MFR Practice Problem

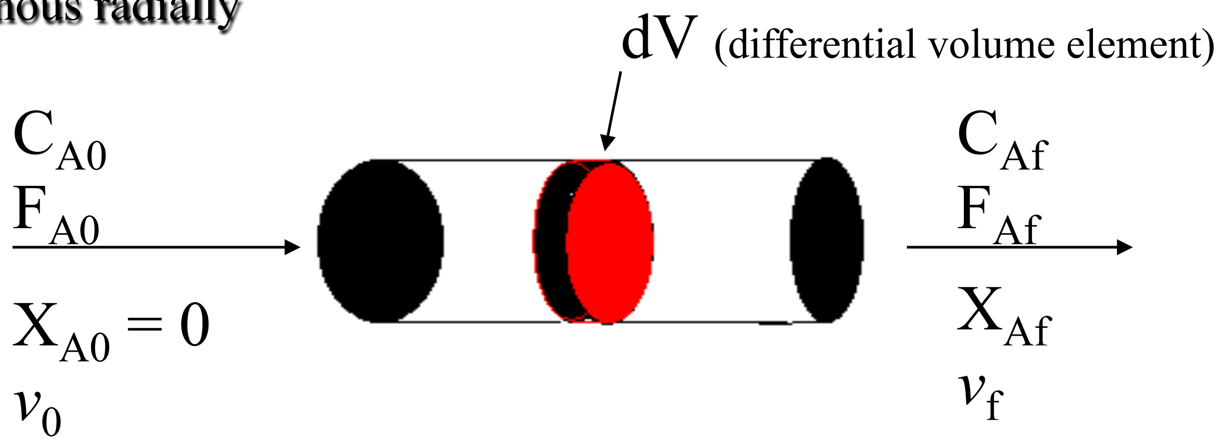
You work for a Pharmaceutical company and need to produce the antibiotic tetracycline. You run a 35 L mixed flow reactor at a constant concentration of tetracycline of 12 mg/L, with a constant flow rate of 1 L/min. Assume tetracycline decomposes in a 2nd order rxn with respect to its concentration, with a kinetic rate constant of 0.015 L/min-mg.

What concentration of tetracycline should be fed into the reactor?

Ideal steady-state plug flow reactor (PFR)

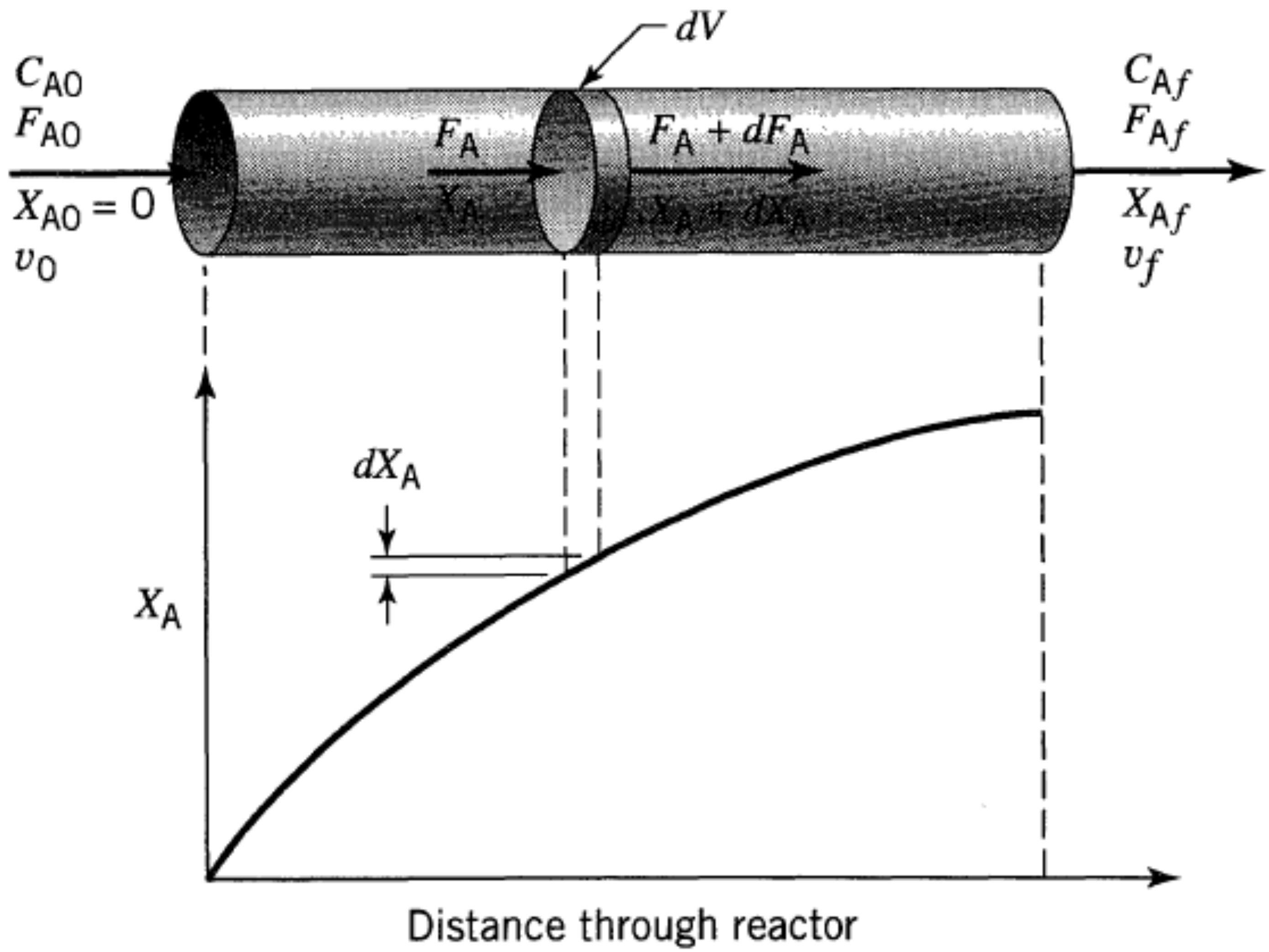
Assumptions:

- no axial mixing
- position variant, time invariant
- homogenous radially



Mass balance on differential volume element: 0

Input - output - disappearance by reaction = ~~accumulation~~


C_{A0}
F_{A0}
$X_{A0} = 0$
v_0
dV
F_A
X_A
$F_A + dF_A$
$X_A + dX_A$
C_{Af}
F_{Af}
X_{Af}
v_f
dX_A
X_A
Distance through reactor

$$\text{input of A, moles/time} = F_A$$

$$\text{output of A, moles/time} = F_A + dF_A$$

$$\begin{aligned}\text{disappearance of A by}\\ \text{reaction, moles/time} &= (-r_A)dV\\ &= \left(\frac{\text{moles A reacting)}}{\text{(time)(volume of fluid)}}\right)\left(\begin{matrix}\text{volume of}\\ \text{element}\end{matrix}\right)\end{aligned}$$

Introducing these three terms in Eq. 10, we obtain

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

Noting that

$$dF_A = d[F_{A0}(1 - X_A)] = -F_{A0}dX_A$$

We obtain on replacement

$$F_{A0}dX_A = (-r_A)dV \tag{16}$$

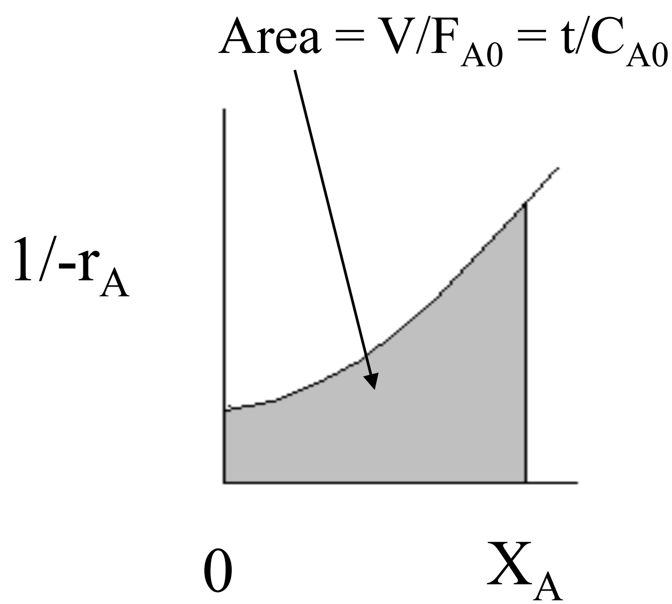
$$\int_0^V \frac{dV}{F_{A0}} = \int_0^{X_{Af}} \frac{dX_A}{-r_A}$$

