Ref. No. : Ex/Che/PC/B/T/216/2025

B.E. CHEMICAL ENGINEERING SECOND YEAR FIRST SEMESTER EXAM 2025

Chemical Process Principles

Full Marks: 100 **PART- I (50 Marks)** **Time: 3 Hours**

Use Separate Answer scripts for each part

All symbols have usual significance, if not stated otherwise

Assume any missing data

CO No.	CO1	CO2	CO3	CO4	CO5
Marks	0	0	10	15	25

	CO3	
Q1	Fresh orange juice contains 12.0 wt% solids and the balance water, and concentrated orange juice contains 42.0 wt% solids. Initially a single evaporation process was used for the concentration, but volatile constituents of the juice escaped with the water, leaving the concentrate with a flat taste. The current process overcomes this problem by bypassing the evaporator with a fraction of the fresh juice. The juice that enters the evaporator is concentrated to 58 wt% solids, and the evaporator product stream is mixed with the bypassed fresh juice to achieve the desired final concentration. a) Draw and label a flowchart of this process, neglecting the vaporization of everything in the juice but water. b) Do degree of freedom analysis of the process and clearly mention all the unknowns for each DOF.	10
	CO4 (Answer total 15 marks)	
Q2	An air conditioner cools 226 m3/min of humid air at 36°C and 98% relative humidity to 10°C. (a) Do a degree-of-freedom analysis to prove that enough information is available to determine the required cooling duty (rate of heat transfer). (b) Calculate the rate of condensation of water in the unit and the cooling duty in tons (1 ton == 12,000 Btu/h). Given data: $p_w^*(36°C) = 44.56$ mm Hg; $p^*(10°C)=9.209$ mm Hg	10
Q3	The radiant energy incident on the earth's surface on a sunny day is roughly 900 W/m^2. Collecting and focusing sunlight and using the focused beam to heat a fluid is an old idea, and as the environmental costs of fossil fuel combustion mount, solar heating becomes an increasingly attractive alternative. Suppose a house is to be designed that will have a circulating forced air central heating unit, and solar energy is contemplated as a heat source (backed up with a conventional furnace to be used on cloudy days). If air is to be fed at a rate of 1000 m3/min at 30°C and 1 atm, and the air is to be heated to 55°C before being discharged into the living space, what is the required area of the solar collector plates? Assume 30% of the radiant energy incident on the plates is used to heat the air.	5
Q4	Humid air is enclosed in a 2.00-liter flask at 40°C. The flask is slowly cooled. When the temperature reaches 20°C, drops of moisture become visible on the flask wall. Although the pressure in the flask changes when the temperature drops, it remains close enough to 1 atm for the psychrometric chart to provide a close representation of the behavior of the system throughout the process. Use the chart to solve the following problems. **(a)** What were the relative humidity, absolute humidity, and wet-bulb temperature of the air at 40°C? **(b)** Calculate the mass of the water in the flask. **(c)** Calculate the enthalpy change in joules undergone by the air in going from 40°C to 20°C. **(d)** Write an energy balance for this closed-system process, taking the wet air in the flask as the system, and use it to calculate the heat in joules that must be transferred from the air to accomplish the cooling. (Assume ideal gas behavior, so that $H = U + RT$.)	10

