## V SEMESTER B.TECH. END SEMESTER EXAMINATIONS JAN-FEB 2021

## SUBJECT: CHEMICAL REACTION ENGINEERING [CHE 3151]

### REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

**Instructions to Candidates:**

- Answer **ALL** the questions.
- Missing data may be suitable assumed.
- Use graphs wherever relevant.

| | | |
|---|---|---|
| **1A.** | A rocket engine burns a stoichiometric mixture of fuel (liquid hydrogen) in oxidant (liquid oxygen). The combustion chamber is a cylinder of length 0.75 m and diameter 0.60 m. The combustion reaction<br>$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$<br>produces 108 kg/s of exhaust gases. If the combustion is complete, find the rate of reaction of i) hydrogen and ii) oxygen in mol/m$^3$. s | **04** |
| **1B.** | The maximum allowable temperature for a reactor is 800 K. At present our operating set point is 780 K. Now, with a more sophisticated control system we would be able to raise our set point to 792 K. By how much can the reaction rate be raised by this change if the reaction has an activation energy of 175 KJ/mol? | **03** |
| **1C.** | Deduce a mechanism that is consistent with the experimentally found rate equation for the following reaction<br>$2A + B \rightarrow A_2B$<br>$+r_{A_2B} = k[A][B]$ | **03** |
| **2A.** | Deduce the performance equation from basic principles for an ideal batch reactor for a gas phase reaction with significant density change. | **05** |
| **2B.** | A homogenous gas phase reaction A-> 3R has a rate $-r_A = 0.01\ C_A^{1/2}$ mol/l sec at 215 $^0$C.<br>i) Choose the best flow reactor to achieve 80% conversion of a 50% A-50% inert feed at 215$^0$C & 5 atm; $C_{A0}$= 0.0625 mol/l.<br>ii) Find the space time needed. | **2+3** |
| **3A.** | i) What is the purpose of using recycle stream in a PFR?<br>ii) Choose among PFR, CSTR and PFR with recycle to perform an autocatalytic reaction. Justify your choice.<br>iii) What is optimum recycle ratio? | **2+3+2** |

| | | |
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| **3B.** | Define Damköhler number. Explain its relevance to reactors in series. | **03** |

**4A.** (**4+3**)

Substance A in a liquid phase reaction produces R and S as follows:

Both are first order reactions with rate constants $k_1$ and $k_2$. A feed ($C_{A0} = 1$, $C_{R0} = 0$, $C_{S0} = 0$) enters two mixed flow reactors in series, ($\tau_1$ = 2.5 min, $\tau_2$ = 5 min). Knowing the composition in the first reactor ($C_{A1} = 0.4$, $C_{R1} = 0.4$, $C_{S1} = 0.2$)

i) Find the rate constants.

ii) Find the composition ($C_{A2}$, $C_{R2}$, $C_{S2}$) leaving the second reactor.

**4B.** (**03**)

Starting with separate feeds of reactant A and B of given concentration, for the competitive-consecutive reactions with stoichiometry and rate as shown

$A + B \rightarrow R_{desired}$ ; $r_{1=} \; k_1 \, C_A C_B$

$R + B \rightarrow S_{unwanted}$; $r_2 = \; k_2 \, C_R C_B^2$

sketch the best contacting patterns for both continuous and batch operations.

| | | |
|---|---|---|
| **5A.** | Discuss the various non ideal flow patterns which exist in process equipment. | **3** |
| **5B.** | Derive an expression for conversion for a first order reaction, in a real CSTR modeled using bypass and dead space. (Evaluation of model parameters **not** required). | **4** |

**5C.** (**3**)

A sample of a tracer at 320 K was injected as a pulse to a reactor, and the effluent concentration was measured as a function of time given in the table. Also, E(t) was calculated.

| t(min) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C(t) g/m$^3$ | 1 | 5 | 8 | 10 | 8 | 6 | 4 | 3 | 2.2 | 1.5 | 0.6 | 0 |
| E(t) min$^{-1}$ | 0.02 | 0.1 | 0.16 | 0.2 | 0.16 | 0.12 | 0.08 | 0.06 | 0.044 | 0.03 | 0.012 | 0 |

Find the mean residence time?