9. An irreversible isomerization reaction is to be carried out in liquid phase in a CSTR.

The reaction is $A \rightarrow R$ and it follows first order kinetics.

Rate of reaction for the reaction $-r_A = k.C_A$

Specific reaction rate constant $k = 0.7/hr$

Activation energy of the reactant E=120kj/gm mole

Heat of reaction $\Delta H_r = 350kj/kg$

Specific heat capacity of the reactants and products = 1.95kj/kg°C

It is desired to have 98% conversion.

Density of the reaction mixture = $900kg/m^3$

Calculate the volume of the reactor to process 300 kg/hr of the reactant and the temperature of the reaction mixture, if the reactor is operated adiabatically. 10

Sixth Semester Examination – 2010

CHEMICAL REACTION ENGINEERING

Full Marks – 70

Time : 3 Hours

*Answer Question No. **1** which is compulsory and any **five** from the rest taking atleast **two** from each Group.*

The figures in the right-hand margin indicate marks.

1. Write the correct answer : 2×10

(a) The reaction $A \rightarrow B$ is conducted in an isothermal batch reactor. If the conversion of A increases linearly with holding time, then the order of the reaction is

(i) 0 (ii) 1

(iii) 1.5 (iv) 2

(b) For the reaction $A \rightarrow B \rightarrow C \rightarrow D$, the rate equation r_B is given by

(i) $k_1 k_2 C_B$ (ii) $(k_1 + k_2) C_B$

(iii) $(k_1 - k_2) C_B$ (iv) $k_1 C_A - k_2 C_B$

(c) At 800°K, the rate of biomolecular reaction is ten times the rate at 400°K. The activation energy for this reaction is

(i) 3360 kcal/kg mole

(ii) 6720 kcal/kg mole

(iii) 336 kcal/kg mole

(iv) 33600 kcal/kg mole

(d) A liquid "L" decomposes according to first order kinetics. In a batch reactor, 50% of "L" is converted in 10 min. How long further it will take to achieve 75% conversions ?

(i) 10 min (ii) 20 min

(iii) 30 min (iv) 100 min

(e) A pyrolosis reaction proceeds with an activation energy of 40 kcal approximately. How much faster will be the decomposition at 723°C, then at 523°C, (800°K)

(i) 15 (ii) 150

(iii) 1500 (iv) 15000

(f) For liquid phase parallel reaction $A \rightarrow R$, $A \rightarrow S$, $r_R = k_1 C_{A2}$, $E_1 = 80$ kj/mole. $r_s = k_2 C_A$, $E_2 = 120$ kj/mole. The desired product is R. A higher selectivity of R will be achieved if the reaction is conducted at

(i) low temperature in a CSTR

(ii) high temperature in a CSTR

(iii) low temperature in a PFR

(iv) high temperature in a PFR

(g) The conversion for first order liquid phase reaction $A \rightarrow B$ in a CSTR is 50%, if another CSTR of same volume is connected in series then percentage conversion at the exits of the second reactor will be

(i) 60 (ii) 75

(iii) 90 (iv) 100

(h) In a solid catalyzed reaction the diffusional effects are more likely to affect the overall rate of reaction for

(i) First reaction in catalyst of small pore diameter

(ii) First reaction in catalyst of large pore diameter

(iii) Slow reaction in catalyst of small pore diameter

(iv) Slow reaction in catalyst of large pore diameter

(i) In most of the catalytic reaction, an inert carrier is used whose primary function is
   (i) To improve catalyst activity
   (ii) To enhance reactor performance
   (iii) To decrease the reaction temperature
   (iv) To provide the large surface area for the catalyst

(j) Thermodynamic equilibrium constant for a reaction system depends on
   (i) temperature
   (ii) pressure
   (iii) temperature, pressure
   (iv) temperature, pressure and the presence of inerts

Group – A

2. (a) The activation energy of a certain chemical reaction is 52.4 kj/mol. If the reaction is carried out at 28°C, for what temperature rise the reaction rate will double ? 5

(b) From the following data, show that the decomposition of hydrogen peroxide in aqueous solution is a first order reaction.

Time in minute	0	5	10	20
$KMnO_4$ (ml)	46.1	37.1	29.8	19.6

5

3. Sulfuryl chloride vapours are heated in a closed vessel for 30 min. at 610°F (321°C) and 1 atm initial pressure. The dissociation of SO_2Cl_2 to SO_2 and Cl_2 is a reaction of the first order and not influenced by the walls of the vessel. The reverse reaction is negligible. The reaction velocity constant is 0.00132 per min. Calculate : 10

(a) the percentage decomposition of SO_2Cl_2 in 30 min.

(b) the weight of SO_2 formed from 1 m^3 of SO_2Cl_2 at the initial conditions in 30 min.

(c) the time required to decompose 90% of SO_2Cl_2.

4. If $C_{B0} = C_{C0} = 0$ initially for the simultaneous reaction system $A \xrightarrow{k_1} B \xrightarrow{k_2} C$. What is the time at which the yield of B is a maximum? What is the maximum yield? 10

5. (a) Calculate A, Arrhenius constant and E, activation energy from the following data:

T,°K	313	319	323	333
K,Sec^{-1}	0.00043	0.00103	0.00180	0.00717

5

(b) Use the collision theory to estimate the specific reaction rate at 321.4°C for the decomposition of hydrogen iodide,

$2HI \rightarrow I_2 + H_2$,

Assume that the collision diameter σ is 3.5 A°(3.5×10^{-8}cm) and activation energy is 44000 cal/gm mole. Also evaluate the frequency factor. 5

Group - B

6. At high temperature nitrogen peroxide decomposes to oxygen and nitrogen dioxide :

$2N_2O_5 \rightarrow 4NO_2 + O_2$ ..... (1)

Experimental observations are found to be good agreement with the following mechanism

$N_2O_5 \underset{k_2}{\overset{k_1}{\Leftrightarrow}} NO_2 + NO_3$ ..... (2)

$NO_3 + NO_2 \xrightarrow{k_3} NO + NO_2 + O_3$ .....(3)

$NO + NO_3 \xrightarrow{k_4} 2NO_2$ ..... (4)

The reaction (3) was found to be slowest step and hence determine the overall rate of reaction. Determine a rate expression from the given mechanism. 10

7. A second order, reversible liquid phase reaction is to be carried out in a CSTR having volume 150 litres.

$P + Q \underset{k_2}{\overset{k_1}{\Leftrightarrow}} R + S$

$k_1 = 8.5$ lit/mol min.

$k_2 = 6.5$ lit/mol min.

The concentration of reactant P is 2.6 mol/lit, while that of Q is 2.0 mol/lit. The reactants are introduced in equal volume in the reactor. It is desired to have 60% conversion of the limiting reactant. Calculate the necessary flow rate of each reactant stream ? 10

8. In order to study the residence time distribution in a CSTR operating at steady state, a tracer is introduced in the feed stream. The tracer concentration in the effluent stream is monitored as a function of time and the data is tabulated as shown below:

T (sec)	0	100	200	300	460	500	670	735	840	960	1100
Tracer concn. (g/m3)	0	2.9	8.7	12.4	10	6.5	3.0	1.5	0.5	0.00	0.0

Time is measured relative to that when the tracer is injected.

Calculate: 10

(i) the average residence time of the fluid and F (t) curve for the system.

(ii) the variance of the response to the pulse input.