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	CO5 (Answer total 25 marks)	
Q5	n-Butane is converted to isobutane in a continuous isomerization reactor that operates isothermally at 149°C. The feed to the reactor contains 90 mole% n-butane, 5% isobutane, and 5% HCl at 149°C, and a 40% conversion of *n-butane* is achieved. (a) Taking a basis of 1 mol of feed gas, calculate the moles of each component of the feed and product mixtures and the extent of reaction, ξ(mol). (b) Calculate the standard heat of the isomerization reaction *(KJ/mol).* Then, taking the feed and product species at 25°C as references, prepare an inlet-outlet enthalpy table and calculate and fill in the component amounts (mol) and specific enthalpies *(KJ/mol).* (c) Calculate the required rate of heat transfer *(kJ)* to or from the reactor (state which it is). Then determine the required heat transfer rate (kW) for a reactor feed of 325 mol/h. (d) Use your calculated results to determine the heat of the isomerization reaction at 149°C, *ΔHr(149°C) (KJ/mol).* $(\Delta \hat{H}_f^\circ)_{i\text{-}C_4H_{10}}$ = -134.5KJ/mol $(\Delta \hat{H}_f^\circ)_{n\text{-}C_4H_{10}}$ = -124.7KJ/mol For Cp data: Isobutane : a= 89.46×10^{-3}, b=30.13×10^{-5} , n-Butane: a= 92.3×10^{-3}, b=27.88×10^{-5}	15
Q6	The synthesis of methanol from carbon monoxide and hydrogen is carried out in a continuous vapor phase reactor at 5.00 atm absolute. The feed contains CO and Hz in stoichiometric proportion and enters the reactor at 25°C and 5.00 atm at a rate of 17.1 m3/h. The product stream emerges from the reactor at 127°C. The rate of heat transfer from the reactor is 17.05 kW. Calculate the fractional conversion achieved and the volumetric flow rate (m3/h) of the product stream. Data Given: $(\Delta H_f^0)_{CH3OH}$ = -201.2 KJ/mol $(\Delta H_f^0)_{CO}$ = -110.52 KJ/mol CH_3OH(g,127 C): Ĥ = 5.009KJ/mol	15
Q7	An aqueous solution containing 0.015 mol/L of species A is fed into a holding tank that initially contains 75 liters of pure water. The reactant decomposes at a rate r[mol A/(L.s)] = $0.0375C_A$ where C_A(mol AIL) is the concentration of A in the tank. The volumetric feed rate of the solution, v(t), increases linearly over a 10-second period from 0 to 25 L/s and stays constant at that rate thereafter until the tank is filled to the desired level. The density of the feed stream is constant. **a)** Write transient balances for the total mass of the tank contents and the mass of A in the tank. Convert the equations to differential equations for V(t) (the volume of the tank contents) and C_A(t) (the concentration of A in the tank) and provide initial conditions. b) Sketch the shapes of the plots you would expect for the volume of the tank contents, V (L), and the concentration of A in the tank, C_A (mol/L), versus time. c) Outline how the equations would be solved to derive an expression for C_A(t) for the period from t = 0 to t = 60 s.	10

Table B.5 Properties of Saturated Steam: Temperature Table[a]

