sheet 1 :-

Q1/ $A \to B$ First order $(-r_A = k C_A)$ $v_0 = v$

1) $$V = \int_{F_{A0}}^{F_A} \frac{dF_A}{-r_A} = \int_{C_{A0}}^{C_A} \frac{d(C_A v)}{-k C_A} = \frac{-v}{k} \int_{C_{A0}}^{C_A} \frac{dC_A}{C_A}$$

$F = C \cdot V$

$$V = \frac{-v}{k} \Big[\ln C_A \Big]_{C_{A0}}^{C_A} = \frac{-v}{k} (\ln C_A - \ln C_{A0})$$

$$V = \frac{v}{k} (\ln C_{A0} - \ln C_A) = \frac{v_0}{k} \ln \frac{C_{A0}}{C_A}$$

②
$$V = \frac{10}{0.23} \ln \frac{C_{A0}}{0.1\, C_{A0}}$$

$C_A = 0.1\, C_{A0}$

$$V = \frac{10}{0.23} \ln \frac{1}{0.1} = 100\, dm^3$$

Q2/ $$\frac{dN_A}{dt} = r_A V$$

$r_A = k C_A$

$$r_A = k \frac{N_A}{V}$$

$$\frac{dN_A}{dt} = -k \frac{N_A}{\cancel{V}} * \cancel{V}$$

$$\frac{dN_A}{dt} = -KN_A \rightarrow dt = \frac{dN_A}{-KN_A}$$

$$\int_0^t dt = \frac{1}{-K} \int_{N_{A0}}^{N_A} \frac{dN_A}{N_A} \rightarrow t = \frac{-1}{K} \ln(N_A - N_{A0})$$

$$t = \frac{1}{K} \ln \frac{N_{A0}}{N_A} \quad 0.01 N_{A0}$$

$$t = \frac{1}{0.23} \ln \frac{\cancel{N_{A0}}}{0.01\cancel{N_{A0}}} = 20\,min$$

Q3) For a reaction $A \rightarrow B$

e) $\boxed{r_A}$:- is the number of moles of A reacting per unit time per unit volume. (moles / $dm^3 \cdot s$).

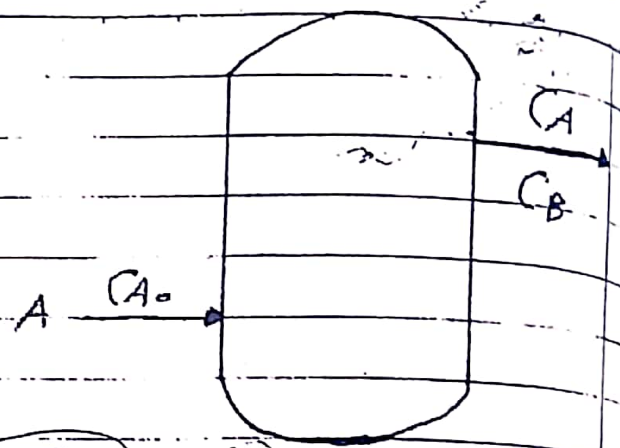
$-r_A'$:- is the rate of disappearance of species A per unit mass of catalyst (moles / time . mass of catalyst).

r_A:- is the rate of formation of species A per unit mass of catalyst (moles / time . mass of catalyst).

r_A:- is an intensive property that is a function of concentration, temperature, pressure, and the type of catalyst, and is defined at any point within the system. It is independent of amount. On the other hand an extensive property is obtained by summing up the properties of individual sub systems within the total system. In the case r_A is independent of the extent of the system

Q5/

$A \rightarrow B$



$F_{A_0} = 5\ mol/hr$

$V_0 = 10\ dm^3/hr = V$

$F_{A_0} = C_{A_0} V_0 \Rightarrow C_{A_0} = \frac{F_{A_0}}{V_0}$ $\quad C_A = 0.01\, C_{A_0}$

$C_{A_0} = \frac{5}{10} = 0.5\ mol/dm^3$

V_{CSTR} and $V_{PFR} = ?$

a) Zero order $\quad -r_A = K (C_A)^0 = K$

① CSTR:

$$V_{CSTR} = \frac{F_{A_0} - F_A}{-r_A}$$

$F_{A_0} = C_{A_0} V_0 \qquad F_A = C_A V = 0.01\, C_{A_0} V_0$

$$V = \frac{C_{A_0}V_0 - 0.01\, C_{A_0} V_0}{K} = \frac{C_{A_0} V_0 (1 - 0.01)}{K}$$

$$V = \frac{0.5 * 10\,(1 - 0.01)}{0.05} = 99\ dm^3$$

② PFR

$$\frac{dF_A}{dV} = r_A \rightarrow \frac{dF_A}{dV} = -K$$

$$F_A = C_A V = C_A V_0$$

$$-r_A = K = \frac{N_A}{V}$$

$$\frac{d(C_A V_0)}{dV} = -K \rightarrow V_0 \frac{dC_A}{dV} = -K$$

$$\frac{V_0}{-K} \int_{C_{A0}}^{C_A} dC_A = \int_0^V dV \rightarrow V = \frac{-V_0}{K} (C_A - C_{A0})$$

$$V = \frac{V_0}{K} (C_{A0} - C_A)$$

$$V = \frac{10}{0.05} (C_{A0} - 0.01 C_{A0}) = \frac{10}{0.05} (0.5 - 0.01 * 0.5)$$

$$V = 99 \, dm^3$$

b) First order $\qquad r_A = K \boxed{C_A}$

① CSTR

$$V = \frac{F_{A0} - F_A}{-r_A}$$

$F_{A0} = C_{A0} V_0$ $\qquad F_A = C_A V = 0.01 C_{A0} V_0$

Cons Volu: $V = V_0$

$$V = \frac{C_{A0}v_0 - 0.01\,C_{A0}v_0}{+KC_A} = \frac{C_{A0}v_0(1-0.01)}{K * 0.01\,C_{A0}}$$

$$V = \frac{(1-0.01)v_0}{K * 0.01} = \frac{(1-0.01) * 10}{0.0001 * 3600 * 0.01}$$

$V = 2750\ dm^3$

② PFR

$$\frac{dF_A}{dV} = r_A \qquad F_A = C_A v = 0.01\,C_{A0}v_0 = C_A v$$

$$\frac{d(C_A v_0)}{dV} = -KC_A$$

$$\frac{v_0}{K}\frac{dC_A}{dV} = -KC_A \rightarrow \frac{v_0}{-K}\int_{C_{A0}}^{C_A}\frac{dC_A}{C_A} = \int_0^V dV$$

$$V = \frac{-v_0}{K}(\ln C_A - \ln C_{A0}) = \frac{v_0}{K}\ln\frac{C_{A0}}{C_A}$$

$$V = \frac{10}{0.0001 * 3600}\ln\frac{C_{A0}}{0.01\,C_{A0}} = \frac{10}{0.36}\ln\frac{1}{0.01}$$

