Model Answer

AS – 2775 (A)

B.Sc. III rd sem – 2013 Exam

(For Forensic Sc.)

Physics

(Heat and thermodynamics – I)

Section – A

Q.1. (i) — (a) 680 Joule

(ii) — (c) Adiabatic curve slope = $\gamma \times$ isothermal curve slope

(iii) — (b) $2/5$

(iv) — (b) parallel to the T axis.

(v) — (b) 1.46 cal / K.

(vi) — (c) entropy.

(vii) — (b) Irreversible

(viii) — (d) $h = U + pV$

(ix) — (a) 2.4

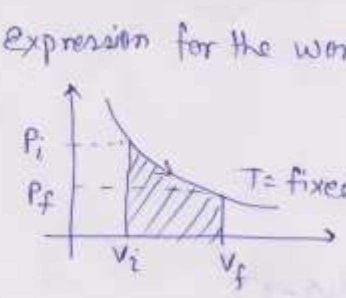
(x) — (a) Weidemann-Franz law.

Section – B.

Q.2 First law of thermodynamics – It is the law of conservation of energy during a thermodynamic process. According to this law, heat given to a system (δQ) is equal to the sum of increase in its internal energy (dU) and the work done by the system, against the surrounding.

$\therefore \quad \delta Q = dU + \delta W$

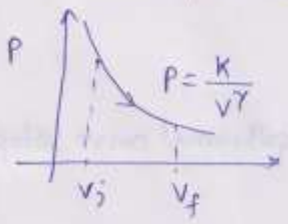
Expression for the workdone in isothermal process —



$$\delta W = \int_{V_i}^{V_f} p\,dV = \int_{V_i}^{V_f} \frac{nRT}{V}\,dV$$

$$\Rightarrow \boxed{\delta W = nRT \ln \frac{V_f}{V_i}}$$

Expression for the workdone in adiabatic process —



$$\delta W = \int_{V_i}^{V_f} p\,dV = \int_{V_i}^{V_f} \frac{K}{V^\gamma}\,dV$$

$$\boxed{\delta W = \frac{nR(T_f - T_i)}{1-\gamma}}$$

(Q.3) From the first law of thermodynamics,

$$\delta Q = dU + \delta W$$

$\therefore$ for an ideal gas undergoing adiabatic process,

$$0 = C_V dT + p\,dV \quad \text{--- (I)}$$

For one mole ideal gas, $PV = RT$

$$\Rightarrow p\,dV + V\,dp = R\,dT \quad \text{--- (II)}$$

~~& also~~, from (I) & (II)

$$C_V\, p\,dV + C_V \cdot V \cdot dp + R\,p\,dV = 0$$

but $C_p - C_V = R$.

$$\Rightarrow C_V V\,dp + C_p \cdot p\,dV = 0$$

$$\Rightarrow \frac{dp}{p} + \left(\frac{C_p}{C_V}\right)\frac{dV}{V} = 0 \qquad \text{But } \frac{C_p}{C_V} = \gamma$$

$$\Rightarrow \ln p + \gamma \ln V = \text{const.}$$

$$\Rightarrow pV^\gamma = \text{Const.}$$

here, $T_i = (273+27)\,K = 300\,K$

$P_i = 1$ atm.

$V_f = \frac{V_i}{2}$, $P_f = ?$ $T_f = ?$

$$\left.\begin{aligned} &\& \quad P_i V_i^{\gamma} = P_f V_f^{\gamma} \Rightarrow P_f = 1 \times 2^{1.4} \text{ atm.} \\ &\& \quad T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1} \Rightarrow T_f = 300 \times 2^{1.4} \text{ atm.} \end{aligned}\right\}$$

(Q.4) Entropy — The criterion for the possibility of occurrence of any physical or chemical change is fixed up by the second law of thermodynamics through the introduction of a new state variable known as entropy.

change in entropy of a system for any reversible process in passing ~~through~~ from state B to state A is

$$S_A - S_B = \int_B^A \frac{\delta Q}{T}.$$

<u>entropy of a perfect gas</u> —

$$\because \quad T\,dS = dU + p\,dV$$

$$\Rightarrow \quad dS = \frac{C_v dT}{T} + R\frac{dV}{V}$$

$$\Rightarrow \quad S - S_0 = \int_{T_0}^{T} \frac{C_v dT}{T} + R\int_{V_0}^{V} \frac{dV}{V}$$

$$= C_v \ln\left(\frac{T}{T_0}\right) + R\ln\left(\frac{V}{V_0}\right).$$

(Q.5) Clausius theorem — According to this theorem

$$\oint \frac{\delta Q}{T} \leq 0$$

change in entropy $\Delta S = \frac{m L_m}{T_0} + mc \ln\left(\frac{T_B}{T_0}\right) + \frac{m L_v}{T_B}$

here, $m = 5$ gm.

