Ex/Che/PC/B/T/223/2022

B. E. Chemical Engineering Examination, 2022

(2nd Year, 2nd Semester)

Chemical Engineering Thermodynamics

Time : Three hours Full Marks : 100

(50 marks for each Part)

Use a separate Answer-script for each Part

PART I (50 Marks)

Answer ***any two*** questions

Assume any missing Data

The symbols have their usual meaning

Problem 1

(i) Calculate the change in enthalpy between the following states of benzene (25)
State 1: Temperature = 55 °C, Pressure = 900 mm Hg
State 2: Temperature = 200 °C, Pressure = 1500 mm Hg

The following data is given

(a) The vapor pressure of liquid benzene is given by:

$$log_{10}P(\text{mm Hg}) = 6.88 - \frac{1196.76}{t(C^o)+219.161}$$

(b) The substance is known to follow generalized virial equation of state

$$Z = 1 + \frac{BP_c}{RT_c}\frac{P_r}{T_r}$$

$$\frac{BP_c}{RT_c} = B^o + \omega B_1, B_o = 0.083 - \frac{0.422}{T_r^{1.6}}, B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

(c) The critical temperature, pressure and acentric factor of benzene are 562.1 K, 49.24 bar and 0.212 respectively.

(d) The heat capacity of liquid benzene may be taken as 2 kJ/kg K

(e) The density of liquid benzene may be assumed constant at 0.77 g/cm^3

(f) The isobaric molar heat capacity of benzene in ideal gas state can be estimated from

$$C_p^o(\text{J/molK}) = -33.89 + 0.472T$$

where T is in kelvin

The latent heat of vaporization Δh_{vn} may be calculated using the following equations

$$\Delta h_{vn}(kJ/kg) = 1.093RT_c\left[T_{br}\frac{\ln lnP_c - 1.013}{0.93 - T_{br}}\right]$$

$$\Delta h_{v2} = \Delta h_{v1}\left(\frac{1-T_{r2}}{1-T_{r1}}\right)^{0.38}$$

Sketch the path used for calculation on a P-v diagram

Problem 2

(i)The excess Gibbs energy of a binary liquid mixture at T and P is given by

$$\frac{G_E}{RT} = (-1.2x_1 - 1.5x_2)x_1x_2$$

Find expression of $\ln\gamma_1$ and $\ln\gamma_2$

[Turn over

(ii) Estimate the saturation temperature and vapor phase composition of this binary mixture if the liquid phase mole fraction of component 1 is 0.4 and equilibrium pressure is 760 mm Hg respectively. The activity coefficient should be calculated based on expression given in problem 2 part (i) (7.5+ 17.5)
The vapor pressure of the components are given by

Component 1: $log_{10}P(\text{mm Hg}) = 7.2 - \frac{1100}{t(C^o)+234}$

Component 2: $log_{10}P(\text{mm Hg}) = 7.1 - \frac{1210}{t(C^o)+230}$

Problem 3
Assuming the gas phase to be ideal, calculate the degree of conversion if the following reaction is carried out at 500K and 40 bar (25)

$$C_2H_4(g) + H_2O(g) \leftrightarrow C_2H_5OH(g)$$

The following data are given

	ΔH_f^o (kJ/mol)	ΔG_f^o (kJ/mol)	C_p^o(J/molK)
$C_2H_4(g)$	*52.335*	*68.245*	*4.196 + 0.154T(K)*
$H_2O(g)$	*-242.0*	*-228.6*	*28.85 + 0.012T*
$C_2H_5OH(l)$	*-277.8*	*-174.9*	

The heat capacity of $C_2H_5OH(g)$ is $C_p^o(\text{J/molK}) = 20.69 + 0.205T(\text{K})$

The vapor pressure of liquid ethanol is given by

$$log_{10}P(\text{mm Hg}) = 8.112 - \frac{1592.8}{t(C^o) + 226.18}$$

PART II (50 Marks)

(Attempt all questions)

Marks

Q1 A) What is the Born diagram? How can it be used to write Maxwell Relation? 5

B) Derive the following relation using the partial derivatives method 5

$$C_P - C_v = \frac{Tv\beta^2}{\kappa}$$

β is the co-efficient of volume expansion, κ is isothermal compressibility

Q2 a) What do you mean by enthalpy of vaporization? 2
b) Derive the Clausious –Clapeyron Equation. 8

Q3 a) Write the significance of Chemical potential and thermodynamic potential. 3
b) Prove that the multiple phases at the same temperature and pressure are in equilibrium when the chemical potential of each species is the same in all phases. 7

Q4 Derive that

a) $\mu_i^{ig} = \Gamma_i(T) + RT \ln y_i P$. 6
b) $\bar{G}_i^E = RT \ln \gamma_i$ 4

μ_i^{ig} is chemical potential of pure species i in the ideal-gas mixture , y_i is the mole fraction of species i in the ideal-gas mixture. $\bar{G}_i^E$ is Partial excess Gibbs energy, γ_i is activity co-efficient of species i in solution

Q5 a) Derive the Gibbs-Duhem Equation for all changes in pressure and temperature. 7
b) Write the application of the Lewis-Randall Equation? Derive that Equation. 3