		$\hat{V}$(m^3/kg)		$\hat{U}$(kJ/kg)		$\hat{H}$(kJ/kg)		
T(°C)	P(bar)	Water	Steam	Water	Steam	Water	Evaporation	Steam
0.01	0.00611	0.001000	206.2	zero	2375.6	+0.0	2501.6	2501.6
2	0.00705	0.001000	179.9	8.4	2378.3	8.4	2496.8	2505.2
4	0.00813	0.001000	157.3	16.8	2381.1	16.8	2492.1	2508.9
6	0.00935	0.001000	137.8	25.2	2383.8	25.2	2487.4	2512.6
8	0.01072	0.001000	121.0	33.6	2386.6	33.6	2482.6	2516.2
10	0.01227	0.001000	106.4	42.0	2389.3	42.0	2477.9	2519.9
12	0.01401	0.001000	93.8	50.4	2392.1	50.4	2473.2	2523.6
14	0.01597	0.001001	82.9	58.8	2394.8	58.8	2468.5	2527.2
16	0.01817	0.001001	73.4	67.1	2397.6	67.1	2463.8	2530.9
18	0.02062	0.001001	65.1	75.5	2400.3	75.5	2459.0	2534.5
20	0.0234	0.001002	57.8	83.9	2403.0	83.9	2454.3	2538.2
22	0.0264	0.001002	51.5	92.2	2405.8	92.2	2449.6	2541.8
24	0.0298	0.001003	45.9	100.6	2408.5	100.6	2444.9	2545.5
25	0.0317	0.001003	43.4	104.8	2409.9	104.8	2442.5	2547.3
26	0.0336	0.001003	41.0	108.9	2411.2	108.9	2440.2	2549.1
28	0.0378	0.001004	36.7	117.3	2414.0	117.3	2435.4	2552.7
30	0.0424	0.001004	32.9	125.7	2416.7	125.7	2430.7	2556.4
32	0.0475	0.001005	29.6	134.0	2419.4	134.0	2425.9	2560.0
34	0.0532	0.001006	26.6	142.4	2422.1	142.4	2421.2	2563.6
36	0.0594	0.001006	24.0	150.7	2424.8	150.7	2416.4	2567.2
38	0.0662	0.001007	21.6	159.1	2427.5	159.1	2411.7	2570.8
40	0.0738	0.001008	19.55	167.4	2430.2	167.5	2406.9	2574.4
42	0.0820	0.001009	17.69	175.8	2432.9	175.8	2402.1	2577.9
44	0.0910	0.001009	16.04	184.2	2435.6	184.2	2397.3	2581.5
46	0.1009	0.001010	14.56	192.5	2438.3	192.5	2392.5	2585.1
48	0.1116	0.001011	13.23	200.9	2440.9	200.9	2387.7	2588.6
50	0.1234	0.001012	12.05	209.2	2443.6	209.3	2382.9	2592.2
52	0.1361	0.001013	10.98	217.7	2446	217.7	2377	2595
54	0.1500	0.001014	10.02	226.0	2449	226.0	2373	2599
56	0.1651	0.001015	9.158	234.4	2451	234.4	2368	2602
58	0.1815	0.001016	8.380	242.8	2454	242.8	2363	2606
60	0.1992	0.001017	7.678	251.1	2456	251.1	2358	2609
62	0.2184	0.001018	7.043	259.5	2459	259.5	2353	2613
64	0.2391	0.001019	6.468	267.9	2461	267.9	2348	2616
66	0.2615	0.001020	5.947	276.2	2464	276.2	2343	2619
68	0.2856	0.001022	5.475	284.6	2467	284.6	2338	2623
70	0.3117	0.001023	5.045	293.0	2469	293.0	2333	2626
72	0.3396	0.001024	4.655	301.4	2472	301.4	2329	2630
74	0.3696	0.001025	4.299	309.8	2474	309.8	2323	2633
76	0.4019	0.001026	3.975	318.2	2476	318.2	2318	2636
78	0.4365	0.001028	3.679	326.4	2479	326.4	2313	2639
80	0.4736	0.001029	3.408	334.8	2482	334.9	2308	2643
82	0.5133	0.001030	3.161	343.2	2484	343.3	2303	2646
84	0.5558	0.001032	2.934	351.6	2487	351.7	2298	2650
86	0.6011	0.001033	2.727	360.0	2489	360.1	2293	2653
88	0.6495	0.001034	2.536	368.4	2491	368.5	2288	2656
90	0.7011	0.001036	2.361	376.9	2493	377.0	2282	2659
92	0.7560	0.001037	2.200	385.3	2496	385.4	2277	2662
94	0.8145	0.001039	2.052	393.7	2499	393.8	2272	2666
96	0.8767	0.001040	1.915	402.1	2501	402.2	2267	2669
98	0.9429	0.001042	1.789	410.6	2504	410.7	2262	2673
100	1.0131	0.001044	1.673	419.0	2507	419.1	2257	2676
102	1.0876	0.001045	1.566	427.1	2509	427.5	2251	2679

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Table B.8 Specific Enthalpies of Selected Gases: SI Units

	$\hat{H}$(kJ/mol) Reference state: Gas, P_{ref} = 1 atm, T_{ref} = 25°C						
T	Air	O_2	N_2	H_2	CO	CO_2	H_2O
0	−0.72	−0.73	−0.73	−0.72	−0.73	−0.92	−0.84
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	2.19	2.24	2.19	2.16	2.19	2.90	2.54
200	5.15	5.31	5.13	5.06	5.16	7.08	6.01
300	8.17	8.47	8.12	7.96	8.17	11.58	9.57
400	11.24	11.72	11.15	10.89	11.25	16.35	13.23
500	14.37	15.03	14.24	13.83	14.38	21.34	17.01
600	17.55	18.41	17.39	16.81	17.57	26.53	20.91
700	20.80	21.86	20.59	19.81	20.82	31.88	24.92
800	24.10	25.35	23.86	22.85	24.13	37.36	29.05
900	27.46	28.89	27.19	25.93	27.49	42.94	33.32
1000	30.86	32.47	30.56	29.04	30.91	48.60	37.69
1100	34.31	36.07	33.99	32.19	34.37	54.33	42.18
1200	37.81	39.70	37.46	35.39	37.87	60.14	46.78
1300	41.34	43.38	40.97	38.62	41.40	65.98	51.47
1400	44.89	47.07	44.51	41.90	44.95	71.89	56.25
1500	48.45	50.77	48.06	45.22	48.51	77.84	61.09

