (c) At any temerature and pressure, ideal gas obeys Boyle's law and charles' law
  - (d) The molecules of real gas do not exert any force on one another.
- 24. 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 (a) a = 16b (b) 16a = b(c) a = 4b (d) a = b
- **25.** The relation between the gas pressure P and average kinetic energy per unit volume *E* is

(a) 
$$P = \frac{1}{2}E$$
 (b)  $P = E$   
(c)  $P = \frac{3}{2}E$  (d)  $P = \frac{2}{3}E$ 

### **EXERCISE -** 2 Applied Questions

- **1.** If the critical temperature of a gas is 100°C, its Boyle temperature will be approximately
  - (a) 337.5°C (b) 500°C
  - (c) 33.3°C (d) 1000°C
- 2. The r.m.s. velocity of oxygen molecule at 16°C is 474 m/sec. The r.m.s. velocity in m/s of hydrogen molecule at 127°C is
  - (a) 1603 (b) 1896
  - (c) 2230.59 (d) 2730
- **3.** The gases are at absolute temperature 300°K and 350°K respectively. The ratio of average kinetic energy of their molecules is
  - (a) 7:6 (b) 6:7
  - (c) 36:49 (d) 49:36
- 4. The total degree of freedom of a  $CO_2$  gas molecule is
  - (a) 3 (b) 6
  - (c) 5 (d) 4

- 5. If one mole of a monatomic gas ( $\gamma = 5/3$ ) is mixed with one mole of a diatomic gas ( $\gamma = 7/3$ ), the value of  $\gamma$  for the mixture is
  - (a) 1.40 (b) 1.50 (c) 1.53 (d) 3.07
- 6. The molecules of a given mass of gas have a root mean square velocity of 200m s<sup>-1</sup> at 27°C and  $1.0 \times 10^5$  N m<sup>-2</sup> pressure. When the temperature is 127°C and the pressure  $0.5 \times 10^5$  Nm<sup>-2</sup>, the root mean square velocity in ms<sup>-1</sup>, is

(a) 
$$\frac{400}{\sqrt{3}}$$
 (b)  $100\sqrt{2}$ 

(c) 
$$\frac{100\sqrt{2}}{3}$$
 (d)  $\frac{100}{3}$ 

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7. If masses of all molecule of a gas are halved and their speed doubled then the ratio of initial and final pressure will be

(a)	2:1	(b)	1:2
(c)	4:1	(d)	1:4

- 8. On a particular day, the relative humidity is 100% and the room temperature is 30°C, then the dew point is
  - (a) 70°C (b) 30°C
  - (d) 100°C (d) 0°C
- **9.** The velocity of the molecules of a gas at temperature 120 K is v. At what temperature will the velocity be 2 v?
  - (a) 120 K (b) 240 K (c) 480 K (d) 1120 K
- 10. The density of a gas is  $6 \times 10^{-2}$  kg/m<sup>3</sup> and the root mean square velocity of the gas molecules is 500 m/s. The pressure exerted by the gas on the walls of the vessel is
  - (a)  $5 \times 10^3 \text{ N} / \text{m}^2$  (b)  $1.2 \times 10^{-4} \text{ N} / \text{m}^2$
  - (c)  $0.83 \times 10^{-4} \text{ N}/\text{m}^2$  (d)  $30 \text{ N}/\text{m}^2$
- 11. 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
  - (a) 600 cal (b) 1200 cal
  - (c) 1800 cal (d) 3600 cal
- 12. Helium gas is filled in a closed vessel (having negligible thermal expansion coefficient) when it is heated from 300 K to 600 K, then average kinetic energy of helium atom will be
  - (a)  $\sqrt{2}$  times (b) 2 times
  - (c) unchanged (d) half
- One mole of a gas occupies 22.4 lit at N.T.P. Calculate the difference between two molar specific heats of the gas. J=4200 J/kcal.
  - (a) 1.979 k cal/kmol K (b) 2.378 k cal/kmol K
  - (c) 4.569 kcal/kmol K (d) 3.028 k cal/ kmol K
- 14. Four molecules have speeds 2 km/sec, 3 km/sec, 4 km/sec and 5 km/sec. The root mean square speed of these molecules (in km/sec) is
  - (a)  $\sqrt{54/4}$  (b)  $\sqrt{54/2}$
  - (c) 3.5 (d)  $3\sqrt{3}$
- 15. The density of air at pressure of  $10^5$  Nm<sup>-2</sup> is 1.2 kg m<sup>-3</sup>. Under these conditions, the root mean square velocity of the air molecules in ms<sup>-1</sup> is

(a)	500	(b)	1000
-----	-----	-----	------

- (c) 1500 (d) 3000
- **16.** How many degrees of freedom are associated with 2 grams of He at NTP ?
  - (a) 3 (b)  $3.01 \times 10^{23}$
  - (c)  $9.03 \times 10^{23}$  (d) 6
- 17. If 2 mole of an ideal monatomic gas at temperature  $T_0$  is mixed with 4 moles of another ideal monatomic gas at temperature  $2T_0$ , then the temperature of the mixture is

(a) 
$$\frac{5}{3}T_0$$
 (b)  $\frac{3}{2}T_0$  (c)  $\frac{4}{3}T_0$  (d)  $\frac{5}{4}T_0$ 

- **18.** The temperature at which the root mean square velocity of the gas molecules would become twice of its value at 0°C is
  - (a) 819°C
     (b) 1092°C

     (c) 1100°C
     (d) 1400°C
  - (c) 1100°C (d) 1400°C
- **19.** At what temperature is the r.m.s. velocity of a hydrogen molecule equal to that of an oxygen molecule at 47°C
  - (a) 80 K (b) -73 K
  - (c) 3 K (d) 20 K
- **20.** One litre of oxygen at a pressure of 1 atm, and 2 litres of nitrogen at a pressure of 0.5 atm. are introduced in the vessel of 1 litre capacity, without any change in temperature. The total pressure would be
  - (a) 1.5 atm. (b) 0.5 atm.
  - (c) 2.0 atm. (d) 1.0 atm.
- **21.** The air in a room has 15 gm of water vapours per cubic metre of its volume. However for saturation one cubic metre of volume requires 20 gm of water vapour then relative humidity is
  - (a) 50% (b) 75%
  - (c) 20% (d) 25%
- 22. A vessel contains air at a temperature of 15°C and 60% R.H. What will be the R.H. if it is heated to 20°C? (S.V.P. at 15°C is 12.67 & at 20°C is 17.36mm of Hg respectively)
  - (a) 262% (b) 26.2%
  - (c) 44.5% (d) 46.2%
- **23.** To what temperature should be the hydrogen at 327°C be cooked at constant pressure so that the root mean square velocity of its molecules becomes half of its previous value
  - (a)  $-123^{\circ}C$  (b)  $120^{\circ}C$
  - (c)  $-100^{\circ}$ C (d)  $0^{\circ}$ C
- 24. 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
  - (a) 250 K (b) 250°C
  - (c) 2500 K (d) 25°C
- 25. N molecules, each of mass m, of gas A and 2 N molecules, each of mass 2 m, of gas B are contained in the same vessel which is maintained at a temperature T. The mean square of the velocity of molecules of B type is denoted by  $v^2$  and the mean square of the X component of the velocity of A type is denoted by  $\omega^2$ ,  $\omega^2/v^2$  is
  - (a) 2 (b) 1
  - (c) 1/3 (d) 2/3
- **26.** At what temperature, pressure remaining constant, will the r.m.s. velocity of a gas be half of its value at 0°C?
  - (a)  $0^{\circ}$ C (b)  $-273^{\circ}$ C
  - (c)  $32^{\circ}$ C (d)  $-204^{\circ}$ C

