

SOLUTION

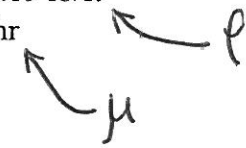
CHE 305 – Separation Processes  
Spring 2010 – Homework #9

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  $5 \times 10^{-3}$  ft/hr. Use your knowledge of mass transfer to determine the production rate for the production scale column.

$$k_c = 5 \times 10^{-3} \frac{\text{ft}}{\text{hr}}$$

Given:

- Assume average molecular weight of bitter component ~ 120 lb/lbmol
- $D_{\text{Bitter-Whiskey}} (77^\circ\text{F}, 1 \text{ atm}) = 3.88 \times 10^{-5} \text{ ft}^2/\text{hr}$  ←  $D_{AB}$
- Liquid density =  $56.19 \text{ lb/ft}^3$
- $\mu_{\text{liquid}} = 483.5 \text{ lb/ft hr}$
- $1 \text{ ft}^3 = 7.4805 \text{ gal}$



$D = 0.15 \text{ in}$  for  $Re + Sh$

Useful Equations:

$$Re = \frac{D u \rho}{\mu}$$

$$Sc = \frac{\mu}{\rho D_{AB}}$$

$$Sh = \frac{k_c D}{D_{AB}}$$

$$Sh = 1.17 Re^{0.585} Sc^{1/3}$$

- a. Determine the Sherwood number.

$$Sh = \frac{5 \times 10^{-3} \text{ ft}}{\text{hr}} \left| \frac{0.15 \text{ in}}{1} \right| \frac{\text{hr}}{3.88 \times 10^{-5} \text{ ft}^2} \left| \frac{1 \text{ ft}}{12 \text{ in}} \right| = 1.611$$

- b. Determine the Schmidt number.

$$Sc = \frac{483.5 \text{ lb}}{\text{ft} \cdot \text{hr}} \left| \frac{\text{ft}^3}{56.19 \text{ lb}} \right| \frac{\text{hr}}{3.88 \times 10^{-5} \text{ ft}^2} = 221,771$$

- c. Determine the Reynolds number.

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

- d. Determine the superficial velocity.

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

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

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