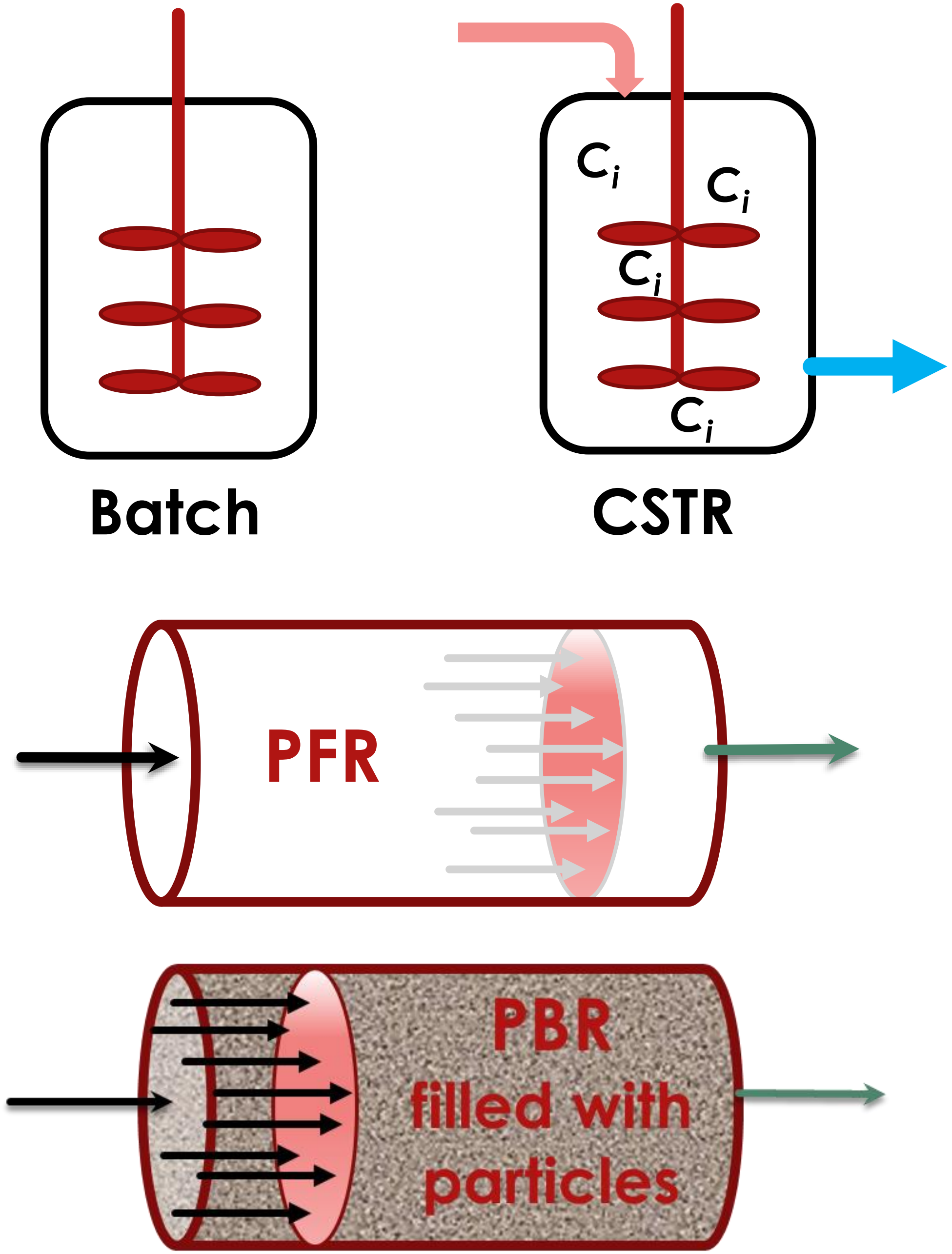


# Lecture # 3.1

- Different reactors for different purposes
- Ideal Reactors and species balance
- Ideal Reactors and more of them

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# Ideal reactors and their design equation

| Ideal Reactor | Design Equation | Integral form | Conc. given by |
|---|---|---|---|
| BR | $\frac{dN_j}{dt} = r_j . V$ | $t = \int \frac{dN_j}{r_j . V}$ | $C_j = \frac{N_j}{V}$ |
| CSTR | $V = \frac{F_{j0} - F_j}{-rj}$ | algebraic | $C_j = \frac{F_j}{\dot{v}}$ |
| PFR | $\frac{dF_j}{dV} = r_j$ | $V = \int \frac{dF_j}{r_j}$ | $C_j = \frac{F_j}{\dot{v}}$ |
| PBR | $\frac{dF_j}{dW} = r_j'$ | $W = \int \frac{dF_j}{r_j'}$ | $C_j = \frac{F_j}{\dot{v}}$ |