$T_0 = 273$ K

$L_m = 80$ cal/gm.

$L_v = 540$ cal/gm.

$T_B = 373$ K. & c = sp. heat of water.

$$\therefore \Delta S = \left(\frac{5 \times 80}{273} + 5 \times c \times \ln\left(\frac{373}{273}\right) + \frac{5 \times 540}{373}\right)$$

(Q.6) since, $dH = T dS + V dp$

& enthalpy remains constant during J-T process

$$\therefore \quad T dS + V dp = 0 \quad \text{---- (I)}$$

Taking $S = S(T, p)$

$$\therefore \quad T dS = T\left(\frac{\partial S}{\partial T}\right)_p dT + T\left(\frac{\partial S}{\partial p}\right)_T dp$$

using Maxwell 4rth relation,

$$\left(\frac{\partial V}{\partial T}\right)_p = -\left(\frac{\partial S}{\partial p}\right)_T$$

$$\Rightarrow \quad T dS = C_p dT - T\left(\frac{\partial V}{\partial T}\right)_p dp \quad \text{--- (II)}$$

using (I) & (II).

$$\left(\frac{\partial T}{\partial p}\right)_H = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right] \quad \text{--- (III)}$$

$$\Rightarrow \quad \mu = \frac{1}{C_p}\left[T\left(\frac{\partial V}{\partial T}\right)_p - V\right] \quad \text{-- (IV)}$$

μ for an ideal gas —

$$\because \quad PV = RT$$

$$\Rightarrow \left(\frac{\partial V}{\partial T}\right)_P = \frac{R}{P}$$

$$\Rightarrow T\left(\frac{\partial V}{\partial T}\right)_P = \frac{RT}{P} = \frac{PV}{P} = V$$

$$\Rightarrow \left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] = 0 \quad \Rightarrow \mu = 0.$$

μ for vander waal gas —

$$\because \left(P + \frac{a}{V^2}\right)(V-b) = RT$$

$$\Rightarrow \left(\frac{\partial V}{\partial T}\right)_P = \frac{R}{\left(P + \frac{a}{V^2}\right) - \frac{2a(V-b)}{V^3}}$$

$$\Rightarrow T\left(\frac{\partial V}{\partial T}\right)_P = \frac{V-b}{1 - \frac{2a}{RTV}}$$ [assuming that $V \gg b$]

$$\Rightarrow T\left(\frac{\partial V}{\partial T}\right)_P = V - b + \frac{2a}{RT}$$

$$\Rightarrow \left[T\left(\frac{\partial V}{\partial T}\right)_P - V\right] = \left(\frac{2a}{RT} - b\right)$$

$$\therefore \mu = \frac{1}{C_P}\left[\frac{2a}{RT} - b\right]$$

(Q.7) First Tds equation —

$$\text{let} \quad S = S(T, V)$$

$$\Rightarrow dS = \left(\frac{\partial S}{\partial T}\right)_V dT + \left(\frac{\partial S}{\partial V}\right)_T dV$$

$$\Rightarrow \quad Tds = T\left(\frac{\partial s}{\partial T}\right)_V dT + T\left(\frac{\partial s}{\partial V}\right)_T dV$$

$$\because \quad C_V = T\left(\frac{\partial s}{\partial T}\right)_V \quad \& \quad \left(\frac{\partial s}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

$$\therefore \quad Tds = C_V dT + T\left(\frac{\partial P}{\partial T}\right)_V dV$$

2nd T-ds equation — Let $S = S(P, T)$

$$\therefore \quad dS = \left(\frac{\partial S}{\partial P}\right)_T dP + \left(\frac{\partial S}{\partial T}\right)_P dT$$

$$\Rightarrow \quad Tds = T\left(\frac{\partial S}{\partial T}\right)_P dT + T\left(\frac{\partial S}{\partial P}\right)_T dP$$

$$\because \quad C_P = T\left(\frac{\partial S}{\partial T}\right)_P \quad \& \quad \left(\frac{\partial S}{\partial P}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_P$$

$$\Rightarrow \quad Tds = C_P dT - T\left(\frac{\partial V}{\partial T}\right)_P dP.$$

(Q.8) Conduction — In this process, heat energy is transferred from one part of a body to another part without actual motion of the particle. ex— flow of heat along a metal rod from hot end to the cold end.

Convection — In this process, heat is transferred from one part of the body to another part by actual motion of the particles caused by the differences in density of the parts maintained at different temperatures.

Radiation — In this process, no material medium is required for the transmission of heat.

Numerical — Thickness of the ice will not be doubled even after infinite time as the temp. of the air = $1^\circ C$.