

# Chapter Thirteen

# KINETIC THEORY



## MCQ I

- 13.1** A cubic vessel (with faces horizontal + vertical) contains an ideal gas at NTP. The vessel is being carried by a rocket which is moving at a speed of  $500\text{ m s}^{-1}$  in vertical direction. The pressure of the gas inside the vessel as observed by us on the ground
- (a) remains the same because  $500\text{ m s}^{-1}$  is very much smaller than  $v_{rms}$  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  $(v_{rms}^2 + (500)^2) / v_{rms}^2$  where  $v_{rms}$  was the original mean square velocity of the gas.
  - (d) will be different on the top wall and bottom wall of the vessel.
- 13.2** 1 mole of an ideal gas is contained in a cubical volume  $V$ , ABCDEFGH at 300 K (Fig. 13.1). 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 be equal.
- (c) the pressure of EFGH would be double the pressure on ABCD.
- (d) the pressure on EFGH would be half that on ABCD.

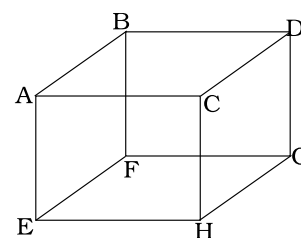


Fig. 13.1

**13.3** Boyle's law is applicable for an

- (a) adiabatic process.
- (b) isothermal process.
- (c) isobaric process.
- (d) isochoric process.

**13.4** 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 (Fig. 13.2). If the temperature is increased,

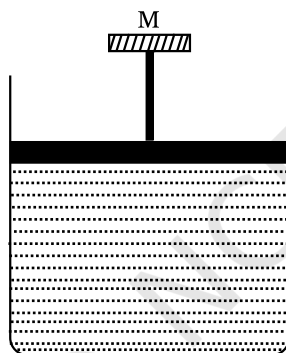


Fig. 13.2

- (a) both  $p$  and  $V$  of the gas will change.
- (b) only  $p$  will increase according to Charle's law.
- (c)  $V$  will change but not  $p$ .
- (d)  $p$  will change but not  $V$ .

**13.5** Volume versus temperature graphs for a given mass of an ideal gas are shown in Fig. 13.3 at two different values of constant pressure. What can be inferred about relation between  $P_1$  &  $P_2$ ?

- (a)  $P_1 > P_2$
- (b)  $P_1 = P_2$
- (c)  $P_1 < P_2$
- (d) data is insufficient.

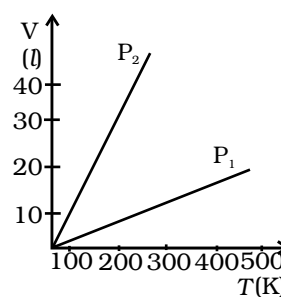


Fig.13.3

- 13.6** 1 mole of  $H_2$  gas is contained in a box of volume  $V = 1.00 \text{ m}^3$  at  $T = 300\text{K}$ . The gas is heated to a temperature of  $T = 3000\text{K}$  and the gas gets converted to a gas of hydrogen atoms. The final pressure would be (considering all gases to be ideal)
- same as the pressure initially.
  - 2 times the pressure initially.
  - 10 times the pressure initially.
  - 20 times the pressure initially.
- 13.7** A vessel of volume  $V$  contains a mixture of 1 mole of Hydrogen and 1 mole of 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
- $f_1(v) + f_2(v) = f(v)$  obeys the Maxwell's distribution law.
  - $f_1(v), f_2(v)$  will obey the Maxwell's distribution law separately.
  - Neither  $f_1(v)$ , nor  $f_2(v)$  will obey the Maxwell's distribution law.
  - $f_2(v)$  and  $f_1(v)$  will be the same.
- 13.8** 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
- $1.1 p$
  - $p$
  - less than  $p$
  - between  $p$  and  $1.1 p$ .

