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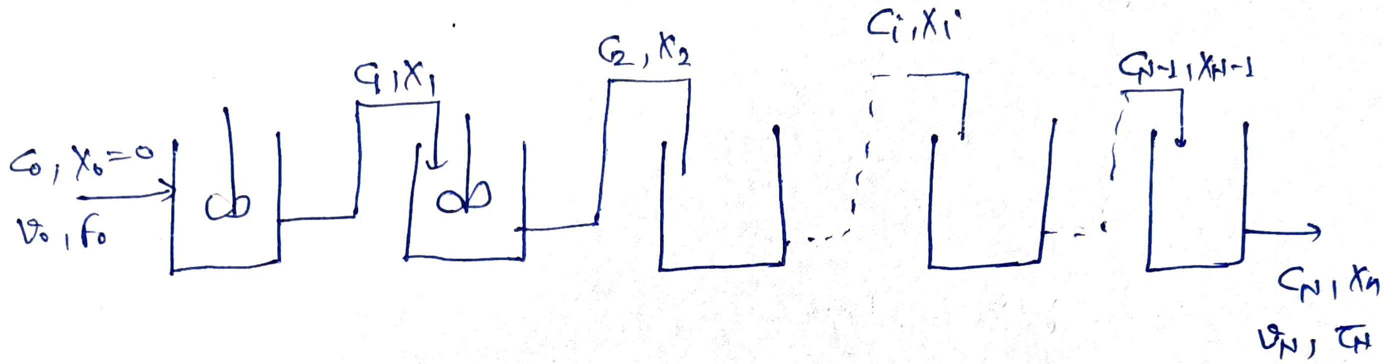
(1)

CL208 (CRE)
Quiz

Ans-1



equal size

$$\Rightarrow \quad V_1 = V_2 = V_i = V_N = V$$

also $\quad \tau_1 = \tau_2 = \tau_i = \tau_N = \tau$

Material balance

$$\text{input} = \text{output} + \text{dissappearance} + \cancel{\text{accumulation}}^{\,0 \text{ (steady state)}}$$

$$F_0(1 - X_{i-1}) = F_0(1 - X_i) + (-\gamma_{Ai})V_i$$

$$\Rightarrow \quad F_0(X_i - X_{i-1}) = (-\gamma_{Ai})V_i$$

$$\Rightarrow \quad \frac{V_i}{F_0} = \frac{X_i - X_{i-1}}{-\gamma_{Ai}}$$

$$\Rightarrow \quad \tau_i = \frac{C_0 V_i}{F_0} = \frac{V_i}{v} = \frac{C_0(X_i - X_{i-1})}{-\gamma_{Ai}}$$

$\because \quad \varepsilon = 0$

$$\cancel{\tau_i = \frac{C_0\left[(1 - \frac{C_i}{C_0}) - (1 - \frac{C_{i-1}}{C_0})\right]}{kC_i}}$$

$$\cancel{= \frac{C_{i-1} - C_i}{kC_i}}$$

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$$\cancel{\tau_i = \frac{C_{i-1} - C_i}{k C_i - r}}$$

$$\boxed{\tau_i = \frac{C_0\left[\left(1-\frac{C_i}{C_0}\right) - \left(1-\frac{C_{i-1}}{C_0}\right)\right]}{-r_{Ai}}}$$

$$\tau_i = \frac{C_{i-1} - C_i}{-r_{Ai}}$$

for 1st order

$$-r_{Ai} = kC_i$$

$$\tau_i = \frac{C_{i-1} - C_i}{kC_i}$$

$$\Rightarrow \frac{C_{i-1}}{C_i} = 1 + k\tau_i$$

for reactor 1: $\frac{C_0}{C_1} = 1 + k\tau_1$

for reactor 2: $\frac{C_1}{C_2} = 1 + k\tau_2$

Similarly,

$$\frac{C_0}{C_1} \times \frac{C_1}{C_2} \times \cdots \frac{C_{N-1}}{C_N} = (1+k\tau_1)(1+k\tau_2)\cdots(1+k\tau_N)$$

$$\because \tau_1 = \tau_2 = \cdots \tau$$

$$\Rightarrow \boxed{\frac{C_0}{C_N} = (1+k\tau)^N} \quad \text{--- (1)}$$

$$1 + k\tau = \left(\frac{C_0}{C_N}\right)^{\frac{1}{N}}$$

$$\Rightarrow \tau = \frac{1}{k}\left[\left(\frac{C_0}{C_N}\right)^{\frac{1}{N}} - 1\right]$$

