Enrolment No./Seat No_____

GUJARAT TECHNOLOGICAL UNIVERSITY

BE- SEMESTER–IV EXAMINATION – WINTER 2025

Subject Code:3140507 Date:28-11-2025

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)**	Define: (1) Partial molar property, (2) Fugacity coefficient and (3) Activity coefficient.	**03**
	(b)	Explain the difference between ideal and non-ideal solution.	**04**
	(c)	Define azeotropes and explain minimum boiling and maximum boiling azeotropes with suitable examples and neat diagrams.	**07**
Q.2	**(a)**	Explain the significance of phase equilibria in chemical engineering.	**03**
	(b)	Write short note on flash vaporization.	**04**
	(c)	Prove that if Raoult's law is valid for one constituent of a binary solution over the whole concentration range, it must also apply to the other constituent.	**07**
		OR	
	(c)	Derive general form of Gibbs- Duhem equation.	**07**
Q.3	**(a)**	Derive summability relation for partial molar properties.	**03**
	(b)	Discuss any one group contribution methods to determine Activity coefficients.	**04**
	(c)	The compressibility factor for oxygen gas at 20°C is given by expression in terms of pressure as $Z = a + bP + cP^2$. Whare, a, b and c are empirical constants and pressure is in bar. Determine the fugacity of oxygen at 20°C and 100 bar for given values of empirical constants. $a = 1.0, b = 0.75X10^{-3}\ and\ c = 0.15X10^{-5}$	**07**
		OR	
Q.3	**(a)**	Define chemical potential and state its significance.	**03**
	(b)	Discuss Margules equation with their merits and demerits.	**04**
	(c)	Discuss any two methods to evaluate fugacity coefficient.	**07**
Q.4	**(a)**	Show that for an ideal gas $\left(\frac{\partial \mu_i}{\partial P}\right)_T = \frac{RT}{P}$	**03**
	(b)	Discuss about liquid – liquid equilibrium (LLE).	**04**
	(c)	The azeotropic mixture of the ethanol-Methyl ethyl ketone has a composition of 52.5 mole% ethanol with boiling point of 250 K at 101.32 kPa. At this temperature the vapour pressure of methyl ethyl ketone is 93.65 kPa and vapour pressure of ethanol is 94.38 kPa. What is the activity	**07**

coefficient in a solution containing 75% methyl ethyl ketone? (Use Van Laar equation)

OR

Q.4 **(a)** With neat diagram explain tangent-intercept method to estimate partial molar volume of a binary solution. **03**

(b) What is gamma-phi formulation of VLE? **04**

(c) The fugacity of ethanol in a binary liquid mixture with methyl-ethyl-ketone at 298 K and 10 bar is given by $\bar{f}_1 = 25x_1 - 40x_1^2 + 20x_1^3$, where $\bar{f}_1$ is in bar and x_1 is mole fraction of ethanol in liquid mixture, Determine; **07**

1. Fugacity of a pure ethanol (f_1).
2. Henry's law constant (K_1).
3. Activity coefficient of ethanol for equimolar binary mixture (γ_1).

Q.5 **(a)** List out various methods for checking the consistency of experimental VLE data. **03**

(b) Derive the relationship between the mole fraction of the components taking part in the reaction and the extent of the reaction. **04**

(c) Industrial grade methanol can be produced according to the reaction **07**

$CO(g) + 2H_2(g) \leftrightarrow CH_3OH\ (g)$

For this reaction, $\Delta G^0_{400} = -1.3484\ kJ$. If an equimolar mixture of CO and H_2 is fed to a reactor maintained at 400 K and 10 bar, determine the fraction of CO that is converted into CH_3OH at equilibrium. Assume that the reaction mixture behaves like an ideal gas.

OR

Q.5 **(a)** Differentiate activity coefficient model and equation of state. **03**

(b) Write the effect of temperature on equilibrium constant. **04**

(c) Establish the relationship between equilibrium constant and standard free energy change. **07**

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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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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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Seat No.: _____ Enrolment No._____

GUJARAT TECHNOLOGICAL UNIVERSITY

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

Subject Code:3140507 Date:20-12-2022

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)**	Explain the significance of phase equilibria.	**03**
	(b)	Discuss Lewis-Randall rule along with its limitations.	**04**
	(c)	Define azeotrope and explain the minimum boiling and maximum boiling azeotropes with suitable examples.	**07**
Q.2	**(a)**	Discuss: ideal solutions and non-ideal solutions.	**03**
	(b)	For a closed system consisting two phases in equilibrium, explain Chemical Potential and Phase Equliibria.	**04**
	(c)	Explain in brief about fundamental property relation. Derive Gibbs/Duhem equations relating molar and partial molar properties.	**07**
		OR	
	(c)	At 300 K and 1 bar ,the volumetric data for a liquid mixture of benzene and cyclohexane are represented by V=109.4 × 10-6 − 16.8 ×10-6 x − 2.64 ×10-6 x2, where x is the mole fraction of benzene and V has the units of m3/mol. Find expressions for the partial molar volumes of benzene and cyclohexane.	**07**
Q.3	**(a)**	Discuss about liquid – liquid equilibrium (LLE).	**03**
	(b)	An equimolar solution of benzene and toluene is totally evaporated at a constant temperature of 363 K. At this temperature, the vapour pressures of benzene & toluene are 135.4 and 54 kPa respectively. What are pressures at the beginning & at the end of the vaporization process?	**04**
	(c)	Write a short note on flash vaporization.	**07**
		OR	
Q.3	**(a)**	Explain gamma-phi formulation of VLE.	**03**
	(b)	A mixture of A and B confirms closely to Raoult's law. At 373 K, the vapour pressure of A and B are 106 and 74 kPa respectively. Determine the composition of the vapour and liquid in equilibrium at 173 K and 101.3 kPa.	**04**
	(c)	Write a brief note on retrograde condensation and its application.	**07**
Q.4	**(a)**	Define activity and activity co efficient	**03**
	(b)	Liquid A and B form an azeotrope containing 46.1 mole percent A at 101.3 kPa and 345 K, the vapour pressure of A is 84.8.kPa and that of B is 78.2 kPa. Calculate the Van Laar Constants.	**04**
	(c)	List out various methods for evaluation of fugacity coefficient of pure component. Discuss any two in detail.	**07**
		OR	
Q.4	**(a)**	Define fugacity and fugacity co efficient	**03**
	(b)	For a binary system, if the activity coefficient for component '1' is $\ln\gamma_1 = \beta x_2^2$, then derive the expression for component '2'.	**04**

(c) Discuss various methods for checking the consistency of experimental VLE data. **07**

Q.5 **(a)** Explain the different factors affecting equilibrium conversions. **03**

(b) Discuss various methods to determine equilibrium constant. **04**

(c) Using the fundamental properties relation for single phase reaction, show that **07**

$$\Delta G^0 = - RT \ln K$$

OR

Q.5 **(a)** Write a brief note on multi reaction equilibria. **03**

(b) Develop expressions for the mole fractions (y_i) of reacting species as functions of the reaction coordinates for a system initially contains 2-mol CH_4 and 3-mol H_2O undergoing the reaction: **04**

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

$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$……(2)

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

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