**Chapter – 13 Kinetic Theory**

1. **Assumptions of kinetic theory of gases:**

(i) A gas consists of a large number of identical, tiny, spherical, neutral and elastic particles called molecules.

(ii) In a gas molecules are moving in all possible directions with all possible speeds in accordance with **Maxwell's distribution law**.

(iii) The space occupied by the molecules is much smaller than the volume of the gas.

(iv) There is no force of attraction among the molecules.

(v) The pressure of a gas is due to elastic collision of gas molecules with the walls of the container.

(vi) The time of contact of a moving molecule with the walls of the container is negligible as compared to the time interval between two successive collisions on the same wall of the container.

2. **Pressure exerted by an ideal gas and root mean square speed:**



(i) Pressure P exerted by an ideal gas is given by: . **(1)**



where is the **mean square velocity**

m ,of each molecule and N, the total number of molecules in the vessel having volume V.

(ii) As mN = mass of gas, so (mN /V ) = ρ = density of gas; hence eqn. (1) takes the following form:



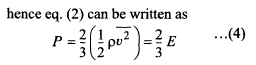


(iii) If we define root mean square speed as :



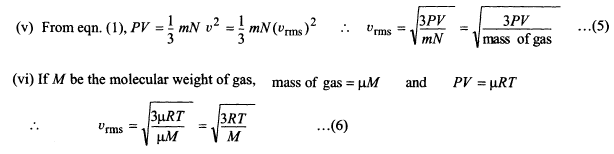
then eqn. (2) can be written as:

which is called as **Graham's Law of Diffusion.**



(iv) As KE/volume,

**i.e., Pressure of a gas is numerically equal to (2/3) of its KE per unit volume.**



3. **Some important points concerning root mean square speed:**

(i) For a given gas **Vrms α √T** i.e., *with rise in temperature (in Kelvin) rms speed of gas molecules increases*, e.g., if temperature is made four times, rms speed of a given gas molecule is doubled.

(ii) **For a given temperature** **Vrms α 1/√M** , i.e., *with increase in molecular weight rms speed of gas molecules decreases*, e.g rms speed of helium molecules is 4 times that of oxygen molecules at the same temperature.



(iii) At NTP the rms speed of hydrogen gas will be

**i,e., rms speed of gas molecules is of the order of km/s.**

(iv) As speed of sound in a gas Vs = √(γRT/M) hence Vs/Vrms = √(γ/3) i.e. Vs ≈ Vrms

**i.e., speed of sound in a gas is of the same order as rms speed of its molecules.**

**4. Different types of speeds of gas molecules:**

(i) **Root mean square speed**: It is defined as the square root of mean of squares of the speed of different molecules, i.e.,



and according to the kinetic theory of gases,

(ii) **Most probable speed**: It is the speed which has maximum number of molecules in a gas at constant

temperature and is given by:

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

i.e Vav = (v1+v2+…..+vn)/N

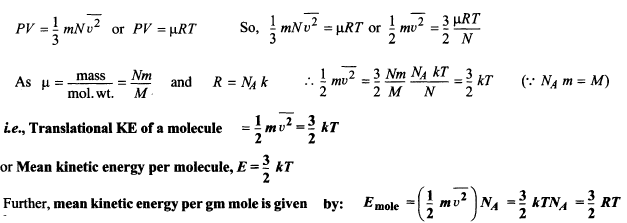


and according to kinetic theory of gases,



(b) **A planet or satellite will have atmosphere only and only if Vrms < Vescape = √(2gR)**

5. **Kinetic interpretation of temperature: Mean kinetic energy:** According to kinetic theory of gases,



(i) **Average translational KE of a gas molecule depends only on its temperature and is independent of its nature** i.e., molecules of different gases say He, H2 and O2, etc., at same temperature will have same translational kinetic energy though their rms speeds are different.

(ii) Mean kinetic energy of molecules is zero at absolute zero if gas continues to remain a gas at that temperature.



6. **Kinetic interpretation of pressure** : According to kinetic theory of gases,

So, the pressure of a gas is controlled by following three independent factors:

(i) **If volume and temperature of a gas are constant** : **P α mN** ie, P α mass of gas (as mN = mass of gas), i.e., if mass of gas is increased, number of molecules and hence number of collisions per sec increases, i.e., pressure will increase.

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

(iii) **If mass and volume of gas are constant**, **P α *v*2 α 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

7. **Kinetic interpretation of evaporation:**

(i) Evaporation is a slow process which takes place from the surface of a liquid at all temperatures.

(ii) Evaporation depends on:

(a) nature of liquid (boiling point) (b) temperature of liquid

(c) temperature of surroundings (d) air currents

(e) relative humidity (f) pressure

(iii) **Cooling results due to process of evaporation**: According to kinetic theory of gases at a given temperature in a liquid, molecules are moving in all possible directions with all possible speeds; so at all temperatures high speed molecules can escape from the surface, i.e., evaporation takes place at all temperatures. As high speed molecules have escaped, the energy and hence the temperature of remaining liquid will decrease, i.e., evaporation produces cooling. Further, greater the area of Liquid surface, greater will be the probability of escaping of high speed molecules and so greater will be the rate of evaporation.

