Name: ______________________________

Chemical Reaction Engineering
ChEE 420
The University of Arizona
Prof. Suchol Savagatrup

Midterm Exam 1

September 29th, 2020

Problem 1 _____________ (/30)

Problem 2 _____________ (/35)

Problem 3 _____________ (/35)

Total ___________ (/100)

Exam Rules:

1. This exam is open book and open notes.
2. You may use a calculator, no other electronic devices.
3. You will have 75 minutes to work on the exam.
4. **Write only on one side of the papers. Extra paper is available.**
5. **Box your final answers.**
6. **Write you name on every page that you wish to be graded**
7. Must show work to receive full credit.
8. Turn off cell phones and any device that makes noise.
9. All work must be your own. No talking during the exam.

DO NOT OPEN THE EXAM UNTIL YOU ARE INSTRUCTED TO DO SO.

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Potentially Useful Equations, Constants, Integrals

Constants

$$R = 8.314 \frac{J}{mol\ \cdot K} \qquad\qquad R = 0.082 \frac{atm\ \cdot L}{mol\ \cdot K}$$

Equations

$$k(T) = Aexp\left(-\frac{E}{RT}\right)$$

$$k(T) = k(T_1)\exp\left[\frac{E}{R}\left(\frac{1}{T_1} - \frac{1}{T}\right)\right]$$

$$P_i = C_i RT$$

$$P_{Total}V = N_{Total}RT$$

$$C_i = \frac{N_i}{V} = \frac{F_i}{\upsilon}$$

$$K_C = \frac{k_f}{k_r}$$

Useful Integrals in Reactor Designs

$$\int_0^x \frac{dx}{1-x} = \ln\frac{1}{1-x}$$

$$\int_{x_1}^{x_2} \frac{dx}{(1-x)^2} = \frac{1}{1-x_2} - \frac{1}{1-x_1}$$

$$\int_0^x \frac{dx}{(1-x)^2} = \frac{x}{1-x}$$

$$\int_0^x \frac{dx}{1+\varepsilon x} = \frac{1}{\varepsilon}\ln(1+\varepsilon x)$$

$$\int_0^x \frac{(1+\varepsilon x)dx}{1-x} = (1+\varepsilon)\ln\frac{1}{1-x} - \varepsilon x$$

$$\int_0^x \frac{(1+\varepsilon x)dx}{(1-x)^2} = \frac{(1+\varepsilon)x}{1-x} - \varepsilon\ln\frac{1}{1-x}$$

$$\int_0^x \frac{(1+\varepsilon x)^2 dx}{(1-x)^2} = 2\varepsilon(1+\varepsilon)\ln(1-x) + \varepsilon^2 x + \frac{(1+\varepsilon)^2 x}{1-x}$$

$$\int_0^x \frac{dx}{(1-x)(\Theta_B - x)} = \frac{1}{\Theta_B - 1}\ln\frac{\Theta_B - x}{\Theta_B(1-x)} \qquad \Theta_B \neq 1$$

$$\int_0^W (1-\alpha W)^{\frac{1}{2}}\,dW = \frac{2}{3\alpha}\left[1 - (1-\alpha W)^{\frac{3}{2}}\right]$$

$$\int_0^x \frac{dx}{ax^2+bx+c} = -\frac{2}{2ax+b} + \frac{2}{b} \qquad for\ b^2 = 4ac$$

$$\int_0^x \frac{dx}{ax^2+bx+c} = \frac{1}{a(p-q)}\ln\left(\frac{q}{p}\cdot\frac{x-p}{x-q}\right) \quad for\ b^2 > 4ac$$

Where p and q are the roots of the equation.

$$ax^2+bx+c = 0 \quad \text{i.e.}, p, q = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$\int_0^x \frac{a+bx}{c+gx}dx = \frac{bx}{g} + \frac{ag-bc}{g^2}\ln\frac{c+gx}{c}$$

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Problem 1a: Residence time in a PFR (6 points)

You have two PFR reactors with the following reactions:

Reactor 1: $A \rightarrow B$
Reactor 2: $A \rightarrow C$

Both are isothermal, isobaric, and irreversible gas-phase reactions. Assume that the rates of reaction for both are identical ($-r_A = k_A C_A$) with the same value of the rate constants. Temperature and pressure are kept constant and identical in both reactors. The inlet molar flowrate of A (F_{A0}) and the inlet volumetric flowrate (v_0) are identical. Both reactors have the same total volume (V). Only A is fed into both reactors.

Will the outlet molar flowrate (F_A) from reactor 1 be larger, equal, or smaller than that of reactor 2? *Justify your answer in 1-2 sentences. Response without justification will not receive credit.*

Hint: Recall that inside a PFR, the residence time can be expressed as $\tau = \frac{V}{v_0}$ *for constant volumetric flow rate and* $\tau = \int_0^V \frac{dV}{v}$ *for varying volumetric flow rate.*

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Problem 1b: Levenspiel Plot (6 points)

The following irreversible, liquid-phase reaction ($A + B \rightarrow C + D$) is carried out in two separate *steady-state* reactors, a PFR and a CSTR. Both reactors achieve the same conversion ($X_{PFR} = X_{CSTR}$). The Levenspiel plot for this reaction is given below. **Is it possible to have a scenario where the volume of the aforementioned CSTR <u>is greater than</u> the volume of the aforementioned PFR (*i.e.*, $V_{CSTR} > V_{PFR}$)?**

*Respond with yes or no **<u>and</u>** a short justification or a qualitative graph. Reponses that guess the correct answer without justification will not receive credit.*