27. Graph of specific heat at constant volume for a monatomic gas is



- **28.** The order of magnitude of the number of nitrogen molecules in an air bubble of diameter 2 mm under ordinary conditions is
  - (a)  $10^5$  (b)  $10^9$
  - (c)  $10^{13}$  (d)  $10^{17}$
- **29.** At identical temperatures, the rms speed of hydrogen molecules is 4 times that for oxygen molecules. In a mixture of these in mass ratio  $H_2: O_2 = 1:8$ , the rms speed of all molecules is n times the rms speed for  $O_2$  molecules, where n is
  - (a) 3 (b) 4/3
  - (c)  $(8/3)^{1/2}$  (d)  $(11)^{1/2}$
- **30.** In Vander Waal's equation the critical pressure  $P_c$  is given by

(a) 3 b (b) 
$$\frac{a}{27b^2}$$

(c) 
$$\frac{27a}{b^2}$$
 (d)  $\frac{b^2}{a}$ 

**31.** 1 mole of a gas with  $\gamma = 7/5$  is mixed with 1 mole of a gas with  $\gamma = 5/3$ , then the value of  $\gamma$  for the resulting mixture is

(a)	7/5	(b)	2/5
(c)	24/16	(d)	12/7

**32.** N molecules, each of mass m, of gas A and 2 N molecules, each of mass 2 m, of gas B are contained in the same vessel which is maintained at a temperature T. The mean square velocity of molecules of B type is denoted by  $V_2$  and the

mean square velocity of A type is denoted by  $V_1$ , then  $\frac{V_1}{V_2}$  is

(b) 1

- (a) 2
- (c) 1/3 (d) 2/3
- **33.** An ideal gas is found to obey an additional law  $VP^2 =$  constant. The gas is initially at temperature T and volume V. When it expands to a volume 2 V, the temperature becomes
  - (a)  $T/\sqrt{2}$  (b) 2 T
  - (c)  $2T\sqrt{2}$  (d) 4T

34. Two monatomic ideal gases 1 and 2 of molecular masses  $m_1$  and  $m_2$  respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to that in gas 2 is given by

(a) 
$$\sqrt{\frac{m_1}{m_2}}$$
 (b)  $\sqrt{\frac{m_2}{m_1}}$ 

(c) 
$$\frac{m_1}{m_2}$$
 (d)  $\frac{m_2}{m_1}$ 

- **35.** If the potential energy of a gas molecule is  $U = M/r^6 N/r^{12}$ , M and N being positive constants, then the potential energy at equilibrium must be
  - (a) zero (b)  $M^{2}/4N$ (c)  $N^{2}/4M$  (d)  $MN^{2}/4$
- **36.** 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
  - (a) 212 kPa(b) 209 kPa (c) 206 kPa (d) 200 kPa
- 37. Work done by a system under isothermal change from a volume V<sub>1</sub> to V<sub>2</sub> for a gas which obeys Vander Waal's

equation 
$$(V - \beta n) \left( P + \frac{\alpha n^2}{V} \right) = nRT$$
 is

(a) 
$$nRT \log_e \left( \frac{V_2 - n\beta}{V_1 - n\beta} \right) + \alpha n^2 \left( \frac{V_1 - V_2}{V_1 V_2} \right)$$

(b) 
$$nRT \log_{10} \left( \frac{V_2 - n\beta}{V_1 - n\beta} \right) + \alpha n^2 \left( \frac{V_1 - V_2}{V_1 V_2} \right)$$

(c) 
$$nRT \log_e \left( \frac{V_2 - n\beta}{V_1 - n\beta} \right) + \beta n^2 \left( \frac{V_1 - V_2}{V_1 V_2} \right)$$

(d) 
$$nRT \log_e \left( \frac{V_1 - n\beta}{V_2 - n\beta} \right) + \alpha n^2 \left( \frac{V_1 V_2}{V_1 - V_2} \right)$$

- **38.** A gas mixture consists of 2 moles of oxygen and 4 moles of Argon at temperature T. Neglecting all vibrational moles, the total internal energy of the system is
  - (a) 4 RT (b) 15 RT
  - (c) 9 RT (d) 11 RT
- **39.** The molar heat capacities of a mixture of two gases at constant volume is 13R/6. The ratio of number of moles of the first gas to the second is 1 : 2. The respective gases may be
  - (a)  $O_2$  and  $N_2$  (b) He and Ne
  - (c) He and  $N_2$  (d)  $N_2$  and He

- **40.** A graph is plotted with PV/T on y-axis and mass of the gas along x-axis for different gases. The graph is
  - (a) a straight line parallel to x-axis for all the gases
  - (b) a straight line passing through origin with a slope having a constant value for all the gases
  - (c) a straight line passing through origin with a slope having different values for different gases
  - (d) a straight line parallel to y-axis for all the gases
- **41.** Four mole of hydrogen, two mole of helium and one mole of water vapour form an ideal gas mixture. What is the molar specific heat at constant pressure of mixture?

(a) 
$$\frac{16}{7}$$
 R (b)  $\frac{7}{16}$  R (c) R (d)  $\frac{23}{7}$  R

42. An ideal gas is taken through a process in which the pressure and the volume are changed according to the equation P = kV. Molar heat capacity of the gas for the process is

(a) 
$$C = C_v + R$$
 (b)  $C = C_v + \frac{R}{2}$   
(c)  $C = C_v - \frac{R}{2}$  (d)  $C = C_v + 2R$ 

**43.** A vessel has 6g of hydrogen at pressure P and temperature 500K. A small hole is made in it so that hydrogen leaks out. How much hydrogen leaks out if the final pressure is P/2 and temperature falls to 300 K?



44. Figure shows a parabolic graph between T and 1/V for a mixture of a gas undergoing an adiabatic process. What is the ratio of  $V_{rms}$  of molecules and speed of sound in mixture?



**45.** Which one the following graphs represents the behaviour of an ideal gas ?



**46.** The molar specific heat at constant pressure of an ideal gas is (7/2)R. The ratio of specific heat at constant pressure to that at constant volume is

DIRECTIONS for Qs. 47 to 50 : Each of these question contains two statements: STATEMENT-1 (Assertion) and STATEMENT-2 (Reason). Answer these questions from the following four options.

