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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY  
07 THRISSUR CLUSTER

SECOND SEMESTER M.TECH. DEGREE EXAMINATION APRIL 2018  
CHEMICAL ENGINEERING  
PROCESS CONTROL  
07CH6102 ADVANCED CHEMICAL REACTION ENGINEERING

Time:3 hours

Max.Marks: 60

Answer all six questions. Part 'a' of each question is compulsory.

Answer either part 'b' or part 'c' of each question

Q.no.	Module 1	Marks
1a	Liquid A decomposes by second order kinetics, and in a batch reactor 50% of A is converted in a 5 minute run. How much longer would it take to reach 75% conversion?	4
Answer b or c		
b	Derive the performance equation for a steady-state back mixed flow reactor.	5
c	The homogeneous gas decomposition of A, $4A \rightarrow R+6S$ proceeds at 649°C with the first order rate $-r_A = (10/\text{hr}) C_A$ . What size of plug flow reactor operating at 649°C and 460kPa can produce 80% conversion of 40 mol of pure A per hour?	5
Q.no.	Module 2	Marks
2a	Explain general graphical design procedure for finding out the volume required for a particular reactor.	4
Answer b or c		
b	Derive the expression for finding the conversion of adiabatic and nonadiabatic operations in PFR/MFR.	5

- c** The concentration readings in table given below represent a continuous response to a pulse input into a closed vessel which is to be used as a chemical reactor. Calculate the mean residence time of fluid in the vessel  $t$ , and tabulate and plot the exit age distribution  $E$ .

Time t, min	0	5	10	15	20	25	30	35
C <sub>pulse</sub> gm/l fluid	0	3	5	5	4	2	1	0

Q.no.	Module 3	Marks
3a	A gas containing A ( $2\text{mol/m}^3$ ) is fed ( $1\text{ m}^3/\text{hr}$ ) to a plug flow reactor with recycle loop ( $0.02\text{ m}^3$ loop volume, $3\text{ kg}$ of catalyst), and the output composition from the reactor is $0.5\text{ mol A/m}^3$ . Find the rate equation for the decomposition of A for very large recycle, $\text{A} \rightarrow 3\text{R}$ , first order kinetics, $50\%\text{A}-50\%\text{ inerts}$ in feed.	4
<b>Answer b or c</b>		
b	Derive the expression for effectiveness factor for a first order reaction on a porous catalyst.	5
c	Derive performance equation for reactions containing porous catalyst for plug flow reactor.	5

Q.no.	Module 4	Marks
4a	Describe in detail different contacting patterns of fixed bed reactors for uniform temperature distribution.	4
<b>Answer b or c</b>		
b	Explain the K-L Model of bubbling fluidised bed by stating the assumptions and salient equations.	5
c	<p>A single catalytic packed bed reactor is to be designed to treat 100mol/s of reactant A and produce product R. Feed gas enters at 2.49MPa &amp; 300K, the maximum allowable temperature is 900K unless otherwise noted, and the inlet temperature is 600K, the product stream is wanted at 300K and thermodynamic and kinetics of the exothermic reaction are given to us (<math>C_p = 40 \text{ J/mol. K}</math>, for all materials and at all temperatures, <math>\Delta H_r = -80000 \text{ J/mol}</math>, same value at all temperatures). Prepare a sketch showing the details of the system you plan to use.</p> <ul style="list-style-type: none"> <li>• Type of reactor-plug, recycled or mixed</li> <li>• Amount of catalyst needed.</li> <li>• Heat duty ahead of the reactor, at the reactor itself and after the reactor.</li> </ul>	5

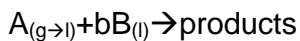
- The temperature of all fluid streams.

Work out a good design for 80% conversion of feed consisting of 1molA and 7mol inert.

$X_A$	0.8	0.78	0.7	0.6	0.5	0.1	0
$-r_A$	0.05	0.1	0.2	0.225	0.2	0.05	0.03

<b>Q.no.</b>	<b>Module 5</b>	<b>Marks</b>
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<b>5a</b>	Write the general rate expression for the reaction on catalyst surface	<b>5</b>
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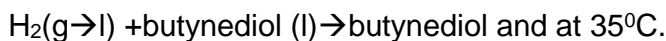


And also the rate expression if

- i. The system with pure liquid B and slightly soluble gas A
- ii. The system with dilute liquid B and highly soluble gas A

