

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:

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

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

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

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

- (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/cm³
 (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

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

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

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 $\ln \gamma_2$

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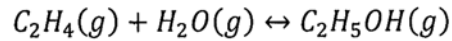
- (ii) Estimate the saturation temperature and vapor phase composition of this binary mixture if the liquid phase mole fraction of component 1 is 0.4 and equilibrium pressure is 760 mm Hg respectively. The activity coefficient should be calculated based on expression given in problem 2 part (i) (7.5+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

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

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

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)



The following data are given

	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	C_p° (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° (J/molK) = $20.69 + 0.205T(K)$

The vapor pressure of liquid ethanol is given by

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

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
$C_p - C_v = \frac{r v \beta^2}{\kappa}$	
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 Clausius –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