

B.E. CHEMICAL ENGINEERING 2nd YEAR 2nd SEMESTER EXAM 2023**CHEMICAL ENGINEERING THERMODYNAMICS**

Time : Three hours

Full Marks : 100

(50 Marks for each Part)

Use separate Answer script for each Part

PART I (50 Marks)

Answer any two questions

The symbols have their usual meaning

Assume any missing data

1. (a) Determine the state (liquid/vapour) of benzene at $P = 5$ bar and $T = 120$ °C and $P = 0.5$ bar and $T = 120$ °C.
 (b) Estimate the difference in enthalpy between state A ($P = 5$ bar, $T = 120$ °C) and state B ($P = 0.5$ bar, $T = 120$ °C) of benzene from the following data:
 Latent heat of vaporization at normal boiling point (353.2 K) = 30.75 kJ/mol;
 $T_c = 562.10$ K; $P_c = 49.24$ bar
 Specific volume of liquid benzene may be assumed to be 9.0×10^{-5} m³/mol

$$\log_{10} P \text{ (mm Hg)} = 6.88 - \frac{1196.7}{t(\text{oC}) + 219.16}$$

Equation of state of the gas is given by $Z = \frac{PV}{RT} = 1 + \frac{BP}{RT}$ where $B = 0.05$ L/gmol.

[1 bar = 750.24 mm Hg]

Sketch the path followed for solving the problem on a P-v diagram.

[20+5]

2. (a) The volume for liquid mixtures of benzene (1) and cyclohexane (2) at 25 °C is given by $V = 109.4 - 16.8x_1 - 2.64x_1^2$. Calculate the volume change of mixing (ΔV) and excess volume (V^E) at $x_1 = 0.4$.
 (b) The solution behaviour of a certain class of substance is described by the following expression $G = \sum x_i \phi_i + RT \sum x_i \ln(x_i P)$, (ϕ_i is a function of T only).
 Obtain the expression of volume of pure liquid (V_i), partial molar Gibbs free energy (\bar{G}) and partial molar volume of component i (\bar{V}).
 (c) For a binary system, the Gibbs free energy of a binary liquid mixture can be represented by $\frac{G^E}{RT} = 0.5x_1x_2$. Derive the expression of activity coefficient of component 1. [10+10+5]
3. (a) Estimate the standard heat of reaction (ΔH_{298}^0), and the equilibrium constant K_a at 750 K for the reaction $CO(g) + 2H_2(g) \leftrightarrow CH_3OH(g)$. Assume standard heat of reaction to be independent of temperature to be constant. Latent heat of vaporization and saturation pressure of CH_3OH at 298.15 K is 38.83 kJ/mol and 16.8 kPa respectively.
 (b) Estimate the mole fraction of carbon monoxide in the gas phase at equilibrium ($T = 750$ K, $P = 2$ bar) if an equimolar mixture of CO and H_2 was fed to the reactor. [15+10]

	ΔH_f^0 (kJ/mol) T = 298.15 K	ΔG_f^0 (kJ/mol) T = 298.15 K
$CO(g)$	-110.5	-137.3
$CH_3OH(l)$	-238.6	-166.2

[Turn over

Ref. No.- Ex/CHE/PC/B/T/223
B.E Chemical Engineering Second Year 2nd Semester Exam-2023

Subject: Chemical Engineering Thermodynamics (CHE/PC/B/T/223)

Time: 3 hr

Full Marks: 100

Part -II(For 50 Marks)
 (Attempt all questions)