$V = 127.9\ dm^3$

c) second order $r_A = K C_A^2$

① CSTR

$$V = \frac{F_{A0} - F_A}{-r_A}$$

$r_A = \int \frac{dF_A}{V}$

~~$F_{A0} = C_{A0} V_0$~~ $F_A = C_A V = 0.01 C_{A0} V_0$

$V = \int \frac{dF_A}{r_A}$

$$V = \frac{C_{A0}V_0 - 0.01 C_{A0} V_0}{+K C_A^2} = \frac{C_{A0} V_0 (1 - 0.01)}{+K (0.01 C_{A0})^2}$$

$$V = \frac{C_{A0} V_0 (1 - 0.01)}{+K\, 0.0001 C_{A0}^2} = \frac{V_0 (1 - 0.01)}{+0.0001 K C_{A0}}$$

$$V = \frac{10 * (1 - 0.01)}{0.0001 * 3 * 0.5} = 66.000\, dm^3$$

② PFR

$$\frac{dF_A}{dV} = r_A$$

$F_A = C_A V = C_A V_0$

$$\frac{d(C_A V_0)}{dV} = -K C_A^2$$

$\frac{1}{+C_A}$

C_A^{-2} ⊖ C_A^{-1}

C_A^{-2+1} ⊖ C_A^{-1}

$\frac{1}{-C_A}$

$$V_0 \frac{dC_A}{dV} = -K C_A^2 \rightarrow \frac{V_0}{-K} \int_{C_{A0}}^{C_A} \frac{dC_A}{C_A^2} = \int_0^V dV$$

$2 C_A$

$$V = \frac{N_0}{K}\left(\frac{1}{C_A} - \frac{1}{C_{A0}}\right) = \frac{N_0}{K}\left[\frac{1}{0.01\,C_{A0}} - \frac{1}{C_{A0}}\right]$$

$$V = \frac{10}{3}\left[\frac{1}{0.5 \times 0.01} - \frac{1}{0.5}\right] = 660\ dm^3$$

d) Batch reactor $t = ?$

① zero order $-r_A = K$

$$\frac{dN_A}{dt} = +r_A V \Rightarrow \frac{dN_A}{+r_A V} = dt$$

$$dt = \frac{\cancel{V}\,d(C_A \cancel{V})}{+r_A \cancel{V}} \Rightarrow dt = \frac{dC_A}{-K} \Rightarrow \int_0^t dt = \int_{C_{A0}}^{C_A} \frac{dC_A}{-K}$$

$$t = \frac{1}{-K}(C_A - C_{A0}) = \frac{1}{K}(C_{A0} - C_A) = \frac{1}{K}(C_{A0} - 0.01 C_{A0})$$

$$t = \frac{1}{0.05}(0.5 - 0.001 \times 0.5) = 9.99\ hr$$

② First order $-r_A = KC_A$

$$\frac{dN_A}{dt} = +r_A V \Rightarrow dt = \frac{dN_A}{+r_A V} \Rightarrow dt = \frac{d(C_A \cancel{V})}{+r_A \cancel{V}}$$

$$dt = \frac{dC_A}{-KC_A} \Rightarrow \int_0^t dt = \frac{1}{-K}\int_{C_{A0}}^{C_A} \frac{dC_A}{C_A}$$

$$t = \frac{1}{-K} \ln(CA - CA_0) \Rightarrow t = \frac{1}{K} \ln \frac{CA_0}{CA}$$

$$t = \frac{1}{K} \ln \frac{CA_0}{0.001\,CA_0} = \frac{1}{0.0001036} \ln \frac{1}{0.001} = 19.2\ hr$$

3) second order :

$$\frac{dN_A}{dt} = r_A V \Rightarrow \frac{dN_A}{r_A V} = dt$$

$NA = CA\,V \quad -r_A = K\,CA^2$

$$dt = \frac{d(CA * V)}{-KCA^2 * V} = \frac{dCA}{-KCA^2} \Rightarrow \int_0^t dt = \int_{CA_0}^{CA} \frac{dCA}{-KCA^2}$$

$$t = \frac{1}{+K}\left[\frac{1}{CA} - \frac{1}{CA_0}\right]$$

$$t = \frac{1}{3}\left[\frac{1}{0.001 * 0.5} - \frac{1}{0.5}\right] = 666\ hr$$

N_3

C

CV

Exercise:

t = ? batch reactor

$N_A = 0.1 N_{A0}$

$A \to B$ First order $K = 0.046 \text{ min}^{-1}$

$$\frac{dN_A}{dt} = +r_A V \qquad -r_A = K C_A$$

$$C_A = \frac{N_A}{V}$$

$$\frac{dN_A}{dt} = \underset{V\!\!E\!D}{+r_A V} \Rightarrow \frac{dN_A}{dt} = -K \frac{N_A}{\cancel{V}} \times \cancel{V}$$

$$\frac{dN_A}{dt} = -K N_A \Rightarrow \int_0^t dt = \frac{1}{-K} \int_{N_{A0}}^{N_A} \frac{dN_A}{N_A}$$

$$t = \frac{-1}{K} (\ln N_A - \ln N_{A0}) = \frac{1}{K} \ln \frac{N_{A0}}{N_A}$$

$$t = \frac{1}{0.046} \ln \frac{\cancel{N_{A0}}}{0.1 \cancel{N_{A0}}} = \frac{1}{0.046} \ln \frac{1}{0.1} = 50.06 \text{ min}$$

Q6/ $v = 1$ L/min $\quad A + B \to C$

$C_{A0} = 0.10$ mol/L $\quad C_{B0} = 0.01$ mol/L $\quad V = 1$ L

$C_{Af} = 0.02$ mol/L $\quad C_{Bf} = 0.03$ mol/L $\quad C_{cf} = 0.04$ mol/L

$$V = \frac{F_{A_0} - F_A}{-r_A} \rightarrow -r_A = \frac{F_{A_0} - F_A}{V}$$

$$F_{A_0} = C_{A_0} V_0 \qquad F_A = C_A V$$

$$-r_A = \frac{C_{A_0} V_0 - C_A V}{V} = \frac{0.10 * 1 - 0.02 * 1}{1} = 0.08 \ \frac{mol}{min \cdot L}$$

$$V = \frac{F_{B_0} - F_B}{-r_B} \rightarrow -r_B = \frac{F_{B_0} - F_B}{V}$$

$\frac{mol}{L \cdot min}$

$$F_{B_0} = C_{B_0} V_0 \ , \ F_B = C_B V$$

$$r_B = \frac{C_{B_0} V_0 - C_B V}{V} = \frac{0.01 * 1 - 0.03 * 1}{1} = -0.02 \ \frac{mol}{min \cdot L}$$

