Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–IV (NEW) EXAMINATION – WINTER 2023

Subject Code:3140507 Date:31-01-2024

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.**

			MARKS
Q.1	**(a)**	Say, whether the following statements are TRUE or FALSE. Give correct statements to the false ones. 1. Real gases behave ideally at low pressures and/or high temperatures. 2. For an ideal gas, the fugacity and pressure are equal 3. For a chemically reacting system at equilibrium at constant temperature and pressure, the Gibbs free energy is maximum	**03**
	(b)	Prove that for a multi component system, chemical potential of each component is the same in all phases.	**04**
	(c)	Molar volume of a binary liquid mixture is given by $V = 90 * 10^{-3}x_1 + 50 * 10^{-3}x_2 + x_1x_2(6 * 10^{-3}x_1 + 9 * 10^{-3}x_2)$ Obtain expressions for $\overline{V_1}$ and $\bar{V}_2$ and show that they satisfy Gibbs- Duhem equations.	**07**
Q.2	**(a)**	Distinguish between Raoult's law and Henry's law	**03**
	(b)	Derive the Gibbs-Duhem equation from fundamentals	**04**
	(c)	The azeotrope of the methanol-benzene system has a composition of 44.8 mole percent ethanol with a boiling point of 68.2°C at 760 mmHg. At 68.2°C, the vapor pressure of pure benzene is 517 mmHg and that of ethanol is 506 mmHg. Calculate the Margules constants for the system and determine the activity coefficients for a solution containing 20 mole percent ethanol	**07**
		OR	
	(c)	Discuss Retrograde condensation	**07**
Q.3	**(a)**	Discuss partial molal properties in brief.	**03**
	(b)	Discuss any two methods for determination of fugacity of pure gases.	**04**
	(c)	Calculate the vapor phase composition of equimolar mixture of Benzene (1) and Toluene (2) mixture in equilibrium with into liquid mixture at one atmosphere and 80°C. Data: At 80°C, P_1^{sat} =760mmHg P_2^{sat} =300mmHg	**07**
		OR	
Q.3	**(a)**	Explain Lewis/Randall rule for ideal solution. Derive equations for fundamental excess property relations.	**03**
	(b)	Estimate the fugacity of iso-butane at 15 atm. and 87°C using the compressibility factor correlation Z= 1+ (BP/RT), given that the second virial coefficient B = - 4.28 *10^{-4} m^3/mol.	**04**

(c) Assuming the validity of Raoult's law, Compute for the system of Benzene (1), and Toluene (2) Given $y_1 = 0.30$ and t= 80°C, find x_1, x_2 and P. Data: At= 80°C , P_1^{sat} =101.05 kPa P_2^{sat} =38.83kPa. **07**

Q.4 **(a)** Define azeotrope and explain maximum boiling azeotrope with a neat diagram **03**

(b) Write steps to determine Dew point temperature using Raoult's Law. **04**

(c) Mixtures of n-Heptane (A) and n-Octane (B) are expected to behave as an ideal solution. The total pressure over the system is 101.3 kPa Using vapor pressure data given below **07**

T,K	371.4	378	383	388	393	398.6
P_A ,kPa	101.3	125.3	140.0	160.0	179.9	205.3
P_B, kPa	44.4	55.6	64.5	74.8	86.6	101.3

Construct: T- x, y diagram

OR

Q.4 **(a)** Define equilibrium constant K of a chemical reaction. How is it related to K_f and K_p? **03**

(b) Explain Liquid-Liquid Equilibrium with suitable example. **04**

(c) In the synthesis of ammonia, stoichiometric amounts of nitrogen and hydrogen are sent to a reactor where the following reaction occurs **07**

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

The equilibrium constant for the reaction at 675K may be taken equal to $2*10^{-4}$. Determine the per cent conversion of nitrogen to ammonia at 675 K and 20 bar.

Q.5 **(a)** What do you mean by the 'extent of reaction'? How is it related to the mole fraction of the species in the reaction mixture? **03**

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

$$CH_4 + H_2O \rightarrow CO + 3H_2 \text{……..} (1)$$

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2 \text{…….} (2)$$

If 3mol CH_4 and 4mol H_2O are initially present, Compute the mole fraction of the product gases for $\varepsilon_1 = 0.5$ and $\varepsilon_2 = 0.5$

(c) Discuss the effect of temperature, pressure and inerts on equilibrium constant. **07**

OR

Q.5 **(a)** Describe phase rule for reacting systems **03**

(b) How would you predict the feasibility of a chemical reaction from the value of standard free energy change? **04**

(c) A gaseous mixture of 30% CO, 50% H_2 and rest inert gas is sent to a reaction chamber for methanol synthesis. The following reaction occurs at 635 K and 310 bar. **07**

$$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(g)}$$

Assuming that the gas mixture behaves as an ideal solution calculate the percentage conversion of CO given that $K_f = 5x10^{-5}$ and $K_\Phi = 0.35$

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