Exercise 20

1. Estimate the Bodenstein number in a fixed-bed reactor of length $L = 0.1\ m$ and internal diameter $d_t = 5\ mm$ filled with spherical particles of diameter $d_p = 0.3\ mm$ at a space-time of liquid reaction mixture of $\tau = 60\ s$. The bed void fraction is $\varepsilon = 0.4$. Transport properties: $D_m = 10^{-9}\ m^2 s^{-1}, \nu = 10^{-6}\ m^2 s^{-1}$. Can the residence time distribution in the reactor be qualified as plug-flow?

2. What would be the Bodenstein number if the reactor had not been filled with particles?

Solution

1. $Q = u\,S = \frac{V\ \varepsilon}{\tau} = \frac{L\,S\ \varepsilon}{\tau} \rightarrow u = \frac{L\,\varepsilon}{\tau} = 6.67 \cdot 10^{-4}\ m/s$ (empty-bed velocity)

$$Re_p = \frac{u \cdot d_p}{\nu} = 0.18$$

$$Pe_{ax} = \frac{0.2 + 0.011 \cdot Re_p^{0.48}}{\varepsilon} = 0.51$$

$$Bo = Pe_{ax}\frac{L}{d_p} = \mathbf{171}\ > 100 \rightarrow \textbf{plug flow}$$

2. $u = \frac{L}{\tau} = 1.67 \cdot 10^{-3}\ m/s$

$$Re = \frac{u \cdot d_t}{\nu} = 8 \rightarrow \text{stratified flow}$$

Taylor-Aris: $Bo \cong 192\frac{D_m}{d_t^2}\frac{L}{u} = \mathbf{0.5} \rightarrow$ **very far from plug flow!**