15.1 Given, a zero order reaction

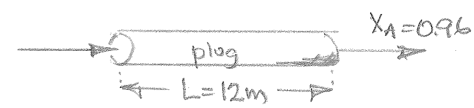
For plug flow: $\frac{C_A}{C_{A0}} = 1 - X_A = 0.2 = 1 - \frac{k\tau}{C_{A0}}$ ... or $\frac{k\tau}{C_{A0}} = 0.8$

For convective flow Eq 9 gives

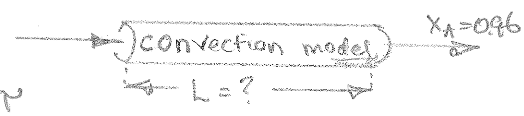
$$\frac{C_A}{C_{A0}} = \left(1 - \frac{k\tau}{2C_{A0}}\right)^2 = \left(1 - \frac{0.8}{2}\right)^2 = 0.36 \quad \therefore X_A = 0.64 \longleftarrow$$

15.3 For second order and plug flow

$$\frac{C_A}{C_{A0}} = \frac{1}{1 + kC_{A0}\tau} \quad \text{or} \quad kC_{A0}\tau = \frac{C_{A0}}{C_A} - 1$$



and because $\frac{C_A}{C_{A0}} = 0.04$ $kC_{A0}\tau = 25 - 1 = 24$



For the convection model let $y = kC_{A0}\tau$

then Eq 11 gives

$$X_A = 1 - \frac{C_A}{C_{A0}} = \underbrace{y\left[1 - \frac{y}{2}\ln\left(1 + \frac{2}{y}\right)\right] = 0.96}_{\text{solve by trial \& error}}$$

guess y	calculate X_A
24	0.9477
36	0.9644
30	0.9577
32	0.9602

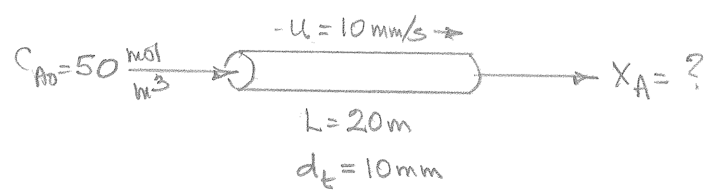
$$\therefore \frac{(kC_{A0}\tau)_{conv}}{(kC_{A0}\tau)_{plug}} = \frac{32}{24} = 1.33$$

$$\therefore \frac{L_{conv}}{L_{plug}} = 1.33 \quad \text{or} \quad L_{conv} = 16\,m \longleftarrow$$

15.5

$A \rightarrow R \quad -r_A = kC_A^2$

$\rho = 1000\ kg/m^3$
$\mathcal{D} = 10^{-9}\ m^2/s$
$k = 10^{-3}\ m^3/mol \cdot s$



First find which regime applies (see Fig 2)

$$Re = \frac{du\rho}{\mu} = \frac{0.01(0.01)1000}{10^{-3}} = 100$$

$$Bo = \frac{u d_t}{\mathcal{D}} = \frac{0.01(0.01)}{10^{-9}} = 10^5$$

$$\frac{L}{d_t} = \frac{20}{0.01} = 2000$$

Fig 2 shows that the reactor is in the intermediate regime between the convection and dispersion models. So average the results.

15.5 (continued)

Dispersion model

$$D = \frac{u^2 d_t^2}{192\mathcal{D}} = \frac{(0.01)^2(0.01)^2}{192(10^{-9})} = 5.21\times10^{-2}\ \frac{m^2}{s}$$

$$\frac{D}{uL} = \frac{5.21\times10^{-2}}{(0.01)(20)} = 0.26$$

$$kC_{A0}\tau = (10^{-3})(50)(20/0.01) = 100$$

From Fig 13.20 $\frac{C_A}{C_{A0}} = 0.022$ ... $X_A = 0.978$

Convection model

$$\frac{C_A}{C_{A0}} = 1 - kC_{A0}\tau\left[1 - \frac{kC_{A0}\tau}{2}\ln\left(1+\frac{2}{kC_{A0}\tau}\right)\right] = 1 - 100\left[1 - \frac{100}{2}\ln\left(1+\frac{2}{100}\right)\right]$$

$$= 0.013$$

$\therefore X_A = 0.987$

Averaging gives $\bar{X}_A = \frac{0.978 + 0.987}{2} = 0.983 \leftarrow$