Time: 3 Hours Total Marks: 80

N.B.:
(i) Question No.1. is compulsory.
(ii) Attempt any three questions out of remaining five questions.
(iii) Assume suitable data and justify the same.
(iv) Figures to the right indicate full marks.

1. (a) Show that the first law of thermodynamics leads to the result that the energy of an isolated system is conserved. 05
(b) Differentiate between energy and exergy. 05
(c) Sketch the pressure-volume diagram for a pure substance and indicate the various regions on it. 05
(d) Explain significance of enthalpy and entropy departure functions. 05

2. One kmol of an ideal gas at 100 kPa and 300 K undergoes the following reversible changes: 20
(i) Compressed adiabatically to 500 kPa.
(ii) Heated at constant pressure to 800 K.
(iii) Expanded adiabatically to 210 kPa.
(iv) Cooled at constant volume to 300 K.
(v) Expanded isothermally to 100 kPa.

Find ΔU, ΔH, Q and W for the individual stage and for the entire cycle.
Data:
C_p = 29.099 J/(mol.K) C_v = 20.785 J/(mol.K)

3. (a) State Carnot principle and derive the formula to calculate efficiency of Carnot engine. 10
(b) Calculate the molar volume for ethane at 400 K and 1 MPa using the P/R equation of state. 10
Data:
T_c = 305.43 K, P_c = 48.84 bar and w = 0.099
P/R equation of state is given by:

$$P = \frac{RT}{(V-b)} - \frac{a\alpha}{V(V+b)+b(V-b)}$$

Where:

$$a = 0.45724\frac{R^2T_c^2}{P_c} \quad \text{and} \quad b = 0.07780\frac{RT_c}{P_c}$$

$$\alpha = [\,1 + S\,(\,1 - \sqrt{T_r}\,)\,]^2$$

$$S = 0.37464 + 1.54226\,w - 0.26992\,w^2$$

4. (a) Derive the relations to estimate the residual enthalpy and residual entropy for a Redlich Kwong gas. 10

Redlich Kwong equation of state is given by:

$$P = \frac{RT}{(V-b)} - \frac{a}{V(V+b)}$$

Where:

$$a = 0.42748 \frac{R^2 T_c^{2.5}}{\sqrt{T} P_c}$$

$$b = 0.08664 \frac{RT_c}{P_c}$$

(b) Find the change in entropy of 1kg of water when heated from 298 K to 500 K at atmosphere pressure. 10

Data:

Cp water = 4.187 kJ/kg K, Cp vapor = 2.093 kJ/kg K, λ = 540 kcal/kg

5. (a) Explain and derive Exergy balance for a closed system. 10

(b) Calculate Joule Thomson coefficient at 25^0C and 1 atmosphere if CO_2 follows van der Waals equation of state 10

Cp = 20.78 kJ/kmol K

a = 365.58 $(m^3)^2$ kPa/$(kmol)^2$

b = 0.0803 m^3/kmol

6. Write short notes on the following: 20

(i) Clausius inequality
(ii) Maxwell Relations.
(iii)Fugacity and fugacity coefficient
(iv)P-H diagram