

B. TECH
(SEM IV) THEORY EXAMINATION 2017-18
CHEMICAL ENGINEERING THERMODYNAMICS

Time: 3 Hours

Total Marks: 70

Note: 1. Attempt all sections. If require any missing data; then choose suitably.

SECTION A

1. Attempt *all* questions in brief.

2 x 7 = 14

- a) Define first law of thermodynamics.
- b) Differentiate between open system and closed system.
- c) Define chemical potential.
- d) What do you mean by reaction co-ordinate?
- e) Define osmotic pressure.
- f) Define activity and activity coefficient.
- g) How is the equilibrium constant K related to the standard free energy change?

SECTION-B

2. Attempt any *three* of the following:

7 x 3 = 21

- a) Steel casting at a temperature 725K and weighing 35 Kg is quenched in 150Kg of oil at 275 K. If there are no heat losses, determine the change in entropy. The specific heat of steel is 0.88 KJ/Kg K and that of oil is 2.5 KJ/Kg K.
- b) Steam flows at steady state through a converging, insulated nozzle, 25 cm long and with an inlet diameter of 10 cm. At the nozzle entrance (state1), the temperature and pressure are 325°C & 700 KPa and velocity is 30 m/s. At the nozzle exit (state2), the steam temperature & pressure are 240°C & 350 KPa. Property values are: - $h_1 = 3112.5$ KJ/kg, $v_1 = 388.65$ m³/kg, $h_2 = 2945.7$ KJ/kg, $v_2 = 667.75$ m³/kg
What is the velocity of steam at the nozzle exit and what is the exit diameter?
- c) A gas initially at 1 MPa & 50° C is contained in a cylinder piston arrangement with an initial volume of 0.1 m³. The gas is then slowly expanded according to the relation $PV = \text{constant}$ until a final pressure of 100 KPa is reached. Determine the work done for this process.
- d) In a binary mixture the activity coefficient of component (1) is given by $\ln \gamma_1 = Ax_2^2$. Derive an expression for activity coefficient of component (2).
- e) With the help of fundamental property relation, show that multiple phases at the same T and P in equilibrium when the chemical potential of each constituent species is same in all phases.

SECTION C

3. Attempt any *one* part of the following:

7 x 1 = 7

- a) Describe the various excess Gibbs free energy models.
- b) The molar volume (cm³/mol) of a binary liquid mixture at T & P is given

$$V = 120x_1 + 70x_2 + x_1x_2(15x_1 + 8x_2)$$

For the given T&P

- (i) Find expression for partial molar volumes of species 1&2.

- (ii) Show that these expressions satisfy the Gibbs/Duhem equation.
 (iii) Show that when these expressions are combined in according to summability equation, the equation for V is recovered.

4. Attempt any *one* part of the following: 7 x 1 = 7

- a) Derive $\Pi(y_i \phi_i)^{vi} = K P^{-v}$
 b) What do you mean by equilibrium constant? Derive $\ln K = -\Delta G^0 / RT$.

5. Attempt any *one* part of the following: 7 x 1 = 7

- a. The excess Gibbs energy for the system chloroform (1)/ ethanol (2) at 55°C is well represented by the equation $G^E/RT = x_1 x_2 (1.42x_1 + 0.59x_2)$ The vapour pressures of chloroform and ethanol at 55°C are $P_1^{sat} = 79.50$ KPa; $P_2^{sat} = 40.20$ KPa
 Make BUBL P calculations at 55°C for liquid phase mole fractions of 0.25, 0.50.
 b. Calculate temperature and vapour phase composition at $P = 101.35$ Kpa and $x_1 = 0.5748$ for a binary system. The Antoine equations for component 1 and 2 are given below

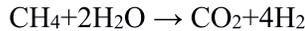
$$\ln P_1^{sat} = 13.8594 - \frac{2773.78}{t + 220.07}$$

$$\ln P_2^{sat} = 14.0098 - \frac{3103.01}{t + 219.79}$$

where t is in °C and vapour pressure in Kpa.

6. Attempt any *one* part of the following: 7 x 1 = 7

- a) A system consisting of 2 mol methane and 3 mol water is undergoing the following reaction
 $CH_4 + H_2O \rightarrow CO + 3H_2$



Derive expressions for mole fractions in terms of the extent of reaction.

- b) A mixture contains 5 g sucrose in 100 g of pure water at 25°C. Determine the osmotic pressure. Molecular weight of sucrose is 342.30.

7. Attempt any *one* part of the following: 7 x 1 = 7

- a) At 50°C a binary liquid mixture obeys $G^E/RT = 1.5 x_1 x_2$. At 50°C, $P_1^{sat} = 0.8$ bar; and $P_2^{sat} = 0.980$ bar. Determine whether this mixture exhibits an azeotrope at 50°C, and if yes determine its composition.

- b) Write notes on

- I. Osmotic Equilibrium
- II. Solid-Liquid Equilibrium
- III. Liquid-Liquid Equilibrium
- IV. Equilibrium Stability