Table B.9 Specific Enthalpies of Selected Gases:
American Engineering Units

	$\hat{H}$(Btu/lb-mole) Reference state: Gas, P_{ref} = 1 atm, T_{ref} = 77°F						
T	Air	O_2	N_2	H_2	CO	CO_2	H_2O
32	−312	−315	−312	−310	−312	−394	−361
77	0	0	0	0	0	0	0
100	160	162	160	159	160	206	185
200	858	875	857	848	859	1132	996
300	1563	1602	1558	1539	1564	2108	1818
400	2275	2342	2265	2231	2276	3129	2652
500	2993	3094	2976	2925	2994	4192	3499
600	3719	3858	3694	3621	3720	5293	4359
700	4451	4633	4418	4319	4454	6429	5233
800	5192	5418	5150	5021	5195	7599	6122
900	5940	6212	5889	5725	5945	8790	7025
1000	6695	7015	6635	6433	6702	10015	7944
1100	7459	7826	7399	7145	7467	11263	8880
1200	8230	8645	8151	7861	8239	12533	9831
1300	9010	9471	8922	8581	9021	13820	10799
1400	9797	10304	9699	9306	9809	15122	11783
1500	10590	11142	10485	10035	10606	16436	12783
1600	11392	11988	11278	10769	11409	17773	13798
1700	12200	12836	12080	11509	12220	19119	14831
1800	13016	13691	12888	12254	13036	20469	15877
1900	13837	14551	13702	13003	13858	21840	16941
2000	14663	15415	14524	13759	14688	23211	18019