**8.Mean free path** **and kinetic interpretation of Brownian motion**:

(i) Robert Brown discovered that pollen-grains suspended in water move following zig-zag paths when viewed under a microscope. This phenomenon is called Brownian motion.

(ii) The pollen-grains are hit successively and randomly by moving water molecules, i.e., in matter molecules are not at rest but moving in all possible directions with all possible velocities. **The average distance travelled by a gas molecule between two successive collisions is called mean free path**.



(iii) According to kinetic theory, it has been shown that the mean free path,

where d is the diameter of the molecule and n is the number of molecules per unit volume. This expression shows that **mean free path depends on nature of molecule (d) and with increase in n (i.e., density) it decreases.**

(iv) At NTP the mean free path for air molecules is 0.01 μm. But as PV = μRT =μ N kT,



so, n =N/V = P/kT Hence

9. **Degrees of freedom:**

(i) The term degrees of freedom of a system refers to the possible independent motions a system can have or number of possible independent ways in which a system can have energy.

(ii) The independent motions of a system can be translational, rotational or vibrational or any combination of these.

(iii) A particle in motion confined to a straight line has only one translational degree of freedom while if same particle is confined to move in a plane, it will have two translational degrees of freedom. If the particle is free to move in space, it will have three translational degrees of freedom.

(iv) If instead of particle, we consider a molecule of a monoatomic gas (like **He, Ar,** etc.) which consists of a single atom, the translational motion can take place in any direction in space, i.e., it can be resolved along three co-ordinate axes and can have three independent motions and **3 degrees of freedom all translational**. A monoatomic molecule can also rotate but due to its small moment of inertia rotational KE is insignificant. Therefore, it does not possess rotational degrees of freedom.

(v) The molecules of a **diatomic gas** such as (H2 , O2 etc.) are made of two atoms joined rigidly to one another through a bond. This cannot only move bodily, but also rotate about two of 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. Hence, it can have only 2 rotational motions. **Thus, a diatomic molecule has 5 degrees of freedom: 3 translational and 2 rotational.**

(vi) A **non-linear polyatomic molecule** (such as CO2, H2O) can rotate about any of three co-ordinate axes. **Hence, it has 6 degrees of freedom: 3 translational and 3 rotational.**

(vii) In case of diatomic or polyatomic molecules, the atoms within the molecule may also vibrate with respect to each other. In such cases, the molecule will have an additional degree of freedom, due to vibrational motion. An object which vibrates in one dimension has two additional degrees of freedom: **one for the PE and one for the KE of vibration.**

This is why:

(a) **A diatomic molecule that is free to vibrate will have 7(i.e., 2 +3 +2) degrees of freedom.**

(b) **An atom in a solid though has no degrees of freedom for translational and rotational motion, but due to vibration along 3 axes has 3 x 2 = 6 degrees of freedom.**

10. **Law of equipartition of energy:**

(i) According to law of equipartition of energy, energy of a gas molecule is equally distributed among its various degrees of freedom and each degree of freedom is associated with energy ½kT ,where k is Boltzmann constant and T temperature of the gas in Kelvin.

(ii) According to equipartition theorem, the mean energy of an ideal gas molecule (i.e., monoatomic gas) will be 3kT/2 as it has 3 degrees of freedom.

(iii) For diatomic and polyatomic gases the average energy per molecule will be 5kT/2 and 6kT/2 respectively ,i.e., **at same temperature gases with different degrees of freedom (e.g., He and H2) will have different average energy or internal energy [though all have same average translational kinetic energy equal to average energy of an ideal gas molecule, i.e., (3/2)kT.**

(iv) If we consider μ moles of an ideal (monoatomic) gas, the total number of molecules in the gas will be μNA as one mole contains NA molecules (with NA as Avogadro's number).



As energy of one molecule is (3/2)kT the internal energy of the gas will be

So, in general, the internal energy of μ moles of a gas in which each molecule has *f* degrees of freedom, will be **U =μfRT/2**

for example, for **diatomic gas**, *f* =5, so **U =5μRT/2 ; while** for **polyatomic gas**, *f* =6, so **U = 3μRT**

11. **Gas-laws**:

**(l) Boyle's law**: According to it, for a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure, i.e **V α 1/P** if mass of gas and T = constant

Graphical forms of the law are as follows



(ii) **Charles' law**: According to it, for a given mass of an ideal gas at constant pressure, volume of a gas is directly proportional to its absolute temperature, i.e., **V α T** if m and P = constant

Graphical form of the law is

(iii) **Gay-Lussac's law:** According to it, for a given mass of an ideal gas at constant volume, pressure of a gas is directly proportional to its absolute temperature, i.e., **P α T** if m and V = constant

Graphical form of the law is

(iv) **Avogadro's law:** According to it, at same temperature and pressure, equal volumes of all the gases contain equal number of molecules, i.e., N1 = N2 if P,V and T are same.