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$$\tau_{N,\,reac} = N\tau_i$$

$$= \frac{N}{k}\left[\left(\frac{C_0}{C_N}\right)^{\frac{1}{N}} - 1\right] \quad — (2)$$

when $N \to \infty$

$$\left(\frac{C_0}{C_N}\right)^{\frac{1}{N}} = 1 + \frac{1}{N}\log\frac{C_0}{C_N} + \left(\frac{1}{N}\right)^2 \frac{1}{2!} \ln\left(\frac{C_2}{C_N}\right)^2 \ldots$$

neglecting higher order terms

$$\left(\frac{C_0}{C_N}\right)^{\frac{1}{N}} = 1 + \frac{1}{N}\ln\frac{C_0}{C_N}$$

$$\left(\frac{C_0}{C_N}\right)^{\frac{1}{N}} - 1 = \frac{1}{N}\ln\frac{C_0}{C_N} \quad — (3)$$

putting eqn (3) in eq (2)

$$\tau_{N,\,reac} = \frac{\cancel{N}}{k}\left[\frac{1}{\cancel{N}}\ln\frac{C_0}{C_N}\right]$$

$$\boxed{\tau_{N,\,reactor} = \frac{1}{k}\ln\frac{C_0}{C_N}} \quad — (4)$$

for $N \to \infty$ it behaves like PFR

as $\boxed{\tau_p = \frac{1}{k}\ln\frac{C_0}{C}}$

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Ans-2

(i) Batch Reactor: Let us ~~If~~ we filled batch reactor with a microfluid. ~~conversion~~ Each ~~reactor~~ aggregate or packet of microfluid acts as its own little batch reactor, conversion will be same in all aggregate as every aggreate acts as its own little batch reactor. Therefore degree of segregation does not affect conversion.

(ii) Plug Flow reactor: All the microfluid and macrofluid flow alike and flow is visualised as a flow of ~~a~~ small batch reactors. Therefore degree of segregation does not influence conversion.

(iii) Mixed flow reactor - Macrofluid: when a macrofluid enters in a mixed flow reactor, ~~a~~ reactant concⁿ in an aggregate does not drop immedictly to a low value but decreases in the same way as it ~~is~~ would in a batch reactor. Thus a molecule in a macrofluid does not lose its identity, its past history is ~~&~~ not unknown and its age can be estimated by examining its neighboring molecules.

Performance eqⁿ for a microfluid in MFR

$$1 - \bar{X}_A = \frac{\bar{C}_A}{C_{A0}} = \int_0^\infty \left(\frac{C_A}{C_{A0}}\right)_{batch} E\,dt$$

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where $E\,dt = \frac{v}{V} e^{-\frac{vt}{V}} dt$

$= e^{-\frac{t}{\bar{t}}} dt$

from above eqn

$$\boxed{1-\bar{X}_A = \frac{\bar{C}_A}{C_{A0}} = \int_0^\infty \left(\frac{C_A}{C_{A0}}\right)_{batch} \frac{e^{-\frac{t}{\bar{t}}}}{\bar{t}} dt} \quad -(1)$$

for first order

$$\frac{C_A}{C_{A0}} = e^{-kt} \quad -(2)$$

putting eqn (2) in eqn (1)

$$\frac{\bar{C}_A}{C_{A0}} = \frac{1}{\bar{t}} \int_0^\infty e^{-kt} \cdot e^{-\frac{t}{\bar{t}}} dt$$

solving above eqn

$$\boxed{\frac{\bar{C}_A}{C_{A0}} = \frac{1}{1+k\bar{t}}}$$

This eqn is identical to that obtained for a microfluid.

$$kt = \frac{C_{A0} - C_A}{C_A}$$

$$kt\, C_A = C_{A0} - C_A$$

$$\Rightarrow \frac{C_A}{C_{A0}} = \frac{1}{1+kt}$$

Thus we conclude that degree of segregation has no effect on conversion for first order reacn.

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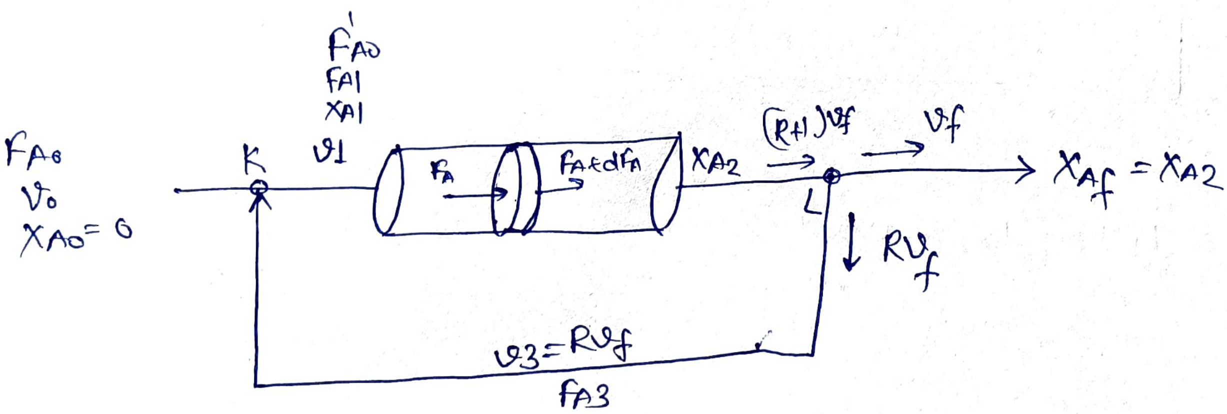
Ans-3