- (a) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement -1
- (b) Statement-1 is True, Statement -2 is True; Statement-2 is NOT a correct explanation for Statement 1
- (c) Statement-1 is True, Statement-2 is False

(a)

- (d) Statement-1 is False, Statement -2 is True
- **47.** Statement 1 : The ratio  $\frac{C_V}{C_P}$  for a monatomic gas is less than for a diatomic gas.

**Statement 2 :** The molecules of a monatomic gas have more degrees of freedom than those of a diatomic gas.

**48.** Statement 1 : Air pressure in a car tyre increases during driving.

**Statement 2 :** Absolute zero temperature is not zero energy temperature.

**49. Statement 1 :** The total translational kinetic energy of all the molecules of a given mass of an ideal gas is 1.5 times the product of its pressure and its volume.

**Statement 2 :** The molecules of a gas collide with each other and the velocities of the molecules change due to the collision.

**50.** Statement 1 : Mean free path of a gas molecules varies inversely as density of the gas.

**Statement 2 :** Mean free path varies inversely as pressure of the gas.

### EXERCISE - 3 Exemplar & Past Years NEET/AIPMT Questions

#### **Exemplar Questions**

- 1. A cubic vessel (with face horizontal + vertical) contains an ideal gas at NTP. The vessel is being carried by a rocket which is moving at a speed of 500 m s<sup>-1</sup> in vertical direction. The pressure of the gas inside the vessel as observed by us on the ground
  - (a) remains the same because 500 ms<sup>-1</sup> is very much smaller than  $v_{\rm rms}$  of the gas
  - (b) remains the same because motion of the vessel as a whole does not affect the relative motion of the gas molecules and the walls
  - (c) will increase by a factor equal to  $(v_{\rm rms}^2 + (500)^2) / v_{\rm rms}^2$ where  $v_{\rm rms}$  was the original mean square velocity of the gas
  - (d) will be different on the top wall and bottom wall of the vessel
- 2. 1 mole of an ideal gas is contained in a cubical volume V, ABCDEFGH at 300K (figure). One face of the cube (EFGH) is made up of a material which totally absorbs any gas molecule incident on it. At any given time,



- (a) the pressure on *EFGH* would be zero
- (b) the pressure on all the faces will the equal
- (c) the pressure of *EFGH* would be double the pressure on *ABCD*
- (d) the pressure on *EFGH* would be half that on *ABCD*
- Boyle's law is applicable for an
- (a) adiabatic process

3.

- (b) isothermal process
- (c) isobaric process
- (d) isochoric process
- 4. A cylinder containing an ideal gas is in vertical position and has a piston of mass *M* that is able to move up or down without friction (figure). If the temperature is increased



- (a) both p and V of the gas will change
- (b) only *p* will increase according to Charles' law
- (c) V will change but not p
- (d) p will change but not V
- 5. Volume versus temperature graphs for a given mass of an ideal gas are shown in figure. At two different values of constant pressure. What can be inferred about relation between  $p_1$  and  $p_2$ ?



(a)  $p_1 > p_2$  (b)  $p_1 = p_2$ 

(c)  $p_1 < p_2$  (d) Data is insufficient

- 6. 1 mole of H<sub>2</sub> gas is contained in a box of volume  $V = 1.00 \text{ m}^3$  at T = 300 K. The gas is heated to a temperature of T = 3000 K and the gas gets converted to a gas of hydrogen atoms. The final pressure would be (considering all gases to be ideal)
  - (a) same as the pressure initially
  - (b) 2 times the pressure initially
  - (c) 10 times the pressure initially
  - (d) 20 times the pressure initially
- 7. A vessel of volume V contains a mixture of 1 mole of hydrogen and 1 mole oxygen (both considered as ideal). Let  $f_1(v)dv$ , denote the fraction of molecules with speed between v and (v + dv) with  $f_2(v)dv$ , similarly for oxygen. Then,
  - (a)  $f_1(v) + f_2(v) = f(v)$  obeys the Maxwell's distribution law
  - (b)  $f_1(v), f_2(v)$  will obey the Maxwell's distribution law separately
  - (c) neither  $f_1(v)$ , nor  $f_2(v)$  will obey the Maxwell's distribution law
  - (d)  $f_2(v)$  and  $f_1(v)$  will be the same
- 8. An inflated rubber balloon contains one mole of an ideal gas, has a pressure *p*, volume *V* and temperature *T*. If the temperature rises to 1.1 *T*, and the volume is increased to 1.05 *V*, the final pressure will be
  - (a) 1.1 p (b) p
  - (c) less than p (d) between p and 1.1

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#### NEET/AIPMT (2013-2017) Questions

- 9. In the given (V T) diagram, what is the relation between pressure P<sub>1</sub> and P<sub>2</sub>? V [2013]
  - (a)  $P_2 > P_1$
  - (b)  $P_2 < P_1$
  - (c) Cannot be predicted
  - (d)  $P_2 = P_1$
- 10. The amount of heat energy required to raise the temperature of 1g of Helium at NTP, from  $T_1K$  to  $T_2K$  is [2013]

 $M_{\theta^1}$ 

(a) 
$$\frac{3}{2} N_a k_B (T_2 - T_1)$$
  
(b)  $\frac{3}{4} N_a k_B (T_2 - T_1)$   
(c)  $\frac{3}{4} N_a k_B \frac{T_2}{T_1}$ 

- (d)  $\frac{3}{8}N_ak_B(T_2-T_1)$
- In a vessel, the gas is at a pressure *P*. If the mass of all the molecules is halved and their speed is doubled, then the resultant pressure will be [NEET Kar. 2013]
  (a) 4P
  (b) 2P
  - (a) 41 (b) 21(c) P (d) P/2
- 12. The mean free path of molecules of a gas, (radius 'r') is inversely proportional to : [2014]
  (a) r<sup>3</sup>
  (b) r<sup>2</sup>
  - (c) r (d)  $\sqrt{r}$
- 13. The ratio of the specific heats  $\frac{C_p}{C_v} = \gamma$  in terms of degrees

[2015]

of freedom (n) is given by

(a) 
$$\left(1+\frac{n}{3}\right)$$
 (b)  $\left(1+\frac{2}{n}\right)$   
(c)  $\left(1+\frac{n}{2}\right)$  (d)  $\left(1+\frac{1}{n}\right)$ 

14. One mole of an ideal diatomic gas undergoes a transition from A to B along a path AB as shown in the figure.



The change in internal energy of the gas during the transition is: [2015]

