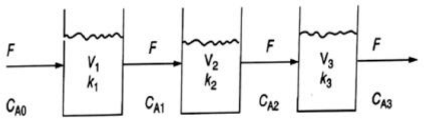
Experiment No 8

Rate Study in Cascade CSTR

Aim: Rate study in a cascade CSTR (CSTR in series)

Description: The Cascade CSTR consist 3 identical CSTRs in series where product stream of the first CSTR enters 2nd one as feed, product stream of the 2nd CSTR enters 3rd as feed and product of the system flows out from the 3rd CSTR. The reactant streams N/20 NaOH Solution (A) and N/10 $CH_3COOC_2H_5$ Solution (B) flows to the 1st CSTR from respective storage tanks via rotameters to control flow rates. Reactor volume = 1.135 L



Procedure:

1. Reactants of prescribed concentration are already prepared and fed in the designated storage tanks.
2. Record the ambient temperature of reaction mixture.8.
3. Calibrate each rotameter with respective liquid.
4. Allow the two reactants streams [NaOH(A) and $CH_3COOC_2H_5$ (B)] to enter the first CSTR at equal feed rate so that in the reactor $C_{A0} = C_{B0}$. Start the mixer and wait till the product flows out from the 3rd CSTR. Give 5-10 min for steady state.
5. Fix and record the flow rates $F_A = F_B$
6. Collect 10 ml sample from each 3 reactor outlets and and titrate with N/50 Succinic Acid Solution to estimate unreacted NaOH
7. Repeat steps 4-6 for different flow rate sets.
8. Record Volume of each reactor ($V_1 = V_2 = V_3$)

Calculations:

Feed conditions are such that $C_{A0} = C_{B0}$, $\quad -r_A = -\frac{dC_A}{dt} = kC_A^2$

Let, F = Volumetric flow rate through the reactor system (constant)

V_n = Volume of reaction mass in the nth reactor

$(C_A)_n$ = molar conc. Of reactant A in the nth reactor

$(C_A)_{n-1}$ = molar conc. Of reactant A in the(n-1)th reactor

θ_n = V_n/F = normal holding time in the nth reactor

A steady flow material balance over nth reactor is

$$F(C_A)_{n-1} + V_n\frac{dC_A}{dt} = F(C_A)_n \qquad \text{---- (1)}$$

or, $$\frac{(C_A)_{n-1}}{(C_A)_n} = 1 - \frac{\theta_n}{(C_A)_n}\left(\frac{dC_A}{dt}\right)_n \qquad \text{---- (2)}$$

For second order reaction, $\quad -\frac{dC_A}{dt} = kC_A^2$

And from Eq. (2) $$\frac{(C_A)_{n-1}}{(C_A)_n} = 1 + k\theta_n(C_A)_n \qquad \text{--- (3)}$$

For the conditions, equal volume of tanks $V_1 = V_2 = V_3 = V$ and $\theta_1 = \theta_2 = \theta_3 = \theta$,

$$(C_A)_{n-1} - (C_A)_n = k\theta_n {(C_A)_n}^2$$

or $$ln[(C_A)_{n-1} - (C_A)_n] = ln(k\theta_n) + 2ln(C_A)_n \qquad \text{--- (4)}$$

Performance Chart to be obtained by plotting $(C_A)_{n-1}$ vs $(C_A)_n$ using Eq. (3)

Rate constant to be obtained from Eq (4) as

$$k = \frac{[(C_A)_{n-1}/(C_A)_n]-1}{\theta_n(C_A)_n}$$