		Marks
CO1 (Answer any one)		
Q1	<p>Refrigerant-134a is to be cooled by water in a condenser. The refrigerant enters the condenser with a mass flow rate of 17.64 lb/min at 12 bar and 70°C and leaves at 35°C. The cooling water enters at 3.7 atm and 15°C and leaves at 25°C. Neglecting any pressure drops, determine (a) the mass flow rate of the cooling water required (in <i>kg/min</i>) and (b) the heat transfer rate from the refrigerant to water (in <i>kJ/min</i>).</p> <p style="text-align: center;">Or</p> <p>Steam at 1972 kpa and 700°F steadily enters a nozzle whose inlet area is 0.18 ft². The mass flow rate of the steam through the nozzle is 10 lbm/s. Steam leaves the nozzle at 198 psia with a velocity of 900 ft/s. The heat losses from the nozzle per unit mass of the steam are estimated to be 1.2 Btu/lbm. Determine (a) the inlet velocity (in <i>ft/s</i>) and (b) the exit temperature of the steam (in °F)</p>	10
CO2		
Q2	<p>(a) What does Vander Waals constant a and b represent? How do you find the a and b from Van der Waals equation?</p> <p>(b) Distinguish the two common term - acentric factor and Generalized compressibility factor.</p>	2+6 2
CO3 (Answer any one)		
Q3	<p>(a) Illustrate the coefficient of volume expansion and isothermal compressibility with certain examples.</p> <p>(b) Prove that $dS = C_v \frac{dT}{T} + \frac{\beta}{\kappa} dV$ using Jaccobian method</p> <p>(C) Prove that $\mu_{JT} = \frac{V}{C_p} + (T\beta - 1)$ using Partial derivative method</p> <p style="text-align: center;">Or</p> <p>(d) Define the partial derivative and Jaccobian method with example.</p> <p>(e) Prove that $C_p - C_v = \frac{TV\beta^2}{\kappa}$ using Jaccobian method</p> <p>(f) Prove that $dS = C_v \frac{dT}{T} + \frac{\beta}{\kappa} dV$ using Partial derivative method</p> <p>[C_p & C_v: The molar heat capacity at constant pressure & constant volume, β & κ: The coefficient of volume expansion and isothermal compressibility, μ_{JT}: Joule thomson coefficient]</p>	2 4 4
CO4		
Q4	<p>(a) The Gibb's-Duhem equation demonstrates how the composition of components in a thermodynamic system is related to the change in their chemical potential at equilibrium-Prove it.</p>	5

	(b) The fugacity of each species in an ideal solution is proportional to its mole fraction-Prove it.	5																												
CO5																														
Q5	<p>A bed of coal (assumed to be pure carbon) in a coal gasifier is fed with steam and air and produces a gas stream containing H₂, CO, O₂, H₂O, CO₂, and N₂. If the feed to the gasifier consists of 1 mol of steam and 2.28 mol of air, calculate the equilibrium composition of the gas stream at P = 21 bar for temperatures of 1000, 1100, 1200, 1300, 1400, and 1500 K. Available data are listed in the following table.</p> <table border="1" data-bbox="331 658 943 927"> <thead> <tr> <th>T/K</th> <th>H₂O</th> <th>CO</th> <th>CO₂</th> </tr> </thead> <tbody> <tr> <td>1000</td> <td>-192,420</td> <td>-200,240</td> <td>-395,790</td> </tr> <tr> <td>1100</td> <td>-187,000</td> <td>-209,110</td> <td>-395,960</td> </tr> <tr> <td>1200</td> <td>-181,380</td> <td>-217,830</td> <td>-396,020</td> </tr> <tr> <td>1300</td> <td>-175,720</td> <td>-226,530</td> <td>-396,080</td> </tr> <tr> <td>1400</td> <td>-170,020</td> <td>-235,130</td> <td>-396,130</td> </tr> <tr> <td>1500</td> <td>-164,310</td> <td>-243,740</td> <td>-396,160</td> </tr> </tbody> </table>	T/K	H ₂ O	CO	CO ₂	1000	-192,420	-200,240	-395,790	1100	-187,000	-209,110	-395,960	1200	-181,380	-217,830	-396,020	1300	-175,720	-226,530	-396,080	1400	-170,020	-235,130	-396,130	1500	-164,310	-243,740	-396,160	10
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