$$V = \frac{F_C - F_{C_0}}{+r_C} \rightarrow +r_C = \frac{F_C - F_{C_0}}{V}$$

$$F_{C_0} = C_{C_0} V_0 \qquad F_C = C_C V$$

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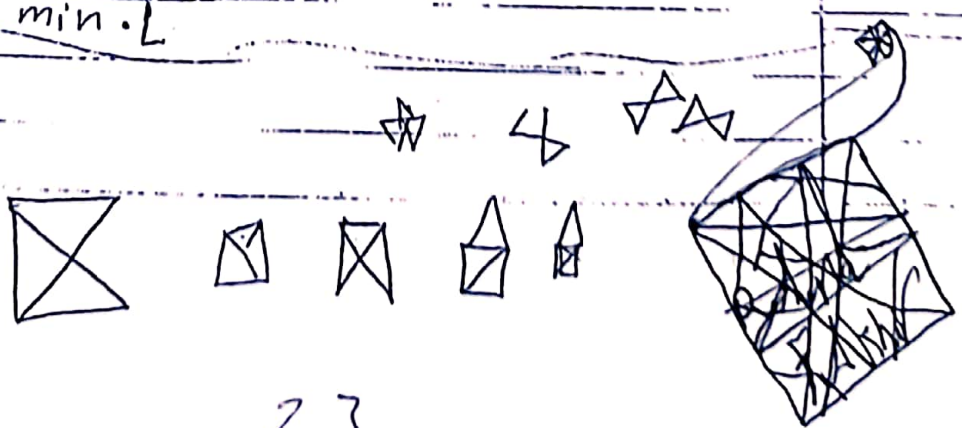
$$r_C = \frac{C_C V - C_{C_0} V_0}{V} = \frac{0.04 * 1 - 0 * 1}{1} = +0.04 \ \frac{mol}{min \cdot L}$$

$$r_C = 0.04 \ \frac{mol}{min \cdot L}$$

"Your words cut deeper
Than a knife, now
I need someone to
breathe me back to
life"



Sheet 3

Q1) A gas of Pure A at 830 KPa (8.2 atm) enters with a Volumetric flowrate of 2 dm^3/s at 500 K. Calcu... entering Concentration of A and the entering mola...

* Because we have gas Phase we can use the following:

$$C_{A0} = y_{A0} \frac{P_0}{R T_0}$$

$P_0 = 830$ KPa (8.2 atm)

y_{A0} = mole fraction = 1 (100 %) Pure (A).

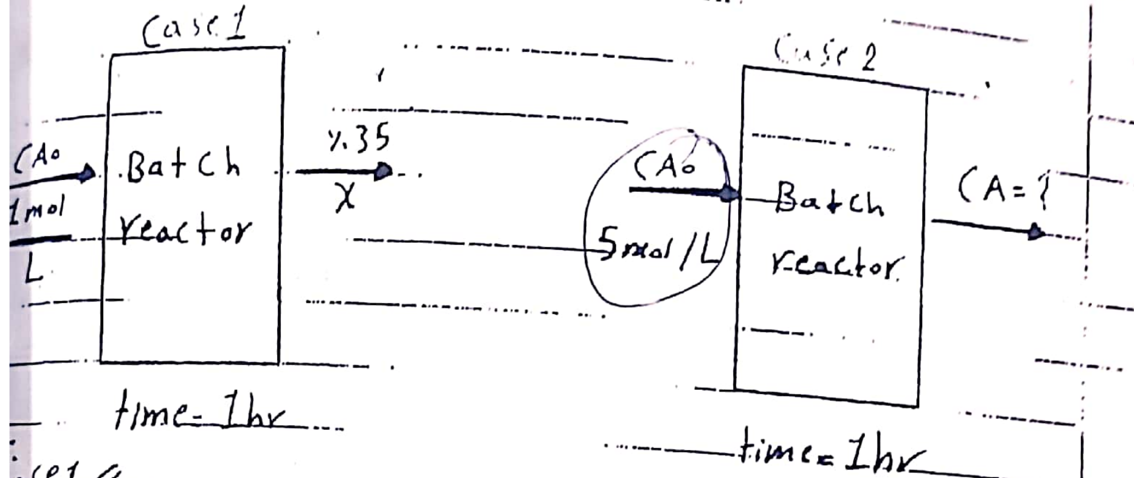
$T_0 = 500$ K

$$R = 8.314 \frac{KPa \cdot m^3}{mol \cdot K}$$

$$C_{A0} = \frac{1 * 830 \, KPa}{8.314 \frac{KPa \cdot m^3}{mol \cdot K} * 500 K} = 0.2 \, mol/dm^3$$

$F_{A0} = C_{A0} V = 0.2 * 2 = 0.4$ mol/s

2) For the liquid phase reaction $A \rightarrow D$ with second order kinetic and initial concentration of 1 mol/Liter, we get % 35 conversion after 1 hour in a batch reactor. What is the concentration of A after 1 hour if our raw material have a concentration of 5 mol/L instead? Explain why?



Case 1

$A \rightarrow D$ second order $\quad -r_A = K C_A^2$

$$\tau = N_{A_0} \int_0^{X_A} \frac{dX_A}{(-r_A)V} \qquad V = V_0$$

$$\tau = \frac{N_{A_0}}{V_0} \int_0^{X_A} \frac{dX_A}{K C_A^2} \qquad \frac{N_{A_0}}{V_0} = C_{A_0}$$

$$\tau = C_{A_0} \int_0^{X_A} \frac{dX_A}{K C_A^2} \qquad C_A = C_{A_0}(1 - X_A) \text{ For liquid Phase}$$

$$= C_{A_0} \int_0^{X_A} \frac{dX_A}{K C_{A_0}^{2}(1 - X_A)^2} = \frac{1}{K C_{A_0}} \int_0^{0.35} \frac{dX_A}{(1 - X_A)^2}$$

$$= \frac{1}{K C_{A_0}} \left[\frac{1}{1 - X_A} \right]_0^{0.35}$$

33

$$1 = \frac{1}{K * 1}\left[\frac{1}{1-0.35} - \frac{1}{1-0}\right] \Rightarrow K = 0.538 \frac{L}{mol}$$

Case 2 // $A \rightarrow D$ second order

$C_{A0} = 5\ mol/L$ $C_A = ?$ $t = 1\ hr$

$C_A = C_{A0}(1-X)$

$$t = \frac{1}{K C_{A0}} \int_0^X \frac{dX}{(1-X)^2} = \frac{1}{K C_{A0}}\left[\frac{1}{1-X}\right]_0^X$$

$$1 = \frac{1}{0.538 * 5}\left[\frac{1}{1-X} - \frac{1}{1-0}\right]$$

$$1 * (0.538 * 5) = \frac{1}{1-X} - 1$$

$$2.69 + 1 = \frac{1}{1-X} \Rightarrow 3.69 = \frac{1}{1-X}$$

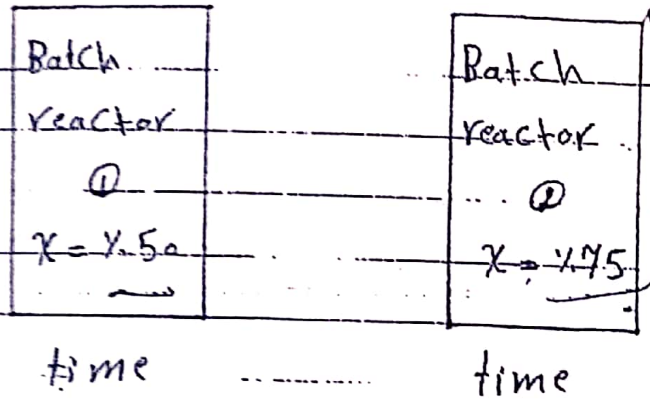
$3.69 - 3.69X = 1 \Rightarrow X = 0.72 = 72\%$

$C_A = 5(1 - 0.72) = 1.4\ mol/L$

* We notice that :- when $C_{A0} = 1\ mol/L$ $X = 35\%$

But $C_{A0} = 5\ mol/L$ $X = 72\%$

Q: For first order irreversible reaction. Show that the time required for 75% conversion is double the time required for 50% conversion. $-r_A = KC_A$, let assume it's a batch reactor.



