Q.1

One dm^3 of an ideal gas at a pressure of 1.013 3 MPa expands reversibly and isothermally from its volume to 10 dm^3. How much of heat is absorbed and how much of work is done in expansion?

For an ideal gas undergoing reversible volume change, we have

$$q = -w = nRT \ln \frac{V_2}{V_1}$$

The temperature in the above expression can be replaced in terms of p_1 and V_1 by using the ideal gas equation. Thus

$$q = (p_1V_1) \ln \frac{V_2}{V_1}$$

Substituting the value of p_1, V_1 and V_2, we have

$$q = (1.013\ 3 \text{ MPa})\ (1 \text{ dm}^3) \times 2.303 \times \log \left(\frac{10 \text{ dm}^3}{1 \text{ dm}^3}\right)$$

$$= 2.333\ 6 \text{ MPa dm}^3 = 2.333\ 6 \text{ kJ}$$

Q.2

77. Correct option is (b)

W_{AB} = -2(46.48 - 23.24) = -46.48 l-atom

At point B, P_BV_B = 2 x 48.48 = 92.96

At point C, P_CV_C = 1x92.96=92.96

Since, in the process BC 'PV' is constant so it is an isothermal process.

$W_{BC} = -nRT\ln\frac{V_2}{V_1} = -PV\ln\frac{V_2}{V_1} = -92.96 \ln\frac{92.96}{4.648} = -65.07$ l-atm

W_{CD} = -1(23.24-92.96)=69.72 l-atm

W_{DA}=0 (ΔV=0)

Total work = $W_{AB} + W_{BC} + W_{CD} + W_{DA}$ = -46.48-65.07+69.72+0 = 41.83 l-atm

Therefore, total work 4183 J

Q.3

79. Correct option is (d)

In adiabatic process

PV^{γ} =Constant

$P \propto \frac{1}{V^{\gamma}}$

In isothermal process

PV=Constant

$P \propto \frac{1}{V}$

For monoatomic gas $p \propto \frac{1}{V^{\frac{5}{3}}}$

20 g of N_2 at 300 K is compressed reversibly and adiabatically from 20 dm^3 to 10 dm^3. Calculate the final temperature, q, w, ΔU and ΔH.

$$\text{Amount of } N_2 = \frac{(20\text{ g})}{(28\text{ g mol}^{-1})}\ 0.714\text{ mol}$$

$$T_1 = 300\text{ K}; \quad V_1 = 20\text{ dm}^3; \quad V_2 = 10\text{ dm}^3$$

For an adiabatic reversible process

$$T_2 V_2^{R/C_{V,\text{m}}} = T_1 V_1^{R/C_{V,\text{m}}}$$

Thus $$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{R/C_{V,\text{m}}} = (300\text{ K})\left(\frac{20\text{ dm}^3}{10\text{ dm}^3}\right)^{2/5} = (300\text{ K})\,(1.32) = 396\text{ K}$$

Hence, $$\Delta U = w = nC_{V,\text{m}}(T_2 - T_1) = (0.714\text{ mol})\left(\frac{5}{2}\times 8.314\text{ J K}^{-1}\text{ mol}^{-1}\right)(96\text{ K})$$

$$= 1\,424.69\text{ J}$$

$$\Delta H = nC_{p,\text{m}}(T_2 - T_1) = (0.714\text{ mol})\left(\frac{7}{2}\times 8.314\text{ J K}^{-1}\text{ mol}^{-1}\right)(96\text{ K})$$

$$= 1\,994.56\text{ J}$$

0.410 mol of a monatomic gas fills a 1 dm^3 container to a pressure of 1.013 3 MPa. It is expanded reversibly and adiabatically until a pressure of 0.101 33 MPa is reached. What are the final volume and temperature? What is the work done in the expansion?

The final volume V_f of gas after adiabatic and reversible expansion can be obtained by using the expression

$$p_i V_i^{\gamma} = p_f V_f^{\gamma}$$

Substituting the values of p_i, V_i, p_f and γ we get

$$(1.013\ 3\ \text{MPa})\ (1\ \text{dm}^3)^{5/3} = (0.101\ 33\ \text{MPa})\ V_f^{5/3}$$

or $$V_f = 10^{3/5}\ \text{dm}^3 = 3.98\ \text{dm}^3$$

The final temperature T_f after the expansion is

$$T_f = \frac{p_f V_f}{nR} = \frac{(0.10133 \times 10^3\ \text{kPa})\,(3.98\,\text{dm}^3)}{(0.410\ \text{mol})\,(8.314\,\text{dm}^3\ \text{kPa mol}^{-1}\ \text{K}^{-1})} = 118.3\ \text{K}$$

The work done during the expansion is

$$w = -\frac{p_i V_i - p_f V_f}{\gamma - 1} = -\frac{(1.0133\ \text{MPa})\,(1\ \text{dm}^3) - (0.10133\ \text{MPa})\,(3.98\,\text{dm}^3)}{(5/3) - 1}$$

$$= -0.915\ \text{dm}^3\ \text{MPa} = -915\ \text{J}$$