Seat No.: _____ Enrolment No.: _____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE- SEMESTER–V (NEW) EXAMINATION – WINTER 2020

Subject Code: 2150503 Date: 03/02/2021

Subject Name: Chemical Engineering Thermodynamics - II

Time: 10:30 AM TO 12:30 PM Total Marks: 56

Instructions:

1. **Attempt any FOUR questions out of EIGHT questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** Discuss ideal and non-ideal solutions. **03**

(b) For binary azeotrope mixture deviating positively form ideality, draw vapor-liquid equilibrium (VLE) diagrams. **04**

(c) Mixture of n-pentane (1) and n-heptane (2) conform to ideal solution behavior. The vapour pressures of pure components are adequately described by Antoine equations. Prepare P-x-y diagram at 70°C. **07**

Use Antoine equation: $\log_{10} P_i^{sat} = A_i - B_i/(t + C_i)$, where pressure P_i^{sat} is in torr and temperature t is in °C.

Component	A	B	C
n-pentane	6.8763	1075.78	233.2
n-heptane	6.8939	1264.37	216.64

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

(b) Write a short note on flash vaporization. **04**

(c) Derive the equation for criteria for phase equilibrium in terms of chemical potential for a mixture of N components and π phases. **07**

Q.3 **(a)** Write a brief note on retrograde condensation. **03**

(b) The enthalpy at 300 K and 1 bar of a binary liquid mixture is represented by the following equation: **04**

$H = 400\ X_1 + 600\ X_2 + X_1 X_2 (40X_1 + 20X_2)$, where H is in J/mol. Determine expressions for $\bar{H}_1$ and $\bar{H}_2$ as functions of X_1.

(c) Define fugacity and fugacity coefficient. Discuss any two methods to evaluate fugacity coefficient. **07**

Q.4 **(a)** Discuss liquid-liquid equilibrium (LLE) in brief. **03**

(b) Explain T-x-y diagram for partial miscible system. **04**

(c) Write a short note on equilibrium and stability. **07**

Q.5 **(a)** Write Raoult's law and Henry's law explaining each term associated with them with their applicability. **03**

(b) The ammonia synthesis reaction written as: $0.5\ N_{2(g)} + 1.5\ H_{2(g)} \rightarrow NH_{3(g)}$ with 0.5 mol nitrogen and 1.5 mol hydrogen as the initial amounts of reactants and with the assumption that the equilibrium mixture is an ideal gas, show that: **04**

$\varepsilon_e = 1 - (1 + 1.299KP)^{-0.5}$

(c) For an ideal gas, the exact mathematical expressions can be developed for the effect of T and P on the reaction co-ordinate at equilibrium. For conciseness we let $\prod (y_i)^{v_i} = K$. Then we can write the mathematical relations: **07**

$$\left(\frac{\partial \varepsilon_e}{\partial T}\right)_P = \left(\frac{\partial K_y}{\partial T}\right)_P \frac{d\varepsilon}{dK_y} \quad \text{and} \quad \left(\frac{\partial \varepsilon_e}{\partial T}\right)_T = \left(\frac{\partial K_y}{\partial T}\right)_T \frac{d\varepsilon_e}{dK_y}$$

Using above equations, show that

$$i)\left(\frac{\partial \varepsilon_e}{\partial T}\right)_P = \frac{K_y}{RT^2}\frac{d\varepsilon}{dK_y}\Delta H^0 \quad \text{and} \quad ii)\left(\frac{\partial \varepsilon_e}{\partial T}\right)_T = \frac{K_y}{P}\frac{d\varepsilon_e}{dK_y}(-v)$$

Q.6 **(a)** Write a short note on bubble point equilibria and dew-point equilibria. **03**

(b) Explain Lewis-Randall Rule, and excess properties. **04**

(c) Derive from the first principles, $\Delta G^o = -RT \ln K$. **07**

Q.7 **(a)** Discuss the area test for checking the thermodynamic consistency of experimental VLE data. **03**

(b) Define partial molar properties. Discuss any one method to evaluate partial molar properties. **04**

(c) Water (1)/hydrazine (2) system forms an azeotrope containing 58.5 mol% hydrazine at 393 K and 101.3 kPa. Calculate the equilibrium vapor composition for a solution containing 20 mol% hydrazine. The relative volatility of water with reference to hydrazine is 1.6 and may be assume to remain constant in the temperature range involved. Vapor pressure of hydrazine at 393 K is 124.76 kPa. **07**

Q.8 **(a)** Derive the Margules[2] equations from the expression $\frac{G^E}{x_1 x_2 RT} = A_{21}x_1 + A_{12}x_2$. **03**

(b) Write a short note on group contribution methods. **04**

(c) A liquid mixture of cyclohexanone (1)/ phenol (2) for which $x_1 = 0.6$ is in equilibrium with its vapour at 417.15 K. Determine the equilibrium pressure P and vapour composition y_1 from the following information: **07**

$\ln \gamma_1 = Ax_2^2$ and $\ln \gamma_2 = Ax_1^2$

At 417.15 K, $p_1^{sat} = 75.20$ and $p_2^{sat} = 31.66$ kPa

The system forms an azeotrope at 417.15 K for which $x_1^{az} = y_1^{az} = 0.294$.

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