$A \rightarrow D \qquad r_A = KC_A^1$

$$t = N_{A0}\int_0^X \frac{dx}{-r_A V} \Rightarrow t = \frac{N_{A0}}{V}\int_0^X \frac{dx}{KC_A} = C_{A0}\int_0^X \frac{dx}{KC_{A0}(1-X)}$$

$$t = \frac{1}{K}\int_0^X \frac{dx}{(1-X)}$$

$$\frac{1}{K}\int_0^{0.5} \frac{1\,dx}{1-X} \Rightarrow t_1K = -\ln(1-X_1)\Big|_0^{0.5}$$

$$K = -\ln(1-0.5) - -\ln(1-0) = 0.693$$

$$\frac{1}{K}\int_0^{0.75} \frac{dx}{1-X} \Rightarrow t_2K = -\ln(1-X_2)\Big|_0^{0.75}$$

$$K = -\ln(1-0.75) - -\ln(1-0) = 1.38$$

t_1K

Aya Dev.

Nozhin 3/12/2018, 11:00 Am, Reactor.

Q4// Liquid A decompose by first order kinetic and in a batch reactor, 50% of A converted in a 5 min run, how longer would it take to reach 75% conversion?

$$t = C_{A0}\int_0^X \frac{dx}{-r_A} = C_{A0}\int_0^X \frac{dx}{K C_A} = C_{A0}\int_0^X \frac{dx}{K C_{A0}(1-x)}$$

$$t = \frac{1}{K}\int_0^X \frac{dx}{(1-x)} \Rightarrow t = \frac{-1}{K}\ln(1-x)\Big|_0^{0.5}$$

$$300 = \frac{-1}{K}\left[\ln(1-0.5) - \ln(1-0)\right] \Rightarrow K = 2.31\times10^{-3}\ s^{-1}$$

$$t = \frac{+1}{K}\int_0^X \frac{dx}{(1-x)} = \frac{+1}{K}\int_0^{0.75}\frac{dx}{(1-x)} = \frac{-1}{K}\ln(1-x)\Big|_0^{0.75}$$

$$t = \frac{-1}{2.31\times10^{-3}}\left[\ln(1-0.75) - \ln(1-0)\right] = 600\ sec = 10\ min$$

Homework// For the Aqueous reaction A → Product, the following data obtained at 25 °C in which the concentration of A given at different intervals of time. batch

t (min)	0	10	20	30	40
C_A (mol/L)	0.86	0.74	0.635	0.546	0.405

$N_A = N_{A0} - N_0 X_A$

$A \rightarrow P$ First order $\quad -r_A = K C_A \quad C_A = C_{A0}(1 - X_A)$

$$\frac{dC_A}{dt} = r_A$$

$$\frac{dC_A}{dt} = -K C_A \Rightarrow dC_A = -K C_A \, dt$$

$$dt = \frac{dC_A}{-K C_A} \Rightarrow \int_0^t dt = \frac{-1}{K} \int_{C_{A0}}^{C_A} \frac{dC_A}{C_A}$$

$$t = \frac{-1}{K} \left[\ln C_A - \ln C_{A0} \right] = \frac{1}{K} \left(\ln C_{A0} - \ln C_A \right)$$

$$t = \frac{1}{K} \ln \left(\frac{C_{A0}}{C_A} \right)$$

t	C_A	$\ln \frac{C_{A0}}{C_A}$
0	0.86	0
10	0.74	0.15
20	0.635	0.30
30	0.546	0.45
40	0.405	0.75

$$\tau = \frac{C_{A0}X}{-r_A} \quad CSTR$$

$$\tau = \frac{C_{A0}}{-r_A} * \frac{C_{A0} - C_A}{\cancel{C_{A0}}} \rightarrow \tau = \frac{C_{A0} - C_A}{-r_A}$$

$$\tau = C_{A0}\int_0^X \frac{dX}{-r_A} \quad PFR$$

$$\tau = \cancel{C_{A0}}\int_{C_A}^{C_{A0}} \frac{1}{-r_A} * \frac{-dC_A}{\cancel{C_{A0}}} \rightarrow \tau = \int_{C_A}^{C_{A0}} \frac{dC_A}{-r_A}$$

$$\tau = C_{A0}\int_0^X \frac{dX}{-r_A}$$

$$\tau = \frac{C_{A0}X}{-r_A}$$

$$\tau = \int_{C_A}^{C_{A0}} \frac{dC_A}{-r_A}$$

Ex// find V for CSTR & PFR at %60 Conversion?

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
A	0.0053	0.0051	0.0050	0.0045	0.0040	0.0033	0.0025	0.0018	0.00125	0.001
$1/-r_A$	189	192	200	222	250	303	400	556	800	1000

CSTR :-

$$V = \frac{F_{A0}X}{-r_A} \rightarrow \frac{V}{F_{A0}} = \frac{X}{-r_A}$$

$\frac{1}{-r_A}$

$= V/F_{A0}$

* PFR :- $V = \int_{0}^{X} \frac{F_{A0}}{-r_A} dX$

$$\frac{V}{F_{A0}} = \int_{0}^{0.6} \frac{1}{-r_A} dX$$

① 2 Point :-

$$\frac{V}{F_{A0}} = \int_{0}^{0.6} \frac{1}{-r_A} dX = \frac{h}{2} \left[f(X_0) + f(X_1) \right]$$

$h = X_1 - X_0 = 0.6 - 0 = 0.6$

$X_0 = 0$, $X_1 = h + X_0 = 0.6 + 0 = 0.6$

$$\frac{V}{F_{A0}} = \frac{0.6}{2} \left[189 + 400 \right] = \checkmark$$

② 3 Point :-

$$\frac{V}{F_{A0}} = \int_{0}^{0.6} \frac{dX}{-r_A} = \frac{h}{3} \left[f(X_0) + 4 f(X_1) + f(X_2) \right]$$

$$h = \frac{X_f - X_0}{2} = \frac{0.6 - 0}{2} = 0.3$$

$X_0 = 0$, $X_1 = X_0 + h = 0 + 0.3 = 0.3$, $X_2 = X_1 + h = 0.3 + 0.3$

$$\frac{V}{F_{A0}} = \int_{0}^{0.6} \frac{dX}{-r_A} = \frac{0.3}{3} \left[189 + 4 \times 222 + 400 \right] = \checkmark$$

3) 4-Point :-

$$\frac{V}{F_{A0}} = \int_0^{0.6} \frac{dX}{-r_A} = \frac{3}{8} h \left[f(X_0) + 3 f(X_1) + 3 f(X_2) + f(X_3) \right]$$

$$h = \frac{X_f - X_o}{3} = \frac{0.6 - 0}{3} = 0.2$$

$X_0 = 0$, $X_1 = X_0 + h = 0 + 0.2 = 0.2$, $X_2 = X_1 + h = 0.2 + 0.2 = 0.4$

$X_3 = X_2 + h = 0.4 + 0.2 = 0.6$

$$\frac{V}{F_{A0}} \int_0^{0.6} \frac{dX}{-r_A} = \frac{3}{8} * 0.2 \left[189 + 3*200 + 3*250 + 400 \right] = V$$

