

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:

$$C_p = 29.099 \text{ J/(mol.K)} \quad C_v = 20.785 \text{ J/(mol.K)}$$

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:

$$T_c = 305.43 \text{ K}, \quad P_c = 48.84 \text{ bar} \quad \text{and} \quad w = 0.099$$

P/R equation of state is given by:

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

Where:

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

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

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

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

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 10
K at atmosphere pressure.

Data:

Cp water = 4.187 kJ/kg K, Cp vapor = 2.093 kJ/kg K, $\lambda = 540$ kcal/kg

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

- (b) Calculate Joule Thomson coefficient at 25°C and 1 atmosphere if CO₂ 10
follows van der Waals equation of state

Cp = 20.78 kJ/kmol K

$$a = 365.58 \text{ (m}^3\text{)}^2 \text{ kPa/(kmol)}^2$$

$$b = 0.0803 \text{ m}^3\text{/kmol}$$

6. Write short notes on the following: 20

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