# We commonly deal with conversions of a species

- For a reaction following the stoichiometric eq$^{n}$: $aA + bB = cC + dD$

  a, b, c and d are stoichiometric coefficients

- In terms of limiting reactant A we have $A + \frac{b}{a}B = \frac{c}{a}C + \frac{d}{a}D$

- Conversion of species *j*, $X_j$, is defined as: $X_j = \frac{moles\ of\ j\ converted}{moles\ j\ fed}$

- For Batch reactors: $X_j = \frac{N_{j0} - N_j}{N_{j0}}$ $\quad also \quad$ $dN_j = -N_{j0}dX_j$

- For flow reactors: $X_j = \frac{F_{j0} - F_j}{F_{j0}}$ $\quad also\ for\ PFR/PBR \quad$ $dF_j = -F_{j0}dX_j$

# Design equations can be written in terms of conversions

- For BR: $\frac{dN_j}{dt} = r_j.V \quad \rightarrow \quad -\frac{N_{j0}dX_j}{dt} = r_j.V$

$$t = N_{j0}\int_{X_j at\ t=0}^{X_j\ at\ t} \frac{dX_j}{-r_j.V}$$

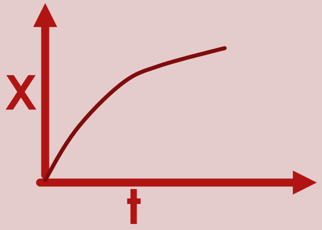
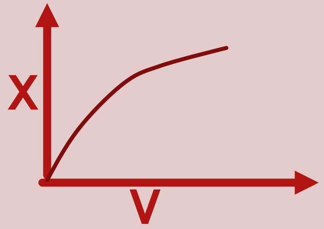
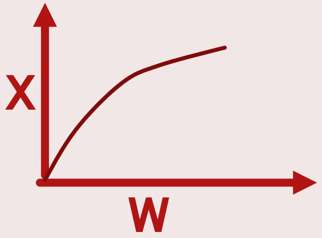
- For CSTR: $V = \frac{F_{j0}-F_j}{-r_j} \rightarrow V = \frac{F_{j0}X_j}{-r_j}$
- For PFR: $\frac{dF_j}{dV} = r_j \quad \rightarrow \quad -\frac{F_{j0}dX_j}{dV} = r_j$

$$V = F_{j0}\int_{X_j at\ V=0}^{X_j\ at\ V} \frac{dX_j}{-r_j}$$

- Similarly, for PBR: $W = F_{j0}\int_{X_j at\ W=0}^{X_j\ at\ W} \frac{dX_j}{-r_j'}$

Usually the subscript j is dropped and conversion is based on the limiting reactant $\rightarrow$ $X_j = X$

# Design equation in terms of conversion

| Reactor | Design Eq$^n$ | Integral form | Conversion | X vs. t or V or W |
|---|---|---|---|---|
| BR | $\frac{dN_j}{dt} = r_j.V$ | $t = \int \frac{dN_j}{r_j}$ | $t = N_{j0} \int_{X_j\,at\,t=0}^{X_j\,at\,t} \frac{dX_j}{-r_j.V}$ |  |
| CSTR | $V = \frac{F_{j0}-F_j}{-r_j}$ algebraic | | $V = \frac{F_{j0}X_j}{-r_j}$ | |
| PFR | $\frac{dF_j}{dV} = r_j$ | $V = \int \frac{dF_j}{r_j}$ | $V = F_{j0} \int_{X_j\,at\,V=0}^{X_j\,at\,V} \frac{dX_j}{-r_j}$ |  |
| PBR | $\frac{dF_j}{dW} = r_j'$ | $W = \int \frac{dF_j}{r_j'}$ | $W = F_{j0} \int_{X_j\,at\,W=0}^{X_j\,at\,W} \frac{dX_j}{-r_j'}$ |  |

# Levenspiel plots useful for sizing flow reactors

- The function $\frac{F_{j0}}{-r_j}$ *or* $\frac{F_{A0}}{-r_A}$ is important in sizing → ***A*** is the limiting reactant
- $-r_A = f(X)$ and thus $\frac{F_{A0}}{-r_A}$ is also a function of ***X***
- Thus, a plot of $\frac{F_{A0}}{-r_A}$ or $\frac{1}{-r_A}$ versus X can be used to size the reactor
- For a CSTR: $V = \left(\frac{F_{A0}}{-r_A}\right)X$ and for a PFR: $V = \int_{X\ at\ V=0}^{X\ at\ V}\left(\frac{F_{A0}}{-r_A}\right)dX$