Space-time and Space-velocity

- The performance measure for a batch reactor is **t**.

- For steady flow reactor (MFR and PFR) the proper performance measures are:

  space-time $\tau = 1/s$

  space-velocity $s = 1/\tau$

Space-time

The time required to process one reactor volume of feed measured at specific conditions.

Units: time

Space-velocity

Number of reactor volumes of feed at specified conditions which can be treated in unit time.

Units: 1/time

Holding time and Space-time for Flow reactors

It is important to note the difference between the two measures of time, **t** and **τ**. (For constant density systems $\tau = V/v$)

Reactor volume volumetric flowrate

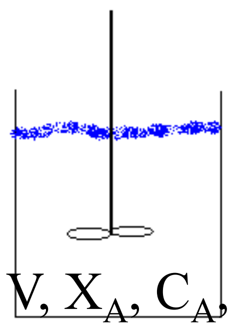
$$\tau = \text{time needed to treat one reactor volume of feed} = \frac{\text{Reactor volume}}{\text{Volumetric feed rate}} = V/v_0 = C_{A0}V/F_{A0}$$

Molar flowrate

$$t = \textbf{\textit{mean residence time}} \text{ of flowing material in the reactor} = C_{A0}\int_0^{X_A} \frac{1}{-rA}\, dXA$$

Ideal steady-state mixed flow reactors (MFR)

C_{A0}
X_{A0}
v_0
F_{A0}



$C_{af} = C_A$
$X_{af} = X_A$
V_f
$(-r_A)_f = -r_A$
F_A

Assumptions:

- *Composition is uniform throughout*
- *Exit stream conditions are the same as the conditions within reactor*

Input - output - disappearance by rxn = ~~accumulation~~ 0

In - out - reaction = 0

$$C_{A0}\, v_0 - C_A\, v_0 + V\, r_A = 0$$

$$-V\, r_A = C_{A0}\, v_0 - C_A\, v_0$$

$$V/v_0 = (C_{A0} - C_A)/ -r_A$$

$$\tau = (C_{A0} - C_A)/ -r_A = C_{A0}\, X_A/-r_A$$

Mixed flow reactors

$F_{A0} = v_0 C_{A0}$ (molar feed rate of component A)

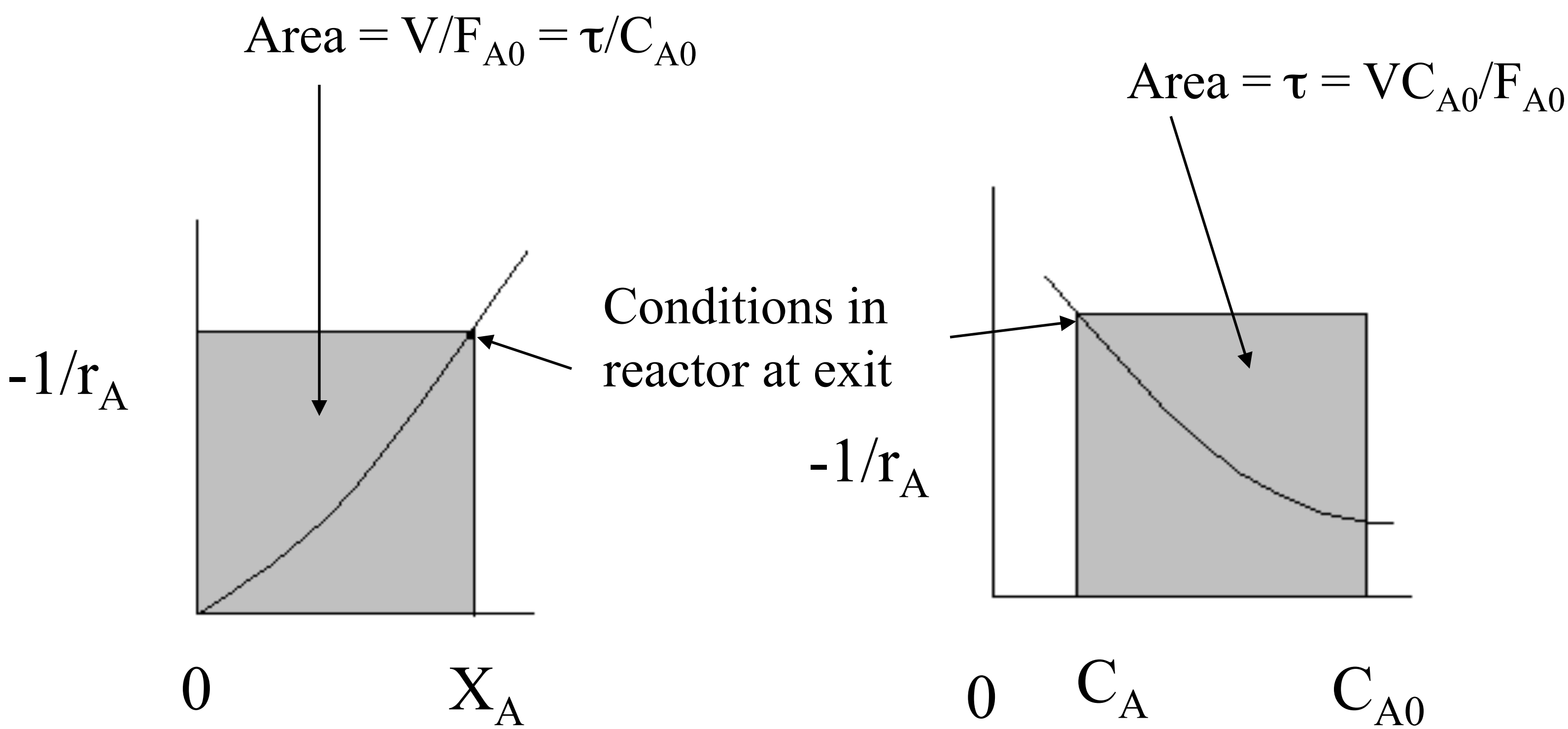
$\tau = V/v_0 = C_{A0}V/F_{A0} = C_{A0}X_A/-r_A$

