SOLUTION

CHE 305 – Separation Processes
Spring 2010 – Homework #9

The production of Jack Daniels whiskey includes an adsorption step, where the whiskey is contacted with charcoal in a packed column. Bitter compounds in the whiskey adsorb on the charcoal, resulting in the finished product. The charcoal can be approximated as 0.15 inch diameter cylinders. The column is 20 ft tall, and has a diameter of 5 ft. Laboratory scale experiments have shown that the mass transfer coefficient for the system is 5×10^{-3} ft/hr. Use your knowledge of mass transfer to determine the production rate for the production scale column.

$k_c = 5\times10^{-3}\ \frac{ft}{hr}$

Given:

- Assume average molecular weight of bitter component ~ 120 lb/lbmol
- $D_{Bitter\text{-}Whiskey}$ (77 °F, 1 atm) = 3.88×10^{-5} ft²/hr ← D_{AB}
- Liquid density = 56.19 lb/ft³ ← ρ
- μ_{liquid} = 483.5 lb/ft hr ← μ
- 1 ft³ = 7.4805 gal

$D = 0.15$ in for Re + Sh

Useful Equations:

$$Re = \frac{Du\rho}{\mu} \qquad Sc = \frac{\mu}{\rho D_{AB}} \qquad Sh = \frac{k_c D}{D_{AB}} \qquad Sh = 1.17\,Re^{0.585}\,Sc^{1/3}$$

a. Determine the Sherwood number.

$$Sh = \frac{5\times10^{-3}\ ft}{hr}\left|\frac{0.15\ in}{1}\right|\frac{hr}{3.88\times10^{-5}\ ft^2}\left|\frac{1\ ft}{12\ in}\right| = \boxed{1.611}$$

b. Determine the Schmidt number.

$$Sc = \frac{483.5\ lb}{ft\cdot hr}\left|\frac{ft^3}{56.19\ lb}\right|\frac{hr}{3.88\times10^{-5}\ ft^2} = \boxed{221,771}$$

c. Determine the Reynolds number.

$$1.611 = 1.17\,(Re)^{0.585}\,(221,771)^{1/3} \Rightarrow \boxed{Re = 0.00156 \text{ (very low)}}$$

d. Determine the superficial velocity.

$$u = \frac{Re\cdot\mu}{D\cdot\rho} = \frac{0.00156}{0.15\ in}\left|\frac{483.5\ lb}{ft\cdot hr}\right|\frac{ft^3}{56.19\ lb}\left|\frac{12\ in}{1\ ft}\right| = \boxed{1.07\ \frac{ft}{hr}}$$

e. Determine the volumetric production rate of whiskey (gal/hr).

$$\dot{V} = \frac{1.07\ ft}{hr}\left|\frac{\pi}{1}\right|\frac{(5\ ft)^2}{4}\left|\frac{7.4805\ gal}{1\ ft^3}\right| = \boxed{157\ \frac{gal}{hr}}$$