### MCQ II

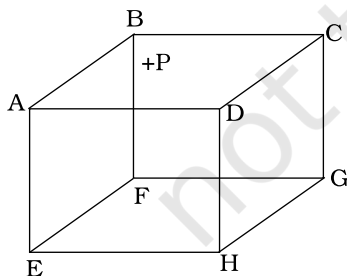


Fig. 13.4

- 13.9** ABCDEFGH is a hollow cube made of an insulator (Fig. 13.4). Face ABCD has positive charge on it. Inside the cube, we have ionized hydrogen.
- The usual kinetic theory expression for pressure
- will be valid.
  - will not be valid since the ions would experience forces other than due to collisions with the walls.
  - will not be valid since collisions with walls would not be elastic.
  - will not be valid because isotropy is lost.

- 13.10** Diatomic molecules like hydrogen have energies due to both translational as well as rotational motion. From the equation in

kinetic theory  $pV = \frac{2}{3} E$ ,  $E$  is

- (a) the total energy per unit volume.
- (b) only the translational part of energy because rotational energy is very small compared to the translational energy.
- (c) only the translational part of the energy because during collisions with the wall pressure relates to change in linear momentum.
- (d) the translational part of the energy because rotational energies of molecules can be of either sign and its average over all the molecules is zero.

**13.11** In a diatomic molecule, the rotational energy at a given temperature

- (a) obeys Maxwell's distribution.
- (b) have the same value for all molecules.
- (c) equals the translational kinetic energy for each molecule.
- (d) is (2/3)rd the translational kinetic energy for each molecule.

**13.12** Which of the following diagrams (Fig. 13.5) depicts ideal gas behaviour?

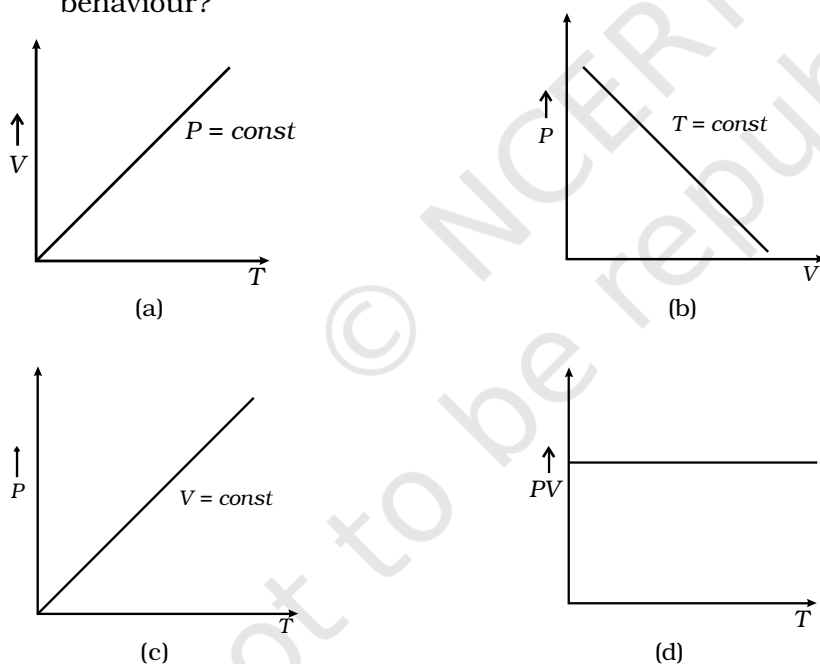


Fig. 13.5

**13.13** When an ideal gas is compressed adiabatically, its temperature rises: the molecules on the average have more kinetic energy than before. The kinetic energy increases,

- (a) because of collisions with moving parts of the wall only.
- (b) because of collisions with the entire wall.

- (c) because the molecules gets accelerated in their motion inside the volume.  
 (d) because of redistribution of energy amongst the molecules.

