Ref. No.- Ex/CHE/PC/B/T/216
B.E Chemical Engineering Second Year 1st Semester Exam-2023
Department of Chemical Engineering, Jadavpur University

Odd Semester –July-Dec'2022 Session: 2022-23 B.Ch.E-2nd Year (A1)

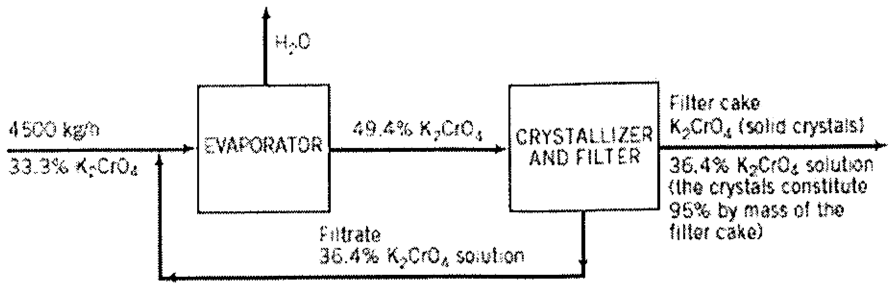
Subject: Chemical Process Principles (**CHE/PC/B/T/216**)

Time: 3 hr Full Marks: 100

Part -1 (For 50 Marks)
(Attempt all questions)

		Marks
	CO1	
Q1	1. Classify the following systems (batch/semi-batch/continuous and steady or unsteady) i) A balloon is filled with air at a steady rate of 2L/min. ii) A bottle of fruit juice is taken from the refrigerator and left on the kitchen table. iii) Water is boiled in an open tank. iv) Carbon monoxide and steam are fed into a tubular reactor at a steady rate and react to form products which are withdrawn at the other end. The reactor is filled with air when it is started up. The temperature of the reactor is constant and the flow rate and composition of the entering reactant stream are also independent of time. Classify the process A) initially; B) after a long period of time elapsed.	5
	CO3	
Q2	An experiment on the growth rate of certain organisms requires an environment of humid air enriched in oxygen. Three input streams are fed into an evaporation chamber to produce an output stream with the desired composition. A: Liquid water, fed at a rate of 20.0 cm /min B: Air (21 mole% O , the balance N) C: Pure oxygen, with a molar flow rate one-fifth of the molar flow rate of stream B The output gas is analyzed and is found to contain 1.5 mole% water. Draw and label a flowchart of the process, do degrees of freedom analysis and calculate all unknown stream variables.	10
	CO4 (Answer any one)	
Q3	A liquid mixture containing 45.0% benzene (B) and 55.0% toluene (T) by mass is fed to a distillation column. A product stream leaving the top of the column (the overhead product) contains 95.0 mole% B, and a bottom product stream contains 8.0% of the benzene fed to the column (meaning that 92% of the benzene leaves with the overhead product). The volumetric flow rate of the feed stream is 2000 L/h and the specific gravity of the feed mixture is 0.872. Draw the labelled flowchart and determine the mass flow rate of the overhead product stream and the mass flow rate and composition (mass fractions) of the bottom product stream.	15
Q4	The flowchart of a steady-state process to recover crystalline potassium chromate (K_2CrO_4) from an aqueous solution of this salt is shown below:	

[Turn over



Forty-five hundred kilograms per hour of a solution that is one-third K_2CrO_4 by mass is joined by a recycle stream containing 36.4% K_2CrO_4, and the combined stream is fed into an evaporator. The concentrated stream leaving the evaporator contains 49.4% K_2CrO_4; this stream is fed into a crystallizer in which it is cooled (causing crystals of K_2CrO_4 to come out of solution) and then filtered. The filter cake consists of K_2CrO_4 crystals and a solution that contains 36.4% K_2CrO_4 by mass; the crystals account for 95% of the total mass of the filter cake. The solution that passes through the filter, also 36.4% K_2CrO_4, is the recycle stream.

1. Calculate the rate of evaporation, the rate of production of crystalline K_2CrO_4, the feed rates that the evaporator and the crystallizer must be designed to handle, and the (mass of recycle)/(mass of fresh feed).