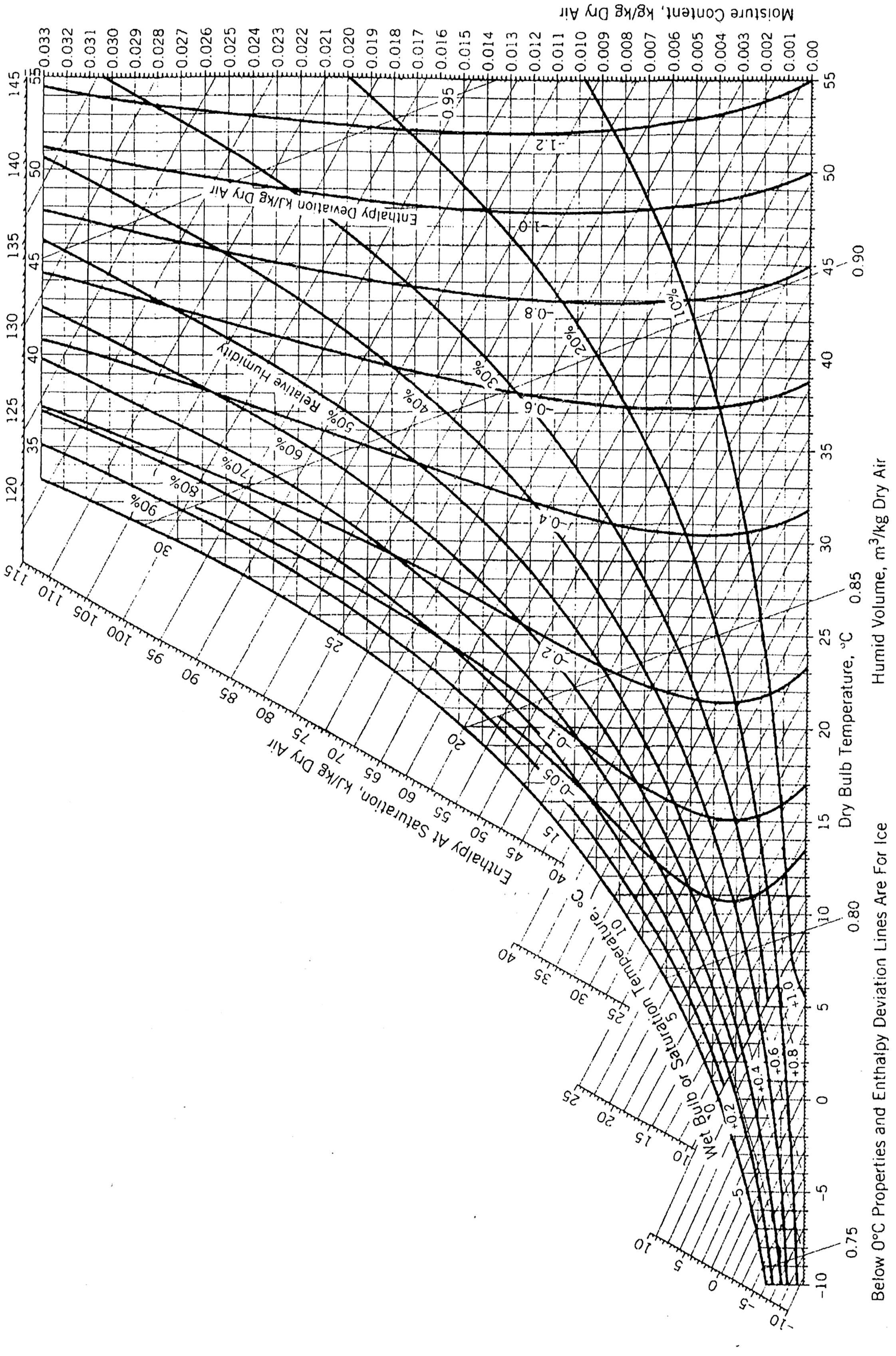

Figure 8.4-1 Psychrometric chart—SI units. Reference states: H_2O (L, 0°C, 1 atm), dry air (0°C, 1 atm). (Reprinted with permission of Carrier Corporation.)

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B.E. CHEMICAL ENGINEERING SECOND YEAR FIRST SEMESTER EXAM 2025

Chemical Process Principles

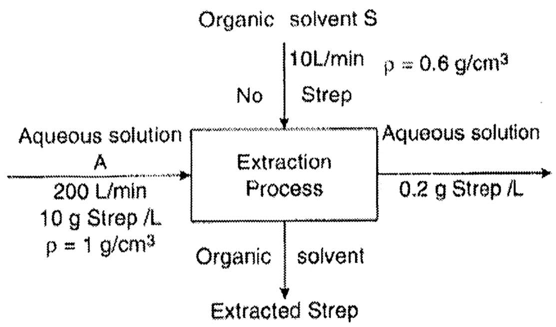
Full Marks: 100 **Time: 3 Hours**

Use Separate Answer scripts for each part

Part -II

(Attempt all questions)

		Marks
	CO1	
Q1	Ensure the unit operation of followings through technical explain in short a) Process of dehydration ethanol and water mixture b) Making of green tea c) Extraction of coconut milk from coconut d) Separation of milk and cream e) Formation of frost	5
	CO2	
Q2	An open cylindrical tank having a diameter D is supported around its bottom circumference and is filled to a depth h with a liquid having a specific weight γ. The vertical deflection, δ, of the center of the bottom is a function of D, h, d, γ, and E where d is the thickness of the bottom and E is the modulus of elasticity of the bottom material. Form the dimensionless groups describing this relationship.	10
	CO4	
Q3	A distillation column is a separation process of the components of a liquid feed mixture of two species –benzene (B) and toluene (T). The flow rate of feed mixture is 2 m^3/h. The 35% B and 65% T by mass are used as feed mixture to column. During process, the column constitutes 85 mole% B as the overhead product and 7.5 mole% B fed to column as bottom product. Using the degree-of –freedom analysis, calculate the mass flow rate of overhead product and, mass flow rate and mass fractions of bottom products through the proper flow-chart. The specific gravity of the feed mixture is 0.872.	8
Q4	Determine the mass fraction of Streptomycin in the exit organic solvent assuming that no water exits with the solvent and no solvent exits with the aqueous solution. Assume that the density of the aqueous solution is 1 g/cm^3 and the density of the organic solvent is 0.6 g/cm^3. Figure shows the overall process	7



	CO5	
Q5	Incomplete combustion of a methane is occurred due to the poor supply of air (oxygen) in the reaction occurred in a continuous steady state combustion reactor. The carbon monoxide (CO), carbon dioxide (CO_2) and water are constituted when methane is burned with air in that combustion reactor. The feed enters the reactor consisting of 22 mole% O_2, 11.3 mole% CH_4 and the rest of N_2. The percentage conversion of methane is 85.0%. 6.5 mole of CO_2 is released from the reactor per mole of CO. Draw the flow chart with degree-of-freedom analysis and determine molar compositions of products through molecular species balance, atomic species balance and the extents of reaction. $$2CH_4 + 3O_2 \rightarrow CO + 2H_2O$$ $$2CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$ How many moles of CO_2 formed when methane undergoes complete combustion?	20