# Exercise problem: calculate breakthrough time

An adsorption process is designed to remove traces of xylene (0.1 mole/m$^3$) from nitrogen gas using a 1.2 meter long silica column bed at 1.0 atm and 0°C. Nitrogen does not absorb at all. Calculate the breakthrough time using following data:

$\rho_{adsorbent}$ = 2100 kg_adsorbent/m$^3$

$\varepsilon_e = 0.43$

$\varepsilon_p = 0.48$

$K_d = 1.0$

$$q = 0.2 * c$$

q is in mole_solute/kg_adsorbent

c is in mole_solute/m$^3$

$$A_c = 0.1 \text{ m}^2$$

$$Q = 0.008 \text{ m}^3/\text{minute}$$

$$v_{inter} = \frac{Q}{\varepsilon_e A_c}$$

$$u_s = \frac{v_{inter}}{1 + \left(\frac{1-\varepsilon_e}{\varepsilon_e}\right) * \left(K_d \varepsilon_p\right) + \left(\frac{1-\varepsilon_e}{\varepsilon_e}\right) * \left(1-\varepsilon_p\right) * \rho\left(\frac{\Delta q}{\Delta c}\right)}$$

Unit of q
mol solute/kg adsorbent

Unit of c
mol solute/m$^3$

$$Breakthrough\ \ time = t_{saturation} - t_{in} = \frac{L}{u_s}$$

# Solution to exercise problem

$\rho_{adsorbent}$ = 2100 kg_adsorbent/m$^3$

$\varepsilon_e$ = 0.43

$\varepsilon_p$ = 0.48

$K_d$ = 1.0

$A_c = 0.1\ \mathrm{m}^2$

$Q = 0.008$ meter/minute

$$v_{int} = \frac{0.008}{0.1 * 0.43} = 0.186 \text{ meter/min}$$

$$u_s = \frac{v_{inter}}{1 + \left(\frac{1-\varepsilon_e}{\varepsilon_e}\right)*\left(K_d \varepsilon_p\right) + \left(\frac{1-\varepsilon_e}{\varepsilon_e}\right)*\left(1-\varepsilon_p\right)*\rho\left(\frac{\Delta q}{\Delta c}\right)}$$

$$u_s = \frac{0.186}{1 + \left(\frac{1-0.43}{0.43}\right)*\left(1*0.48\right) + \left(\frac{1-0.43}{0.43}\right)*\left(1-0.48\right)*2100*\left(0.2\right)}$$

$$= 6.39 * 10^{-4} \text{ meter/min}$$

$$Breakthrough\ \ time = t_{saturation} - t_{in} = \frac{L}{u_s} = \frac{1.2}{6.39*10^{-4}} = 1880\ \ minute$$