QP Code: RA23BTECH110 Reg. No | | | | | | | | | | | AY 23

GANDHI INSTITUTE OF ENGINEERING AND TECHNOLOGY, ODISHA, GUNUPUR
(GIET UNIVERSITY)

B. Tech (Fourth Semester - Regular) Examinations, April – 2025

23BCHPC24001 - Chemical Engineering Thermodynamics

(Chemical Engineering)

Time: 3 hrs Maximum: 60 Marks

Graph paper is to be provided.

(The figures in the right hand margin indicate marks)

PART – A (2 x 5 = 10 Marks)

Q.1. Answer ***ALL*** questions

		CO #	Blooms Level
a.	Classify the term thermodynamic system and give one example of each.	CO1	K1
b.	A renowned laboratory reports quadruple-point coordinates of 10.2 Mbar and 24.1^{o}C for four phase equilibrium of allotropic solid forms of the exotic chemical β-miasmone. Evaluate the claim.	CO2	K3
c.	Write the reason behind the death of aquatic animals in summer season, explain it through Henry's law.	CO2	K3
d.	Write the application of Gibbs-Duhem equation.	CO1	K2
e.	How will you know about the feasibility of a chemical reaction from its Gibbs free energy?	CO2	K2

PART – B (10 x 5 = 50 Marks)

<u>Answer ***ALL*** the questions</u>

		Marks	CO #	Blooms Level
2. a.	Derive the expression of first law of thermodynamics for closed system.	5	CO1	K2
b.	Express the volume expansivity and isothermal compressibility as function of density ρ and its partial derivatives. For water at 500C and 1 bar, κ = 44.18×10-6 bar-1. To what pressure must water be compressed at 500C to change its density by 1%? Assume that κ is independent of pressure P.	5	CO2	K4
	(OR)			
c.	Air is compressed from an initial condition of 1 bar and 298.15 K (25^0C) to a final state of 5 bar and 298.15K (25^0C) by two different mechanically reversible processes in a closed system. (a) Heating at constant volume followed by cooling at constant pressure. (b) Adiabatic compression followed by cooling at constant volume. Assume air to be an ideal gas with the constant heat capacities, C_v = (5/2) R and C_p = (7/2)R. Calculate the work required, heat transferred, and the changes in internal energy and enthalpy of the air for each process.	10	CO2	K4
3.a.	Write short notes on P-T diagram for pure substances.	4	CO1	K2
b.	A particular power plant operates with heat source reservoir at 350 ^{0}C and a heat sink reservoir at 30 ^{0}C. It has a thermal efficiency equal to 55% of the Carnot engine thermal efficiency for the same temperatures. (a) What is the thermal efficiency of the plant? (b) To what temperature must the heat source reservoir be raised to increase the thermal efficiency of the plant to 40%? Again η is the 55% of the Carnot engine value	6	CO2	K4

(OR)

c.	Derive the expression of entropy change for ideal gas.	5	CO1	K2
d.	A 40 kg steel casting ($C_p = 0.5$ kJ kg^{-1} K^{-1}) at temperature of 450 ^{0}C is quenched in 150 kg of oil ($C_p = 2.5$ kJ kg^{-1} K^{-1}) at 25 ^{0}C. If there are no heat losses, what is the change in entropy of (a) the casting (b) the oil (c) both considered together?	5	CO2	K4
4.a.	Binary system of acetonitrile (1)/ nitromethane (2) conforms closely to Raoults law. Vapor pressures for the pure species are given by the following Antoine equations: $\ln P_1^{sat}/kPa = 14.2724 - \frac{2945.47}{T-49.15}$ $\ln P_2^{sat}/kPa = 14.2043 - \frac{2972.64}{T-64.15}$ Given T is in K in the Antoine equation Prepare a graph showing T vs x_1 and T vs y_1 for a pressure of 70 kPa by using the above Antoine equation.	10	CO3	K3
	(OR)			
b.	For the system methanol (1)/ methyl acetate (2), the following equations provide a reasonable correlation of the activity coefficients: $\ln \gamma_1 = Ax_2^2$ $\ln \gamma_2 = Ax_1^2$ where A= 2.771-0.00523 T In addition, the following Antoine equations provide vapor pressures. $\ln P_1^{sat}/kPa = 16.59158 - \frac{3643.31}{T-33.424}$, $\ln P_2^{sat}/kPa = 14.25326 - \frac{2665.544}{T-53.424}$ Where T is in K and vapor pressures in kPa. Assuming the validity of modified Raoult's law, calculate (a) P and $\{y_i\}$ for T= 318.15K and x_1= 0.25 (b) P and $\{x_i\}$ for T= 318.15 K and x_1=0.60	10	CO2	K4
5.a.	Derive the expression for Gibbs-Duhem theorem from partial molar properties.	5	CO2	K3
b.	The enthalpy of a binary liquid system of species 1 and 2 at fixed T and P is represented by the equation $H = 400x_1 + 600 x_2 + x_1 x_2 (40x_1 + 20x_2)$ Where H is in J mol-1. Determine expressions for H_1 and H_2 as a function of x_1, numerical values for the pure species enthalpies H_1 and H_2 , and the numerical values for the partial enthalpies at infinite dilution $\overline{H_1^\infty}$ and $\overline{H_2^\infty}$.	5	CO3	K4
	(OR)			
c.	Prove that (a) $dH = C_p dT + (1 - \beta T)\, V\, dP$ (b) $dS = C_p \frac{dT}{T} - \beta V\, dP$	6	CO2	K4
d.	Derive the expression for criteria of phase equilibrium in terms of fugacity.	4	CO1	K3
6.a.	For the system in which the following reaction occurs, $CH_4 + H_2O = CO + 3H_2$	5	CO2	K3

	Assume there are present initially 2 mol CH_4, 1 mol H_2O, 1 mol CO, and 4 mol H_2. Determine expressions for the mole fractions y_i as functions of ε.			
b.	Derive the expression relating standard Gibb's energy change and equilibrium constant.	5	CO2	K4
	(OR)			
c.	Determine the number of degrees of freedom F for the following: (i) A system of two miscible non-reacting species which exists as an azeotrope in vapor/liquid equilibrium (ii) A system consisting of the gases CO, CO_2, H_2, H_2O, CH_4 in chemical equilibrium	5	CO2	K3
d.	The water gas shift reaction $CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$ is carried out under following condition. The reactants consist of 1 mole of H_2O and 1 mole of CO. The temperature is 1100 K and the pressure is 1 bar. Given at 1100 K the value of lnK = 0 for this reaction. Calculate the fraction of steam reacted assuming ideal gas mixture	5	CO2	K4

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