(v) **Graham's law:** According to it, at constant pressure and temperature, the rate of diffusion of a gas is inversely proportional to the square root of its density, i.e., Rate of diffusion α 1/√ρ , if P and T = constant

(vi) **Dalton's law**: According to it, the pressure exerted by a gaseous mixture is equal to the sum of partial pressure of each component present in the mixture, i.e., P = P1+P2+...

12. **Ideal gas equation:**

(i) A relation connecting macroscopic properties pressure, volume and temperature of a gas describes the state, i.e., physical condition of the system and is called equation of state.

(ii) For a system containing N particles of a gas, when macroscopic properties P,V and T are studied through experiments, it was found that: **V α N**; if P and T are constant

- **V α 1/P** if N and T are constant.

-- **V α T** if P and N are constant.

Combining all these, we get **V α NT/P i.e. PV/NT = constant = k**  The constant k is called Boltzmann's constant.

(iii) As number of moles,μ =m/M =N/NA

hence, **PV/μT = NAk = R** [ because NAk = R ] i.e. PV =μRT with R = 8.316 J/mol K

This equation is called **equation of state for an ideal gas** and R, the universal gas constant. The equation

of state for 1 mole of an ideal gas will therefore be:

**PV = RT ('.' μ = 1)**

**Recap of important points**

**Gas Laws :**

1.**Boyle’s law (Isothermal law)** :Volume of a given mass of an ideal gas is inversely proportional to its pressure at constant absolute temperature.

*V* α1/P or *PV* = constant or *P*1*V*1 = *P*2*V*2

2. **Charle’s Law (Isobaric law)** :Volume of a given mass of an ideal gas is directly proportional to its absolute temperature at constant pressure.

*V* α*T or*  *V/T = constant or V1/T1 =V2/T2  or Vi  = V0 (1 + t /273)*

*3.* **Pressure Law (Isochoric law)** :

Pressure of a given mass of an ideal gas is directly proportional to its absolute temperature at constant volume.

*P* α *T or P/T = constant or P1/T1 =P2/T2  or Pi  = P0 (1 + t /273)*

4.**Ideal Gas Equation** :From the gas law it is clear that pressure, volume and temperature of a given mass of an ideal gas are interrelated. This relation is called Ideal gas equation.

*PV* = *nRT or P*1*V* 1/T1 = P2V2/T2

*PV* = *nRT = (m RT /M ) or m/V = PM/RT = ρ*

5. **Avogadro’s hypothesis** :One mole of each substance contains same number of particles. It is *N* = 6.02 x 1023 particles per gram-mole

6.**Dalton’s law of partial pressure** :The pressure exerted by a mixture of mutually inert gases is the sum of the pressures exerted by the individual gases (their partial pressures) occupying the same volume alone.

The pressure that a gas would exert if it occupied the container alone and if it behaved perfectly is called the partial pressure of the gas.

*P = Σpi* where *pi = ni RT/V*

*7.***Grahm’s law of diffusion** :Rate of diffusion of a gas is inversely proportional to square root of the density of the gas

*r α* 1/√ρ

8. *C*P – *CV =*  *R* called Mayor’s result, and *C*P/*CV =*  *γ* called poisson’s ratio.

CP & CV for a mixture of gases of no. of moles n1 and n2

CP = (n1CP1 + n2CP2)/(n1+n2) ; CV = (n1CV1 + n2CV2)/(n1+n2)

9. Kirchoff’s law :

At any node (point where two or more than two conductors meet) the net rate of inflow of heat is always same as the net rate of outflow of heat.

*Σhin = Σhout*

To apply Kirchoff’s law in a thermal circuit, consider one node at a time. Consider currents in all branches connected to that node as incoming to the node. Put the sum of all these currents equal to zero. Repeat this for all the nodes with unknown temperature.

10.Wein’s Displacement Law : According to this law,the wavelength (λm) of maximum intensity of emission of black body radiation is inversely proportional to absolute temperature (T) of the black body i.e.

λm α 1/T =b/T , where b is called wein’s constant.

11.Pressure due to an ideal gas :

P =1/3 ρC2 where C is rms speed of gas molecules

P= 2 E /3 where E is the K.E. of translation per unit volume of gas.

12. Specific heat capacity of Mono , Dia and Triatomic gases

(a) In monoatomic gases a molecule has 3 degrees of freedom

Average energy per molecule per degree of freedom = ½ kBT

Average energy per molecule with 3 degrees of freedom = 3/2 kBT

The total internal energy of one gram mole of monoatomic gases U = 3/2 kBT x NA = 3/2RT

if dU is small amount of heat energy required to raise the temperature of 1 gm mole of the gas at constant volume thru a temperature dT, then