(a) -20 kJ (b) 20 J(c) -12 kJ (d) 20 kJ

- 15. Two vessels separately contain two ideal gases A and B at the same temperature. The pressure of A being twice that of B. Under such conditions, the density of A is found to be 1.5 times the density of B. The ratio of molecular weight of A and B is : [2015 RS]
  - (a)  $\frac{3}{4}$  (b) 2 (c)  $\frac{1}{2}$  (d)  $\frac{2}{3}$
- 16. 4.0 g of a gas occupies 22.4 litres at NTP. The specific heat capacity of the gas at constant volume is  $5.0 \text{JK}^{-1}$ . If the speed of sound in this gas at NTP is 952 ms<sup>-1</sup>, then the heat capacity at constant pressure is (Take gas constant R =  $8.3 \text{ JK}^{-1} \text{ mol}^{-1}$ ) [2015 RS]
  - (a)  $7.5 \, \text{JK}^{-1} \, \text{mol}^{-1}$
  - (b) 7.0 JK<sup>-1</sup> mol<sup>-1</sup>
  - (c)  $8.5 \, \text{JK}^{-1} \, \text{mol}^{-1}$
  - (d) 8.0 JK<sup>-1</sup> mol<sup>-1</sup>
- 17. The molecules of a given mass of a gas have r.m.s. velocity of 200 ms<sup>-1</sup> at 27°C and  $1.0 \times 10^5$  Nm<sup>-2</sup> pressure. When the temperature and pressure of the gas are respectively, 127°C and  $0.05 \times 10^5$  Nm<sup>-2</sup>, the r.m.s. velocity of its molecules in ms<sup>-1</sup> is : [2016]
  - (a)  $100\sqrt{2}$  (b)  $\frac{400}{\sqrt{3}}$

(c) 
$$\frac{100\sqrt{2}}{3}$$
 (d)  $\frac{100}{3}$ 

- A gas mixture consists of 2 moles of O<sub>2</sub> and 4 moles of Ar at temperature T. Neglecting all vibrational modes, the total internal energy of the system is :- [2017]
  - (a) 15 RT (b) 9 RT
  - (c) 11 RT (d) 4 RT

## **Hints & Solutions**

#### EXERCISE - 1

(d) 2. (b) 3. (b) 4. (d) 1. Since  $v_{\rm rms}$  is doubled by increasing the temp. so by 5. (d)  $v_{rms} = \sqrt{\frac{3KT}{m}}$ , the temp. increase by four times. Now for constant pressure  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$  $V_1 = V, T_1 = T^{\circ}K, T_2 = 4T^{\circ}K, V_2 = ?$  $V_2 = 4V$ 7. (a) 8. 6. (d) (c) 9. (c) For a given pressure, volume will be more if temperature is more (Charle's law)



From the graph it is clear that  $V_2 > V_1 \Longrightarrow T_1 > T_2$ 

10. (c) At constant pressure 
$$V \propto T \implies \frac{\Delta V}{V} = \frac{\Delta T}{T}$$

Hence ratio of increase in volume per degree rise in kelvin temperature to it's origianl volume

$$= \frac{(\Delta V / \Delta T)}{V} = \frac{1}{T}$$
11. (d)  $C_v = dE/dT = \frac{3}{2}R$   
 $C_p = \frac{3}{2}R + R = \frac{5}{2}R = 2.5 R$ 

12. (c)  $v_{\rm rms} = \sqrt{\frac{3RT}{M}}$ . According to problem T will become 2T and M will becomes M/2 so the value of  $v_{\rm rms}$  will increase by  $\sqrt{4} = 2$  times i.e. new root mean square velocity will be 2v.

13. (d) The difference of  $C_P$  and  $C_V$  is equal to R, not 2R.

14. (b) 
$$\gamma = 1 + \frac{2}{f}, \Rightarrow \gamma - 1 = \frac{2}{f} \Rightarrow \frac{f}{2} = \frac{1}{\gamma - 1} \Rightarrow f = \frac{2}{\gamma - 1}$$

16. (a) 
$$v_{rms} \propto \frac{1}{\sqrt{M}} \Rightarrow (v_{rms})_1 < (v_{rms})_2 < (v_{rms})_3$$
 also in

mixture temperature of each gas will be same, hence kinetic energy also remains same.

17. (d) We know that PV = n R T = (m/M) R Twhere M = Molecular weight.

Now 
$$P \times \left(\frac{m}{d}\right) = \left(\frac{m}{M}\right) R T$$

where d = density of the gas

$$\frac{P}{d} = \frac{R T}{M} = \frac{k N_A T}{M} \qquad \dots (2)$$

where  $R = k N_A$ , k is Boltzmann constant.

But 
$$\frac{M}{N_A} = m = mass of each molecule so$$

$$d = \frac{P \times m}{kT}$$

18. (a)

19. (a) For one mole of gas 
$$v_{\rm rms} = \sqrt{\frac{3 \, \text{KI}}{M}}$$

$$1930 = \sqrt{\frac{3 \times 8.31 \times 300}{M}} \implies M = 2 \times 10^{-3} \text{ kg} = 2 \text{ g}$$

So that di-atomic gas is hydrogen.

20. (a) Here, initially 
$$P_1 = P$$
,  $V_1 = V + V = 2V$ ;  
Finally,  $P_2 = P$ ;  $V_2 = V$ 

As 
$$P_1V_1 = P_2V_2$$
 or  $P_2 = \frac{P_1V_1}{V} = \frac{P \times 2V}{V} = 2P$ 

21. (b) 
$$n = \frac{4}{2} = 2$$

- 22. (a) Based on Maxwell's velocity distribution curve.
- 23. (a, b, c)
- 24. (d) Both are diatomic gases and  $C_p C_v = R$  for all gases.
- 25. (d)  $P = \frac{2}{3}E$

#### EXERCISE - 2

$$T_{\rm B} = \frac{a}{\rm Rb} = \frac{27}{8} \left(\frac{8a}{27\rm Rb}\right) = \frac{27}{8} T_{\rm c} = 3.375 \, T_{\rm c}$$
$$= 3.375 \times 100 = 337.5^{\circ}\rm C$$

2. (c) 
$$v_{oxg.} = \sqrt{\frac{3R \times 289}{32}} \left( v_{rms} = \sqrt{\frac{3RT}{M}} \right)$$
  
 $v_{H} = \sqrt{\frac{3R \times 400}{2}}$  so  $v_{H} = 2230.59$  m/sec

5. (c) Let  $\gamma_1$  and  $\gamma_2$  denote the ratio of two specific heats of gas 1 and gas 2 respectively when they are mixed in the ratio of  $n_1$  and  $n_2$  mole. The resultant value of  $\gamma$  is the weighted mean of  $\gamma_1$  and  $\gamma_2$  i.e.,

$$\gamma = \frac{n_1 \gamma_1 + n_2 \gamma_2}{n_1 + n_2} = \frac{1(5/3) + 1(7/5)}{1+1}$$
$$= \frac{25 + 21}{15 \times 2} = \frac{46}{30} = 1.53$$

6. (a) 
$$\frac{c_2}{c_1} = \sqrt{\frac{400}{300}} = \frac{2}{\sqrt{3}} \implies c_2 = \frac{2}{\sqrt{3}} \times 200 = \frac{400}{\sqrt{3}} \text{ ms}^{-1}$$

7. (b) Since  $P = \frac{1}{3} \frac{mNv_{rms}^2}{V}$ 

since m is halved & speed is doubled so pressure become twice.

