Problem 1.
Mixed flow reactors are relatively cheap compared to plug flow reactors.
Assume MFRs cost \$23/L to construct vs. \$47/L for PFRs.

Your are conducting a reaction with following parameters:

$k = 0.17\ sec^{-1}$
$Co = 16.7$ mol/L
$q = 10$ L/s

You would like to have a 95% conversion.

A. Which reactor would be cheaper to construct?

For an MFR, performance equation for a 1st order reaction is
$k\tau = X/(1-X)$
or $V = (q/k)X/(1-X) = 1117.65$ L * \$23/L = \$25,705

For a PFR, the performance eqn for a 1st order reactor is:
$k\tau = \ln (1/(1-X)$
or $V = (q/k) \ln (1/(1-X) = 176.21$ L * \$47/L = \$8,282

Clearly, it is cheaper to build a PFR.

B. If you purchased 4 equal size MFR reactors to accomplish the task, what would be the cost?

For equal size reactors, the performance equation is
$\tau_I = (1/k)[(Co/C)^{1/N} - 1] = (1/k)[(1/(1-X))^{1/N} - 1]$
so $V_i = (q/k)\ [(1/(1-X))^{1/N} - 1]$

or Vi = 65.57 L
for 4 reactors 4*65.57*\$23 = \$6,032

C. If you purchased 4 equal size PFR reactors to accomplish the task, what would the cost be?

PFR in series give the exact same performance equation as a single PFR, hence the price is the same, \$8,282.

Problem 2.

MCO has a new vitamin pill which dissolves slowly (ie. shrinks) to release vitamins over an entire day (12 hours). Assuming the dissolution of the vitamins is rate-limiting (ie. ignore diffusion constraints), calculate the required size (radius) of the spherical pill. You may assume that the dissolution reaction is 1st order and that the vitamin solution leaving the pill is saturated.

<u>Data:</u>

k_S = 0.01 cm/s (dissolution rate constant)

C_{water} = 0.056 gmol/cm^3 (water concentration in bulk fluid, assumed constant)

r_B = 0.2 gmol/cm^3 (density/concentration of vitamin in pill)

Vitamin solubility is 1 gmol in 100 gmol of water

Solution

$ks := 0.01\frac{cm}{s} \quad Cwater := 0.056\frac{mol}{cm^3} \quad density := 0.2\frac{mol}{cm^3} \quad b := \frac{1}{100} \quad tau := 12hr$

$$tau := \frac{density \cdot R}{b \cdot ks \cdot Cwater}$$

re-arranging and solving for R

$$R := \frac{tau \cdot b \cdot ks \cdot Cwater}{density} = 1.21cm$$

Problem 3.

You are loading a drug (D) onto a porous spherical carrier pellet from an ethanol solution. The process is controlled by film diffusion f om the bulk ethanol solution to the pellet.

$k_f = 9.3 \times 10^{-4}$ cm/s $R = 1.2$ cm

$C_{DB} = 2.4$ gmol/cm^3 $\rho_B = 0.72$ gmol/cm^3

Adsorption stoichiometry -> 1 mole drug requires 3 mole of carrier to bind

1. Calculate the time needed to fully saturate the pellet with D (min).

2. Calculate the time needed to reach 85% saturation of the pellet.

Film diff. controlled, sphere

$$\tau = \frac{\nu_a \rho_b R}{3 \nu_b K_f C_{bulk}}$$

$$= \frac{1}{3} \left| \frac{1}{3} \right| \frac{0.72 \text{ mol}}{\text{cm}^3} \Big| \frac{1.2 \text{ cm}}{} \Big| \frac{\text{s}}{9.3 \times 10^{-4} \text{ cm}} \Big| \frac{\text{cm}^3}{2.4 \text{ gmol}}$$

$$= 43.01 \text{ s} = \underline{\underline{0.717 \text{ min}}}$$

for 85% saturation

$$\Theta = X \Rightarrow t = X \cdot \tau$$

$$= (.85)(0.717) = \underline{\underline{0.609 \text{ min}}}$$