dU = CV.1.dT or CV = dU/dT

Therefore CV = 3R/2 ; CP= 5R/2 ; γ = CP/ CV = 5/3 =1.67

(b) In Diaatomic gases a molecule has 5 degrees of freedom

Therefore CV = 5R/2 ; CP= 7R/2 ; γ = CP/ CV = 7/5 =1.4

(c) In Triatomic gases a molecule has 7 degrees of freedom

Therefore CV = 7R/2 ; CP= 9R/2 ; γ = CP/ CV = 9/7 =1.28

**Home Assignment- Kinetic Theory of Gases**

1. What are the different assumptions in the molecular model of an ideal gas?
2. Derive an expression for the pressure exerted by a gas?
3. Derive relation between the Kinetic energy of molecules and temperature ?
4. State theorem of equipartition of energy ?
5. Find an expression for RMS speed ?
6. Find expression for Cv of monoatomic gases ?
7. Define and find expression for **γ ?**
8. Define an adiabatic process and find relation between P-V ,V-T & P-T for an adiabatic process
9. Write expressions for RMS , average and most probable speed of molecules ?
10. Derive an expression for the mean free path and collision frequency ?
11. Write all points in “**Recap of important points”** as given in notes.
12. Define an ideal gas?
13. What do you mean by Avogadro’s hypothesis?
14. Find the numerical value of gas constant ‘R’?
15. What is expression for γ for polyatomic gases in terms of degrees of freedom?
16. Find relation between γ and n ,where n denotes degrees of freedom?
17. Derive an expression for molar specific heat of solid?
18. Write an expression for mean free path in terms of (a) number density & diameter of molecule

(b) Boltzmann’s constant , temperature T and pressure P

1. What do you mean by Brownian motion?
2. Obtain the dimensional formula of gas constant R?
3. The ratio of vapour densities of two gases at the same temperature is 8:9.Compare the rms velocities of their molecules?
4. Two gases A & B each at temperature T, Pressure P and Volume V are mixed. If the mixture be at same temperature T and it’s volume is also V , then what should be its pressure?

**NCERT**

1. A flask contains argon and chlorine in the ratio of 2:1 by mass. The temperature of the mixture is 27 °C. Obtain the ratio of (i) average kinetic energy per molecule, and (ii) root mean square speed *v*rms of the molecules of the two gases. Atomic mass of argon = 39.9 u; Molecular mass of chlorine = 70.9 u.
2. Estimate the fraction of molecular volume to the actual volume occupied by oxygen gas at STP. Take the diameter of an oxygen molecule to be 3 Å
3. An air bubble of volume 1.0 cm3 rises from the bottom of a lake 40 m deep at a temperature of 12 °C. To what volume does it grow when it reaches the surface, which is at a temperature of 35 °C ?
4. Estimate the total number of air molecules (inclusive of oxygen, nitrogen, water vapour and other constituents) in a room of capacity 25.0 m3 at a temperature of 27 °C and 1 atm pressure.
5. At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the rms speed of a helium gas atom at – 20 °C? (atomic mass of Ar = 39.9 u, of He = 4.0 u).

**Exemplar**

1. Calculate the number of atoms in 39.4 g gold. Molar mass of gold is 197g/mole.
2. Two molecules of a gas have speeds of 9 x 106 m/s and 1 x 106m/s, respectively. What is the root mean square speed of these molecules.
3. 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.)
4. Calculate the ratio of the mean free paths of the molecules of two gases having molecular diameters 1A0 and 2 A0. The gases may be considered under identical conditions of temperature, pressure and volume.
5. A gas mixture consists of molecules of types A, B and C with masses *mA* > *mB* > *mC* . Rank the three types of molecules in decreasing order of (a) average K.E., (b) rms speeds.
6. 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?
7. Calculate the number of degrees of freedom of molecules of hydrogen in 1 cc of hydrogen gas at NTP.
8. An insulated container containing monoatomic gas of molar mass *m* is moving with a velocity *vo*. If the container is suddenly stopped, find the change in temperature.
9. Explain why (a) there is no atmosphere on moon. (b) there is fall in temperature with altitude.

**Objective Kinetic Theory of Gases**

1.Which of the following gases possesses maximum rms velocity, all being at the same temperature?

(a) Oxygen (b) Air (c) Carbon dioxide (d) Hydrogen.

2. Hydrogen has maximum rms speed at NTP because:

(a) it is the lightest gas (b) it absorbs heat rapidly

(c) it is a good conductor of heat (d) it has only one electron in its atom

3. 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

(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 gas enclosed

4. If the masses of all molecules of a gas are halved and their speeds doubled, then the ratio of initial and final pressures would be: (a) 2 : 1 (b) l: 2 (c) 4:1 (d) 1:4

5. At a given volume and temperature the pressure of a gas

(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

6. If the Avogadro’s number was to tend to infinity; the phenomenon of Brownian motion would :

(a)remain completely unaffected

(b)become more vigorous than that observed with present finite values of Avogadro's number, for all sizes of the Brownian particles

(c)become more vigorous than that observed with the present finite value of Avogadro's number, only for

relatively large Brownian particles

(d) become practically unobservable as the molecular impact would tend to balance one another for practically all sizes of Brownian particles

7. Two vessels A and B having equal volume contain equal masses of hydrogen in A and helium in B at 300 K. Then mark the correct statement.

(a) The pressure exerted by hydrogen is half that exerted by helium.

(b) The pressure exerted by hydrogen is equal to that exerted by helium.

