Ex/ChE/T/223/2018

BACHELOR OF ENGINEERING IN CHEMICAL ENGINEERING EXAMINATION, 2018

(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

Answer any two questions

All the symbols have their usual meaning

Assume any missing data

		CO
Q1.	Water at 10 atm and 40 °C enters a boiler at a flow rate of 100kg/h. The stream exiting the boiler is at 10 atm and 300 °C. (5 + 20) (a) Sketch the path of P-V diagram? (b) Determine the rate of heat energy that needs to be supplied from the following data? The critical temperature, critical pressure and acentric factor of water is 647.3 K, 221.2 bar and 0.344. The equation for determining the molar volume of water is $Z = 1 + \frac{BP}{RT}$, $\frac{BP}{RT} = B_o + \omega B_1$ $B_o = 0.083 - \frac{0.422}{T_r^{1.6}}$, $B_1 = 0.139 - \frac{0.172}{T_r^{4.2}}$ The heat capacity in ideal gas state is $C_p^o\left(\frac{\text{J}}{\text{mol K}}\right) = 28.85 + 0.01205T^2$ The vapor pressure of water can be estimated from the following relation $\log_{10}(\text{mm Hg}) = 7.97 - \frac{1668.21}{t(^oC) + 228}$ (25)	CO1
Q2.	(A) The volume change of mixing of the system ethanol (1)/methyl butyl ether (2) at 25 °C is given by $\Delta V\left(\text{cm}^3/\text{mol}\right) = x_1x_2\left\{-1.026 + 0.22\left(x_1 - x_2\right)\right\}$ The pure species volume V_1=110 cm^3/mol and V_2=90 cm^3/mol (a) 750 cm^3 of pure species of 1 is mixed with 1500 cm^3 of pure species 2 at 25 °C. (i) What would be the volume if an ideal solution is formed? (ii) Estimate the volume of the mixture is formed. (b) Derive the expression of $\overline{V}_1$ and $\overline{V}_1^E$. (8+7)	CO2

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	(B) If the equation $\mu_1 = G_1 + RT\ln x_1$ is a valid expression for the chemical potential in a binary liquid system at constant T and P show that $\mu_2 = G_2 + RT\ln x_2$. (5) (C) The following equations have been proposed to represent activity coefficient for a system at a fixed T and P $\ln\gamma_1 = Ax_2^2 + Bx_2^2(3x_1 - x_2)$ $\ln\gamma_2 = Ax_1^2 + Bx_1^2(x_1 - 3x_2)$ Check whether the system satisfies Gibbs Duhem equation. (5)	
Q3.	(A) The following data are available for the molar volume of liquid mixtures of cyclohaxane (1) and carbon tetrachloride at 1 atm and 60 °C	CO3

x_1	$V(\text{cm}^3/\text{gmol})$	x_1	$V(\text{cm}^3/\text{gmol})$	x_1	$V(\text{cm}^3/\text{gmol})$
0	101.46	0.2	104.002	0.9	112.481
0.02	101.717	0.3	105.253	0.92	112.714
0.04	101.973	0.4	106.49	0.94	112.946
0.06	102.228	0.5	107.715	0.96	113.178
0.08	102.483	0.6	108.926	0.98	113.409
0.1	102.737	0.7	110.125	1.0	113.64
0.15	103.371	0.8	111.31		

(a) Use the above data to determine V_1, V_2, $\bar{V}_1^{\infty}$ and $\bar{V}_2^{\infty}$

(b) Determine the value of ΔV from the data at x_1=0.4. (10 + 5)

(B) The solution behavior of a certain class of substances is described by the equation

$$G = \sum_i x_i\Gamma_i + RT\sum_i x_i \ln(x_i P) \text{ where } \Gamma_i \text{ is a function of temperature}$$

Derive the formulas for (a) G_i (b) μ_i (c) S_i (d) V_i (e) $\bar{S}_i$ (10)

