More examples: batch, PFR, MFR

Your boss wants you to choose a reactor for the enzymatic conversion of glucose to ethanol.

$$\mathbf{C_6H_{12}O_6 + 3H_2O \longrightarrow 3C_2H_5OH + 3O_2}$$

The rxn is run in a large excess of water so the rxn only depends on the concentration of glucose [G].

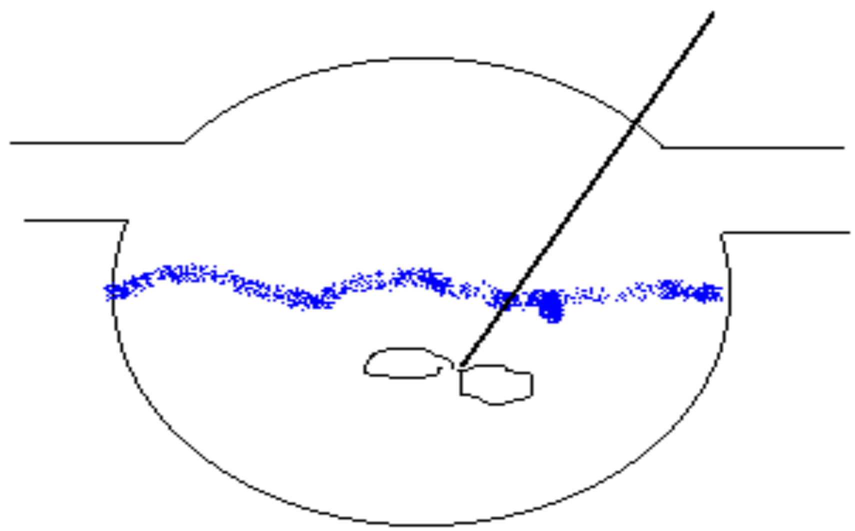
Assume a fixed amount of enzyme.

$K_m = 5$ mol/m^3

$V_m = 0.1$ mol/m^3-min

$[G_0] = 15$ mol/m^3

A) You have a tank of volume 350 L. Using it as a batch reactor, find the time needed to reach a conversion of 75%.



Answer:

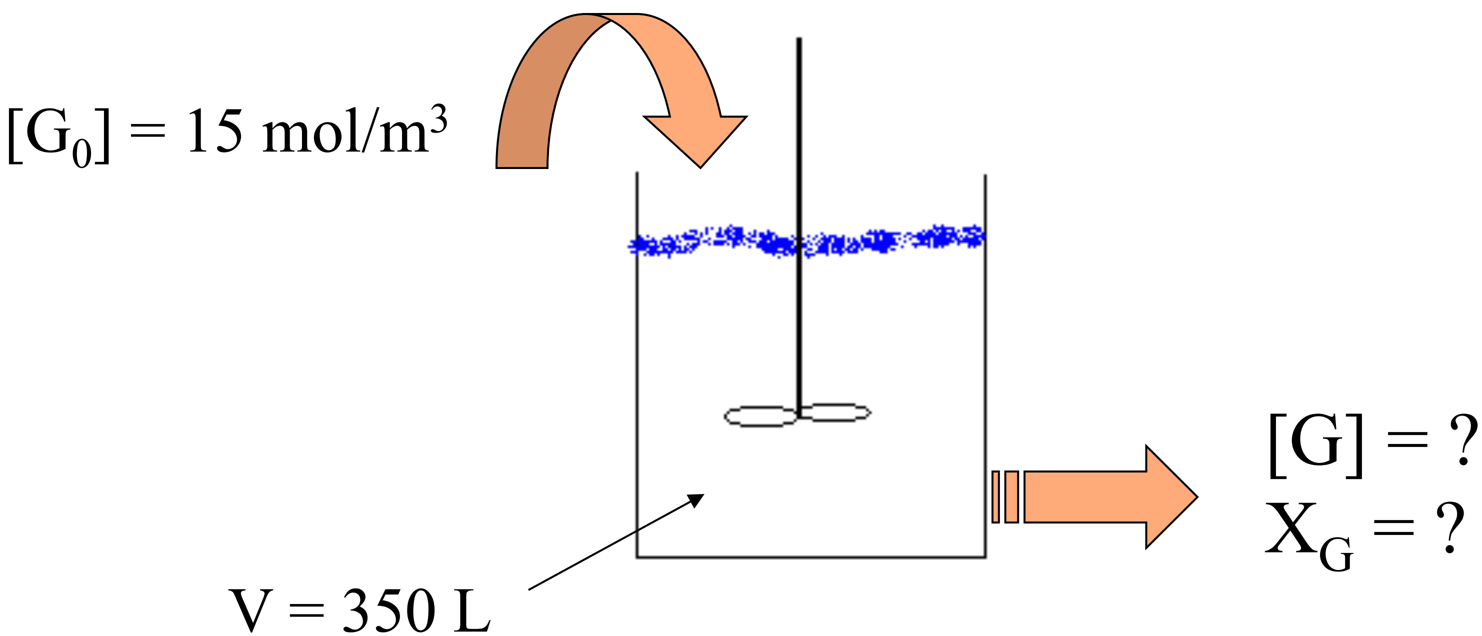
$$t = \frac{dC_A}{r_A} = -\int \frac{d[G]}{\dfrac{V_m[G]}{K_m + [G]}} = -\int_{[G_0]}^{[G]} \frac{K_m d[G]}{V_m[G]} - \int_{[G_0]}^{[G]} \frac{d[G]}{V_m}$$