(c) Average KE of the molecules of hydrogen is half the average KE of the molecules of helium.

(d) The pressure exerted by hydrogen is twice that exerted by helium

8. A closed vessel A having volume V contains N2 at pressure P and temperature T. Another closed vessel B having the same volume V contains He at the same pressure P but temperature 2T. The ratio of masses of N2 and He in the vessels A and B is: (a) l:2 (b) 3:2 (c) 5:2 (d) l4: I

9. By what percentage should the pressure of a given mass of a gas be increased so as to decrease its volume by 10% at a constant temperature? (a) 8.1% (b) 9.1 % (c) 10.1% (d) l1.l%

10. To expel half the mass of air from a large flask at 270 C it must be heated to:

(a) 540C (b) 1770C (c) 2770C (d) 3270C

11. 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 which are maintained at a temperature T. The mean square of the velocity of molecules of B type is denoted by v2 and the mean square of the X component of the velocity of A type is denoted by w2; then w2/v2 is : (a) 2 (b) 1 (c) ⅓ (d) ⅔

12. A sample of gas is at 00C; to what temperature must it be raised in order to double the rms speed of its molecules :(a) 103 0C (b) 273 0C (c) 819 0C (d) 1092 0C

13. The temperature of gas is produced by :

(a) the potential energy of its molecule (b) the kinetic energy of its molecules

(c) the attractive force between its molecules (d) the repulsive force between its molecules

14. The root mean square velocity of the gas molecules is 300m/3. What will be the root mean square speed of the molecules if the atomic weight is doubled and absolute temperature is halved

(a) 300 m/s (b) 150 m/s (c) 600 m/s (d) 75 m/s

15. RMS velocity of a particle is vrms at pressure P. If pressure is increased to two times , then rms velocity becomes (a) 2vrms (b) 3vrms (c) 0.5 vrms (d) vrms

16. A closed vessel of fixed volume contains a mass m of an ideal gas, the root mean square speed being *v*. Additional mass m of the same gas is pumped into the vessel and the pressure rises to 2P,the temperature remaining the same as before. The root mean square speed of the molecules now is :

(a) v/√2 (b) v √2 (c) 2v (d) v

17. The total KE of all the molecules of helium having a volume V exerting a pressure P is 1500 J. The total KE (in joules) of all the molecules of N2 having the same volume V and exerting a pressure 2P is:

(a) 3000 (b) 4000 (c) 5000 (d) 6000

18. Nitrogen is in equilibrium state at T = 421K. The value of most probable speed *Vmp*  is :

(a) 400 m/s (b) 421 m/s (c) 500 m/s (d) 600 m/s

19. Half a mole of helium at 27 0C and at a pressure of 2 atmosphere is mixed with 1.5 mole of N2 at 77 0C and at a pressure at 5 atmosphere so that the volume of the mixture is equal to the sum of their initial volumes. If the temperature of the mixture is 690C, its pressure is:

(a) 3.5 atm (b) 3.8 atm (c) 3.95 atm (d) 4.25 atm

20. A sample of a perfect gas occupies a volume V at a pressure P and absolute temperature T. The mass of each molecule is m. Which of the following expressions gives the density of the gas?

(a) mkT (b) m/V (c) Pm/kT (d) P/kTV

21. The root mean square velocity, Vrms, the average velocity Vavg and the most probable velocity Vmp of the molecules of the gas are in the order : (a) Vmp > Vavg > Vrms (b) Vrms > Vavg > Vmp (c) Vavg > Vmp > Vrms (d) Vmp > Vrms > Vavg

22. The relation between rms velocity, Vrms , and the most probable velocity Vmp of a gas is:

(a) Vmp = Vrms (b) Vrms =√(3/2) Vmp (c) Vrms = √(2/3) Vmp (d) Vrms = (2/3) Vmp

23. The root mean square velocity of the molecules of a gas is 1260 m/s. The average speed of the molecules is: (a) 1029 m/s (b) 1161 m/s (c) 1671 m/s (d) 917 m/s

24. The root mean square velocity of the molecules of a gas is 1260 m/s. The most probable velocity of the molecules is: (a) 1029 m/s (b) 1161 m/s (c) 1671 m/s (d) 917 m/s

25. If the intermolecular forces vanish away, the volume occupied by the molecules contained in 4.5 kg water at STP will be given by (a) 5.6 m3 (b) 4.5 m3 (c) 11.2 m3 (d) 5.6 litre

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

(a) High pressure and high temperature (b) Low pressure and low temperature

(c) Low pressure and high temperature (d) High pressure and low temperature

27. Consider 1 cc sample of air at absolute temperature To at sea level and another 1 cc sample of air at a height, where pressure is one-third atmosphere. The absolute temperature T of the sample at the height is:

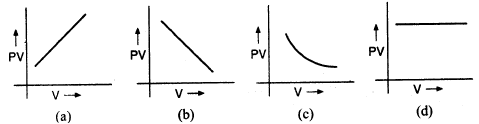
(a) equal to (To/3) (b) equal to (3/To )

