(3 Hours) **(Total Marks: 80)**

N.B.: 1) **Question No.1** is **compulsory**.
2) Attempt **any three** questions out of remaining **five** questions.
3) Assume suitable **data** and **justify the same**.
4) **Figures** to the **right** indicate **full marks**.

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(a) Liquid A decomposes by first order kinetics. In a batch reactor, 50 % of A is converted in 5 minutes. How long it would take to reach 75 % conversion. **05**

(b) The pyrolysis of ethane proceeds with an activation energy of about 300 kJ/mol. How much faster is the decomposition at 650 ^{0}C than at 500^{0}C.? **05**

(c) Derive performance equation of a mixed flow reactor for constant density system for first order reaction. **05**

(d) Short note on Recycle Reactor. **05**

2 (a) The rule of thumb that the rate of reaction doubles for a 10 0C in temperature occurs only at a specific temperature for a given activation energy (for specific combination of temperature and activation energy). Show that the relationship between activation energy and temperature for which the rule holds is **10**

$$T = \left[\frac{10\ (K)E}{R\ln 2}\right]^{1/2}$$

(b) Find the first order reaction rate constant k, (referred to A) of the gas reaction 2A→ P, if by keeping the pressure constant, the volume of the reaction mixture, starting with 80 mole% A and 20 mole % inerts, decreases by 20 %in 3 min. **10**

3 (a) It is required to produce 9.5 kg /s of ethylene by cracking a feed stream of pure ethane in a plug flow reactor operated at 1100 K and 6 atm. The cracking reaction is first order with k= 3.07 s^{-1} at 1100 K **10**
$C_2H_6 \rightarrow C_2H_2 + H_2$ find the volume of reactor to achieve 80% conversion of ethane.

(b) The elementary irreversible liquid phase reaction A + B → R + S takes place in a plug flow reactor using equimolar amounts of A and B , $CA_0 = CB_0$ = 1 mol/l and results in 96 % conversion of A. If a mixed flow reactor ten times as large as the plug flow reactor were placed in series with the existing reactor, which reactor should come first and by what fraction could the production rate be increased for that set up. **10**

4 (a) Consider the competitive liquid phase reactions : **12**

$A + B \xrightarrow{k_1} R$ (desired) $\frac{dC_R}{dt} = 1.0\ C_A\ {C_B}^{0.3}$ mol/l/min

$A + B \xrightarrow{k_2} S$ (undesired) $\frac{dC_s}{dt} = 1.0\ {C_A}^{0.5} {C_B}^{1.8}$ mol/l.min

Equal volumetric flow rates of the A and b streams are fed to the reactor . each stream has concentration of 20 mol/l. Find the concentration of R in the product stream for $X_A = 0.90$, if the flow pattern in the reactor is
i) Plug flow and ii) mixed flow

(b) Consider a gaseous feed at T_0 = 1000 K, P_0 = 5 atm, CA_0= 100 , CB_0= 200 entering a flow reactor in which the gas phase reaction A+ B → 5R occurs. The Product stream leaves the reactor at T = 400 K, P = 4 atm. For C_A at the reactor exit =20 , find X_A, C_B, and X_B **08**

5 (a) An aqueous solution of ethyl acetate is to be saponified with sodium hydroxide. The initial concentration of ethyl acetate is 5 g/l and that of caustic is 0.1 normal. The values of second order rate constant at 0^0C and 20 ^{0}C are k= 0.235 and 0.924 (l/mol) $(min)^{-1}$ respectively. The reaction is irreversible . Calculate the time required to saponify 95 % of ester at 40^0C **12**

(b) At 500 K the rate of a biomolecular reaction is ten times the rate at 400 K. Find the activation energy for this reaction (a) from Arrhenius law (b) from collision theory (c) what is the percentage difference in rate of reaction at 600 K predicted by these two methods. **08**

6 (a) An irreversible isomerisation reaction is carried out in the liquid phase in a mixed flow reactor **10**

A→R , First order reaction.

Rate constant at 165^0C =0.7 h^{-1}, Activation energy =120000 J/mol, Heat of reaction = -350 kJ/kg

Heat capacity of reactants and products =1.95 kJ/kg.K, Volumetric flow rate = 0.33 m^3/h,

Feed Temperature = 20^0C, conversion expected = 95 %, Calculate the reactor size and temperature of the reaction mixture if the reactor is operated adiabatically.

(b) N_2O_4 gas dissociates according to the following reaction at 27^0C and 1 atm , 20 % of N_2O_4 is dissociated , calculate **10**

$\mathbf{N_2O_4\,(g) \rightleftharpoons 2\,NO_{2\,(g)}}$

i) Equilibrium constant K_p

ii) Percent dissociation of N_2O_4 at 27 ^{0}C when total pressure becomes 0.2 atm

iii) What will be the degree of dissociation when we start with 73.6 g of N_2O_4 in 10 litres vessel at 27^0C