CO5

Q4	Combustion of Ethane: Ethane is burned with 50% excess air. The percentage conversion of the ethane is 90%; of the ethane burned, 25% reacts to form CO and the balance reacts to form CO. Calculate the molar composition of the stack gas on a dry basis and the mole ratio of water to dry stack gas	20

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B.E. CHEMICAL ENGINEERING SECOND YEAR FIRST SEMESTER EXAM 2023

Chemical Process Principles

Full Marks: 100 **PART-II (50 Marks)** **Time: 3h**

Use Separate Answer scripts for each part

All symbols have usual significance, if not stated otherwise

Assume any missing data

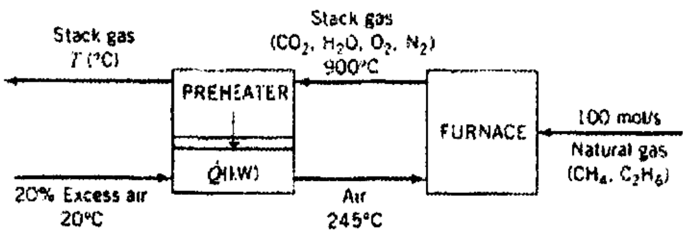
CO No.	CO1	CO2	CO3	CO4	CO5
Marks	0	10	0	15	25

CO2

Q1 3.The rate of heat transfer by forced convection in an incompressible fluid travelling in turbulent flow in pipe of uniform diameter at constant mass flow rate has been found to be influenced by d, u, ρ, k, c_p *and* μ . Determine the complete set of dimensionless groups involving heat transfer coefficient, h, and other parameters. (All symbols have usual significance.) **10**

CO4

Q2 A natural gas containing 95 mole% methane and the balance ethane is burned with 20.0% excess air. The stack gas, which contains no unburned hydrocarbons or carbon monoxide, leaves the furnace at 900°C and 1.2 atm and passes through a heat exchanger. The air on its way to the furnace also passes through the heat exchanger, entering it at 20°C and leaving it at 245°C. **15**



(a) Taking as a basis 100 mol/s of the natural gas fed to the furnace. calculate the required molar flow rate of air. the molar flow rate and composition of the stack gas. the required rate of heat transfer in the preheater. Q (write an energy balance on the air), and the temperature at which the stack gas leaves the preheater (write an energy balance on the stack gas). *Note:* The problem statement does not give you the fuel feed temperature. Make a reasonable assumption. and state why your final results should be nearly independent of what you assume.

(b) What would Q be if the actual feed rate of the natural gas were 350 SCMH [standard cubic meters per hour. m^3(STP)/h]?

Compound	Mol Wt.	Unit	ax10^3	bx10^5
Air	29	°C	28.94	0.4147
Carbon dioxide	44.01	°C	36.11	4.233
Nitrogen	28.02	°C	29	0.2199
Oxygen	32	°C	29.1	1.158
Water		°C	33.46	0.688

[Turn over

	CO5 **Answer Question no. s 3 and 4 or 5**	
Q3	n-Butane is converted to isobutane in a continuous isomerization reactor that operates isothermally at 149°C. The feed to the reactor contains 93 mole% n-butane, 5% isobutane, and 2% 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).* $(\Delta \hat{H}_f^\circ)_{i-C_4H_{10}}$ = -134.5KJ/mol $(\Delta \hat{H}_f^\circ)_{n-C_4H_{10}}$ = -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
Q4	A 2000-liter tank initially contains 400 liters of pure water. Beginning at t = 0, an aqueous solution containing 1.00 giL of potassium chloride flows into the tank at a rate of 8.00 Lis and an outlet stream simultaneously starts flowing at a rate of 4.00 Lis. The contents of the tank are perfectly mixed, and the density of the feed stream and of the tank solution. p(g/L), may be considered constant. Let V(t)(L) denote the volume of the tank contents and C(t)(g/L) the concentration of potassium chloride in the tank contents and outlet stream. (a) Write a total mass balance on the tank contents. convert it to an equation for dV/dt, and provide an initial condition. Then write a potassium chloride balance, convert it to an equation of the form dC/ dt = f(C, V), and provide an initial condition. **(b)** Without solving either equation, sketch the plots you would expect to obtain for V versus t and C versus t. Briefly explain your reasoning. (c) Solve the mass balance equation to obtain an expression for V(t). Then substitute for V in the potassium chloride balance and solve for C(t). Calculate the KCl concentration in the tank at the moment the tank overflows.	10
Q5	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 $r[\text{mol A/(L.s)}] = 0.0375C_A$ 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 l0-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.	