(c) equal to To (d) cannot be determined in terms of To from the above data

28. The equation of state corresponding to 8 g of 02 is.

(a) PV = 8RT b) PV = RT/4 (c) PV = RT (d) PV = RT/2

29. Which one of the following graphs represents the behaviour of an ideal gas



30. Two thermally insulated vessels 1 and 2 are filled with air at temperatures (T1 ,T2), volume (V1,V2 ) and pressure (P1 , P2 ) respectively. If the valve joining the two vessels is opened, the temperature inside the vessel at equilibrium will be:



31. The root mean square velocity of 02 at atmospheric pressure and at 00C is:

(a) more than that of air (b) less than that of air

(c) equal to that of air (d) nothing can be said

32. Equal volume of monoatomic and diatomic gases at the same temperature are given equal quantities of heat. Then: (a) the temperature of diatomic gas will be more (b) the temperature of monoatomic gas will be more (c) the temperature of both will be zero (d) nothing can be said

33. A gas at a temperature of 250 K is contained in a closed vessel. If the gas is heated through l0C, the percentage increase in its pressure is nearly: (a) 0.4 % (b) 0.6 % (c) 0.8 % (d) l %

34. If the pressure in a closed vessel is reduced by drawing out some of the gas, the mean free path of two molecules: (a) is increased (b) is decreased

(c) remains unchanged (d) increases or decreases according to the nature of the gas

35. We have a jar A filled with gas characterised by parameters P,V and T and another jar B filled with gas with parameters 2P, V/4 and 2T, when the symbols have their usual meanings. The ratio of the number of molecules of jar A to those of jar B is (a) l:1 (b) 1:2 (c) 2:1 (d) 4: I

36. A container has N molecules at absolute temperature T. If the number of molecules is doubled but kinetic energy in the box remains the same as before, the absolute temperature of the gas is:

(a) T (b) T/2 (c) 2T (d) zero

37. 10,000 small balls, each weighing 1 g, strike one square cm of area per second with a velocity 100 m/s in a normal direction and rebound with the same velocity. The value of pressure on the surface will be:

(a) 2 x 103 N/m2 (b) 2 x 105 N/m2 (c) 107 N/m2 (d) 2 x 107 N/m2

38. Some gas at 300 K is enclosed in a container. Now, the container is placed on a fast moving train. While the train is in motion, the temperature of the gas:

(a) rises above 300 K (b) falls below 300 K

(c) remains unchanged (d) becomes unsteady

39. During an experiment an ideal gas is found to obey an additional Law VP2 = constant. The gas is initially at temperature T and volume V, when it expands to volume 2V , the resulting temperature is

(a) T/2 (b) 2T (c) √2T (d) T/√2

40. A vessel has 6 g of hydrogen at pressure P and temperature 500 K. 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? (a) 2g (b) 3g (c) 4g (d) 1g

41. The gas in a vessel is subjected to a pressure of 20 atmosphere at a temperature 270 C. The pressure of the gas in the vessel after one half of the gas is released from the vessel and the temperature of the remainder is raised by 500C, is:(a) 8.5 atm (b) 10.8 atm (c) 11.67atm (d) 17 atm

42. One gram mole of nitrogen occupies 2 x 104 cc at a pressure of 106 dynes/cm2. The average energy of a nitrogen molecule (in erg) will be: (Avogadro's number = 6 x 1023 )

(a) 14 x 10-13 (b) 10 x 10-12 (c) 106 (d) 2 x 106

43. If oxygen (O2) has root mean square velocity of C m/s then root mean square velocity of hydrogen (H2 ) will be: (a) C m/s (b) 1/C m/s (c) 4C m/s (d) C/4 m/s

44. The mass of oxygen gas occupying a volume of 11.2 litres at a temperature 270C and a pressure of 760 mm of mercury is: (a) 0.001456 kg (b) 0.01456 kg (c) 0.1456 kg (d) 1.1456 kg

45. A gas is heated through 10C in a closed vessel. Its pressure is increased by 0.4%. The initial temperature of the gas is: :(a) 250 0C (b) 100 0C (c) -75 0C (d) -23 0C

46. A balloon contains 1500 m3 of helium at 270C and 4 atmospheric pressure. The volume of helium at -30C

temperature and 2 atmospheric pressure will be:

(a) 1500 m3 (b) 1700 m3 (c) 1900 m3 (d) 2700 m3

47. If the pressure and temperature of an ideal gas is doubled and volume is halved, the number of molecules of the gas:

(a) remains constant (b) becomes half (c) becomes two times (d) becomes four times

48. A gas at pressure Po is contained in a vessel. If the masses of all the molecules are halved and their speeds doubled, the resulting pressure would be: (a) 4Po  (b) 2Po  (c) Po  (d) Po/2

49. Pressure versus temperature graph of the ideal gas at constant volume V of an ideal gas is shown(fig 12.4) by a straight line A. Now, pressure P 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

50. One mole of an ideal gas undergoes a process

Here Po and Vo are constants. Change in temperature of the gas when volume is changed from V = Vo to V = 2Vo is:

51.In the process PV = constant, pressure (P) versus density (ρ), graph of an ideal gas is:

(a) a straight line parallel to P-axis (b) a straight line parallel to ρ-axis

(c) a straight line passing through origin (d) a parabola

52. The root mean square speed of hydrogen molecules at a certain temperature is 300 m/s. If the temperature is doubled and hydrogen gas dissociates into atomic hydrogen, the rms speed will become:

(a) 424.26 m/s (b) 300 m/s (c) 600 m/s (d) 150 m/s

53. The pressure versus temperature graphs of an ideal gas are as shown in fig (12.5).Chose the wrong statement.

(a) Density of gas is increasing in graph (i).