For constant density systems:

$X_A = 1-C_A/C_{A0}$

$\tau = V/v = (C_{A0}V)/F_{A0} = (C_{A0}X_A)/-r_A = (C_{A0} - C_A)/-r_A$

Graphical representation of MFR



Performance expressions for MFR

1st order MFR:

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

$$C_A = (C_{A0}/(1+ k\tau)$$

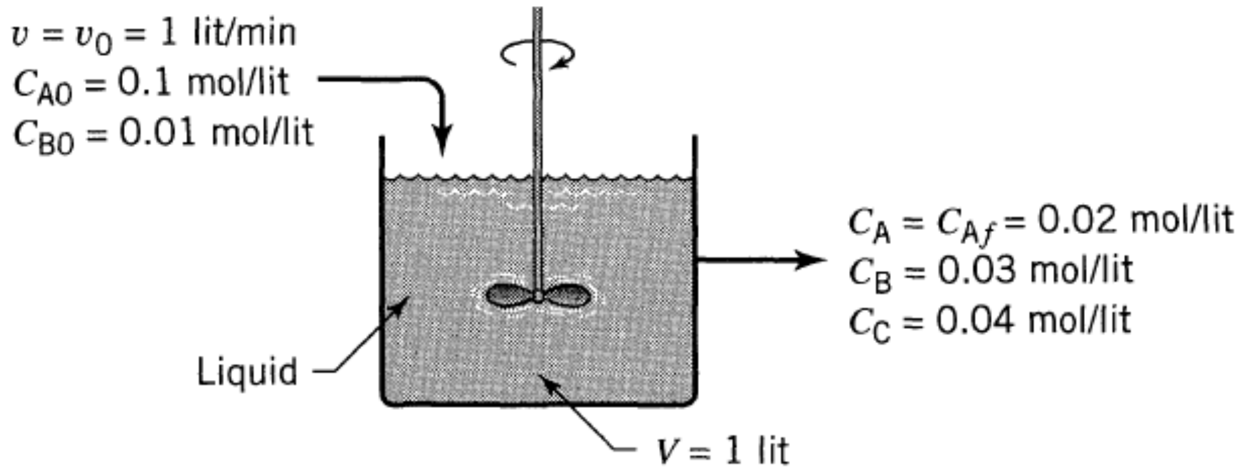
$$X_A = k\tau /(1+ k\tau)$$

2nd order MFR: $-r_A = kC_A^2$

$$k\tau = (C_{A0} - C_A)/C_A^2$$

$$C_A = [-1 + (1+ 4\ C_{A0}k\tau)^{1/2}]/2k\tau$$

One liter per minute of liquid containing A and B (C_{A0} = 0.10 mol/liter, C_{B0} = 0.01 mol/liter) flow into a mixed reactor of volume V = 1 liter. The materials react in a complex manner for which the stoichiometry is unknown. The outlet stream from the reactor contains A, B, and C (C_{Af} = 0.02 mol/liter, C_{Bf} = 0.03 mol/liter, C_{Cf} = 0.04 mol/liter), as shown in Fig. E5.1. Find the rate of reaction of A, B, and C for the conditions within the reactor.



The elementary liquid-phase reaction

$$A + 2B \underset{k_2}{\overset{k_1}{\rightleftharpoons}} R$$

with rate equation

$$-r_A = -\frac{1}{2} r_B = (12.5\ \text{liter}^2/\text{mol}^2 \cdot \text{min}) C_A C_B^2 - (1.5\ \text{min}^{-1}) C_R, \qquad \left[\frac{\text{mol}}{\text{liter} \cdot \text{min}}\right]$$

is to take place in a 6-liter steady-state mixed flow reactor. Two feed streams, one containing 2.8 mol A/liter and the other containing 1.6 mol B/liter, are to be introduced at equal volumetric flow rates into the reactor, and 75% conversion of limiting component is desired (see Fig. E5.3). What should be the flow rate of each stream? Assume a constant density throughout.