8. (b) Relative humidity (R.H) = 
$$\frac{S.V.P \text{ at dew point}}{S.V.P \text{ at room temp.}}$$

since here R.H is 100%  $\Rightarrow$  room temp. = dew point = 30°C

9. (c) 
$$v \propto \sqrt{T}$$
  $\therefore \frac{v'}{v} = \sqrt{\frac{T}{T}}$   
Given  $v' = 2v$  or,  $\frac{2}{1} = \sqrt{\frac{T}{T}}$   
 $\therefore T' = 4T = 4 \times 120K = 480 K$   
10. (a)  $P = \frac{1}{3}\rho v^{\overline{2}} = \frac{1}{3} \times (6 \times 10^{-2}) \times (500)^2$   
 $= 5 \times 10^3 \text{ N/m}^2$   
11. (b)  $(C_p)_{mix} = \frac{\mu_1 C_{p_1} + \mu_2 C_{p_2}}{\mu_1 + \mu_2}$   
 $(C_{p_1}(He) = \frac{5}{2}R \text{ and } C_{p_2}(H_2) = \frac{7}{2}R)$   
 $(C_p)_{mix} = \frac{1 \times \frac{5}{2}R + 1 \times \frac{7}{2}R}{1+1} = 3R = 3 \times 2 = 6 \text{ cal/mol.}^{\circ}C$   
 $\therefore$  Amount of heat needed to raise the temperature  
from 0°C to 100°C  
 $(\Delta Q)_p = \mu C_p \Delta T = 2 \times 6 \times 100 = 1200 \text{ cal}$   
12. (b) Average K.E.  $= \frac{1}{2}mc^2 = \frac{3}{2}kT \propto T$   
 $\therefore \frac{(Av.K.E.)_{600K}}{M} = \frac{600}{2} = 2$ 

- $(Av.K.E.)_{300K} = 300^{-2}$
- $\therefore$  At 600K it will be 2 times than that at 300K.

13. (a) V = 22.4 litre  $= 22.4 \times 10^{-3}$  m<sup>3</sup>, J = 4200 J/kcal by ideal gas equation for one mole of a gas,

$$R = \frac{PV}{T} = \frac{1.013 \times 10^5 \times 22.4 \times 10^{-3}}{273}$$
$$C_p - C_v = \frac{R}{J} = \frac{1.013 \times 10^5 \times 22.4}{273 \times 4200} = 1.979 \text{ kcal/kmol K}$$

14. (a) 
$$v_{\rm rms} = \left[\frac{(2)^2 + (3)^2 + (4)^2 + (5)^2}{4}\right]^{1/2} = \sqrt{\left[\frac{54}{4}\right]}$$

15. (a) 
$$c = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3 \times 10^5}{1.2}} = 500 \text{ ms}^{-1}$$

16. (c) Moles of He = 
$$\frac{2}{4} = \frac{1}{2}$$

Molecules = 
$$\frac{1}{2} \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$$

As there are 3 degrees of freedom corresponding to 1 molecule of a monatomic gas.

- $\therefore \text{ Total degrees of freedom} = 3 \times 3.01 \times 10^{23}$  $= 9.03 \times 10^{23}$
- 17. (a) Let T be the temperature of the mixture, then  $U = U_1 + U_2$

$$\Rightarrow \frac{f}{2}(n_1 + n_2) RT$$
  
=  $\frac{f}{2}(n_1) (R) (T_0) + \frac{f}{2}(n_2) (R) (2T_0)$   
$$\Rightarrow (2+4)T = 2T_0 + 8T_0 (\because n_1 = 2, n_2 = 4)$$
  
$$\therefore T = \frac{5}{3}T_0$$

18. (a) 
$$\frac{c_t}{c_0} = \sqrt{\frac{273 + t}{273}} \Rightarrow 4 \times 273 - 273 = t \Rightarrow t = 819^{\circ}C$$

19. (d) The r.m.s. velocity of the molecule of a gas of molecular weight M at Kelvin temperature T is given by,

$$v_{r.m.s.} = \sqrt{\frac{3RT}{M}}$$

Let  $M_O$  and  $M_H$  are molecular weight of oxygen and hydrogen and  $T_O$  and  $T_H$  the corresponding Kelvin temperature at which  $v_{r.m.s.}$  is same for both,

$$v_{r.m.s.} = \sqrt{\frac{3RT_O}{M_O}} = \sqrt{\frac{3RT_H}{M_H}}$$

Hence, 
$$\frac{T_O}{M_O} = \frac{T_H}{M_H}$$
  
 $T_o = 273^\circ + 47^\circ = 320 \text{ K}, M_o = 32, M_H = 2$   
 $T_H = \frac{2}{32} \times 320 = 20 \text{ K}$ 

20. (c) According to Dalton's Law  $P = P_1 + P_2$ .....

here 1 litre of orygen at a pressure of 1 atm, & 2 litre of nitrogen at a pressure of 5 atm are introduced in a vessel of 1 litre capacity.

so 
$$P = \frac{V_1P_1 + P_2V_2}{\text{volume of vessel}} = \frac{1 \times 1 + 2 \times .5}{1} = 2 \text{ atm}$$

21. (b) Relative humidity = 
$$\frac{\text{m}}{\text{M}} \times 100\%$$

where m is the mass of vapour actually present in certain volume of air & M is the mass required to saturate the air fully of that volume

so R.H = 
$$\frac{15}{20} \times 100 = 75\%$$

22. (c) By definition

$$\Rightarrow R.H = \frac{V.P \text{ at room temp.}}{S.V.P \text{ at room temp.}} \times 100; \frac{60}{100}$$

$$=\frac{(V.P.)_{15}}{12.67}$$

 $(V.P)_{15} = 7.6 \text{mm of Hg.}$ 

Now since unsaturated vapour obeys gas equation & mass of water remains constant so

$$\mathbf{P} = \left(\frac{\mathbf{n}\mathbf{R}\mathbf{T}}{\mathbf{V}}\right) \Longrightarrow \mathbf{P}\boldsymbol{\alpha}\mathbf{T}$$

$$\frac{(V.P)_{15}}{(V.P)_{20}} = \frac{273 + 15}{273 + 20} \Rightarrow (V.P)_{20} = 7.73 \text{ mm of Hg}$$

So 
$$(R.H)_{20} = \frac{(V.P)_{20}}{(S.V.P)_{20}} \times 100 = 44.5\%$$

23. (a) 
$$\frac{(v_{rms})_2}{(v_{rms})_1} = \sqrt{\frac{t+273}{327+273}}$$
 or  $\frac{1}{2} = \sqrt{\frac{t+273}{600}}$   
or  $t = -123^{\circ}C$ 

24. (a) 
$$\frac{P_1V_1}{T_1}$$
 = constant for one mole

&  $\frac{P_1}{T_1}$  = constant for constant volume

so 
$$\frac{P_1}{T_1} = \frac{1.004P_1}{(T_1 + 1)} \Rightarrow T_1 = 250K$$

25. (d) Total K.E. of A type molecules 
$$=\frac{3}{2}m\omega^2$$
  
Total K.E. of A type of molecule is

K.E<sub>A</sub> = 
$$\frac{1}{2}$$
 m  $\left[ (v_{r,ms})_x^2 + (v_{r,ms})_y^2 + (v_{r,ms})_z^2 \right]$ 

but  $(v_{r.ms})_x = \omega$ 

so  $(v_{r.ms})_y = (v_{r.ms})_z = \omega$ 

Total K.E. of B type molecules  $=\frac{1}{2} \times 2 \text{ m v}^2 = \text{m v}^2$ 