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B.E. CHEMICAL ENGINEERING SECOND YEAR SECOND SEMESTER EXAM 2018

CHEMICAL ENGINEERING THERMODYNAMICS **PART II**

<u>Answer any 2 (two) questions</u>

All symbols have their usual meanings

Assume any missing data

		CO
Q1(A)	1. (A) A binary liquid mixture contains equimolar amounts benzene (1) and toluene (2). The activity coefficients of the two species in liquid phase are given by one constant Margule's equations. Prove that the vapour phase equilibrium mole fraction of benzene may be described by the following equation. (8) $$y_1 = \frac{P_1^{sat}}{(P_1^{sat} + P_2^{sat})}$$	CO2
Q1(B)	(B) A binary mixture containing 40 mol% isobutane and rest n-pentane flows continuously into a flash chamber which is maintained at a constant temperature of 49^{0}C. I. determine the pressure below which the flash chamber must be maintained for the liquid mixture to flash. (5) II. If the flash chamber is maintained at 49^{0}C and 3.2 bar, predict (a) the liquid and vapour flow rates per mole of the entering feed (7) (b) compositions of the liquid and vapour streams. (5) Assume that the liquid mixture is ideal and the K values for isobutane and n-pentane at 49^{0}C and 3.2 bar are 2.0 and 0.5 respectively. Antoine constants for isobutane and n-pentane are given below:	CO2,CO3

	A	B	C
Isobutane	15.5381	2032.72	-33.15
n-pentane	15.8333	2477.07	-39.34

$$\ln P^{sat}(mm\,Hg) = A - \frac{B}{T(K) + C}$$

Q2(A)	2. (A) Prove that for a gas phase reaction at low pressure, the equilibrium constants, K_p and K_y are related by the following expression (5) $$K_p = K_y P^{\Sigma \nu_i}$$ K_p and K_y are the reaction equilibrium constants expressed in terms of species partial pressures and mole fractions and ν_i's are the stoichiometric coefficients	CO2
Q2(B)	(B) Calculate the pressure required for 50% dissociation of phosphorus pentachloride to phosphorous trichloride and chlorine at 250^{0}C (8)	CO2,CO1

	ΔH_f^0 (kcal/mol)	ΔG_f^0 (kcal/mol)
$PCl_5(g)$	-91	-73.2
$PCl_3(g)$	-70	-65.2

Q2(C)	(C) A feed mixture containing equimolar amounts of ethylene and benzene enters a continuous alkylation reactor to form ethylbenzene. The reaction may be represented as follows: $$C_6H_6\ (g) + C_2H_4\ (g) \rightleftharpoons C_6H_5C_2H_5\ (g)$$ The reactor is maintained at a constant temperature of 325^{0}C. Calculate (i) the pressure at which the reactor must be operated to achieve an equilibrium conversion of 92.6 mol% of benzene (8) (ii) Amount of heat that must be removed continuously to maintain the reactor at a constant temperature of 325^{0}C. (4)	CO2

	ΔH_f^0 (kcal/mol)	ΔG_f^0 (kcal/mol)
$C_6H_6(g)$	19.820	30.989
C_2H_4 (g)	12.496	16.282
$C_6H_5C_2H_5$ (g)	7.120	31.208

Q3(C)	(C) Calculate the fugacity of water at 40^0C and 80 bar pressure. Vapour pressure and saturated molar volume of water at 50^0C are 7.384kPa and 18.018×10^{-3} $m^3/kmol$ respectively. List your assumptions. (7)	CO3
Q3(D)	(D) Estimate the fugacity of methane in an equimolar mixture of nitrogen (1) and methane(2) at -70^0C and 20 bar. Experimental values of virial coefficients are given below: (5) B_{11}= -35.2 B_{22}= -105.0 B_{12} = -59.8 cm^3/mol $\ln\phi_1 = \frac{P}{RT}(B_{11} + y_2^2\,\delta_{12})$ $ln\phi_2 = \frac{P}{RT}(B_{22} + y_1^2\,\delta_{12})$ $\delta_{12} = 2B_{12} - B_{11} - B_{22}$	CO3