CHAPTER 13

Kinetic Theory

TRY YOURSELF — ANSWERS

1. At low pressure and high temperature, real gases behaves like ideal gases.

2. $PV = nRT = \frac{M}{M_0}RT$

or $V = \frac{MRT}{M_0 P}$

or $V = \frac{2\times10^{-3}\times8.31\times300}{32\times10^{-3}\times1.01\times10^{5}}$

or $V = 1.53\times10^{-3}\ \text{m}^3 = 1.53$ litre

3. $P = \frac{RT\rho}{M_0}$

where ρ is is the mass density and M_0 is the molar mass of the gas.

4. Atoms are much freer in gases. The interatomic spacing is maximum (about 10 Å) in gases. Thus, the interatomic forces are much weaker in gases as compared to solids and liquids.

5. Specific gas constant (r) : For one gram of gas, gas constant is,

$r = \frac{R}{M}$

where M is the molecular weight of the gas. As M is different for different gases, therefore, gas constant (r) for one gram of gas is different for different gases.

6. The ratio of number of molecules will be 1 : 1, as per Avagadro's law.

7. For a given mass of an ideal gas at constant temperature, the volume of a gas is inversely proportional to its pressure.

i.e., $V \propto \frac{1}{P}$ or PV = constant or $P_1V_1 = P_2V_2$.

8. $V_1 = 160\ \text{cm}^3$, $T_1 = (91 + 273)\ \text{K} = 364\ \text{K}$

$V_2 = ?$, $T_2 = (0.00°\text{C} + 273)\ \text{K} = 273\ \text{K}$

According to Charles' law,

$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow V_2 = \frac{V_1T_2}{T_1}$

$\therefore\ V_2 = \frac{160\ \text{cm}^3\times273\ \text{K}}{364\ \text{K}} = 120\ \text{cm}^3$

9. Ideal gas law: $PV = nRT$

Boyle's law: $PV = C \Rightarrow C = nRT$

Thus, C depends on n or quantity of the gas enclosed and T the temperature.

10. Gay Lussac's law is known as Charles' law for pressure.

11. According to kinetic theory of gases, the collision between molecules is perfectly elastic.

12. For each molecule, the force will be $2mv$.

$\therefore$ Total force on the surface $= 2mNv$

$= 2\times4\times10^{-30}\times10^{23}\times10^{7} = 8$ N

Pressure $= \frac{\text{Force}}{\text{Area}} = \frac{8\ \text{N}}{4\ \text{m}^2} = 2\ \text{Pa}$

13. $E = \frac{3}{2}k_BT$ or $E \propto T$

The average translation kinetic energy of a gas only depends on absolute temperature of a gas. It is independent of pressure, volume or nature of the gas.

14. Root mean square speed, $v_{rms} = \sqrt{\frac{3RT}{M}}$

$\therefore\ \frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{T_{O_2}}{T_{H_2}}\times\frac{M_{H_2}}{M_{O_2}}}$ As $T_{H_2} = T_{O_2}$ (Given)

$\therefore\ \frac{(v_{rms})_{O_2}}{(v_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \sqrt{\frac{1}{16}} = \frac{1}{4}$

15. The graph representing Maxwell's distribution of speeds of gas molecules indicates that, at most probable speed (v_{mp}), the number of molecules is maximum.

16. Total number of degrees of freedom of a rigid diatomic molecule is 5.

i.e., 3 + 2 = 5 degrees of freedom.

Rigid diatomic molecules have 3 translational degrees of freedom and 2 rotational degrees of freedom.

17. The average energy of a molecule in a diatomic gas excluding vibration is $\frac{5}{2}k_BT$ whereas if the molecule is vibrating then the average energy is given by $\frac{7}{2}k_BT$ because the degree of freedom in this case is 7.

18. $C_V = \frac{R}{0.67} = 1.5\,R = \frac{3}{2}R$

This is the value of C_V for a monatomic gas.

19. In case of linear triatomic gas molecules, there are seven degrees of freedom. The total internal energy of a mole of such a gas is

$$U = 7\times\frac{1}{2}k_BT\times N_A = \frac{7}{2}RT$$

$$C_V = \frac{dU}{dT} = \frac{d}{dT}\left(\frac{7}{2}RT\right) = \frac{7}{2}R$$

From, $C_P - C_V = R$, $C_P = \frac{9}{2}R$

$$\therefore \quad \gamma = \frac{C_P}{C_V} = \frac{9}{7}$$

20. Mean free path, $\lambda \propto 1/P$ *i.e.*, if λ is doubled then pressure P becomes half.