**Answer b or c**

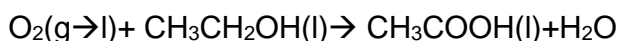
<b>b</b>	Hydrogen gas is bubbled into an agitated tank ( $V_r = 2 \text{ m}^3$ ) containing liquid butynediol ( $C_{B0} = 2500 \text{ mol/m}^3$ ) plus a dilute suspension of palladium-impregnated porous catalyst pellets ( $d_p = 5 \times 10^{-5} \text{ m}$ cat, $\rho = 1450 \text{ kg/m}^3$ cat, $D_e = 5 \times 10^{-10} \text{ m}^2/\text{s}$ , $f_s = 0.0055$ ). Hydrogen dissolves in the liquid ( $H_A = 148000 \text{ Pa.m}^3/\text{mol}$ ) and reacts with the butynediol on the catalyst surface as follows:	<b>7</b>
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$$-r_A = k' C_A C_B \text{ and } k' = 5 \times 10^{-5} \text{ m}^6/\text{kg.molcat.s}$$

Unused hydrogen is recompressed and recirculated, and the whole operation takes place at 1.46 atm and  $35^\circ\text{C}$ . Find out how it will take for 90% conversion of reactant. The mass transfer rates are given as  $(K a_i)_{g+l} = 0.2777 \text{ m}^3/\text{m}^3\text{r.s}$ ,  $K_{AC} = 4.4 \times 10^{-4} \text{ m}^3/\text{m}^3\text{r.s}$

<b>c</b>	Dilute aqueous ethyl alcohol is oxidised to acetic acid by the action of pure oxygen at 10 atm in a trickle bed reactor maintained at $30^\circ\text{C}$ and packed with Pd- $\text{Al}_2\text{O}_3$ catalyst pellets. The reaction proceeds as follows:	<b>7</b>
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The reaction is first order with respect to Hydrogen and zero order with respect to ethyl alcohol with rate constant  $K'$  at  $30^\circ\text{C} = 1.77 \times 10^{-5} \text{ m}^3/(\text{kg cat.s})$

Calculate the fractional conversion of ethyl alcohol if gas and liquid are fed to the top of a reactor.

Data:

Gas:  $v_g = 0.01 \text{ m}^3/\text{s}$ ,  $H_A = 86000 \text{ Pa} \cdot \text{m}^3/\text{mol}$

Liquid:  $v_l = 2 \cdot 10^{-4} \text{ m}^3/\text{s}$ ,  $C_{B0} = 400 \text{ mol/m}^3$

Reactor: 5 m high,  $0.1 \text{ m}^2$  cross section,  $f_s = 0.58$

Catalyst:  $d_p = 5 \text{ mm}$ ,  $\rho = 1800 \text{ kg/m}^3$ ,  $De = 4.16 \cdot 10^{-10} \text{ m}^2/\text{s}$

Kinetics:  $k_{Ag} a_i = 3 \cdot 10^{-4} \text{ mol/m}^3 \text{ Pa} \cdot \text{s}$ ,  $k_{Al} a_i = 0.02 \text{ s}^{-1}$ ,  $k_{AC} = 3.86 \cdot 10^{-4} \text{ m/s}$

Q.no.	Module 6	Marks
6a	Derive the rate equation for straight mass transfer for gas liquid reaction. $A_{(g)} + bB_{(l)} \longrightarrow R_{(l)}$	5
<b>Answer b or c</b>		
b	Air with gaseous A bubbles through a tank containing aq. B. Reaction occurs as follows. $A_{(g)} + 2B_{(l)} \longrightarrow R_{(l)}$ <p>For this system,</p> <p><math>k_{Ag} a = 0.01 \text{ mol/hr} \cdot \text{m}^3 \cdot \text{Pa}</math>, <math>f_l = 0.98</math>, <math>k_{Al} a = 20 \text{ hr}^{-1}</math>, <math>H_A = 10^5 \text{ Pa} \cdot \text{m}^3/\text{mol}</math>. very low solubility. <math>D_{Al} = D_{Bl} = 10^{-6} \text{ m}^2/\text{hr}</math>. <math>A = 20 \text{ m}^2/\text{m}^3</math></p> <p>for a point in the absorber-reactor where, <math>p_A = 0.0005 \text{ Pa}</math>. and <math>C_B = 100 \text{ mol/m}^3</math></p> <ol style="list-style-type: none"> <li>locate the resistance to reaction ( what % in gas film, in the liquid film, in the main body of liquid)</li> <li>locate the reaction zone.</li> <li>Determine the behaviour in the liquid film (Whether pseudo first order reaction, instantaneous, physical transport etc)</li> <li>Calculate the rate of reaction (<math>\text{mol/m}^3/\text{hr}</math>)</li> </ol>	7
c	Illustrate the design procedure for straight mass transfer in countercurrent towers.	7