U.S.N.										

B.M.S. College of Engineering, Bengaluru-560019

Autonomous Institute Affiliated to VTU

February 2025 Semester End Main Examinations

Programme: B.E. **Semester: IV**
Branch: Chemical Engineering **Duration: 3 hrs.**
Course Code: 23CH4PCTD2 / 22CH4PCTD2 **Max Marks: 100**
Course: Process Engineering Thermodynamics-II

Instructions: 1. Answer any FIVE full questions, choosing one full question from each unit.
2. Missing data, if any, may be suitably assumed.

Important Note: Completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. Revealing of identification, appeal to evaluator will be treated as malpractice.

			CO	*PO*	**Marks**
		UNIT - I			
1	a)	Derive Clausius-Clapeyron equation using Clapeyron equation given below: $$\frac{dP}{dT} = \frac{\Delta\hat{H}_{vap}}{T(\hat{V}_g - \hat{V}_l)}$$ Where P, T, $\Delta\hat{H}_{vap}$, $\hat{V}_g$ & $\hat{V}_l$ are vapor pressure, temperature, molar enthalpy of vaporization, molar volume of gas & molar volume of liquid respectively. Then, using Clausius-Clapeyron equation, determine the vapor pressure in mm Hg of a substance at 45°C if its boiling point at 1 atm is 115°C and its enthalpy of vaporization is 57.9 kJ/mol.	*CO 1*	*PO 1*	**10**
	b)	The equation of state of a certain substance is given by the expression V = RT/P – C/T^3, and the specific heat is given by the relation C_P = A + BT where A, B, and C are constants. Derive expressions for changes in internal energy (dU) and entropy (dS) for an isothermal process. Given $$dU = C_P dT - \left[PdV + T\left(\frac{\partial V}{\partial T}\right)_P dP\right]$$ $$dS = \frac{C_P}{T}dT - \left(\frac{\partial V}{\partial T}\right)_P dP$$	*CO 1*	*PO 1*	**10**
		OR			
2	a)	At 573 K and pressures of 0–6.0 MPa, the Joule-Thomson coefficient of N_2 (g) can be represented as $$\mu = 0.14 - 2.533 \times 10^{-2}P$$ Where, μ is in $\left(\frac{K}{MPa}\right)$. Assuming this equation to be temperature-independent near 573 K, find the temperature drop which may be expected in the Joule-Thomson expansion of the gas from 6.0 MPa to 2.0 MPa pressure.	*CO 3*	*PO2*	**12**
	b)	Derive Gibbs Helmholtz equation with suitable assumptions.	*CO 3*	*PO2*	**08**

			UNIT - II			
	3	a)	A compound whose vapor phase is described by the equation of state given below: $$V = \frac{RT}{P} + 0.3TP^2$$ Where, V is molar volume of vapor phase in $\left(\frac{cm^3}{mol}\right)$. Compute the fugacity for this compound in the vapor phase at T = 50 ˚C and P = 0.1 bar.	*CO 3*	*PO 2*	**10**
		b)	Henry law constant for CO_2 in water is 1.67×10^8 Pa at 298 K. Calculate the amount of CO_2 in 500 ml soda water when packed under 2.5 atm CO_2 pressure at 298 K.	*CO 3*	*PO 2*	**10**
			OR			
	4	a)	Derive the expression for Gibb's-Duhem equation for a system that comprises of n type of constituents with n_1, n_2.... moles. $$\sum n_i \, d\mu_i = 0$$ Where μ represents the chemical potential of species.	*CO2*	*PO2*	**12**
		b)	The need arises in a laboratory for 2 m^3 of an antifreeze solution consisting of 30 mol % methanol (1) in water (2). What volumes of pure methanol and of pure water at 25 °C must be mixed to form the 2 m^3 of antifreeze? Data: Partial molar volumes ($\bar{V}$) for methanol and water in a 30 mol % methanol solution and their pure species molar volumes ($\bar{V}^0$), both at 25 ˚C, are: • Methanol (1): $\bar{V}_1 = 38.632\times10^{-6}$ m^3/mol & $\bar{V}_1^0 = 40.727\times10^{-6}$ m^3/mol • Water (2): $\bar{V}_2 = 17.765\times10^{-6}$ m^3/mol and $\bar{V}_2^0 = 18.068\times10^{-6}$ m^3/mol	*CO 3*	*PO 2*	**08**
			UNIT - III			
	5	a)	Define chemical potential and derive the criteria for phase equilibrium.	*CO 4*	*PO 3*	**10**
		b)	Binary system benzene (1) and toluene (2) conforms closely Raoult's law. Vapor pressures for the pure species are given by the following equations: $$\ln P_1^{sat}(kPa) = 13.7819 - \frac{2726.81}{T(°C) + 217.572}$$ $$\ln P_2^{sat}(kPa) = 13.9320 - \frac{3056.96}{T(°C) + 217.625}$$ Calculate the y_1 & P, if x_1 = 0.33 & T = 100°C	*CO4*	*PO 3*	**10**
			OR			
	6	a)	Derive the criteria for phase equilibrium for the following conditions i. Constant U and V ii. Constant T and V iii. Constant P and T	*CO4*	*PO3*	**10**

