Plug Flow Reactor – Second Order Reaction

- 1.9 A second order reaction is conducted in a tubular flow reactor at 5 atm and at a 325 °C.
- $A \rightarrow 0.5Q; -r_A = kC_A^2, k = 0.015$ L/mol•s
- The feed contains A and inert, I at a mole fraction of 0.75 and 0.25, respectively. Calculate the size of the reactor if the design feed rate of A is 40000 lb/d and the design conversion is 45 %. Molecular weight of A = 65.

- 1.9 Solution
- Conversion, X_A = 0.45, Pressure, P = 5 atm
- Temperature, T = 598.15 K
- Gas constant, R = 0.08206 (atm·L)/(mol·°K)
- Fractional volume change, ε (Equation 1.15):
- $\varepsilon = \frac{V_{x=1} - V_0}{V_0} = \frac{\Delta N_{x=1}}{N_0} = \frac{0.75(-1+0.5)}{1} = -0.375$

- Concentration of component A, C_{Ao}:
- $C_{A0} = \frac{yP}{RT} = \frac{0.75(5)}{0.08206(598.15)} = 0.0764 \text{ mol/L}$
- $k\tau_p C_{Ao}$ (Second order, variable volume, Equation 1.53):
- $k\tau_p C_{Ao} = \int_0^x \frac{(1+\varepsilon x)^2}{(1-x)^2} dx = \int_0^{0.45} \frac{(1-0.375x)^2}{(1-x)^2} dx = 0.663$

- Residence time, $\tau_p = 0.663/(0.015(0.0764)) = 578.62$ s
- Molar flow rate of component A, F_{Ao}:
- $F_{A0} = \frac{(4.0\times10^4)(453.59)}{24(3600)(65)} = 3.231$ mol/s
- Volumetric flow rate, υ (Equation 1.48):
- $\upsilon = \frac{F_{A0}}{C_{A0}} = \frac{3.231}{0.0764} = 42.29$ L/s
- Reactor volume, V (Equation 1.49):
- $V = \upsilon\tau_p = 42.29(578.62) = 2.45\times10^4$ L