Recycle ratio, $R = \dfrac{\text{volume of fluid returned to the reactor entrance}}{\text{volume of leaving the system}}$

$0 \le R < \infty$



Material balance :

Input = Output + dissappearance + accumulation (steady state) $\to 0$

$$\cancel{F_A} = (\cancel{F_A} + dF_A) + (-r_A)dV$$

$$-dF_A = (-r_A)dV$$

$$-d[F'_{A0}(1-X_A)] = (-r_A)dV$$

$$\Rightarrow \quad F'_{A0}\, dX_A = (-r_A)dV$$

$$\Rightarrow \quad \frac{dV}{F'_{A0}} = \int_{X_{A1}}^{X_{A2}=X_{Af}} \frac{dX_A}{-r_A}$$

$$\Rightarrow \quad \boxed{\frac{V}{F'_{A0}} = \int_{X_{A1}}^{X_{Af}} \frac{dX_A}{-r_A}} \quad \longleftarrow (1)$$

Also,

The flow entering the reactor includes both fresh feed and recycle stream.

$\Rightarrow$ F'_{A0} = fresh feed + unconverted recycle stream

$= F_{A0} + RF_{A0}$

$$F'_{A0} = F_{A0}(R+1) \quad \text{—— (2)}$$

Also

$$X_{A1} = \frac{1 - \frac{C_{A1}}{C_{A0}}}{1 + \varepsilon_A \frac{C_{A1}}{C_{A0}}} \quad \text{—— (3)}$$

$\because$ ~~$\varepsilon_A \neq 0$~~

~~$X_{A1} = 1 - \frac{C_{A1}}{C_{A0}}$~~

$\therefore$ $C_{A1} = \frac{F_{A1}}{v_1} = \frac{F_{A0} + F_{A3}}{v_0 + Rv_f}$ (material balance at point K)

$$= \frac{F_{A0} + RF_{A0}(1 - X_{Af})}{v_0 + Rv_0(1 + \varepsilon_A X_{Af})}$$

$$= C_{A0}\left(\frac{1 + R - RX_{Af}}{1 + R + R\varepsilon_A X_{Af}}\right) \quad \text{—— (4)}$$

from ~~above~~ eqn (3) & (4)

$$X_{A1} = \left(\frac{R}{R+1}\right) X_{Af} \quad \text{—— (5)}$$

Putting eqn (5) in eqn (1)

$$\boxed{\frac{V}{F_{A0}} = (R+1)\int_{\left(\frac{R}{R+1}\right)X_{Af}}^{X_{Af}} \frac{dX_A}{-r_A}}$$

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for $\varepsilon = 0$

$$\boxed{\tau = \frac{C_{A0}V}{F_{A0}} = -(R+1)\int_{\frac{C_{A0}+RC_{Af}}{R+1}}^{C_{Af}} \frac{dC_A}{-r_A}}$$

for $R = 0$

$$\boxed{\frac{V}{F_{A0}} = \int_{A}^{X_{Af}} \frac{dX_A}{-r_A}}$$ acts like PFR

for $R = \infty$

it behaves like MFR

$\Rightarrow$ $(-r_A)$ will be constant

$$\Rightarrow \frac{V}{F_{A0}} = \frac{R+1}{(-r_A)} \int_{\left(\frac{R}{R+1}\right)X_{Af}}^{X_{Af}} dX_A$$

$$= \frac{R+1}{(-r_A)} \, X_A \Big|_{\frac{R}{R+1}X_{Af}}^{X_{Af}}$$

$$= \frac{R+1}{(-r_A)}\left(X_{Af} - \frac{R}{R+1}X_{Af}\right)$$

$$\Rightarrow \boxed{\frac{V}{F} = \frac{X_{Af}}{-r_A}}$$ acts like MFR

for $\varepsilon = 0$, 1st order kinetics

$$\boxed{\frac{k\tau}{R+1} = \ln\left[\frac{C_{A0} + RC_{Af}}{(R+1)C_{Af}}\right]}$$