

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-x₁, y₁ vapor-liquid equilibrium diagram. **03**

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

(c) Assuming validity of Raoult's law, draw P-x₁, y₁ diagram for binary mixture at 75 °C. Clearly show vapor region, liquid region, bubble point and dew point curves. **07**

Data given:

At 75 °C, P₁^{sat} = 83.21 kPa and P₂^{sat} = 41.98 kPa

OR

(c) System acetone(1)/acetonitrile(2)/nitromethane(3) at 353.15 K has the overall composition z₁ = 0.45, z₂ = 0.35 and z₃ = 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:

P₁^{sat} = 195.75 kPa, P₂^{sat} = 97.84 kPa and P₃^{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**

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

(c) Will it be possible to prepare 0.1 m³ of ethanol-water solution by mixing 0.03 m³ ethanol with 0.07 m³ 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/m³, respectively. The partial molar volumes of ethanol and water at the desired compositions are: Ethanol = 53.6 × 10⁻⁶ m³/mol; water = 18 × 10⁻⁶ m³/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

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

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

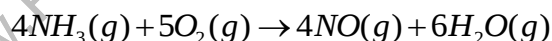
(c) The activity coefficients in a binary system are given by $\ln \gamma_1 = Ax_2^2$ and $\ln \gamma_2 = Ax_1^2$. Show that if the system forms an azeotrope, then azeotropic composition is given by 07

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

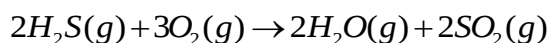
Q.5 (a) Describe effect of temperature on reaction equilibrium constant. 03

(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:



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



(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