) 5 Point :-

$$\frac{V}{F_{A0}} = \int_0^{0.6} \frac{dX}{-r_A} = \frac{h}{3} \left[f_0 + 4 f_1 + 2 f_2 + 4 f_3 + f_4 \right]$$

$$h = \frac{X_f - X_o}{4} = \frac{0.6 - 0}{4} = 0.15$$

$X_0 = 0$

0100 52

$X_1 = X_0 + h = 0 + 0.15 = 0.15$

$X_2 = X_1 + h = 0.15 + 0.15 = 0.3$

$X_3 = X_2 + h = 0.3 + 0.15 = 0.45$

$X_4 = X_3 + h = 0.45 + 0.15 = 0.6$

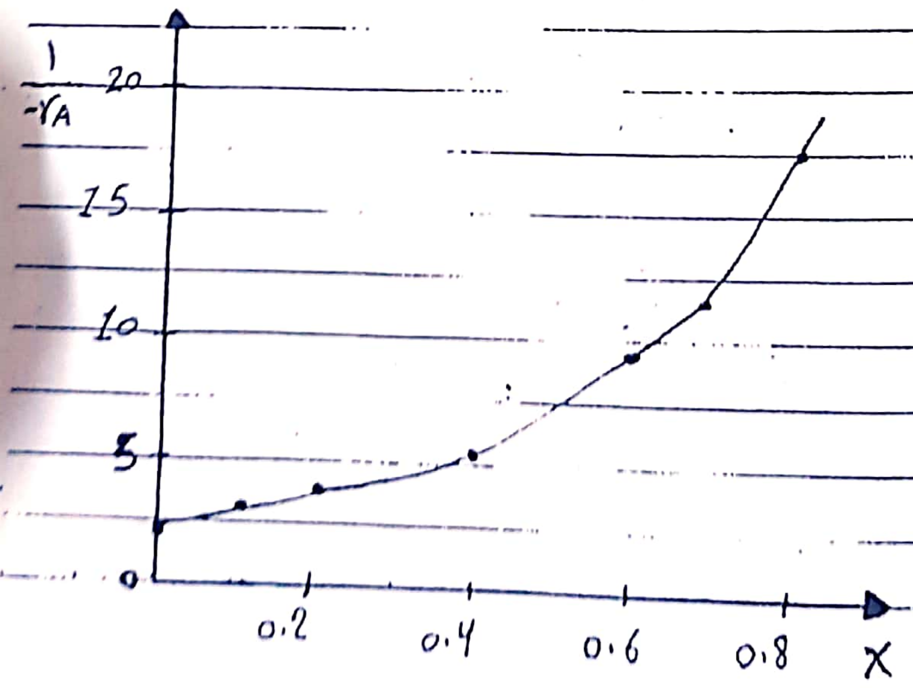
Q/ why V_{CSTR} is bigger than V_{PFR} at same conversion

Ans// For isothermal reactions greater than zero order CSTR volume will usually be greater than the PFR ... for the same conversion and reaction conditions. The ... is always operating at the lowest reaction rate. The ... the other hand starts at a high rate at the entrance ... gradually decreases to the exit rate, thereby requiring ... volume because the volume is inversely proportional to ...

*Sheet 4 [redacted] : Q1// V_{PFR} = ? to achieve 80% conversion

a)

X	0	0.1	0.2	0.4	0.6	0.7	0.8
$-r_A\left(\frac{mol}{m^3.s}\right)$	0.45	0.37	0.30	0.195	0.113	0.079	0.05
$1/-r_A$	2.22	2.70	3.33	5.13	8.85	12.7	20



$F_{A_0} = 0.4\ \frac{mol}{s}$

$$V = \int_0^X \frac{F_{A0}}{-r_A} dx$$

$$\frac{V}{F_{A0}} = \int_0^{0.8} \frac{1}{-r_A} dx = \frac{h}{3} \left[f_0 + 4f_1 + 2f_2 + 4f_3 + f_4 \right]$$

$$h = \frac{X_f - X_0}{4} = \frac{0.8 - 0}{4} = 0.2$$

$X_0 = 0$

$X_1 = X_0 + h = 0 + 0.2 = 0.2$, $X_2 = X_1 + h = 0.2 + 0.2 = 0.4$

$X_3 = X_2 + h = 0.4 + 0.2 = 0.6$, $X_4 = X_3 + h = 0.6 + 0.2 = 0.8$

$$\frac{V}{F_{A0}} = \int_0^{0.8} \frac{1}{-r_A} dx = \frac{0.2}{3} \left[2.22 + 4*3.33 + 2*5.13 + 4*8.85 + 20 \right]$$

$$\frac{V}{F_{A0}} = 5.4133 \Rightarrow V = 5.4133 * 0.4 = \boxed{2.165 \ m^3}$$

$F_{A0} = C_{A0} \nu_0$, 0.2×2

$\nu_0 = \frac{2 \ dm^3}{s} = 0.002 \ m^3/s$

$C_{A0} = 0.2 \ mol/dm^3$ $\tau = ?$ and $SV = ?$

$$\tau = \frac{V}{\nu_0} = \frac{2.165}{0.002} = 1082.5 \ sec = 18 \ hr$$

$$SV = \frac{\nu_0}{V} = \frac{0.002}{2.165} = 9.24 * 10^{-4} \ s^{-1}$$

Q2// $X = 80\%$

$\tau = 5\ hr$

$v_0 = 1\ dm^3/min = 60\ dm^3/hr$ $\frac{dm}{dm}$ $\frac{1\ dm}{min}$ $\frac{1\ hr}{60\ min}$

