30 cm in height; segmentation reduces the bed-compression problem. Another approach is to increase A and volumetric flow to maintain a constant v and hence constant σ. This yields a "pancake" reactor. It is quite workable if the liquid can be applied uniformly over the surface of the column.

Recent advances in the design of packings (particles) for chromatography columns have also assisted in scale-up. Rigid, mechanically strong particles with macropores allow convective flow both around and through particles. The macropores are intimately connected with the micropores, so good mass transfer is maintained. These particles allow fast flow of solvent and solutes and reduce problems of bed compression, allowing column length to be increased.

Example 11.4.

In a chromatographic separation column used for the adsorption of solute A onto an adsorbent solid B, the adsorption isotherm is given by

$$C_S = k_1 C_L^3 = f(C_L)$$

where C_S is mg solute adsorbed/mg adsorbent, C_L is the solute concentration in liquid medium (mg solute/ml liquid), and k_1 is a constant. $k_1 = 0.2$ (mg solute adsorbed/mg adsorbent)/(mg solute/ml liquid)^3. The porosity (void fraction) of the packed column is $\varepsilon = 0.35$. The cross-sectional area of the column is 10 cm^2 and M is 5 g adsorbent per 100 ml column volume. If the volume of the liquid added is $\Delta V = 250$ ml:

a. Determine the position (ΔX) of the solute band in the column when the solute concentration in the liquid phase at equilibrium is $C_L = 5 \times 10^{-2}$ mg/ml.

b. Find the ratio of the travel distance of solute A (L_A) to that of solvent B in the column (R_f) when $C_L = 5 \times 10^{-2}$ mg/ml (i.e., R_f).

Solution

a. $C_L = 5 \times 10^{-2}$ mg/ml

$$f(C_L) = k_1 C^3, \quad f'(C_L) = 3k_1 C_L^2$$

$$f'(C_L) = 3(0.2)(5 \times 10^{-2})^2 = 0.0015$$

$$M = 5\,\text{g}/100\ \text{ml} = 50\ \text{mg/ml}$$

$$\Delta X = \frac{\Delta V}{A(\varepsilon + Mf'(c))} = \frac{250\ \text{cm}^3}{10\ \text{cm}^2[0.35 + 50(0.0015)]}$$

$$\Delta X = 58.5\ \text{cm}$$

b. $$R_f = \frac{\varepsilon}{\varepsilon + MK} = \frac{0.35}{0.35 + 50(0.0015)}$$

$$R_f = 0.824$$

Example 11.5.

Consider an ion-exchange chromatography column used to purify 20 g of a particular protein. At a superficial velocity of 20 cm/h the peak exits the column with $y_{\max}$ at 80 min. The standard deviation of the peak is 10 min. Estimate:

a. How long must the column be run to achieve 95% yield?

b. How long must we run if the flow is increased to 40 cm/h and Taylor dispersion controls?