(b) Density of gas is decreasing in graph (ii).

(c) Density of gas is constant in graph (iii).

(d) None of the above.

54. If gas molecules undergo inelastic collision with the wall of the container:

(a) the temperature of the gas will decrease (b) the pressure of the gas will increase

(c) neither the temperature nor the pressure will change (d) the temperature of the gas will increase



55. Pressure versus temperature graph of an ideal gas is as shown in fig 12.6.Density of the gas at point A is ρo. Density at point B will be :

(a) 3 ρo /4 (b) 3 ρo /2 (c) 4 ρo /3 (d) 2 ρo

56.The quantity PV/kT ;(k = Boltzmann's constant) represents:

(a) number of moles of the gas (b) total mass of the gas

(c) number of molecules in the gas (d) density of the gas

57. 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

58. Two identical containers A and B with frictionless pistons contain the same ideal gas at the same temperature and the same volume V. The mass of gas A is mA and that of B is mB . The gas in each cylinder is now allowed to expand isothermally to the same final volume 2V.The change in the pressure in A and B are found to be ∆P and 1.5 ∆P respectively. Then:

(a) 4mA = 9mB (b) 3mA = 3mB (c) 3mA = 2mB (d) 9mA = 4mB

59. Two balloons are filled, one with pure He gas and other by air, respectively. If the pressure and temperature of these balloons are same, then the number of molecules per unit volume is:

(a) more in the He filled balloon (b) same in both balloons

(c) more in air filled balloon (d) in the ratio of I : 4

60. The root mean square speeds of molecules of ideal gases at the same temperature are:

(a) the same (b) inversely proportional to the square root of the molecular weight

(c) directly proportional to the molecular weight (d) inversely proportional to the molecular weight

61. The temperature of a gas contained in a closed vessel increases by 20C,when the pressure is increased by 2%.The initial temperature of the gas is: (a) 200 K (b) 100 K (c) 2000C (d) 1000C

62. At a certain temperature, radius of an air bubble is doubled when it comes to the top from the bottom of a mercury column of height 'h'. If the pressure at the top is two atmospheres, the value of 'h' (in metres) is:

(a) 5.5 (b) 10.64 (c) 12.45 (d) 15.00

63. If the rms velocity of a gas is *v*, then

(a) *v* 2 T = constant (b) *v* 2 /T = constant (c) *v* T2 = constant (d) *v* is independent of T

64. If the earth did not have atmosphere, the temperature would be:

(a) too variable (b) more (c) same (d) none of these

65.A bubble is at the bottom of the lake of depth *h*. As the bubble comes to sea level, its radius increases three times. If atmospheric pressure is equal to *l* metres of water column, then *h* is equal to:

(a) 26 *l* (b) *l* (c) 25 *l* (d) 30 *l*

66. At what temperature the kinetic energy of a gas molecule is half of the value at 270C?

(a) 13.5 0C (b) 150 0C (c) 75K (d) 13.5K (d) -123K (e) none of these

67. one litre of oxygen at a pressure of 1 atm and two litres of nitrogen at a pressure of 0.5 am are introduced into a vessel of volume I L. If there is no change in temperature, the final pressure of the mixture of gas (in-atm) is:-(a) 1.5 (b) 2.5 (c) 2 (d) 4

68.One kg of a diatomic gas is at a pressure of 8 x 104 N/m2. The density of the gas is 4 kg/m3. What is the energy of the gas due to its thermal motion ;

(a) 3 x 104 J (b) 5 x 104 J (c) 6 x 104 J (d) 7 x 104 J

69. The temperature at which protons in proton gas would have enough energy to overcome Coulomb barrier of 4.14 x 10-14 J is: (Boltzmann constant 1.38 x 10-23 JK-l)

(a) 2 x 109 K (b) 109 K (c) 6 x 109 K (d) 3 x 109 K (e) 4.5 x 109 K

70. Two monoatomic ideal gases A and B occupying the same volume V, are at the same temperature T and pressure P. If they are mixed, the resultant mixture has volume V and temperature T. The pressure of the mixture is: (a) P (b) P/2 (c) 4P (d) 2P

71. When the temperature of a gas is increased : (a) its molecular kinetic energy increases.

(b) molecular potential energy decreases and molecular kinetic energy also decreases; total energy remaining constant

(c) molecular potential energy increases and molecular kinetic energy decreases; total energy remaining constant

(d) its molecular potential energy increases.