$C_{A0} = 2.5$ molar $= \frac{mol}{dm^3}$

$-r_A = ?$

$C_A = ?$

$V = ?$

$\tau = \frac{V}{v_0} \Rightarrow V = \tau * v_0$

$V = 5 * 60 = 300\ dm^3$

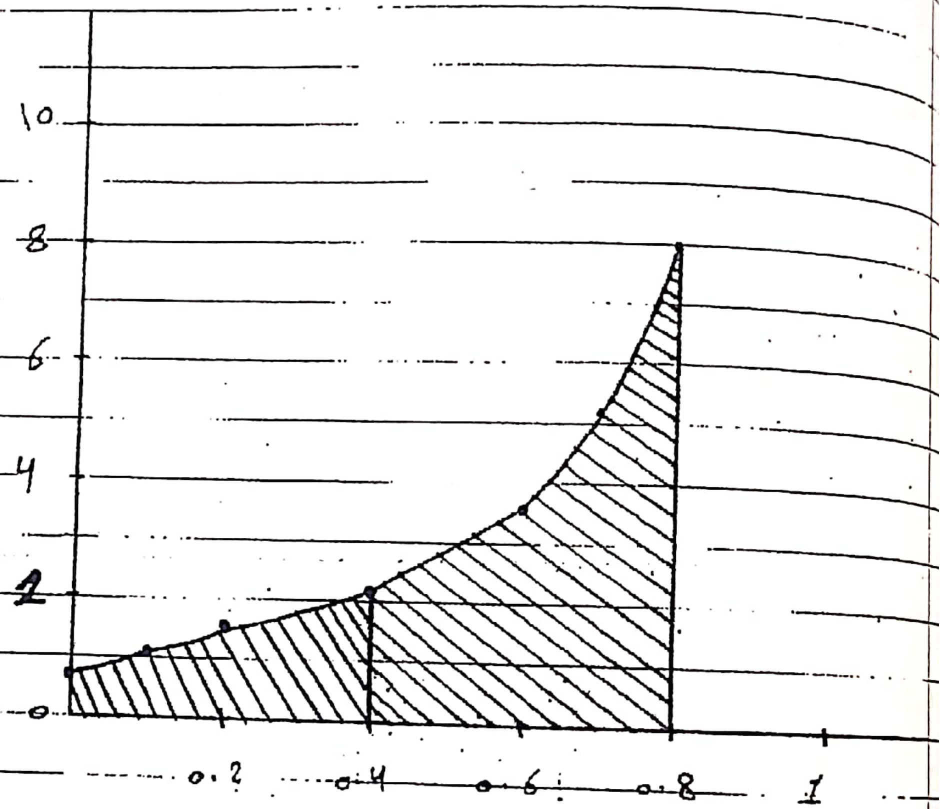
$C_A = C_{A0}(1 - X) = 2.5(1 - 0.8)$

$= 0.5\ mol/dm^3$

$\tau_{CSTR} = \frac{C_{A0}X}{-r_A} \Rightarrow -r_A = \frac{C_{A0}X}{\tau}$

$-r_A = \frac{2.5 * 0.8}{5} = 0.4\ mol/dm^3 \cdot hr$

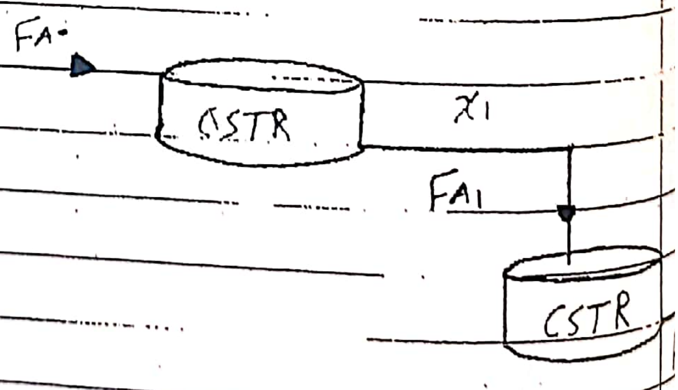
$V = V_1 + V_2 = 0.551 + 1.614 = 2.165\ m^3$



Home work //

① $A \rightarrow B + C$ at A CSTR $X = 70\%$ liquid ph

A) CSTR — CSTR :-



$V_{CSTR} = \dfrac{F_{A0}\,X}{-r_A}$

$F_{A0} = C_{A0}\,V_0$

$r_A = K\,C_A$

$C_A = C_{A0}(1-x)$ [liquid Phase]

$-r_A = K C_{A0}(1-x)$

$$V = \frac{\cancel{C_{A0}} v_0 * x}{K \cancel{C_{A0}} (1-x)} \Rightarrow \frac{V}{v_0} = \frac{x}{K(1-x)} \Rightarrow t = \frac{x}{K(1-x)}$$

$$tK = \frac{x}{(1-x)} = \frac{0.7}{(1-0.7)} = 2.33$$

$tk = 2.33$

$tk =$

2CSTR in series have a half size of orignal reactor for each one.

$$t_1K = t_2K = \frac{2.33}{2} = 1.17$$

$$V_1 = \frac{F_{A0} \cdot x_1}{-r_{A1}}$$

~~$F_{A0} = C_{A0} v_0$~~

~~$-r_{A1} = K C_{A1}$, $C_{A1} = C_{A0}(1-x_1)$~~

~~$-r_{A1} = K \cdot C_{A0}(1-x_1)$~~

$$V_1 = \frac{\cancel{C_{A0}} v_0 * x_1}{K(\cancel{C_{A0}}(1-x_1))} \Rightarrow \frac{V_1}{v_0} = \frac{x_1}{K(1-x_1)}$$

$V_1 = \frac{\cancel{F_{A0}}}{-r_A}$ $1.17 = \frac{x}{1-x}$

$$t_2 = \int_{X_1}^{X_2} \frac{dx}{K * (1 - X_2)} \Rightarrow t_2 K = \int_{X_1}^{X_2} \frac{dx}{(1 - X_2)}$$

$$1.17 = \int_{0.53}^{X_2} \frac{dx}{(1 - X_2)}$$

$$1.17 = \int_{0.53}^{X_2} \frac{dx}{(1 - X_2)} \Rightarrow 1.17 = \Big[- \ln(1 - X_2) \Big]_{0.53}^{X_1}$$

$$1.17 = - \Big[\ln(1 - X_2) - \ln(1 - 0.53) \Big]$$

$$1.17 = - \Big[\ln(1 - X_2) + 0.755 \Big] \qquad e^{\ln(1-X_2)} \quad (1 - X_2)^{-1}$$

$$1.17 = - \ln(1 - X_2) - 0.755$$

$$\boxed{1.17 + 0.755 = \ln(1 - X_2)^{-1}} \times e$$

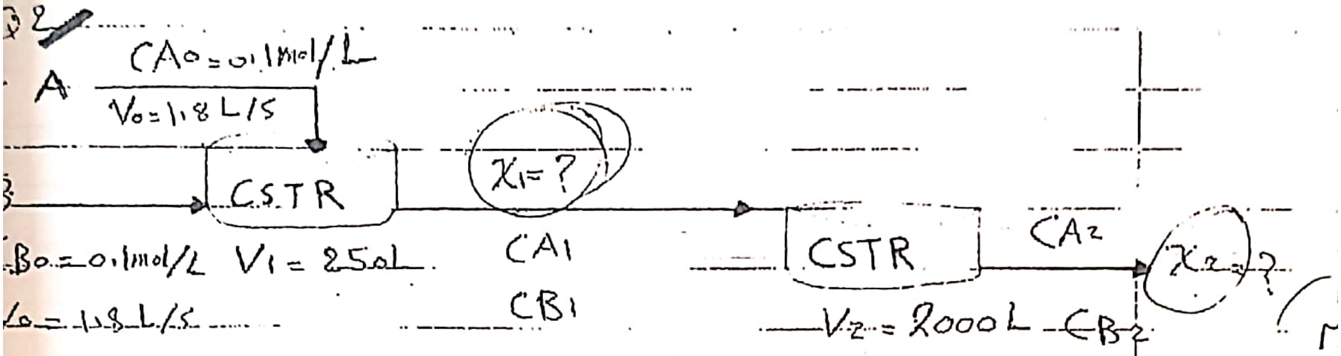
$$e^{1.925} = \frac{1}{(1 - X_2)} \Rightarrow \boxed{X_2 = 0.85}$$