Now, 
$$\frac{3}{2} \times m \omega^2 = m v^2$$
 or  $(\omega^2 / v^2) = \frac{2}{3}$ 

26. (d)  $v_{rms} \propto \sqrt{T}$ At 0°C,  $v_{rms} \propto \sqrt{273}$ At temp. T,  $\frac{v_{rms}}{2} \propto \sqrt{T}$   $\therefore \frac{1}{2} = \frac{\sqrt{T}}{\sqrt{273}}$  or  $T = \frac{273}{4} = 68.2 \text{ K} \approx 69 \text{ K}$   $T = 69 - 273 = -204^{\circ} \text{ C}$ 27. (c) For a monatomic gas

$$C_v = \frac{3}{2}R$$

So correct graph is



28. (d) Molar volume = 
$$22400 \text{ cm}^3$$

Bubble volume = 
$$\frac{4}{3}\pi \frac{d^3}{8} = \frac{4}{3}\pi 10^{-3}$$

No. of molecules 
$$=\frac{6 \times 10^{23} \times 4\pi 10^{-3}}{22400 \times 3} \approx 10^{17}$$

- 29. (d) Molecule number ratio is  $H_2: O_2 = \frac{2}{3}: \frac{1}{3}$ .
  - That gives  $(c_{rms})^2 = 16\left(\frac{2}{3}\right) + 1\left(\frac{1}{3}\right)$  times the value for O<sub>2</sub>.

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$
 or  $P = \frac{RT}{V - b} - \frac{a}{V^2}$ 

At the critical point,  $P = P_c$ ,  $V = V_c$ , and  $T = T_c$ 

$$\therefore \quad P_{c} = \frac{RT_{c}}{V_{c} - b} - \frac{a}{V_{c}^{2}} \quad \dots(i)$$

At the critical point on the isothermal,  $\frac{dP_c}{dV_c} = 0$ 

:. 
$$0 = \frac{-RT_c}{(V_c - b)^2} + \frac{2a}{V_c^3}$$
 or  $\frac{RT_c}{(V_c - b)^2} = \frac{2a}{V_c^3}$  ....(ii)

Also at critical point,  $\frac{d^2 P_c}{dV_c^2} = 0$ 

$$\therefore \quad 0 = \frac{2RT_c}{(V_c - b)^3} - \frac{6a}{V_c^4} \text{ or } \frac{2RT_c}{(V_c - b)^3} = \frac{6a}{V_c^4} \quad ..(iii)$$

Dividing (ii) by (iii), we get

$$\frac{1}{2}(V_c - b) = \frac{1}{3}V_c \text{ or } V_c = 3 b \dots(iv)$$

Putting this value in (ii), we get

$$\frac{\text{RTc}}{4\text{ b}^2} = \frac{2\text{ a}}{27\text{ b}^3} \text{ or } \text{T}_{\text{c}} = \frac{8\text{ a}}{27\text{ b}\text{ R}} \quad \dots(\text{v})$$

Putting the values of  $V_c$  and  $T_c$  in (i), we get

$$P_{c} = \frac{R}{2b} \left( \frac{8a}{27bR} \right) - \frac{a}{9b^{2}} = \frac{a}{27b^{2}}$$

31. (c)  $\gamma$  for resulting mixture should be in between 7/5 and 5/3.

32 (b) For 1 molecule of a gas, 
$$v_{rms} = \sqrt{\frac{3KT}{m}}$$
  
where m is the mass of one molecule

For N molecule of a gas, 
$$v_1 = \sqrt{\frac{3KT \times N}{m}}$$
  
For 2N molecule of a gas  $v_2 = \sqrt{\frac{3KI \times N}{(2m)}} \times N$ 

$$\therefore \frac{v_1}{v_2} = 1$$

33. (a) Since  $VP^2 = constant$ ,

$$VP^2 = 2VP'^2$$
$$\therefore P' = \frac{P}{\sqrt{2}}$$

As  $\frac{P}{T}$  = constant or T  $\alpha$  P, thus T becomes T/ $\sqrt{2}$ 

34. (a) We know that, 
$$C_{rms} = \sqrt{\left(\frac{\gamma RT}{M}\right)}$$
  
Here  $C_{rms} \propto \sqrt{\frac{1}{M}}$ ;  $\therefore \frac{C_{rms_1}}{C_{rms_2}} = \sqrt{\left(\frac{m_2}{m_1}\right)}$ 

35. (b) 
$$F = \frac{dU}{dr} = -\frac{d}{dr} \left[ \frac{M}{r^3} - \frac{N}{R^{12}} \right] = -\left[ \frac{-6M}{r^2} + \frac{12N}{r^{13}} \right]$$
  
In equilibrium position,  $F = 0$   
 $\therefore \frac{6M}{r^2} - \frac{12N}{r^{13}} = 0$  or,  $r^6 = \frac{2N}{M}$   
 $\therefore$  Potential energy at equilibrium position  
 $U = \frac{M}{(2N/M)} = \frac{N}{(2N/M)^2} = \frac{M^2}{2N} - \frac{M^2}{4N} = \frac{M^2}{4N}$   
36. (b)  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$  Here,  $P_1 = 200kPa$   
 $T_1 = 22^\circ C = 295 \text{ K}$   $T_2 = 42^\circ C = 315 \text{ K}$   
 $V_2 = V_1 + \frac{2}{100} V_1 = 1.02V_1$   
 $\therefore P_2 = \frac{200 \times 315V_1}{295 \times 1.02V_1} = 209.37kPa$ 

$$P = \frac{nRT}{V - n\beta} - \frac{\alpha n^2}{V^2}$$
  
Work done,  $W = \int_{V_1}^{V_2} P dV = nRT \int_{V_1}^{V_2} \frac{dV}{V - n\beta} - \alpha n^2 \int_{V_1}^{V_2} \frac{dV}{V^2}$ 
$$= nRT \left[ \log_e (V - n\beta) \right]_{V_1}^{V_2} + \alpha n^2 \left[ \frac{1}{V} \right]_{V_1}^{V_2}$$
$$= nRT \log_e \left( \frac{V_2 - n\beta}{V_1 - n\beta} \right) + \alpha n^2 \left[ \frac{V_1 - V_2}{V_1 V_2} \right]$$

38. (d) Internal energy of 2 moles of oxygen

$$Uo_2 = \mu\left(\frac{5}{2}RT\right) = 2.\frac{5}{2}RT = 5RT$$

Internal energy of 4 moles of Argon.