$$= \frac{K_m}{V_m} \ln \frac{[G_0]}{[G]} + \frac{1}{V_m}\{[G_0] - [G]\}$$

$$= \frac{K_m}{V_m} \ln \frac{1}{1 - X_G} + \frac{[G_0]}{V_m} X_G = \frac{5}{0.1} \ln \frac{1}{1 - 0.75} + \frac{15}{0.1}(0.75)$$

t = 181.8 min = 3.03 hrs

B) You can install pumps in the 350 L tank that will provide a flow rate of 25 L/min. If you run the tank as a mixed flow reactor what conversion can you obtain?



Answer:

$$\tau = \frac{C_{A0} - C_A}{-r_A} = \frac{[G_0] - [G]}{\dfrac{V_m[G]}{K_m + [G]}} = \frac{([G_0] - [G])(K_m + [G])}{V_m[G]}$$

$$= \frac{K_m[G_0]}{V_m[G]} + \frac{[G_0] - K_m}{V_m} - \frac{[G]}{V_m}$$

$$= \frac{K_m}{V_m(1 - X_G)} + \frac{[G_0] - K_m}{V_m} - \frac{[G_0](1 - X_G)}{V_m}$$

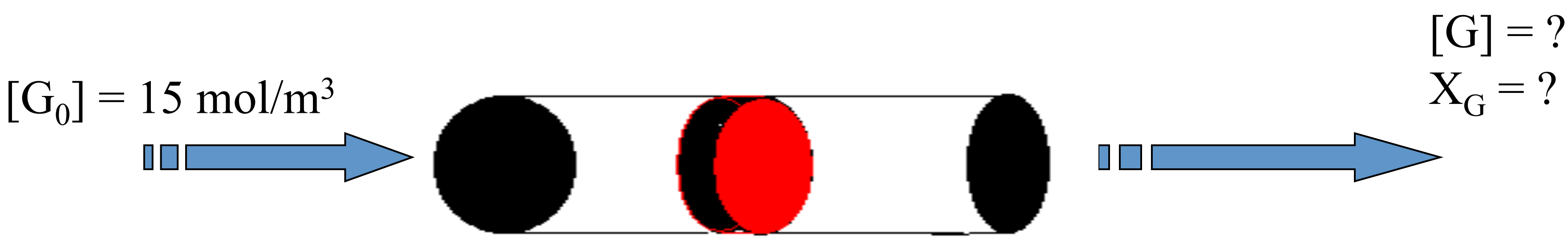
$$\tau = \frac{K_m}{V_m}\left(\frac{X_G}{1-X_G}\right) + \frac{[G_0]X_G}{V_m}$$

$\tau = V/q = (350\ \text{L})/(25\ \text{L/min}) = 14\ \text{min}$

Plug τ into above equation, and solve for X_G

$X_G = 0.0687$

C) You may instead use a large pipe as a plug flow reactor. Its length is 20 m and its diameter is 0.6 m.
What conversion can you get?



Answer:

Volume of reactor = $\pi r^2 L$
= (20 m)*(π)*(0.3 m)^2*(1000L)/ (1 m^3) = 5655 L

τ = V/q = (5655 L)/(25 L/min) = 226.2 min

$$\tau = \frac{K_m}{V_m}\ln\left(\frac{1}{1-X_G}\right)+\frac{[G_0]X_G}{V_m}$$

Plug in τ and solve for X_G
==> $\mathbf{X_G = 0.858}$

PFR gives the best conversion of the three reactors.