B. Tech.

(SEM. VI) EXAMINATION, 2006-07
CHEMICAL REACTION ENGINEERING - II

Time : 3 Hours] [Total Marks : 100

Notes : (1) Attempt all questions.
(2) Be precise in your answers
(3) In case of numerical problem assume data wherever not provided.

I Attempt any four parts of the following 5×4=20

(a) How does the catalysed reaction change with energy of reacting particles?

(b) What are the factors in a solid-fluid catalitic reaction which control a reaction?

(c) What is Active-site theory and under which conditions it is applicable?

(d) For catalytic kinetics discuss differential and integral reactors.

(e) A catalytic reaction takes place A → 4R at 3.2 atm and 110°C in a plug flow reactor. The reactor contains 0.01 kg of catalyst and uses a feed consisting partially converted product of 20 litre/hr of pure unreacted A. The results are as follows:

<table>
<thead>
<tr>
<th>Run</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_{A, in} mole</td>
<td>0.100</td>
<td>0.080</td>
<td>0.060</td>
<td>0.040</td>
</tr>
<tr>
<td>C_{A, out} mole</td>
<td>0.084</td>
<td>0.070</td>
<td>0.055</td>
<td>0.038</td>
</tr>
</tbody>
</table>

Find a rate equation to represent this reaction.

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(f) A first order catalytic reaction is carried out in a packed bed reactor. Feed rate is 1450 md/h of reactant at 2.8 atm and 123°C. For a 52% conversion calculate the quantity of catalyst required for the reaction. Given the reaction is first order A \rightarrow 3R, volumetric flow 78.33 lit/h kg. of catalyst and the rate of reaction is \((-r_A) = 78.33 \text{ C}_A\). Assume plug flow conditions.

2 Attempt any four parts of the following: \(5 \times 4 = 20\)
(a) Explain continuous reaction model for porous catalysts and give electrical analog of a pore.
(b) What is effectiveness factor? Explain and discuss.
(c) Show that the selectivity of two concurrent first order reactions occurring in flat shaped porous catalysts is independent of the effect of either heat or mass transfer if the activation energies of both reactions are equal.
(d) An approximate design procedure for packed tabular reactors entails the assumption of plug flow conditions throughout the reactor. Discuss those effects which would (i) invalidate plug flow assumptions and (ii) enhance plug flow.
(e) For a catalytic reaction of type A+B ⇄ P what is possible driving force if (i) Adsorption of A controls rate? and (ii) Surface reaction controls rate?
(f) Give reasons for catalyst poisoning.

3 Attempt any two parts of the following: \(10 \times 2 = 20\)
(a) In a fluidized catalytic reactor, under isothermal conditions, a first order reaction is carried out in the bubbling regime. Given overall mass transfer
coefficient between bubbles and the dense phase $k_{ga} = 0.7 \text{ sec}^{-1}$, catalytic first order reaction rate constant $K = 0.07 \text{ m}^3/\text{kg-sec}$, bubbles superficial velocity $U_b = 0.13 \text{ m/s}$, Bed reactor height $Z = 0.55\text{m}$, Fraction of the fluidized bed reactor occupied by the dense phase $\varepsilon_d = 0.76$ and density of catalyst particles in dense phase $\rho_d = 15 \text{ kg/m}^3$. Calculate fractional conversion in the fluidized bed.

(b) For the data in 3(a) calculate the conversion in CSTR and PER with the same bubble residence time. If different in conversion values discuss the results.

(c) What factors have to be considered for selecting a single of multiple reactor system?

4 Attempt any two parts of the following: \(10 \times 2 = 20\)

(a) The decomposition of cyclohexane to benzene and hydrogen is mass transfer limited at high temperatures. The reaction is carried out in a 5cm i.d. pipe 20 m in length packed with cylindrical pellets 0.5cm in diameter and 0.5cm in length. If the pellets are coated with catalyst only on the outside, the bed porosity is 40\% and inlet flow rate is 60 dm$^3$/min. Calculate the number of pipes necessary to achieve 99.9\% conversion of cyclohexane from an entering gas stream of 5\% cyclohexane and 95\% hydrogen at 2 atm and 500°C.

(b) A catalytic reaction $A \rightarrow 3R$ is carried out in a mixed flow reactor for 45\% conversion of reactant A to product. The feed rate is 1800 mol/h of pure A at 3.5 atm and 110°C. If the rate expression for the reaction is \(c \cdot r_A = 79.5 \text{ C}_A \text{ mid/kg cal} \), calculate the volume of catalyst bed needed for the operation.
(c) Dehydrogenation of ethylbenzene is carried out for manufacturing styrene in a tabular reactor. The reaction is carried out in presence of a catalyst at 560°C. Following reaction takes place.
\[ C_6H_5CH_2CH_3 \rightarrow C_6H_5CH = CH_2 + H_2 \]
and the equilibrium constant for the reaction (Kp) is \(1.85 \times 10^{-4}\) N/m\(^3\). Calculate
(i) The maximum possible conversion of ethylbenzene at 1 bar if pure reactant is used and
(ii) The maximum possible conversion of ethylbenzene if it is diluted with steam in the molar ratio 1:20.

5 Attempt any two parts of the following: 10*2=20
(a) Derive Michaelis-Menten equation and explain under which conditions it is valid. What is its importance?
(b) At room temperature sucrose is hydrolyzed by the catalytic action of an enzyme as follows:

\[ S + E \xrightleftharpoons[^{\mu_1}]^{^{\mu_2}} [S.E.]^* \xrightarrow[^{\mu_3}] P + E \]

Where \(S\) is sucrose, \(E\) is enzyme and \(P\) is the product. Starting with a sucrose concentration \(S_0 = 1.0\) m.mol/l and enzyme concentration \(E_0 = 0.01\) m.mol/l, the following kinetic data are obtained in a batch reactor.

<table>
<thead>
<tr>
<th>(S, \text{ml/ml})</th>
<th>0.84</th>
<th>0.38</th>
<th>0.16</th>
<th>0.09</th>
<th>0.04</th>
<th>0.018</th>
<th>0.0025</th>
</tr>
</thead>
<tbody>
<tr>
<td>(t, \text{hr})</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>11</td>
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</table>

Determine whether these data satisfy the Michaelis-Menten relationship. Evaluate the Michaelis constant.
(c) Discuss the enzymatic and microbial fermentation kinetics. Give examples of each.