$$U_{Ar} = \mu \left(\frac{3}{2}RT\right) = 4.\frac{3}{2}RT = 6RT$$

$$\therefore \text{ Total internal energy}$$
$$U = U_{O_2} + U_{Ar} = 11RT$$

39. (c) 
$$C_{v_{mix}} = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$
  
 $\Rightarrow \frac{13R}{6} = \frac{n_1 C_{v_1} + 2n_1 C_{v_2}}{n_1 + 2n_1} \qquad \left[ \because \frac{n_1}{n_2} = \frac{1}{2} \right]$   
 $\Rightarrow \frac{13R}{2} = C_{v_1} + 2C_{v_2}$ 

Possible values are,  $C_{v_1} = \frac{3R}{2}$ ,  $C_{v_2} = \frac{5R}{2}$ 

 $\therefore$  Gases are monatomic (like He) and diatomic (like N<sub>2</sub>)

40. (c) 
$$\frac{PV}{T} = nR = \left(\frac{m}{M}\right)R$$
 or  $\frac{PV}{T} = \left(\frac{R}{M}\right)m$ 

i.e.  $\frac{PV}{T}$  versus m graph is straight line passing

through origin with slope R/M, i.e. the slope depends on molecular mass of the gas M and is different for different gases.

41. (d) 
$$C_v$$
 for hydrogen =  $\frac{5}{2}R$ 

$$C_v$$
 for helium =  $\frac{3R}{2}$ 

$$C_v$$
 for water vapour =  $\frac{6R}{2} = 3R$ 

$$\therefore (C_v)_{mix} = \frac{4 \times \frac{5}{2}R + 2 \times \frac{3}{2}R + 1 \times 3R}{4 + 2 + 1} = \frac{16}{7}R$$
  
$$\therefore C_p = C_v + R$$
  
$$C_p = \frac{16}{7}R + R \text{ or } C_p = \frac{23}{7}R$$

42. (b)  $P = kV \Rightarrow PV^{-1} = k$ It is polytropic process ( $PV^n = constant$ ) So n = -1

So, 
$$C = C_V + \frac{R}{1-n} = C_V + \frac{R}{2}$$

43. (d)  $PV = \frac{m}{M}RT$ 

44.

Initially, 
$$PV = \frac{6}{M}R \times 500$$

Finally, 
$$\frac{P}{2}V = \frac{(6-x)}{M}R \times 300$$
 (if x g gas leaks out)

.....(1)

Hence, 
$$2 = \frac{6}{6-x} \times \frac{5}{3}$$
 :  $x = 1$  gram

(b) From graph,  $T^2V = \text{const.}$ As we know that  $TV^{\gamma-1} = \text{const}$ 

$$\Rightarrow VT^{\gamma-1} = cons. \qquad \dots (2)$$

On comparing (1) and (2), we get  $\Rightarrow \gamma = 3/2$ 

Also 
$$v_{rms} = \sqrt{\frac{3P}{\rho}}$$
 and  $v_{sound} = \sqrt{\frac{P\gamma}{\rho}}$   
 $\Rightarrow \frac{v_{rms}}{v_{sound}} = \sqrt{\frac{3}{\gamma}} = \sqrt{2}$ 

- 45. (b) For an ideal gas PV = constant i.e. PV doesn't vary with V.
- 46. (c) Molar specific heat at constant pressure  $C_P = \frac{7}{2}R$

Since, 
$$C_P - C_V = R \Longrightarrow C_V - C_P - R = \frac{7}{2}R - R = \frac{5}{2}R$$

$$\therefore \frac{C_P}{C_V} = \frac{(7/2)R}{(5/2)R} = \frac{7}{5}.$$

47. (c) For monatomic gas, f=3,

$$C_v = \frac{3R}{2}, C_p = \frac{5R}{2}; \frac{C_v}{C_p} = \frac{3}{5}$$

For diatomic gas, f = 5

$$C_v = \frac{5R}{2}, C_p = \frac{7R}{2}; \frac{C_v}{C_p} = \frac{5}{7}$$

48. (b) When a person is driving a car then the temperature of air inside the tyre is increased because of motion. From the Gay Lussac's law,

 $P \propto T$ 

Hence, when temperature increases the pressure also increase.

49. (b) Total translational kinetic energy  $=\frac{3}{2}nRT = \frac{3}{2}PV$ 

In an ideal gas all molecules moving randomly in all direction collide and their velocity changes after collision.

 (a) The mean free path of a gas molecule is the averge distance between two successive collisions. It is represented by λ.

$$\lambda = \frac{1}{\sqrt{2}} \frac{kT}{\pi \sigma^2 P}$$
 and  $\lambda = \frac{m}{\sqrt{2} \cdot \pi \sigma^2 d}$ 

Here,  $\sigma = 0$  diameter of molecule and k =Boltzmann's constant.

 $\Rightarrow \lambda \propto 1/d, \lambda \propto T \text{ and } \lambda \propto 1/P.$ 

Hence, mean free path varies inversely as density of the gas. It can easily proved that the mean free path varies directly as the temperature and inversely as the pressure of the gas.

#### EXERCISE - 3

#### **Exemplar Questions**

(b) As the relative velocity of molecule with respect to the walls of container does not change in rocket, due to the mass of a molecule is negligible with respect to the mass of whole system and system of gas moves as a whole and (g = 0) on molecule energy where. Hence pressure of the gas inside the vessel, as observed by us, on the ground remain the same.

2. (d) Pressure on the wall due to force exerted by molecule on walls due to its rate of transfer of momentum to wall.

In an ideal gas, when a molecule collides elastically with a wall, the momentum transferred to each molecule will be twice the magnitude of its normal momentum is 2 mv. For the wall *EFGH*, absorbs those molecules. Which strike to it so rate of change in momentum to it become only mv so the pressure of *EFGH* would half of *ABCD*.

3. (b) Boyle's law is applicable at constant temperature and temperature remains constant in isothermal process. For ideal gas, pV = nRT = constant

So, pV = constant (at constant temperature)

$$p \propto \frac{1}{V}$$

4.

5.

So, this process can be called as isothermal process.

(c) Let us consider the given diagram where an ideal gas is contained in a cylinder, having a piston of mass *M*. The pressure on gas does not change.



The pressure inside the gas will be  $p = p_a + Mg / A$ 

where,  $p_a$  = atmospheric pressure

A =area of cross-section of the piston.

Mg = weight of piston

Hence, p = constant.

As the piston and cylinder is frictionless so the equation for ideal gas

pV = nRT, volume (V) increases at constant pressure. as p, R, n are constant so,

$$V \propto T$$

so on increasing temperature of system its volume increased but p will remain constant.

