Total Pages—6

(Set-K)

B.Tech-5 (Chem. Engg.)

Chemical Engineering Thermodynamics

Full Marks : 70

Time : 3 hours

Answer six questions including Q.No.1 which is compulsory.

The figures in the right-hand margin indicate marks.

Symbols carry usual meaning.

1. Answer *all* : 2 × 10

(*a*) State the limitations of first law of thermodynamics wit example.

(*b*) An egg, initially at rest, is dropped onto a concrete surface and breaks. With the egg treated as the system, what is the sign of W, Q and ΔE_p.

(*c*) Calculate ΔU and ΔH for 1 kg of water when it is vaporized at the constant temperature of 373.15 K and the constant pressure of 101.325

(*Turn Over*)

kPa. The specific volumes of liquid and vapour water at the conditions are 0.00104 and 1.673 $m^3 kg^{-1}$. For this change, heat in the amount of 2256.9 kJ is added to the water.

(*d*) One mole of an ideal gas is compressed in a piston cylinder assembly from the initial state 0.1 MPa and 300 K till its volume is reduced to 1/15 of the original volume. The process of compression can be approximated as a polytropic process with $n = 1.2$. Determine the final temperature, pressure and work done on the gas.

(*e*) State Kelvin-Plank and Clausius statement of second law of thermodynamics.

(*f*) Define partial molar properties of a component in a solution.

(*g*) Define activity and activity coefficients of a component in a solution.

(*h*) Define Raoults law and its limitations.

(*i*) State third law of thermodynamics.

(*j*) Write the effect of temperature on equilibrium constant in a reaction mixture.

(*Continued*)

2. (*a*) With neat sketch explain the PT and TV diagram of pure substance. 5

(*b*) Reported values for the virial coefficients of isopropanol vapor at 473.15 K (200 °C) are :

$B = -0.3888\ m^3\ kmol^{-1}$

$C = -26 \times 10^{-3}\ m^6 kmol^{-2}$

Calculate V and Z for isopropanol vapour at 473.15 K (200 °C) and 10 bar by :

(*i*) The ideal gas equation

(*ii*) Virial equation with 2nd term

(*iii*) Virial equation with 3rd term. 5

3. Air is compressed from an initial condition of 1 bar and 298.15 K (25 °C) to a final state of 5 bar and 298.15 K (25 °C) by three different mechanically reversible processes in a closed system :

(*i*) Heating at constant volume followed by cooling at constant pressure

(*ii*) Isothermal compression

(*iii*) Adiabatic compression followed by cooling at constant volume.

Assume air to an ideal gas with the constant heat capacities, $C_v = (5/2)R$ and $C_p = (7/2)R$. Calculate the work required, heat transferred and the changes in internal energy and enthalpy of the air for each process. At 298.15 K and 1 bar the molar volume of air is 0.02479 m^3/mol. 10

4. (*a*) Derive the expression of Gibbs Duhem equation for a solution containing multi component mixture. 5

(*b*) The molar enthalpy of a binary solution at constant T and P is given by the relation

$$h = 500x_1 + 1000x_2 + (50x_1 + 40x_2)x_{12}$$

where h is in J/mol. Determine $\bar{h}_1$ and $\bar{h}_2$ as function of x_1 and the numerical values of the pure component h_1 and h_2. Also determine the partial molar enthalpies at infinite dilution. 5

5. Derive the expression of fugacity and fugacity coefficient for a component in a mixture which obeys van der Waals equation of state. 10

6. Mixture of Benzene (1) and Tolune (2) conform to ideal solution behaviour. The vapor pressure of pure components are adequately described by the Antoine equation. Prepare : 10

(*a*) P-x-y diagram at 95 °C

(*b*) T-x-y diagram at a pressure of 101.325 kPa (760 Torr).

Antoine constant	A	B	C
Benzene	6.87987	1196.760	219.161
Tolune	6.95087	1342.310	219.187

7. (*a*) A system formed initially of 2 mol CO_2, 5 mol H_2 and 1 mol CO undergoes the reactions

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

$$CO_2 + H_2 \rightarrow CO + H_2O$$

Develop expressions for the mole fractions of the reacting species as function of the reaction coordinates for the two reactions. 4

(*b*) Write the effect of operating condition on degree of conversion at equilibrium. 6

8. Write short notes on any *two* : 5 × 2

(*a*) Virial equation of state

(*b*) van der Waals equation of state

(*c*) Acentric factor

(*d*) Chemical potential.
