PHYSICS OF CLASS XI
CHAPTER – 13 KINETIC THEORY

Q.1. Is molar specific heat of a solid a constant quantity?

Ans. Yes, the molar specific heat of a solid is a quantity as its value is 3 cal/mol-K.

Q.2. What is the number of degree of freedom of a bee flying in a room?

Ans. Three, because bee is free to move along x-direction or y-direction or z-direction.

Q.3. If a molecule having N atoms has k number of constraints, how many degree of freedom does the gas possess?

Ans. Degree of freedom f = 3N – K.

Q.4. Calculate the ratio of the mean free paths of the molecules of two gases having moleculer diameters 1 A and 2 A. The gases may be considered under identical conditions of temperature, pressure and volume.

Ans. As, we know, mean free path, $\lambda \propto \frac{1}{d^2}$

Given, d_1 = 1 A and d_2 = 2A $\Longrightarrow$ $l_1 : l_2$ = 4 : 1

Q.5. What is mean free path of a gas?

Ans. The average distance travelled by a molecule between two successive collisions is known as mean free path of the molecule.

Q.6. How is mean free path depends on number density of the gas?

Ans. The mean free path is inversely proportional to the number density of the gas.

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Q.7. The specific heat of argon at constant volume is 0.075 kcal $kg^{-1}K^{-1}$, then what will be its atomic weight? [Given, R = 2 cal mol^{-1} K^{-1}]

Ans. Argon is a monotonic gas, so

$$C_V = \frac{3}{2}R = \frac{3}{2}\times 2 = 3 \text{ cal mol}^{-1}\text{K}^{-1}$$

$$C_V = Mc_v$$

$$\Longrightarrow \quad M = \frac{C_V}{c_v} = \frac{3}{0.075} = 40$$

Q.8. If there are f degrees of freedom with n moles of a gas, find the internal energy possessed at a temperature T.

Ans. For 1 mole with f degrees of freedom,

Internal energy, $U = 1 \times C_V \times T = \frac{f}{2}RT$

For n moles, $U = nC_VT = \frac{nf}{2}RT$

Q.9. How degree of freedom of a gas molecule is related with the temperature?

Ans. Degree of freedom will increase when temperature is very high because at high temperature, vibrational motion of the gas will contribute to the kinetic energy. Hence, there is an additional kinetic energy associated with the gas, as a result of increased degree of freedom.

Q.10. Name an experimental evidence in support of random motion of gas molecules.

Ans. Brownian motion and diffusion of gases provide experimental evidence in support of random motion of gas molecules.

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Q.11. Equal masses of monoatomic and diatomic gases are supplied heat at the same temperature, pressure and volume.

If same amount of heat is supplied to both the gases, which of them will undergo greater temperature rise?

Ans. For monoatomic gas, temperature rise will be greater because monoatomic gas possesses only translational degree of freedom whereas diatomic gas translation, rotation and vibrational (at higher temperature), so temperature size for diatomic gases is lower.

Q.12. Although velocity of air molecules is very fast but fragnance of a perfume spreads at a much slower rate, explain?

Ans. This is because scent vapour molecules do not travel uninterrupted, they undergo a number of collisions and trace a zig-zag path, due to which their effective displacement per unit time is low so spreading is at a much slower rate.

Q.13. In terms of kinetic theory of gases, explain why the pressure of a gas in a container increases when a gas is heated?

Ans. When a gas is heated, its temperature increases. The increase in temperature increases the pressure of the gas due to following reasons

(i) With the increase in temperature of the gas, the velocity of gas molecules increases. Therefore, the number of collisions per second against the walls of the container and so does the gas pressure.

(ii) Due to increased velocity, the transfer of momentum per second to the walls increases and so does the pressure.

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Q.14. Adiamotic gas is heated in a vessel to a temperature of 10000 K. If each molecule possess an average energy E_1. After sometime a few molecule escape into the atmosphere at 300 K. Due to which their energy changes to E_2 . Calculate the ratio of $\frac{E_1}{E_2}$.

Ans. Number of degrees of freedom of diatomic gas at 10000 K = 7.

Number of degrees of freedom of diatomic gas at 300 K = 5

$\therefore \frac{E_1}{E_2} = \frac{\left(\frac{7}{2}\right)k_B T_1}{\left(\frac{5}{2}\right)k_B T_2} = \frac{7}{2} \times \frac{T_1}{T_2} = \frac{7}{5} \times \frac{10000}{300} = \frac{140}{3}$

Q.15. Calculate the number of degrees of freedom of molecules of hydrogen in 1 cc of hydrogen gas at NTP.