 (a) As we know that an ideal gas equation, as the pressure and quantity of gas in system are constant

$$pV = nRT \Longrightarrow V = \left(\frac{nR}{p}\right)T$$

$$V \propto \frac{T}{p}$$
 as *n*, *R* are constant  $\frac{V}{T} \propto \left(\frac{1}{p}\right)$ 

Slope of the V - T graph,

$$m = \frac{dV}{dT} = \frac{nR}{p} \qquad [m = \text{slope of } V - t \text{ graph}]$$
$$\frac{dV}{dT} \propto \frac{1}{p} \text{ or } m \propto \frac{1}{p} \qquad [\because nR = \text{constant}]$$
So,  $p \propto \frac{1}{m}$ 

hence, 
$$\frac{p_1}{p_2} = \frac{m_2}{m_1}$$

where,  $m_1$  is slope of the graph corresponding to  $p_1$ and similarly  $m_2$  is slope corresponding to  $p_2$ . So slope of  $p_1$  is smaller than  $p_2$ . Hence,  $(p_1 > p_2)$ .

(d) Pressure exerted by gas is due to rate of change of momentum (p) imparted by particles to wall.
When the molecules breaks into atoms, the number of moles would become twice.
From ideal gas equation,

pV = nRT

6.

7.

8.

where, p = Pressure of gas, n = Number of moles R = Gas constant, T = temperature As gases breaks number of moles becomes twice of

initial, so  $n_2 = 2n_1$ 

So,  $p \propto nT$ 

or 
$$\frac{p_2}{p_1} = \frac{n_2 T_2}{n_1 T_1} = \frac{(2n_1)(3000)}{n_1(300)} = 20$$

So,  $p_2 = 20p_1$ 

Hence, final pressure of the gas would be 20 times to the initial pressure.

(b) For a function f<sub>1</sub>(v) the number of molecules (n) which will have their speeds between v and v + dv.
For each function f<sub>1</sub>(v) and f<sub>2</sub>(v) number of molecules remain same 1 mole each but due to mass difference their speed will be different.
Hence both gases of each function f<sub>1</sub>(v) and f<sub>2</sub>(v) will obey the Maxwell's distribution law separately.

(d) As we know that an ideal gas equation,  
$$pV = nRT$$

where, 
$$n =$$
 Number of moles,  $p =$  Pressure,  
 $V = V_{0}$  lump,  $P = C_{0}$  constant

V = Volume, R = Gas constant,

T = Temperature

$$n = \frac{pV}{RT}$$

If *n*, *R* are constant for the system or as number of moles of the gas remains fixed, hence, we can write

$$\frac{pV}{T} = \text{ constant}$$
  
or 
$$\frac{p_1V_1}{RT_1} = \frac{p_2V_2}{RT_2}$$

$$p_{2} = (p_{1}V_{1})\left(\frac{T_{2}}{V_{2}T_{1}}\right)$$

$$= \frac{(p)(V)(1.1 T)}{(1.05)V(T)} \qquad [p_{1} = p, V_{2} = 1.05 V]$$
and  $T_{2} = 1.1 T$ ]
$$= p \times \left(\frac{1.1}{1.05}\right)$$

$$= p (1.0476)$$

So, final pressure  $p_2$  will lies between p and 1.1p. NEET/AIPMT (2013-2017) Questions

9. (b) 
$$P_1 > P_2$$

10.



As  $V = constant \Rightarrow P \propto T$ Hence from V–T graph  $P_1 > P_2$ (d) From first law of thermodynamics

$$\Delta Q = \Delta U + \Delta W = \frac{3}{2} \cdot \frac{1}{4} R (T_2 - T_1) + 0$$
$$= \frac{3}{8} N_a K_B (T_2 - T_1) [\because K = \frac{R}{N}]$$

11. (b)  $\therefore P = \frac{1}{3} \frac{mn}{V} V_{\text{rms}}^2$ 

When mass is halved and speed is doubled then

Resultant pressure, 
$$P^t = \frac{1}{3} \times \frac{m}{2} \times \frac{n}{V} (2v_{\rm rms})^2$$
  
= 2 *P*.

(b) Mean free path  $\lambda_m = \frac{1}{\sqrt{2\pi} d^2 n}$ 12.

where d = diameter of molecule and d = 2r1

$$\therefore \ \lambda_m \propto$$

 $\therefore \ \lambda_m \propto \frac{1}{r^2}$ (b) Let 'n' be the degree of freedom 13.

$$\gamma = \frac{C_p}{C_v} = \frac{\left(\frac{n}{2} + 1\right)R}{\left(\frac{n}{2}\right)R} = \left(1 + \frac{2}{n}\right)$$

(a) Change in internal energy from  $A \rightarrow B$ 14.

$$\Delta U = \frac{f}{2} nR\Delta T = \frac{f}{2} nR (T_f - T_i)$$
$$= \frac{5}{2} \{P_f V_f - P_i V_i\}$$

(As gas is diatomic  $\therefore$  f=5)

$$= \frac{5}{2} \{2 \times 10^{3} \times 6 - 5 \times 10^{3} \times 4\}$$
$$= \frac{5}{2} \{12 - 20\} \times 10^{3} \text{ J} = 5 \times (-4) \times 10^{3} \text{ J}$$
$$\Delta U = -20 \text{ KJ}$$
(a) From PV = nPT

15. (a) 
$$From PV = nRT$$

$$P_{A} = \frac{\rho_{A}M_{A}}{RT} \text{ and } P_{B} = \frac{\rho_{B}M_{B}}{RT}$$
  
From question,  
$$\frac{P_{A}}{P_{B}} = \frac{\rho_{A}}{\rho_{B}}\frac{M_{A}}{M_{B}} = 2\frac{M_{A}}{M_{B}} = \frac{3}{2}$$
  
So, 
$$\frac{M_{A}}{M_{B}} = \frac{3}{4}$$

(d) Molar mass of the gas = 4g/mol16. Speed of sound

$$V = \sqrt{\frac{\gamma RT}{m}} \Rightarrow 952 = \sqrt{\frac{\gamma \times 3.3 \times 273}{4 \times 10^{-3}}}$$
$$\Rightarrow \gamma = 1.6 = \frac{16}{10} = \frac{8}{5}$$
$$Also, \gamma = \frac{C_P}{C_V} = \frac{8}{5}$$
$$So, C_P = \frac{8 \times 5}{5} = 8JK^{-1}mol^{-1} \ [C_V = 5.0 JK^{-1} \text{ given}]$$

17. (b) Here 
$$v_1 = 200 \text{ m/s}$$
;  
temperature  $T_1 = 27^{\circ}\text{C} = 27 + 273 = 300 \text{ k}$   
temperature  $T_2 = 127^{\circ}\text{C} = 127 + 273 = 400 \text{ k}, \text{V} = ?$   
R.M.S. Velocity,  $V \propto \sqrt{T}$ 

$$\Rightarrow \frac{v}{200} = \sqrt{\frac{400}{300}}$$
$$\Rightarrow v = \frac{200 \times 2}{\sqrt{3}} m/s \Rightarrow v = \frac{400}{\sqrt{3}} m/s$$

(c) Internal energy of the system is given by 18.

$$U = \frac{f}{2}nRT$$

Degree of freedom  $F_{diatomic} = 5$  $f_{monoatomic} = 3$ and, number of moles  $n(O_2) = 2$ n(Ar) = 4 $U_{total} = \frac{5}{2}(2)RT + \frac{3}{2}(4)RT = 11RT$