13. HEAT & THERMODYNAMICS

Total translational K.E. of gas = $\frac{1}{2} M < V > = \frac{3}{2}$ PV = $\frac{3}{2}$ nRT

$< V > = \frac{3P}{\rho}$ $\qquad V_{rms} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3RT}{M_{mol}}} = \sqrt{\frac{3KT}{m}}$

Important Points :

$V_{rms} \quad \sqrt{T}$ $\qquad \overline{V} = \sqrt{\frac{8KT}{\pi m}} = 1.59\sqrt{\frac{KT}{m}}$ $\qquad V_{rms} = 1.73\sqrt{\frac{KT}{m}}$

Most probable speed $V_p = \sqrt{\frac{2KT}{m}} = 1.41\sqrt{\frac{KT}{m}}$

$\therefore V_{rms} > \overline{V} > V_{mp}$

Degree of freedom :

Mono atomic f = 3

Diatomic f = 5

polyatomic f = 6

Maxwell s law of equipartition of energy :

Total K.E. of the molecule = $\frac{1}{2}$ f KT

For an ideal gas :

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

Workdone in isothermal process : $\qquad W = [2.303 \text{ nRT} \log_{10} \frac{V_f}{V_i}]$

Internal energy in isothermal process : $\qquad \Delta U = 0$

Work done in isochoric process : $\qquad dW = 0$

Change in int. energy in isochoric process :

$\Delta U = n\frac{f}{2}R\Delta T$ = heat given

Isobaric process :

Work done $\Delta W = nR(T_f \quad T_i)$

change in int. energy $\Delta U = nC_V \Delta T$

heat given $\Delta Q = \Delta U + \Delta W$

Specific heat : $\qquad C_V = \frac{f}{2}R \qquad Cp = \left(\frac{f}{2}+1\right)R$

Molar heat capacity of ideal gas in terms of R :

(i) for monoatomic gas : $\qquad \frac{C_p}{C_v} = 1.67$

(ii) for diatomic gas : $\qquad \frac{C_p}{C_v} = 1.4$

(iii) for triatomic gas : $\frac{C_p}{C_v} = 1.33$

In general : $\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$

Mayer s eq. $C_p \quad C_v = R$ for ideal gas only

Adiabatic process :

Work done $\Delta W = \frac{nR(T_i - T_f)}{\gamma - 1}$

In cyclic process :

$\Delta Q = \Delta W$

In a mixture of non-reacting gases :

Mol. wt. $= \frac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$

$$C_v = \frac{n_1 C_{v_1} + n_2 C_{v_2}}{n_1 + n_2}$$

$$\gamma = \frac{C_{p(mix)}}{C_{v(mix)}} = \frac{n_1 C_{p_1} + n_2 C_{p_2} + ...}{n_1 C_{v_1} + n_2 C_{v_2} + ...}$$

Calorimetry and thermal expansion

Types of thermometers :

(a) Liquid Thermometer : $T = \frac{\ell - \ell_0}{\ell_{100} - \ell_0} \quad 100$

(b) Gas Thermometer :

Constant volume : $T = \frac{P - P_0}{P_{100} - P_0} \quad 100$; $P = P_0 + \rho g h$

Constant Pressure : $T = \frac{V}{V - V} \quad T_0$

(c) Electrical Resistance Thermometer :

$$T = \frac{R_t - R_0}{R_{100} - R_0} \quad 100$$

Thermal Expansion :

(a) Linear :

$\alpha = \frac{\Delta L}{L_0 \Delta T}$ or $L = L_0 (1 + \alpha \Delta T)$

(b) Area/superficial :

$\beta = \frac{\Delta A}{A_0 \Delta T}$ or $A = A_0 (1 + \beta \Delta T)$

(c) volume/ cubical :

$$r = \frac{\Delta V}{V_0 \Delta T} \qquad \text{or} \qquad V = V_0 (1 + \gamma\, \Delta T)$$

$$\boxed{\alpha = \frac{\beta}{2} = \frac{\gamma}{3}}$$

Thermal stress of a material :

$$\frac{F}{A} = Y \frac{\Delta \ell}{\ell}$$

Energy stored per unit volume :

$$E = \frac{1}{2} K (\Delta L)^2 \qquad \text{or} \qquad E = \frac{1}{2} \frac{AY}{L} (\Delta L)^2$$

Variation of time period of pendulum clocks :

$$\Delta T = \frac{1}{2} \quad \Delta \theta T$$

T < T - clock-fast : time-gain

T > T - clock slow : time-loss

CALORIMETRY :

Specific heat $S = \dfrac{Q}{m.\Delta T}$

Molar specific heat $C = \dfrac{\Delta Q}{n.\Delta T}$

Water equivalent $= m_W S_W$

HEAT TRANSFER

Thermal Conduction : $\dfrac{dQ}{dt} = KA \dfrac{dT}{dx}$

Thermal Resistance : $R = \dfrac{\ell}{KA}$

Series and parallel combination of rod :

(i) **Series :** $\dfrac{\ell_{eq}}{K_{eq}} = \dfrac{\ell_1}{K_1} + \dfrac{\ell_2}{K_2} + ...$ (when $A_1 = A_2 = A_3 = ...$)

(ii) **Parallel :** $K_{eq} A_{eq} = K_1 A_1 + K_2 A_2 + ...$ (when $\ell_1 = \ell_2 = \ell_3 = ...$)

for absorption, reflection and transmission

$$r + t + a = 1$$

Emissive power : $E = \dfrac{\Delta U}{\Delta A\,\Delta t}$

Spectral emissive power : $E_\lambda = \dfrac{dE}{d\lambda}$

Emissivity : $e = \dfrac{\text{E of a body at T temp.}}{\text{E of a black body at T temp.}}$

Kirchoff s law : $\dfrac{E\,(\text{body})}{a\,(\text{body})} = E\ (\text{black body})$

Wein s Displacement law : $\lambda_m \,.\, T = b.$

$$b = 0.282\ \text{cm-k}$$

Stefan Boltzmann law :

$u = \sigma T^4$ $\qquad$ $s = 5.67 \quad 10^{8}\ W/m^2\,k^4$

$\Delta u = u \quad u_0 = e\,\sigma A\,(T^4 \quad T_0^4)$

Newton’s law of cooling : $\dfrac{d\theta}{dt} = k\,(\theta \quad \theta_0)$; $\theta = \theta_0 + (\theta \quad \theta_0)\,e^{kt}$