Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

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

Subject Code:3140507 Date:24/02/2021

Subject Name:Chemical Engineering Thermodynamics II

Time:02:30 PM TO 04:30 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)** Write down Raoult's law and Henry's law explaining each term associated with them with their applicability. **03**

(b) Write a brief note on retrograde condensation and its application. **04**

(c) Define azeotrope and explain the minimum boiling and maximum boiling azeotropes with suitable examples. **07**

Q.2 **(a)** Discuss the phase rule and Duhem's theorem. **03**

(b) At 303 K, vapour pressures of benzene (1) and toluene (2) are 15.75 kPa and 4.89 kPa respectively. Determine the partial pressure and composition of the benzene vapour in equilibrium with a liquid mixture consisting of equal weight of the two components. **04**

(c) Define partial molar properties. Discuss various methods for evaluation of partial molar properties. **07**

Q.3 **(a)** Estimate activity coefficient of methanol for chloroform (1) / methanol (2) system at 35^oC. The vapour pressures of chloroform and methanol at 35^o are 39.54 kPa and 27.95 kPa respectively. The mole fraction of methanol in the liquid mixture is 0.25. Margules' parameters are $A_{12} = 0.738$, $A_{21} = 1.868$. **03**

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

(c) The enthalpy at 300 K and 1 bar of a binary liquid mixture is represented by the following equation: **07**

$H = 400\ X_1 + 600\ X_2 + X_1\ X_2\ (40X_1 + 20X_2)$, where H is in J/mol. Determine expressions for $\bar{H}_1$ and $\bar{H}_2$ as functions of X_1, numerical values for the pure species enthalpies H_1 and H_2, and numerical values of partial enthalpies at infinite dilution $\bar{H}_1^{\infty}$ and $\bar{H}_2^{\infty}$.

Q.4 **(a)** Methanol (1) / acetone (2) system is described by the Van Laar activity coefficient model. At 60^oC, the model parameters are $A_{12} = 0.47$ and $A_{21} = 0.78$. Estimate the activity coefficient of methanol for a solution containing 15 mol% of methanol. **03**

(b) Consider a vessel which initially contains only n_o moles of water vapor. If decomposition occurs according to the reaction: $H_2O \rightarrow H_2 + 0.5O_2$. Find 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. **04**

(c) Using fundamental property relations, establish the expression of standard Gibbs free energy change of a chemical reaction as a function of the thermodynamic equilibrium constant. **07**

Q.5 **(a)** Define K-value and explain its importance in vapour-liquid equilibrium calculations. **03**

(b) Derive the expression of vapour composition at equilibrium using flash vapourization. **04**

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

Q.6 **(a)** Write a brief note on ideal solutions. **03**

(b) Derive the Margules[2] equations from the expression $\frac{G^E}{x_1 x_2 RT} = A_{21}x_1 + A_{12}x_2$. **04**

(c) The experimental pressure volume data for benzene at 675 K from a very low pressure to about 75 bar may be approximated by the equation, V = 0.0561(1/P – 0.0046), where V is in m^3/mol and P is in bar. What is fugacity of benzene at 1 bar and 675 K ? **07**

Q.7 **(a)** Discuss the Gamma/Phi formulation for vapor-liquid equilibrium. **03**

(b) Discuss criteria of chemical reaction equilibrium with neat sketch. **04**

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

$$\ln p_1^{sat} = 14.5463 - \frac{2940.46}{T - 35.93} \quad \text{and} \quad \ln p_2^{sat} = 14.2724 - \frac{2945.47}{T - 49.15}$$

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

i) x_1 and y_1 at 327 K and 65 kPa

ii) T and y_1 at 65 kPa and $x_1 = 0.4$

Q.8 **(a)** Discuss about liquid-liquid equilibrium (LLE). **03**

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

i) A system initially containing 2 mol of NH_3 & 5 mol of O_2 and undergoing the reaction

$4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$

ii) A system initially containing 3 mol of H_2S & 5 mol of O_2 and undergoing the reaction

$2H_2S_{(g)} + 3O_{2(g)} \rightarrow 2H_2O_{(g)} + 2SO_{2(g)}$

(c) Explain effect of temperature, pressure and total stoichiometric number on equilibrium constant. **07**

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