Plug flow reactors

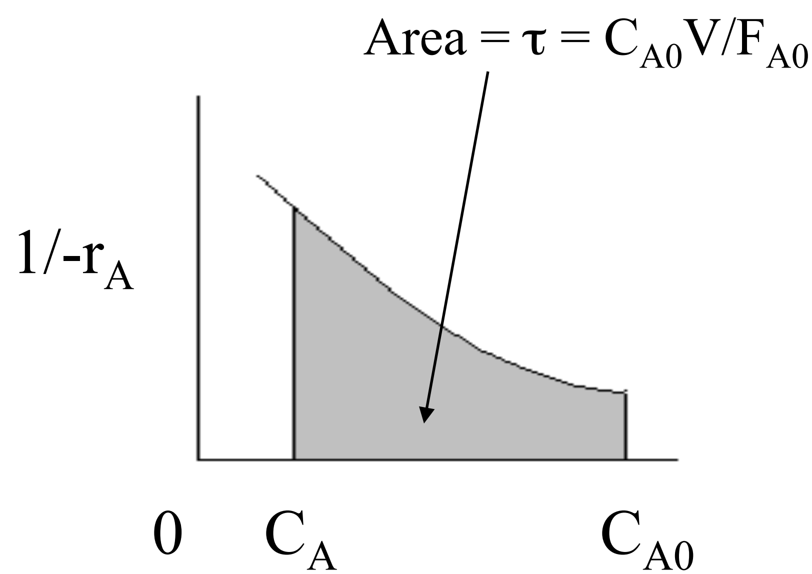
Plug flow reactors differ from MFR, because in plug flow r_A varies with position, whereas in mixed flow r_A is constant.

$$\tau = V/v_0 = VC_{A0}/F_{A0} = C_{A0} \int_{0}^{X_{Af}} \frac{1}{-rA} dXA = - \int_{C_{A0}}^{C_{Af}} \frac{1}{-rA} dCA$$

Graphical representation of performance eqns for PFR



General Case



Constant density systems

Integrated forms of performance eqns for PFR

Zero-order homogeneous reaction

$$\mathbf{k\tau = kC_{A0}V/F_{A0} = C_{A0}X_A}$$

First-order irreversible reaction ($A \rightarrow$ products)

$$\mathbf{k\tau = -\ln(1-X_A) = -\ln(C_A/C_{A0})}$$

Second-order irreversible reaction ($A+B \rightarrow$ products with equimolar feed or $2A \rightarrow$ products)

$$\mathbf{C_{A0}k\tau = X_A/(1-X_A)}$$

Equations for various rate models are located in your text on in chapter 5, on pages 111-112.

For any nth order mixed flow reactor of constant volume:

$$\mathbf{k\tau = (C_{A0}-C_A)/C^n{}_A \;=\; X_A/[C^{n-1}{}_{A0}(1-X_A)^n]}$$

For any nth order plug flow or batch reactor ($\varepsilon_A = 0$):

$$\mathbf{(n-1)C^{n-1}{}_{A0}k\tau = (C_A/C_{A0})^{1-n}-1 = (1-X_A)^{1-n}-1}$$

Ideal Single Reactor Performance Equations

- Batch

  $\tau = \int dC/r = Co \int dX/(-r)$

- MFR

  $\tau = [Co - C]/(-r) = CoX/(-r)$

- PFR

  $\tau = \int dC/r = Co \int dX/(-r)$

So given any kinetic rate model, you can solve for ideal reactor performance

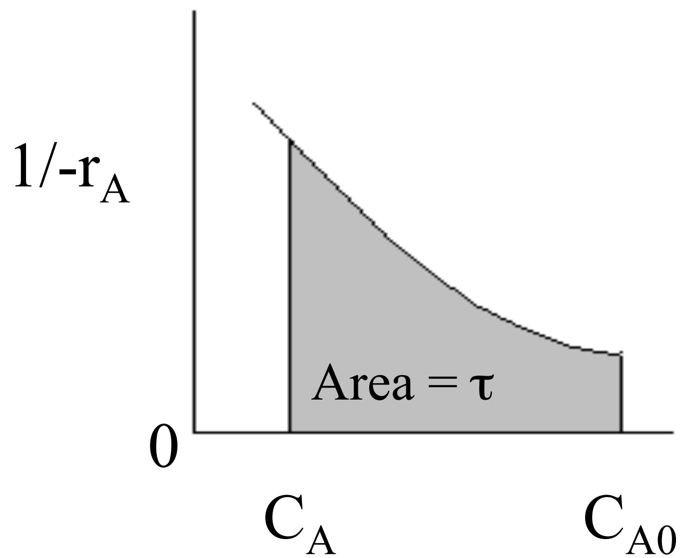
Graphical comparison of ideal flow reactors