<table>
<tr><td></td><td></td><td>b)</td><td>Mixtures of n-Heptane (A) and n-Octane (B) behave ideally. The total pressure over the system is 101.3 kPa. Using the vapour pressure data given below

<table>
<tr><td>Temperature (T), K</td><td>371</td><td>378</td><td>383</td><td>388</td><td>393</td><td>399</td></tr>
<tr><td>P_A, kPa</td><td>101.3</td><td>125.3</td><td>140.0</td><td>160.0</td><td>179.9</td><td>205.3</td></tr>
<tr><td>P_B, kPa</td><td>44.4</td><td>55.6</td><td>64.5</td><td>74.8</td><td>86.6</td><td>101.3</td></tr>
</table>
i. Construct the boiling point diagram.
ii. The equilibrium diagram.
Deduce an equation for the equilibrium diagram using an arithmetic average $\propto$ value.</td><td>CO4</td><td>PO3</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td>UNIT - IV</td><td></td><td></td><td></td></tr>
<tr><td></td><td>7</td><td>a)</td><td>Classify and explain azeotrope with examples. How do azeotropes affect the separation process in distillation?</td><td>CO 5</td><td>PO 3</td><td>10</td></tr>
<tr><td></td><td></td><td>b)</td><td>Derive the Van Laar equation for activity coefficients γ_1 and γ_2 of components in a binary non-ideal solution.</td><td>CO 5</td><td>PO 3</td><td>10</td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td></td><td></td><td></td></tr>
<tr><td></td><td>8</td><td>a)</td><td>What are azeotropes? With a neat diagram explain the importance of minimum boiling azeotrope.</td><td>CO4</td><td>PO3</td><td>08</td></tr>
<tr><td></td><td></td><td>b)</td><td>The following values refer to the Wilson parameters for the system acetone (1) – water (2): a_{12} = 1225.31 J/mol, a_{21} = 6051.01 J/mol, $V_1 = 74.05 \times 10^{-6} \frac{m^3}{mol}$, $V_2 = 18.07 \times 10^{-6} \frac{m^3}{mol}$. The vapour pressures are estimate using Antoine equation. The Antoine constants for both the components are A_1= 14.39, B_1= 2795.81, C_1= -14.39, A_2= 16.26, B_2= 3799.88, C_2= -46.85.
Calculate the equilibrium pressure and composition of

i. Vapour in equilibrium with a liquid of composition x_1 = 0.43 at 349 K.
ii. The liquid in equilibrium with a vapour of concentration y_1 = 0.8 at 349 K.</td><td>CO 5</td><td>PO3</td><td>12</td></tr>
<tr><td></td><td></td><td></td><td>UNIT - V</td><td></td><td></td><td></td></tr>
<tr><td></td><td>9</td><td>a)</td><td>Define the criteria for chemical reaction equilibrium.</td><td>CO 6</td><td>PO 3</td><td>04</td></tr>
<tr><td></td><td></td><td>b)</td><td>Derive the relationship between equilibrium constant and the standard free energy change.</td><td>CO 6</td><td>PO 3</td><td>08</td></tr>
<tr><td></td><td></td><td>c)</td><td>Evaluate the equilibrium constant at 600 K for the reaction
$$CO\ (g) + 2H_2\ (g) \rightarrow CH_3OH\ (g)$$
Given that the Gibbs free energy function
$$\emptyset_{298} = \frac{G_T^0 - H_{298}^0}{T}$$
For CO, H_2 and methanol at 600 K are -203.81, -136.39 and -249.83 J/mol K. The heats of formation at 298 K of CO(g) and CH_3OH (g) at 298 K are -1,10,500 J/mol and -2,00,700 J/mol.</td><td>CO6</td><td>PO3</td><td>08</td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td></td><td></td><td></td></tr>
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	10	a)	Explicate the effect of temperature and pressure on equilibrium constant.	*CO*6	*PO3*	**10**
		b)	A gas mixture containing 25% CO, 55% H_2 and 20% inert gas is to be used for methanol synthesis. The gases issue from the catalyst chamber in chemical equilibrium with respect to the reaction. $CO\ (g) + 2H_2\ (g) \rightarrow CH_3OH\ (g)$ at a pressure of 300 bar and temperature of 625 K. Assume that the equilibrium mixture forms an ideal solution and K and $K_\emptyset$ are 4.5×10^{-5} and 0.35 respectively. Find the percentage conversion of CO.	*CO*6	*PO3*	**10**

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