Register No.: .... Name: ....

SAINTGITS COLLEGE OF ENGINEERING (AUTONOMOUS)

(AFFILIATED TO APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY, THIRUVANANTHAPURAM)

FIFTH SEMESTER B.TECH DEGREE EXAMINATION (R,S), DECEMBER 2023
CHEMICAL ENGINEERING
(2020 SCHEME)

Course Code : **20CHT305**

Course Name: **Chemical Reaction Engineering**

Max. Marks : **100** **Duration: 3 Hours**

PART A

(Answer all questions. Each question carries 3 marks)

1. Differentiate elementary and non-elementary reactions. Explain the kinetics of non- elementary reactions.
2. Compute K_y at 10 min, if K_p at this pressure is 0.00381 atm^{-1} for ammonia synthesis reaction from hydrogen and nitrogen at 500°C. (Assume ideal gas holds good).
3. Define Recycle ratio (R) and mention its significance.
4. Compare plug flow reactor and continuous stirred tank reactor.
5. Differentiate selectivity and yield in multiple reactions.
6. The pyrolysis of ethane proceeds with an activation energy of about 300 kJ/mol. How much faster is the decomposition at 650°C than at 500°C.
7. Mention the difference between microfluid and macrofluid.
8. Draw the concentration profile and explain how the performance of 'N' equal sized CSTR's in series is equivalent to a plug flow reactor.
9. Define standard heat of reaction (ΔH°_R) and mention the significance of (ΔH°_R).
10. List the advantages and disadvantages of batch reactor and mention its applications.

PART B

(Answer one full question from each module, each question carries 14 marks)

MODULE I

11. a) Derive an expression for an irreversible reaction in parallel and series. (7)

    b) Derive the integrated rate equation for first order reaction in terms of conversion and concentration. (7)

OR

12. a) Derive the rate equation for varying volume batch reactor for an irreversible second order reaction of the type $2A \rightarrow P$. (7)

    b) A liquid phase reaction $A \rightarrow R + S$ proceeds as follows (7)

Time, min	0	36	65	100	160	∞
C_A, mol/l	0.1823	0.1453	0.1216	0.1025	0.0795	0.0494

With C_{A0} = 0.1823 mol/l, C_{R0} = 0 and C_{S0} = 55 mol/l. Find the rate expression for this reaction.

MODULE II

13. a) Derive the performance equation for steady state mixed flow reactor for (i) constant density system (ε_A= 0) and (ii) varying density system for first order kinetics. (7)

b) Assuming a stoichiometry $A \rightarrow R$ for a first order gas phase reaction. The volume of a plug flow reactor for 99% conversion of pure A is calculated to be 32 litres. Calculate the volume of plug flow reactor, if the reaction stoichiometry is $A \rightarrow 3R$. (7)

OR

14. a) A homogeneous liquid phase reaction $A \rightarrow S$, $-r_A = kC_A^2$ takes place with 50% conversion in a mixed flow reactor. (7)

(i) Calculate the conversion, if this reactor is replaced by another mixed flow reactor having volume 6 times that of the original reactor.

(ii) Calculate the conversion, if the original reactor is replaced by a plug flow reactor of same size.

b) Derive the performance equation for a steady state plug flow reactor for (i) constant density system (ε_A= 0) and (ii) varying density system for first order kinetics. (7)

MODULE III

15. a) Derive the performance equations/relationships for the different sized MFR in series with a neat model graph. (7)

b) With suitable schematic diagrams, explain the different contacting patterns for reactions in parallel. (7)

OR

16. a) Laboratory measurements of rate as a function of conversion for an isothermal gaseous decomposition $A \leftrightarrow 3B$ (reversible reaction) are given below. The data was collected at 149°C and total presure of 10 atm with the initial charge of an equimolar mixture of A and inerts. (7)

X_A	$(-r_A)$, mol/(l.s)
0	0.0053
0.10	0.0052
0.20	0.0050
0.30	0.0045
0.40	0.0040
0.50	0.0033
0.60	0.0025
0.70	0.0018
0.80	0.00125
0.85	0.00100

(i) Find out the total volume of two CSTRs in series necessary to achieve 80% overall conversion of A entering the reactor system, if the conversion of A in first CSTR is 50%. The volumetric flow rate is 6 l/s.

(ii) Find out the total volume of two plug flow reactors in series necessary to achieve 80% overall conversion of A entering the reactor system, if the conversion of A in first PFR is 50%. The volumetric flow rate is 6 l/s.

b) Draw the rate-concentration curve for autocatalytic reactions and explain autocatalytic reactions with relevant points. (7)

MODULE IV

17. a) A first order liquid phase reaction is carried out in a mixed flow reactor. The concentration of reactant in feed is 3 kmol/m^3 and volumetric flow rate is 60×10^{-6} m^3/s. The density and specific heat of reaction mixture are constant at 10^3 kg/m^3 and 4.19×10^3 J/(kg. K). The volume of reactor is 18×10^{-3} m^3. The reactor operates adiabatically. If feed enters at 298K, Determine the steady state conversions and temperatures in the product stream. (7)

Take ΔH^0_R = -2.09×10^8 J/ kmol, and rate = $4.48 \times 10^6 \exp\left(-\frac{62800}{RT}\right) C$, kmol/(m^{3}s), C is the concentration of reactant. T is in K and E (activation energy) is in J/mol.

b) Represent the energy balance equation for an adiabatic operation and derive the expression starting from heat balance. Draw the graphical representation of energy balance equation for adiabatic operations. (7)

OR

18. a) Explain optimum temperature progression with suitable model graphs. (7)

b) The elementary liquid phase reaction $A + B \rightarrow C$ is carried out in a mixed flow reactor. An equal molar feed in A and B enters the reactor at 27°C and the volumetric flow rate is 2 l/s. Calculate the volume of the reactor to achieve 85% conversion when the reaction is carried out adiabatically. (7)

ΔH°_f for A = -20 kcal/mol, for B = -15 kcal/mol and for C = -41 kcal/mol. C_{A0}= 0.10 kmol/m^3, C_{pA}= C_{pB} = 15 cal/(mol. K), C_{pC} = 30 cal/(mol.K). k = $0.01\left(\frac{l}{mol.s}\right)$ at 300 K, E = 10000 cal/mol.

MODULE V

19. a) Explain the models for non-ideal flow (i) Dispersion model (ii) Tank in series model. (7)

b) Define E curve and derive the relationship between E curve and F curve with suitable graphs. (7)

OR

20. a) A sample of tracer was injected as pulse into a vessel to be used as reactor and the effluent concentration is measured as a function of time. The data collected is given below. Calculate the mean residence time and plot E curve. (7)

t, min	0	1	2	3	4	5	6	7	8	9	10	12	14
C (g/m^3)	0	1	5	8	10	8	6	4	3	2.2	1.5	0.6	0

b) Explain the pulse tracer experiment to characterize the non-ideality of chemical reactors and derive the expression for residence time distribution E. (7)

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