Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–IV (NEW) EXAMINATION – SUMMER 2022

Subject Code:3140507 Date:08-07-2022

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)**	State and explain Duhemn Theorem.	**03**
	(b)	Evaluate the fugacity coefficient at 5 bar for a gas that follows the equation of state PV = RT (1 – 0.005 P), where P is pressure in bar.	**04**
	(c)	In the laboratory of mass transfer, will it be possible to prepare 0.12m^3 of alcohol-water solution by mixing 0.04m^3 alcohol with 0.08m^3 pure water? If not possible, Assess the volume which should have been mixed in order to prepare a mixture of the same strength and of the required volume? Density of ethanol and water are 789kg/m^3 and 997kg/m^3 respectively. Data: The partial molar volumes of ethanol and water at the desired compositions are: Ethanol = 53.6*$10^{-6}$$m^3$/mol; Water = 18*$10^{-6}$$m^3$/mol.	**07**
Q.2	**(a)**	Derive the equation for determination of fugacity of pure gases using any two methods.	**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 binary solution is expresses as: $H = 400x_1 + 600\,x_2 + (40x_1 + 20\,x_2)x_1\,x_2$ (i) Acquire the expression for partial molar enthalpies. (ii) Compute pure component enthalpy (iii) Compute enthalpy at infinite dilution.	**07**
		OR	
	(c)	Prove that if Henry's law is obeyed by component 1 in a binary solution over certain concentration range, Lewis–Randall rule (Raoult's law) will be obeyed by component 2 over the same concentration range.	**07**
Q.3	**(a)**	For a binary solution consider M_1 and M_2 are properties of component 1 and component 2 in a solution. Derive equations to calculate partial properties of component 1 and component 2 in a solution.	**03**
	(b)	The activity coefficients for component 2 in a binary solution can be represented by $\ln\gamma_2 = Ax_1 + Bx_1^2$, where A and B are concentration independent parameters. Derive an expression for $\ln\gamma_1$.	**04**
	(c)	The ethanol-benzene system forms azeotrope with azeotropic composition of 44.8mol% ethanol with boiling point of 341.4K at 101.3kPa. At this temperature the vapor pressure of benzene is 68.9kPa and the vapor pressure of ethanol is 67.4kPa. Compute the activity co-efficient in a solution of Ethanol-Benzene containing 20mol% ethanol using Van Laar equation.	**07**
		OR	
Q.3	**(a)**	State applications and limitations of Wilson and NRTL equation.	**03**

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

(c) A certain experiment was carried out in the laboratory. The results of the data are as shown below. Verify whether the following data are thermodynamically consistent or not? **07**

x_1	0	0.2	0.4	0.6	0.8	1.0
γ_1	0.576	0.655	0.748	0.856	0.950	1.0
γ_2	1.0	0.985	0.930	0.814	0.626	0.379

Q.4 **(a)** Explain Liquid-Liquid Equilibrium with suitable example. **03**

(b) Define azeotrope and explain maximum and minimum boiling azeotrope with a neat diagram. **04**

(c) Assuming Raoult's law to be valid for the system benzene (1)–ethyl benzene (2) and the vapour pressures are given by the Antoine equation: **07**

$\ln P_i^{sat} = \left[A - \left(\frac{B}{T+C}\right)\right]$, where P is in kPa and T is in K.

Species, i	A	B	C
1	13.8858	2788.51	-52.41
2	14.0045	3279.47	-60.00

Construct the P-x-y diagram at 100°C.

OR

Q.4 **(a)** What is retrograde condensation and write its application in chemical industry. **03**

(b) Two suffix Margules equation is the simplest expression for excess Gibbs free energy. $G^E=\beta x_1 x_2$ where β is an empirical constant. Derive the expression for the activity coefficient of component 1 that results from this equation. **04**

(c) Assuming the validity of Raoult's law, Evaluate for the system of Acetone (1), Acetonitrile (2) and Nitromethane (3), given the mole fraction of component $x_1 = 0.30$ and $x_2=0.40$and temperature T = 75°C, Compute y_1 and P. **07**

$\ln P_i^{sat} = \left[A - \left(\frac{B}{T+C}\right)\right]$, where P is in kPa and T is in K.

Component	A	B	C
Acetone(1)	14.3916	2795.82	230.0
Acetonitrile (2)	14.2724	2945.47	224.0
Nitromethane (3)	14.2043	2972.64	209.0

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

(b) The water–gas shift reaction takes place at 373K, $CO + H_2O \rightarrow CO_2 + H_2$ **04**
The equilibrium constant K_P for this reaction at 537K = 9.8×10^{-4}. The heats of formation at 298K are: CO = –110,525J/mol, CO_2 = –393,509 J/mol, H_2O= –241,818 J/mol. Calculate the equilibrium constant at 1000 K.

(c) A gas mixture containing 1.25 moles hydrogen, 0.75 moles oxygen and 0.25 mole water initially, is undergoing the following reaction: **07**

$$H_2 + 1/2O_2 \rightarrow H_2O$$

(i) Derive expressions for the mole fractions of various components in the reaction mixture in terms of the extent of reaction.

(ii) Explain how the conversion of limiting reactant is related to the extent of reaction.

OR

Q.5 **(a)** How would you predict the feasibility of a chemical reaction from the value of standard free energy change? **03**

(b) What is the effect of temperature on equilibrium constant? Using Van't Hoff equation predict the effect of increasing temperature on endothermic and exothermic reactions. **04**

(c) Consider a system in which the following reactions occur: **07**

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

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

If 3mol CH_4 and 4mol H_2O are initially present, Compute the mole fraction of the product gases for $\varepsilon_1 = 0.25$ and $\varepsilon_2 = 0.5$