Seat No.: _____ Enrolment No.

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–V (NEW) EXAMINATION – WINTER 2018

Subject Code:2150503 **Date:16/11/2018**

Subject Name: Chemical Engineering Thermodynamics-II

Time: 10:30 AM TO 01:00 PM **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** For binary azeotropic mixture deviating positively from ideality, draw vapor-liquid equilibrium (VLE) diagrams. **03**

(b) Describe phase rule and Duhem's theorem for non-reacting system. **04**

(c) Define Lewis/Randall Rule. Derive Raoult's law. What are the limitations of Raoult's law? **07**

Q.2 **(a)** With neat diagram describe the effect of increasing pressure on binary T-x_1,y_1 vapor-liquid equilibrium diagram. **03**

(b) Describe the phenomena of retrograde condensation. **04**

(c) Assuming validity of Raoult's law, draw P-x_1,y_1 diagram for binary mixture at 75 ^{0}C. Clearly show vapor region, liquid region, bubble point and dew point curves. **07**
Data given:
At 75 ^{0}C, P_1^{sat} =83.21 kPa and P_2^{sat} =41.98 kPa

OR

(c) System acetone(1)/acetonitrile(2)/nitromethane(3) at 353.15 K has the overall composition z_1 = 0.45, z_2 = 0.35 and z_3 = 0.20. Assuming that the Raoult's law is appropriate to this system, determine equilibrium pressure and vapor-liquid composition to carry out 40% vaporization. **07**
Date Given: The vapor pressures of the pure species at the 353.15 K are:
P_1^{sat} = 195.75 kPa, P_2^{sat} = 97.84 kPa and P_3^{sat} = 50.32 kPa

Q.3 **(a)** Define: (1) thermodynamic equilibrium, (2) chemical potential, and (3) fugacity coefficient for pure species i. **03**

(b) Describe graphical interpretation of following two equations relating partial molar properties with solution properties. **04**

$$\overline{M}_1 = M + x_2 \frac{dM}{dx_1} \quad \text{and} \quad \overline{M}_2 = M - x_1 \frac{dM}{dx_1}$$

(c) Will it be possible to prepare 0.1 m^3 of ethanol-water solution by mixing 0.03 m^3 ethanol with 0.07 m^3 pure water? If not possible, what volume should have been mixed in order to prepare a mixture of the same strength and of required volume? Density of ethanol and water are 789 and 997 kg/m^3, respectively. The partial molar volumes of ethanol and water at the desired compositions are: Ethanol = 53.6 x 10^{-6} m^3/mol; water = 18 x 10^{-6} m^3/mol. **07**

OR

Q.3 **(a)** For ideal gases, prove that the partial molar volume is identical with the pure species volume at the mixture T and P. **03**

$$\bar{V}_i^{ig} = V_i^{ig}$$

(b) For binary mixture derive following equations to calculate fugacity coefficient from virial equation of state. **04**

$$\ln\hat{\varphi}_1 = \frac{P}{RT}\left(B_{11} + y_2^2\,\delta_{12}\right)$$

(c) Derive an expression for the fugacity coefficient of a gas obeying the equation of state P(V-b)=R T and estimate the fugacity of ammonia at 10 bar and 298 K, given that b = 3.707 x 10^{-5} m^3/mol. **07**

Q.4 **(a)** Liquids A and B form an azeotrope containing 46.1 mole percent A at 101.3 kPa and 345 K. At 345 K, the vapor pressure of A is 84.8 kPa and that of B is 78.2 kPa. Calculate the van Laar constants. **03**

(b) Explain any one method for testing consistency of VLE data. **04**

(c) Describe Wilson and NRTL equations with their applications and limitations. **07**

OR

Q.4 **(a)** Describe Poynting correction. **03**

(b) Discuss the effect of temperature, pressure and liquid phase composition on relative volatility of binary mixture following modified Raoult's law. **04**

(c) The activity coefficients in a binary system are given by $\ln\gamma_1 = Ax_2^2$ and $\ln\gamma_2 = Ax_1^2$. Show that if the system forms an azoetrope, then azeotropic composition is given by **07**

$$x_1^{az} = \frac{1}{2}\left[1 - \frac{1}{A}\ln\left(\frac{P_2^{sat}}{P_1^{sat}}\right)\right].$$

Q.5 **(a)** Describe effect of temperature on reaction equilibrium constant. **03**

(b) Develop expressions for the mole fractions of reacting species as functions of the reaction coordinate for: **04**

(1) A system initially containing 2 mol NH_3 and 5 mol O_2 and undergoes the reaction:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

(2) A system initially containing 3 mol H_2S and 5 mol O_2 and undergoing the reaction:

$$2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(g) + 2SO_2(g)$$

(c) Explain block diagram for dew point pressure calculation. **07**

OR

Q.5 **(a)** If $G^E/RT = A\,x_1\,x_2$ for a liquid phase, show by stability analysis that LLE is predicted for $A \geq 2$. **03**

(b) Briefly describe constant pressure liquid/liquid solubility diagrams. **04**

(c) Explain the method of Lagrange's undetermined multipliers for gas phase reaction to minimize total Gibbs free energy. **07**

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