0.17

0.143

0.65

Q2



$A + B \rightarrow C + D \qquad T = 75\,°C$

$K = 0.65\ L/mol \cdot s$

$$V_1 = \frac{F_{A0} X_1}{-r_A}$$

$F_{A0} = C_{A0} v_0 \quad , \quad -r_A = K C_A C_B$

$C_A = C_{A0}(1 - X_1) \quad , \quad C_B = C_{B0}(1 - X_1)$

$$V_1 = \frac{\cancel{C_{A0}}\, v_0 * X_1}{K \cancel{C_{A0}}(1 - X_1) C_{B0}(1 - X_1)} = \frac{v_0 * X_1}{K C_{B0}(1 - X_1)^2}$$

$$250 = \frac{1.8 * X_1}{0.65 * 0.1 (1 - X_1)^2} \Rightarrow X_1 = 0.718$$

$$V_2 = \frac{F_{A0}(X_2 - X_1)}{-r_A}$$

$F_{A0} = C_{A0} v_0 \quad , \quad -r_A = K C_{A1} C_{B1}$

$C_{A1} = C_{A0}(1-X_2)$

$C_{B1} = C_{B0}(1-X_2)$

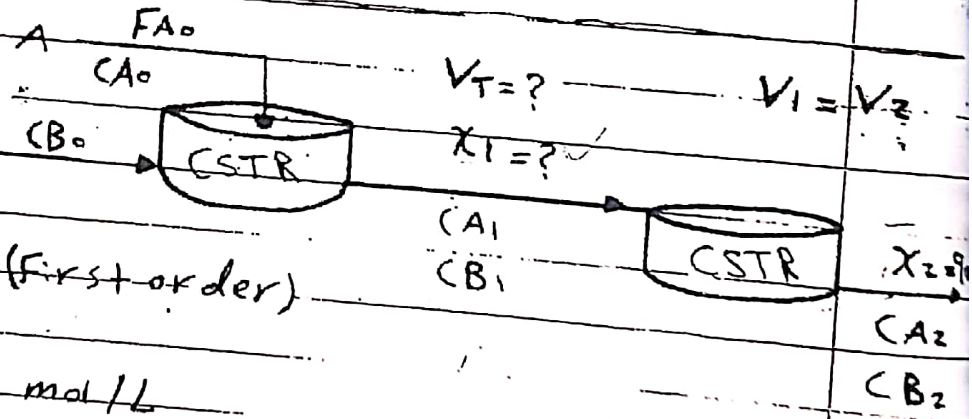
$$V_2 = \frac{C_{A0} V_0 * (X_2 - X_1)}{K C_{A0} (1-X_2)(1-X_2) C_{B0}}$$

$$V_2 = \frac{V_0 (X_2 - X_1)}{K C_{B0} (1-X_2)^2}$$

$(1-X)(1-X)$

$$2000 = \frac{1.8 * (X_2 - 0.718)}{0.65 * 0.1 (1-X_2)^2} \Rightarrow X_2 = 0.94$$

Q3 /



$A + B \rightarrow C + D$ (first order)

$C_{A0} = C_{B0} = 0.1$ mol/L

$V_0 = 1.8$ L/s , $T = 75$ °C , $k = 0.65$ L/mol.s

$V_1 = V_2$

$$\frac{F_{A0} X_1}{-r_{A1}} = \frac{F_{A0}(X_2 - X_1)}{-r_{A2}}$$

$F_{A0} = C_{A0} V_0 \rightarrow -r_{A1} = K C_{A1}$

$C_{A1} = C_{A0}(1 - X_1) \rightarrow -r_{A1} = C_{A0}(1 - X_1) K$

$-r_{A2} = K C_{A2}$, $C_{A2} = C_{A0}(1 - X_2)$

$-r_{A2} = K C_{A0}(1 - X_2)$

$$\frac{\cancel{C_{A0}} V_0 * X_1}{K \cancel{C_{A0}} (1 - X_1)} = \frac{\cancel{C_{A0}} V_0 * (X_2 - X_1)}{K \cancel{C_{A0}} (1 - X_2)}$$

0.9

$$\frac{V_0 * X_1}{K(1 - X_1)} = \frac{V_0 * (X_2 - X_1)}{K(1 - X_2)}$$

$$\frac{1.8 * X_1}{0.65(1 - X_1)} = \frac{1.8 * (0.9 - X_1)}{0.65 * (1 - 0.9)} \Rightarrow X_1 = 0.1$$

$$V_1 = \frac{F_{A0} X_1}{-r_{A1}} = \frac{C_{A0} V_0 * X_1}{K C_{A0} (1 - X_1)} = \frac{V_0 * X_1}{K(1 - X_1)}$$

$$V_1 = \frac{1.8 * 0.1}{0.65(1 - 0.1)} = \boxed{5.88 L} = V_2$$

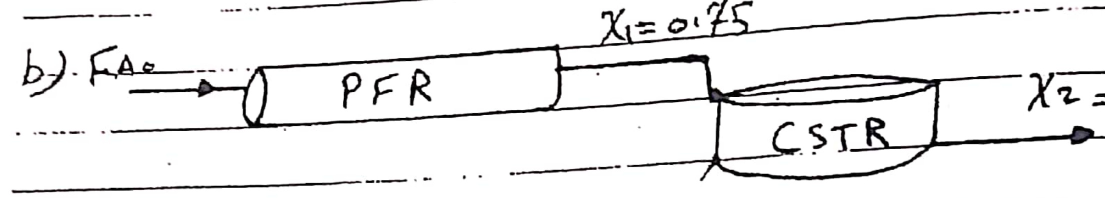
$\therefore V_T = V_1 + V_2 = 5.88 + 5.88 = 11.76 L$

Q4

a)

- First order: CSTR-PFR or PFR-CSTR not affect
- Second order: PFR CSTR

b)



$V_1 = V_2 = 100\,L$

$$V_1 = \int_0^{X_1} \frac{F_{A0}}{-r_A}\,dX \Rightarrow \frac{V_1}{F_{A0}} = \int_0^{X_1} \frac{1}{-r_A}\,dX$$

