CH-503 **Roll No.** | | | | | | | | | | |

B. Tech.
(SEM. V) EXAMINATION, 2015-16
CHEMICAL ENGINEERING THERMODYNAMICS

Time: 3Hours] **[Total Marks: 100**

Note: (1) Attempt all questions
(2) Graph paper is required.
(3) In case of numerical problems assume data wherever not provided

Q1. Attempt any four parts of the following: **5x4=20**

a) Define the thermodynamic state and state factions?

b) For an idea gas prove that

$$\frac{\Delta S}{R} = \int_{T_0}^{T} \frac{C_V^{ig}}{R}\frac{dT}{T} + ln\frac{V}{V_0}$$

c) Derive the mathematical statement of the thermodynamic second law.

d) A center power plant, rated at $8x10^5$KW generated steam at 585K and discard heat to river at 295K. A thermal efficiency of plant is 70% of the maximum possible value how much heat is discarded to the river at rated power.

e) A 40-kg steel casting (C_P=0.5 kJ/kg.K) at a temperature of 450^0C is quenched in 150 kg of oil (C_P=2.5 kJ/kg.K) at 25^0C. If there are no heat losses, what is change in entropy of (i) the casting (ii) the oil, and (iii) both consider together?

f) An insulated, electrically heated tank for hot water contains 190 Kg liquid water at 60^0C when a power outage occurs. If water is withdrawn from the tank at a steady rate of $\dot{m} = 0.2$ kg/s, how long will it take for the temperature of water in the tank to drop from 60^0C to 35^0C? Assume cold water enters the tank at 10^0C, and negligible heat losses from the tank. For liquid water let $C_P=C_V=C$, independent on T and P.

Q2. Attempt any two parts of the following: **10x2=20**

a) For the system methanol (1)/methyl acetate (2), the following equations provide a reasonable correlation for the activity coefficients:

$ln\gamma_1 = Ax_2^2$ $ln\gamma_2 = Ax_1^2$ Where A=2.771-0.00523 T

In addition, the following Antoine equations provide vapor pressures:

$lnP_1^{sat} = 16.59158 - \frac{3643.31}{T-33.424}$ $lnP_2^{sat} = 14.25326 - \frac{2665.54}{T-53.424}$

Where T is in kelvins and the vapor pressures are in kPa. Assuming the validity of modified Raoult's law. Calculate

(i) P and $\{y_i\}$, for t/T=45^0C/318.15 K and x_1 = 0.25

(ii) T and $\{y_i\}$, for P=101.33 kPa and x_1 = 0.85

b) A binary system of species 1 and 2 consists of vapor and liquid phases in equilibrium at temperature T, for which

$ln\gamma_1 = 1.8x_2^2$ $ln\gamma_2 = 1.8x_1^2$

$lnP_1^{sat} = 1.24\ bar$ $lnP_2^{sat} = 0.89\ bar$

Assuming the validity of modified Raoult's law. Calculate

(i) Range of value of the overall mole fraction z_1 can this two phase system exist with a liquid mole fraction x_1=0.65?

(ii) The pressure P and vapor mole fraction y_1 within this range?

c) Shows that the Gibbs/Duhem equation insures validity of the Lewis/Randall rule for the other species as it approaches purity.

Q3. Attempt any two parts of the following: **10x2=20**

a) A vessel, divided into two parts by a partition, contains 4 mol of N_2 gas at 75^0C and 30 bar on one side and 2.5 mol of argon gas at 130^0C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is the change in entropy? Assume N_2 to be an ideal gas with C_V= (5/2) R and argon to be an ideal gas with C_V= (3/2) R.

b) Develop a general equation to calculate $ln\widehat{\Phi}_i$ values from compressibility-factor data.

c) Determine the fugacity coefficients for nitrogen and methane in a N_2 (1) / CH_4 (2) mixture at 200 K and 30 bar if the mixture contains 40 mole% N_2. Experimental virial-cofficient data are as follows: B_{11}= -35.2, B_{22}= -105.0, B_{12}= -59.8 $cm^3\ mol^{-1}$,

Q4. Attempt any two parts of the following: **10x2=20**

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

$$CO_2\,(g) + 3\,H_2\,(g) \rightarrow CH_3OH\,(g) + H_2O\,(g)$$
$$CO_2\,(g) + 3\,H_2\,(g) \rightarrow CO\,(g) + H_2O\,(g)$$

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

b) For the given reaction written as $\frac{1}{2}N_2\,(g) + \frac{3}{2}H_2\,(g) \rightarrow NH_3\,(g)$ with 0.5 mol N and 1.5 mol H as the initial amounts of reactants and with the assumption that the equilibrium mixture is an ideal gas, show that

$$\mathcal{E}_e = 1 - \left(1 + 1.299K\frac{P}{P^0}\right)^{-1/2}$$

c) Acetic acid is esterified in the liquid phase with ethanol at 100^0C and atmospheric pressure to produce ethyl acetate and water according to the reaction:

$$CH_3COOH\,(l) + C_2H_5OH\,(l) \rightarrow CH_3COOC_2H_5\,(l) + H_2O\,(l)$$

If initially there is one mole each of acetic acid and ethanol, estimate the mole fraction of ethyl acetate in the reacting mixture at equilibrium.

Data given:

	$CH_3COOC_2H_5$ (l)	CH_3COOH (l)	C_2H_5OH (l)	H_2O (l)
ΔH^0_{f298} in J	-480000	-484500	-277690	-285830
ΔG^0_{f298} in J	-332200	-389900	-174780	-237129

Q5. Attempt any two parts of the following: **10x2=20**

a) Develop the equations that apply to the limiting case of binary LLE for which the α phase is very dilute in species 1 and the β phase is very dilute in species 2.

b) Shows that all irreversible processes occurring at constant T and P proceed in such a direction as to cause a decrease in the Gibbs energy of the system.

c) Write the short notes on Osmotic equilibrium and discuss the osmotic virial coefficient for an ideal solution.