Enrolment No./Seat No_____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–IV (NEW) EXAMINATION – SUMMER 2024

Subject Code:3140507 Date:08-07-2024

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.**
4. **Simple and non-programmable scientific calculators are allowed.**
5. **Notation used have their conventional meanings.**

Q.1 **(a)** Write down Raoult's Law and Henry's Law and explain each term associated with them with their applicability. **03**

(b) Consider a system in which following reactions occur: **04**

$CH_{4(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2(g)}$ and

$CH_{4(g)} + 2H_2O_{(g)} \rightarrow CO_{2(g)} + 4H_{2(g)}$

If there are 2 moles of CH_4 and 3 moles of H_2O present initially then derive the expressions for the mole fractions of the components in terms of extent of the reactions.

(c) Derive Margules equations for determination of activity coefficients of a binary system from the expression: **07**

$$\frac{G^E}{x_1 x_2 RT} = A_{21}x_1 + A_{12}x_2$$

Q.2 **(a)** Discuss the Gamma/Phi formulation for vapor-liquid equilibrium. **03**

(b) Estimate the fugacity of iso-butane at 15 atm and 87ºC using the compressibility factor correlation $Z = 1 + \left(\frac{BP}{RT}\right)$; given that the second virial coefficient B = -4.28 x 10^{-4} m^3/mol. **04**

(c) The vapour pressures of acetone (1) and acetonitrile (2) can be evaluated by the Antoine equations: **07**

$$lnP_1^{sat} = 14.5463 - \frac{2940.46}{T - 35.93} \quad \text{and} \quad lnP_2^{sat} = 14.2724 - \frac{2945.47}{T - 49.15}$$

where T in K and P_i^{sat} in kPa. Assuming that the solution formed is ideal, calculate:

i) P and y_1 at 327 K and $x_1 = 0.4$

ii) P and x_1 at 327 K and $y_1 = 0.4$

iii) x_1 and y_1 at 327 K and 65 kPa

OR

(c) Derive from the first principles, $\Delta G^0 = -RTlnK$ **07**

Q.3 **(a)** Explain modified Raoult's law with all its terms. **03**

(b) Discuss about liquid-liquid equilibrium (LLE). **04**

(c) Explain the minimum boiling and maximum boiling azeotropes with suitable examples. **07**

OR

Q.3 **(a)** Define and explain K-value and its importance in vapour-liquid equilibrium calculations. **03**

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

(c) Derive the expression used to estimate fraction of initial mixture that is vaporized at equilibrium using flash vaporization calculation. **07**

Q.4 **(a)** Discuss about partial molar properties. **03**

(b) Explain that if Henry's law is obeyed by component 1 in a binary solution over certain concentration range, Lewis-Randall rule will be obeyed by component 2 over the same concentration range. **04**

(c) Derive the Gibbs – Duhem equation for a binary solution in terms of activity and activity coefficient. **07**

OR

Q.4 **(a)** Discuss Wilson equations with their merits and demerits. **03**

(b) Discuss the area test for checking the thermodynamic consistency of experimental vapour-liquid equilibrium (VLE) data. **04**

(c) Discuss the effect of temperature and pressure on chemical potential. **07**

Q.5 **(a)** Discuss the concept of group contribution methods to determine activity coefficients. **03**

(b) A 30 mol% methanol-water solution is to be prepared. How many cubic meters of pure methanol (molar volume 40.727 x 10^{-6} m^3 /mol) and pure water (molar volume 18.068 x 10^{-6} m^3 /mol) are to be mixed to prepare 2 m^3 of the desired solution? The partial molar volumes of methanol and water in 30% solution are 38.632 x 10^{-6} m^3/mol and 17.765 x 10^{-6} m^3/mol respectively. **04**

(c) Explain the effect of temperature and pressure on equilibrium constant. **07**

OR

Q.5 **(a)** Discuss the feasibility of chemical reactions. **03**

(b) Consider a vessel which initially contains only n_o moles of water vapor. If decomposition occurs according to the reaction: $H_2O \rightarrow H_2 + \frac{1}{2}O_2$ **04**

Derive the expressions which relate the number of moles and mole fraction of each chemical species to the reaction co-ordinate and fractional decomposition of water vapor.

(c) The ammonia synthesis reaction written as: **07**

$$\frac{1}{2}N_{2(g)} + \frac{3}{2}H_{2}{}_{(g)} \rightarrow NH_{3(g)}$$

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, derive the following expression:

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

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