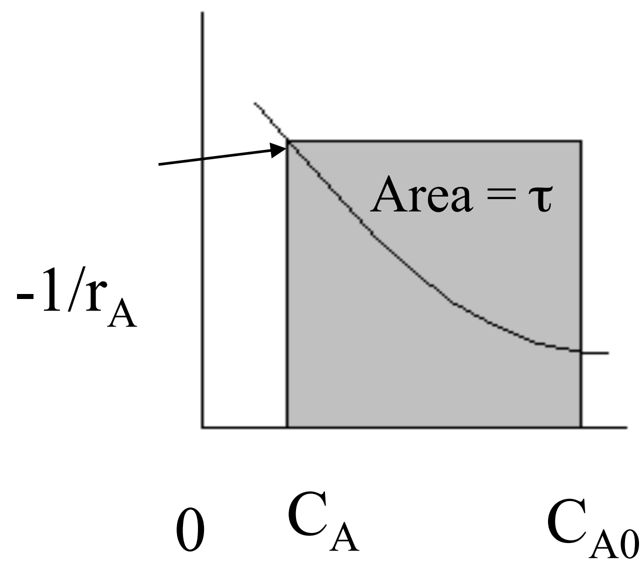
PFR

$$\tau = -\int_{C_{A0}}^{C_{Af}} \frac{1}{-rA}\, dCA$$

MFR

$$\tau_m = (C_{A0} - C_A)/-r_A$$

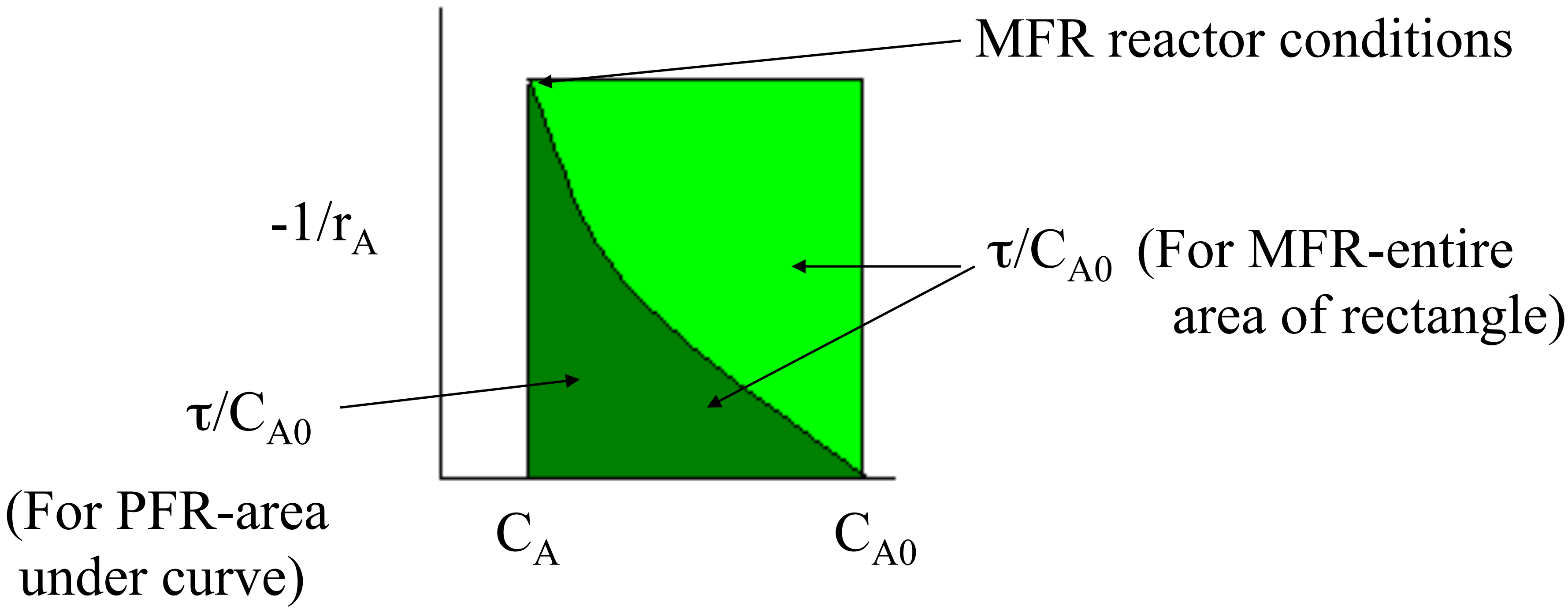




For same flow rate, which reactor has better performance?

MFR vs PFR

A plug flow reactor provides the same conversion as a mixed flow reactor for a smaller area.



PFR/MFR practice problem

An ideal plug flow reactor has a volume of 120 L with a flow rate of 15 L/min and an initial concentration of 28 mol/L. The reaction A=> B has a kinetic rate constant of 4.7 L/mol-min.

A. Determine the outlet concentration of reactant from the reactor.

B. A mixed flow reactor of 600 L is available at the same conditions. Calculate the outlet concentration of species A.