Ans. Volume occupied by 1 g mole gas at NTP = 22400 cc

∴ Number of molecules in 1cc of hydrogen

$$= \frac{6.023 \times 10^{23}}{22400} = 2.688 \times 10^{19}$$

As each diatomic molecule has five degrees of freedom, hydrogen being diatomic also has five degrees of freedom.

∴ Total number of degrees of freedom = $5 \times 2.688 \times 10^{19}$

$$= 1.3444 \times 10^{20}$$

Q.16. Give a formula for mean free path of the molecules of a gas. Briefly explain how its value is affected by (i) change in temperature and (ii) change in pressure.

Ans. As, we know that the value of mean free path of the molecules of a given gas is given by

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Mean free path, $\lambda = \frac{1}{\sqrt{2}\pi n d^2}$

Here, n = number of gas molecules present in unit volume of given gas and d = moleculer diameter.

(i) Effect of temperature As temperature of a gas is increased at constant pressure, volume of gas increases and hence n, the number of molecules pet unit volume decrease. In fact

$$n \propto \frac{1}{V} \text{ and } V \propto T, \text{ thus } n \propto \frac{1}{T}$$

Due to decrease in moleculer number density, the value of mean free path of the gas increase i.e., $\lambda \propto \frac{1}{n} \propto T$. Thus, pressure remaining constant the mean free path of a gas is direct proportional to its absolute temperature.

(ii) Effect of pressure At constant temperature, on increasing pressure the volume V decrease the moleculer number density n increases and consequently the mean free path decreases

i.e., $p \propto \frac{1}{V} \propto n$

∴ $\lambda \propto \frac{1}{n}$ or $\lambda \propto \frac{1}{p}$

Thus, at a constant temperature the mean free path of a gas is inversely proportional to its pressure.

Q.17. Calculate the number of degrees of freedom in 15 cm^3 of nitrogen at NTP.

Ans. Number of nitrogen molecule in 22400 cm^3 of gas at NTP

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$= 6.023 \times 10^{23}$

∴ Number of nitrogen molecule's in 15 cm^3 of gas at NTP

$$= \frac{6.023\times10^{23}\times15}{22400} = 4.03 \times 10^{20}$$

Number of degree of freedom of nitrogen (diatomic) molecule at 273 K = 5

∴ Total degree of freedom of 15 cm^3 of gas

$$= 4.03 \times 10^{20} \times 5 = 2.015 \times 10^{21}$$

Q.18. What is basic law followed by equipartition of energy?

Ans. The law of equipartition of energy for any dynamical system in thermal equilibrium, the total energy is distributed equally amongst all the degrees of freedom. The energy associated with each molecule per degree of freedom is $\frac{1}{2}$ k_BT where, k_B is constant and T is temperature of the system.

Q.19. A cylinder of fixed capacity contains 44.8 L of helium gas at STP. Calculate the amount of heat required to raise the temperature of container by 15°C? [given R = 8.31 J $mol^{-1}K^{-1}$]

Ans. At STP, 1 mole of gas occupy 22.4 L of volume.

∴ Moles of helium in container, $\mu = \frac{44.8}{22.4}$ = 2 moles

Now, helium is monoatomic so, $C_v = \frac{3}{2}$ R

Change in temperature,

$$\Delta T = T_2 - T_1 = (15 + 273)K - 273K = 15K$$

$$= 288K - 273K = 15K$$

∴ Volume of gas remain constant

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∴ $\Delta W = p\Delta V = 0 \Rightarrow \Delta Q = \Delta U + \Delta W$

Amount of heat required, $\Delta Q = \Delta U = \mu C_V \Delta T$

$$= 2 \times \frac{3}{2} R \times 1.5 = 45\ R$$

$$= 45 \times 8.31 = 374\ J$$

Q.20.(i) What do you understand by specific heat capacity of water?

(ii) If one mole of ideal monoatomic gas (y = 5/3) is mixed with one mole of diatomic gas (y = 7/5). What is the value of y for the mixtures?

(here, y represents the ratio of specific heat at constant pressure to that at constant volume)

Ans. (i) Refer to text

(ii For diatomic gas, $C_V = \frac{3}{2}R$

For diatomic gas, $C_v' = \frac{5}{2}R$

Let, μ and μ' be moles of mono and diatomic gases then, C_V (mixture) = $\frac{\mu C_V + \mu' C_V'}{\mu + \mu'}$

$$C_V = \frac{1 \times \frac{3}{2}R + 1 \times \frac{5}{2}R}{1+1} = 2R$$

$$Y\ (\text{mixture}) = 1 + \frac{R}{C_{V(mixture)}} = 1 + \frac{R}{2R} = 1.5$$

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