Enrolment No./Seat No_____

GUJARAT TECHNOLOGICAL UNIVERSITY

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

Subject Code:3140507 Date:30-11-2024

Subject Name:Chemical Engineering Thermodynamics II

Time:02:30 PM TO 05:00 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)**	Explain phase rule for Non-reacting system with example.	**03**
	(b)	Discuss the applications of Gibbs Duhem equation in solution thermodynamics.	**04**
	(c)	Define chemical potential. Prove that the alternative definition of chemical potential that $$\mu_i = (\partial U/\partial\, n_i)_{S,V,nj}$$	**07**
Q-2	**(a)**	Write a short note on ideal solutions and Roult's law.	**03**
	(b)	Explain the physical significance of partial molar properties.	**04**
	(c)	The enthalpy change of mixing for a binary liquid solution at 298 K and 1 bar is given by the equation $\Delta H = x_1 x_2(40x_1 + 20x_2)$, Where ΔH is in J/mol and x_1 and x_2 are the mole fraction of components 1 and 2 respectively. The enthalpies of the pure liquids at the same temperature and pressure are 400 and 600 J/mol respectively. Determine numerical values of the partial molar enthalpies at infinite dilution $\overline{H_1}^{\alpha}$ and $\overline{H_2}^{\alpha}$ at 298 K and 1 bar.	**07**
		OR	
	(c)	Define fugacity in gaseous solutions. Show that the fugacity of component in a mixture of ideal gases is equal to the partial pressure of that component in the mixture.	**07**
Q-3	**(a)**	Define and explain excess properties.	**03**
	(b)	The two suffix-Margules equation is the simplest expression for excess Gibbs free energy that is obeyed by chemically similar materials. $$G^E = Ax_1x_2$$ Where A is an empirical constant independent of composition. Derive the expressions for the activity coefficients that result from this expression.	**04**
	(c)	Discuss and derive the criteria of chemical reaction equilibrium in brief.	**07**
		OR	
Q-3	**(a)**	Calculate the fugacity of liquid water at 303 K and 10 bar if the saturation pressure at 303 K is 4.241 kPa and the specific volume of liquid water at 303 K is $1.004*10^{-4}$ m^3/kg.	**03**

(b) Derive Lewis-Randall Rule. Also state the systems where it is valid. **04**

(c) Discuss the phase equilibria in multicomponent heterogeneous system. **07**

Q-4 **(a)** Calculate the equilibrium constant at 298 K of the reaction **03**

$N_2O_4(g) \rightarrow 2NO_{2(g)}$

Given that the standard free energies of formation at 298 K are 97540 J/mol for N_2O_4 and 51310 J/mol for NO_2.

(b) Discuss and explain the compressibility factor method for determination of fugacity of pure gases. **04**

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

$N_2 + 3H_2 \rightarrow 2NH_3$

The equilibrium constant for the reaction at 675 K may be taken equal to $2*10^{-4}$.

Determine the percent conversion of nitrogen to ammonia at 675 K and 20 bar.

OR

Q-4 **(a)** Define : (1) Activity (2) fugacity (3) Henry's law **03**

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

$CH_4 + H_2O \rightarrow CO + 3H_2$ (1)

$CH_4 + H_2O \rightarrow CO + 3H_2$ (2)

Where the numbers (1) and (2) indicate the value of j, the reaction index. If there are present initially 2 mol CH_4 and 3 mol H_2O, determine expressions for the y_i as function of ε_1 and ε_2.

(c) Derive the relationship of standard free energy change and equilibrium constant. **07**

Q-5 **(a)** Draw the minimum boiling azeotrope diagrams. **03**

(b) State the two parameter van Laar equations. **04**

(c) The activity coefficients in a mixture of components A and B at 313 K are given by **07**

$RTln\,\gamma_A = bx_B^2$ and $RTln\,\gamma_B = bx_A^2$

At 313 K, A and B form an azerotrope containing 49.4 mol% A at a total pressure of 27 kPa. If the vapor pressure of pure A and pure B are 25 and 24.3 kPa, respectively, calculate the total pressure of the vapor at temperature 313 K in equilibrium with a liquid mixture containing 12.5 mol% A.

OR

Q-5 **(a)** Write a short note on Duhem's Theorem. **03**

(b) Discuss the equilibrium constant for liquid phase reactions. **04**

(c) Discuss the boiling point diagram for a binary system where one of component is more volatile than other component. **07**

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