$-r_A = K C_A^2 \quad , C_A = C_{A0}(1 - X_1)$

$$\frac{V_1}{F_{A0}} = \int_0^{X_1} \frac{1}{K C_{A0}^2 (1-X_1)^2} \Rightarrow \frac{V_1}{F_{A0}} = \frac{1}{K C_{A0}^2} \int_0^{X_1} \frac{1}{(1-X_1)^2}$$

$$\frac{V_1 K C_{A0}^2}{F_{A0}} = \frac{1}{(1-X_1)}\Bigg|_0^{X_1 = 0.75} \Rightarrow \frac{V_1 K C_{A0}^2}{F_{A0}} = \frac{1}{(1-0.75)} - \frac{1}{(1-0)}$$

$$\frac{V_1 K C_{A0}^2}{F_{A0}} = 3$$

$$V_2 = \frac{F_{A0}}{-r_A}(X_2 - X_1)$$

$$\frac{V_2}{F_{A0}} = \frac{1}{-r_A}(X_2 - X_1)$$

$-r_A = K C_{A2}^2$, $C_{A2} = C_{A0}(1 - X_2)$

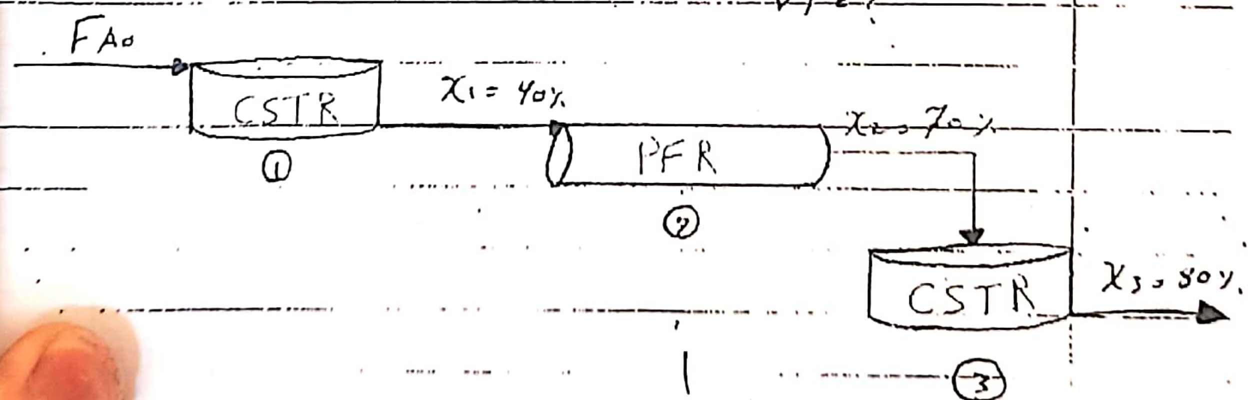
$$\frac{V_2}{F_{A0}} = \frac{(X_2 - X_1)}{K C_{A0}^2 (1-X_2)^2} \Rightarrow \frac{V_2 K C_{A0}^2}{\cancel{F_{A0}}} = \frac{(X_2 - X_1)}{(1 - X_2)^2}$$

$$3 = \frac{(X_2 - 0.75)}{(1 - X_2)^2} \Rightarrow X_2 = 0.83$$

5.5

CSTR PFR CSTR

$V_T = ?$



$$\frac{1}{(1-X_1)^2}$$

$(1 - X_1)^{-n+1}$

$$\frac{1}{(X-1)}$$

x	0	0.2	0.4	0.6	0.8
$-r_A$ mol/dm³.s	0.010	0.0091	0.008	0.005	0.002
$\frac{1}{-r_A}$	100	110	125	200	500

$$V_1 = \frac{F_{A0} X_1}{-r_A}$$

$$\frac{V_1}{F_{A0}} = \frac{1}{-r_A} x_1 = 125 * 0.4 = 50 \Rightarrow V_1 = 50 * F_{A0}\ dm^3$$

$$V_2 = \int_{x_1}^{x_2} \frac{F_{A0}\, dx}{-r_A} \Rightarrow \frac{V_2}{F_{A0}} = \int_{x_1}^{x_2} \frac{dx}{-r_A}$$

$$\frac{V_2}{F_{A0}} = \int_{x_1}^{x_2} \frac{dx}{-r_A} = \frac{h}{3}\left[f(x_0) + 4 f(x_1) + f(x_2) \right]$$

$$h = \frac{0.7 - 0.4}{2} = 0.15 \quad , X_0 = 0.4$$

$$x_1 = x_0 + h = 0.4 + 0.15 = 0.55$$

$$x_2 = x_1 + h = 0.55 + 0.15 = 0.7$$

$X = 0.4 \qquad \frac{1}{-r_A} = 125$

$X = 0.55 \qquad \frac{1}{-r_A} = ?$ Interpolation $\frac{1}{-r_A} = 181.25$

$X = 0.6 \qquad \frac{1}{-r_A} = 200$

$X = 0.6 \qquad \frac{1}{-r_A} = 200$

$X = 0.7 \qquad \frac{1}{-r_A} = ?$ Interpolation $\frac{1}{-r_A} = 350$

$X = 0.8 \qquad \frac{1}{-r_A} = 500$

$$\frac{V_2}{F_{A0}} = \frac{0.15}{3}\left[125 + 4 \times 181.25 + 350\right] = 60$$

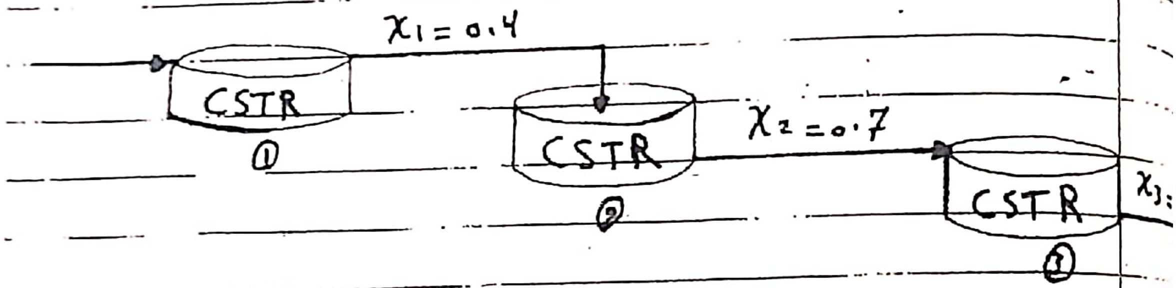
$V_2 = 60 * F_{A0}$

$$V_3 = \frac{F_{A0}}{-r_A}(X_3 - X_2) \Rightarrow \frac{V_3}{F_{A0}} = \frac{1}{-r_A}(X_3 - X_2)$$

$$\frac{V_3}{F_{A0}} = 500\,(0.8 - 0.7) = 50 \Rightarrow V_3 = 50 * F_{A0}$$

$$V_T = V_1 + V_2 + V_3 = 50 F_{A0} + 60 * F_{A0} + 50 F_{A0} = 160 * F_{A0}$$

② CSTR CSTR CSTR :=



$$V_1 = \frac{F_{A0} X_1}{-r_A} \Rightarrow \frac{V_1}{F_{A0}} = \frac{1}{-r_A} X_1 = 125 * 0.4 = 50$$

$$V_1 = 50 * F_{A0}$$

$$V_2 = \frac{F_{A0}}{-r_A}(X_2 - X_1) \Rightarrow \frac{V_2}{F_{A0}} = \frac{1}{-r_A}(X_2 - X_1)$$

$$\frac{V_2}{F_{A0}} = 350 * (0.7 - 0.4) = 105 \Rightarrow V_2 = 105 * F_{A0}$$

$$V_3 = \frac{F_{A0}}{-r_A}(X_3 - X_2) = \frac{V_3}{F_{A0}} = \frac{1}{-r_A}(X_3 - X_2)$$

$$\frac{V_3}{F_{A0}} = 500(0.8 - 0.7) = 50 \Rightarrow V_3 = 50 * F_{A0}$$

$$V_T = V_1 + V_2 + V_3 = 50 F_{A0} + 105 F_{A0} + 50 F_{A0} = 205 * F_{A0}$$