

Exercise 16

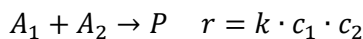
It is planned to carry out a second order reaction in a circular microchannel at a Reynolds number of 200 in order to benefit from accelerated mixing by stretching and engulfment. The two reactants are fed separately and contacted in a T-mixer.

Physical properties and geometric factors

Kinematic viscosity: $\nu = 10^{-6} \text{ m}^2 \cdot \text{s}^{-1}$

Density: $\rho = 1000 \text{ kg} \cdot \text{m}^{-3}$

Characteristic reaction time: $t_r = 1 \text{ s}$



Equal inlet molar flowrates of the two reactants

Questions

1. Calculate the diameter and length of a single channel circular micro-reactor to carry out this reaction at $Re = 200$ with 96% conversion in the absence of segregation. Assume plug flow behavior of the micro-channel.
2. What flowrate can be processed in this reactor?
3. What is the pressure drop?

Solution

For negligible effect of segregation: $t_{mx} = 0.1 \cdot t_r = 0.1 \text{ s}$

$$t_{mx} = 0.215 \cdot \varepsilon^{-0.5} \rightarrow \varepsilon = \left(\frac{0.215}{t_{mx}} \right)^2 = 4.62 \text{ W} \cdot \text{kg}^{-1}$$

Equal molar flowrates: $c_1 = c_2 = c$; $r = kc^2$

PFR with 2nd order kinetics: $DaI = \frac{\tau}{t_r} = \frac{X}{1-X} = 24$

$$\tau = DaI \cdot t_r = 24 \text{ s}$$

$$Re = \frac{u \cdot d_t}{\nu} ; \quad \varepsilon = \frac{32 \cdot \nu \cdot u^2}{d_t^2} \rightarrow u = \left(\frac{\varepsilon \cdot \nu \cdot Re^2}{32} \right)^{1/4} = 0.276 \text{ m} \cdot \text{s}^{-1}$$

$$d_t = \frac{\nu \cdot Re}{u} = 7.3 \cdot 10^{-4} \text{ m}$$

$$L = \tau \cdot u = 6.6 \text{ m}$$

$$Q = u \cdot \pi \frac{d_t^2}{4} = 1.14 \cdot 10^{-7} \text{ m}^3 \cdot \text{s}^{-1} = 0.41 \text{ l} \cdot \text{h}^{-1}$$

$$\Delta p = \frac{\varepsilon \cdot L \cdot \rho}{u} = 1.11 \cdot 10^5 \text{ Pa} = 1.1 \text{ bar}$$