### VSA

- 13.14** Calculate the number of atoms in 39.4 g gold. Molar mass of gold is  $197 \text{ g mole}^{-1}$ .
- 13.15** The volume of a given mass of a gas at  $27^\circ\text{C}$ , 1 atm is 100 cc. What will be its volume at  $327^\circ\text{C}$ ?
- 13.16** The molecules of a given mass of a gas have root mean square speeds of  $100 \text{ m s}^{-1}$  at  $27^\circ\text{C}$  and 1.00 atmospheric pressure. What will be the root mean square speeds of the molecules of the gas at  $127^\circ\text{C}$  and 2.0 atmospheric pressure?
- 13.17** Two molecules of a gas have speeds of  $9 \times 10^6 \text{ m s}^{-1}$  and  $1 \times 10^6 \text{ m s}^{-1}$ , respectively. What is the root mean square speed of these molecules.
- 13.18** A gas mixture consists of 2.0 moles of oxygen and 4.0 moles of neon at temperature  $T$ . Neglecting all vibrational modes, calculate the total internal energy of the system. (Oxygen has two rotational modes.)
- 13.19** Calculate the ratio of the mean free paths of the molecules of two gases having molecular diameters  $1 \text{ \AA}$  and  $2 \text{ \AA}$ . The gases may be considered under identical conditions of temperature, pressure and volume.

### SA

$V_1$	$V_2$
$\mu_1, p_1$	$\mu_2, p_2$

Fig 13.6

- 13.20** The container shown in Fig. 13.6 has two chambers, separated by a partition, of volumes  $V_1 = 2.0$  litre and  $V_2 = 3.0$  litre. The chambers contain  $\mu_1 = 4.0$  and  $\mu_2 = 5.0$  moles of a gas at pressures  $p_1 = 1.00$  atm and  $p_2 = 2.00$  atm. Calculate the pressure after the partition is removed and the mixture attains equilibrium.
- 13.21** A gas mixture consists of molecules of types A, B and C with masses  $m_A > m_B > m_C$ . Rank the three types of molecules in decreasing order of (a) average K.E., (b) rms speeds.

- 13.22** We have 0.5 g of hydrogen gas in a cubic chamber of size 3cm kept at NTP. The gas in the chamber is compressed keeping the temperature constant till a final pressure of 100 atm. Is one justified in assuming the ideal gas law, in the final state? (Hydrogen molecules can be consider as spheres of radius  $1 \text{ \AA}$  ).
- 13.23** When air is pumped into a cycle tyre the volume and pressure of the air in the tyre both are increased. What about Boyle's law in this case?
- 13.24** A ballon has 5.0 g mole of helium at  $7^\circ\text{C}$ . Calculate  
 (a) the number of atoms of helium in the balloon,  
 (b) the total internal energy of the system.
- 13.25** Calculate the number of degrees of freedom of molecules of hydrogen in 1 cc of hydrogen gas at NTP.
- 13.26** An insulated container containing monoatomic gas of molar mass  $m$  is moving with a velocity  $v_0$ . If the container is suddenly stopped, find the change in temperature.

## LA

- 13.27** Explain why  
 (a) there is no atmosphere on moon.  
 (b) there is fall in temperature with altitude.
- 13.28** Consider an ideal gas with following distribution of speeds.

Speed (m/s)	% of molecules
200	10
400	20
600	40
800	20
1000	10

- (i) Calculate  $V_{rms}$  and hence  $T$ . ( $m = 3.0 \times 10^{-26} \text{ kg}$ )  
 (ii) If all the molecules with speed 1000 m/s escape from the system, calculate new  $V_{rms}$  and hence  $T$ .

- 13.29** Ten small planes are flying at a speed of 150 km/h in total darkness in an air space that is  $20 \times 20 \times 1.5 \text{ km}^3$  in volume. You are in one of the planes, flying at random within this space with no way of knowing where the other planes are. On the average about how long a time will elapse between near collision with your plane. Assume for this rough computation that a safety region around the plane can be approximated by a sphere of radius 10m.
- 13.30** A box of  $1.00\text{m}^3$  is filled with nitrogen at 1.50 atm at 300K. The box has a hole of an area  $0.010 \text{ mm}^2$ . How much time is required for the pressure to reduce by 0.10 atm, if the pressure outside is 1 atm.
- 13.31** Consider a rectangular block of wood moving with a velocity  $v_0$  in a gas at temperature  $T$  and mass density  $\rho$ . Assume the velocity is along  $x$ -axis and the area of cross-section of the block perpendicular to  $v_0$  is  $A$ . Show that the drag force on the block is  $4\rho Av_0\sqrt{\frac{kT}{m}}$ , where  $m$  is the mass of the gas molecule.