72. A vessel contains 32 gm of 02 at temperature T. The pressure of the gas is P. An identical vessel containing 4 gm of H2 at a temperature 2T has a pressure of: (a)8P (b) 4P (c) P (d) P/8

73. The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K, the root mean square speed of gas molecules is v, then at 480 K it will be: (a)4v (b) 2v (c) v/2 (d) v/4



74. The density (ρ)versus pressure (P) graphs of a given mass of an ideal gas is shown(fig 12.9) at two temperatures T1 and T2. Then relation between T1 and T2 may be:

(a) T1 >T2 (b) T2 >T1 (c) T1 = T2  (d) all the three are possible

75. Let V, Vrms and Vmp, 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 the molecule is m Then :

(a) no molecule can have a speed greater than √2Vrms

(b) no molecule can have a speed less than Vmp /√2

(c) V < Vmp < Vrms

(d) the average kinetic energy of the molecule is ¾ m V2mp

76. Three perfect gases at absolute temperatures T1, T2 and T3 are mixed. The masses of molecules are m1 ,m2 and m3 the number of molecules are n1 , n2 and n3 respectively. Assuming that each gas has F degrees of freedom and no loss of energy, the final temperature of the mixture is [AIEEE 2011]

77. The potential energy function for the force between two atoms in a diatomic molecule is approximately given by U(x) = a/x12 - b/x6 ,where a and b are constants and x is the distance between the atoms. If the dissociation energy of the molecules is D = [ U(x = ∞) – Uat equilibrium].Then D is [AIEEE 2010]

(a) b2/2a (b) b2/12a (c) b2/4a  (d) b2/6a

78. One kg of a diatomic gas is at a pressure of 8 x 104 Nm-2. The density of the gas is 4 kgm-3. What is the energy of the gas due to its thermal motion? [AIEEE 2009]

(a) 3 x 104 J (b) 5 x 104 J (c) 6 x 104 J (d) 7 x 104 J

79. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V1, and contains ideal gas at pressure P1, and temperature T1. The other chamber has volume V2, and contains ideal gas at pressure P2 and temperature T2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be : .

[AIEEE 2008 ,04 ]



80. If CP and CV, denote the specific heats of nitrogen per unit mass at constant pressure and constant volume respectively, then (a) CP - CV = R/28 (b) CP - CV = R/14 (c) CP - CV = R (d) CP - CV = 28 R

81. Two rigid boxes containing different ideal gases are placed on a table. Box A contains one mole of nitrogen at temperature To, while box B contains one mole of helium at temperature (7/3) To. The boxes are then put into thermal contact with each other, and heat flows between them until the gases reach a common

final temperature (Ignore the heat capacity of boxes). Then, the final temperature of the gases, TF, in terms of To is (a) TF = 3To/7 (b) TF = 7To/3 (c) TF = 3To/2 (d) TF = 5To/2 [AIEEE 2006]

82. A gaseous mixture consists of 16 g of helium and 16 g of oxygen. The ratio CP/CV of the mixture is :

(a) 1.59 (b) 1.62 (c) 1.4 (d) 1.54 [AIEEE 2005]

83. One mole of ideal monoatomic gas (γ = 5/3) is mixed with one mole of diatomic gas (γ = 7/5 ). What is γ for the mixture ? (a) 3/2 (b) 23/15 (c) 35/23 (d) 4/3 [AIEEE 2004]

84. One mole of a gas (γ = 7/5) is mixed with one mole of a gas (γ = 5/3 ). What is γ for the mixture ?

(a) 7/5 (b) 2/5 (c) 24/16 (d) 12/7 [AIEEE 2002]

85. At what temperature is the rms velocity of a hydrogen molecule equal to that of an oxygen molecule at 470C : (a) 80K (b) -73K (c) 3K (d) 20K [AIEEE 2002]

**Answers Objective (Kinetic theory Of Gases)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. D | 1. A | 1. D | 1. B | 1. C | 1. D |
| 1. D | 1. D | 1. D | 1. D | 1. D | 1. C |
| 1. B | 1. B | 1. D | 1. D | 1. A | 1. C |
| 1. B | 1. C | 1. B | 1. B | 1. B | 1. A |
| 1. A | 1. C | 1. D | 1. B | 1. D | 1. C |
| 1. B | 1. B | 1. A | 1. A | 1. D | 1. B |
| 1. D | 1. C | 1. C | 1. D | 1. C | 1. A |
| 1. C | 1. B | 1. D | 1. D | 1. B | 1. B |
| 1. B | 1. B | 1. C | 1. C | 1. C | 1. C |
| 1. B | 1. C | 1. C | 1. C | 1. B | 1. B |
| 1. B | 1. B | 1. B | 1. A | 1. A | 1. E |
| 1. C | 1. B | 1. A | 1. D | 1. A | 1. B |
| 1. B | 1. B | 1. D | 1. A | 1. C | 1. B |
| 1. A | 1. A | 1. C | 1. B | 1. A | 1. C |
| 1. D |  |  |  |  |  |

**Answers Explanations Objective Questions- Kinetic Theory of Gases**

