Chemical Reactor Design I

Lecture (2) :
Conversion and Reactor Sizing
Part -2

Chemical and Petrochemical Engineering Department

5th Semester

Salahaddin University

Reactors in Series

Many times, reactors are connected **in series** so that the **exit stream** of one reactor is the **feed stream** for **another reactor**.

Reactors in Series

When this arrangement is used, it is often **possible to speed calculations** by defining **conversion** in terms of **location** at **a point downstream** rather than with respect to **any single reactor**.

Reactors in Series

That is, the conversion X is the **total** number of moles of A that have reacted up to that point **per mole of A fed** to the **first reactor**.

Reactors in Series

For reactors in series

$$X_i = \frac{\text{Total moles of A reacted up to point } i}{\text{Moles of A fed to the first reactor}}$$

Only valid for NO side streams!!

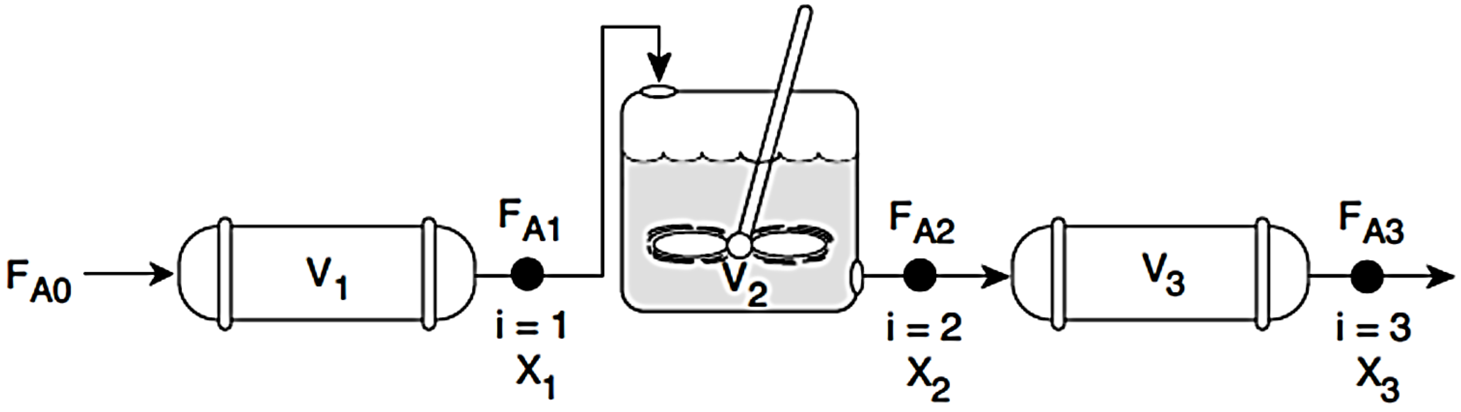
Reactors in Series

The molar flow rate of $\boldsymbol{A}$ at point $\boldsymbol{i}$ is equal to the moles of A fed to **the first reactor, minus all the moles** of A **reacted up to point i.**

$$F_{Ai} = F_{A0} - F_{A0}X_i$$

Reactors in Series

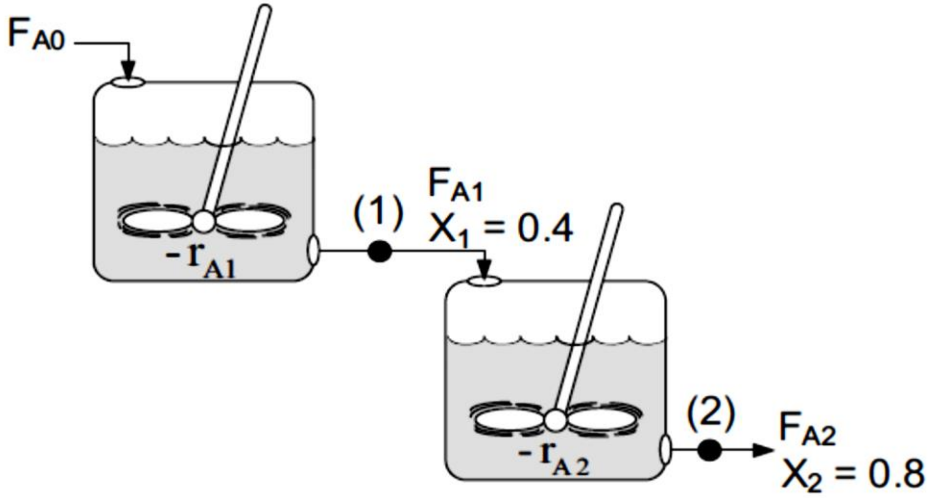
For the reactors shown in the figure, $\boldsymbol{X_1}$ at point $\boldsymbol{i}$ = **1** is the conversion achieved in the **PFR**, $\boldsymbol{X_2}$ at point $\boldsymbol{i}$ = **2** is the **total conversion achieved at this point in the PFR and the CSTR**, and $\boldsymbol{X_3}$ is the total conversion achieved by **all three reactors**.



1.CSTRs in Series

Two CSTRs in series shown

in the figure.



For the **first reactor**, the rate of disappearance of A is $-\boldsymbol{r_{A1}}$at conversion $\boldsymbol{X_1}$.

1.CSTRs in Series

A mole balance on reactor **1** gives

$$\textbf{In} - \textbf{Out} + \textbf{Generation} = 0$$

$$\textbf{Reactor 1:} \quad F_{A0} - F_{A1} + r_{A1}V_1 = 0$$

The molar flow rate of A at point 1 is

$$F_{A1} = F_{A0} - F_{A0}X_1$$

Rearrange the last equations yields

$$\boxed{V_1 = \frac{F_{A0}X_1}{-r_{A1}}}$$

1.CSTRs in Series

In the **second reactor**, the rate of disappearance of A, $-\boldsymbol{r_{A2}}$, is evaluated at the conversion of the **exit stream** of reactor **2**, $\boldsymbol{X_2}$.

A steady-state mole balance on the **second reactor** is

$$\textbf{In} - \textbf{Out} + \textbf{Generation} = 0$$

$$\textbf{Reactor 2:} \qquad F_{A1} - F_{A2} + r_{A2}V_2 = 0$$

The molar flow rate of A at point 2 is

$$F_{A2} = F_{A0} - F_{A0}X_2$$

1.CSTRs in Series

Combining and rearranging

$$V_2 = \frac{F_{A1} - F_{A2}}{-r_{A2}} = \frac{(F_{A0} - F_{A0}X_1) - (F_{A0} - F_{A0}X_2)}{-r_{A2}}$$

Reactor 2

$$\boxed{V_2 = \frac{F_{A0}}{-r_{A2}}(X_2 - X_1)}$$

<u>Assignments:</u>

- **P2-4B page 66**
- **P2-7B page 67**
- **P2-10C page 68**

The reference : Elements of chemical reaction engineering book by H. S. Fogler and S. H. Fogler , 5th edition.