Problem 1.

You are developing a process to extract exciting new flavors from MCO's novel cola nuts for a new soft drink.

The nuts are basically spherical, with a radius of 2 cm. The density of flavoring agents in the nuts is 0.02 gm/cm^3. Using pure water as the extraction solvent, the effective diffusivity through nut is $D_{eff} = 8.7 \times 10^{-3}$ cm^2/min. The aqueous solubility of the flavoring agents is 50 gm/L of water. Assume that the extraction is controlled by diffusion of the flavoring agents through the nut matrix and that the flavor solution leaving the nut is saturated.

A. Calculate the time (min) needed to extract 100% of the flavoring agents.

B. Calculate the time (min) needed to extract 90% of the flavoring agents.

Part A $\tau = \dfrac{\rho R^2}{\text{solubility} \cdot 6 \mathcal{D} \cdot C_w}$

$\rho = 0.02\ g/cm^3$ $R = 2cm$ $\mathcal{D} = 8.7 \times 10^{-3}\ cm^2/min$

solubility $= 50\ gm/L$ $C_w = 1\ g/cm^3$

$$\tau = \frac{0.02\,g}{cm^3}\left|\frac{2^2\,cm^2}{}\right|\frac{L}{50\,g}\left|\frac{}{6}\right|\frac{min}{8.7\times10^{-3}\,cm^2}\left|\frac{cm^3}{1\,g}\right.$$

$= 0.03065\ \dfrac{L \cdot min}{g}$

Must convert solubility to g/g not L/g

Assume sol'n has density of water ($1\ gm/cm^3$)

$\therefore$ 50 gm flavoring/1000 gm sol'n $= 0.05\ \dfrac{g\ flavor}{g\ soln.}$

$\tau = 30.65$ min

Part B $t = \tau\left[1 - 3(1-x)^{2/3} + 2(1-x)\right]$

$x = 0.9$

$t = 17$ min

Problem 2.
For a 1st order reaction in a catalyst particle, calculate the effectiveness factors for a flat plate (thickness 2 cm), a cylinder (R=2 cm) and a sphere (R=2 cm). For the cylinder, use the chart. For the flat plate and the sphere, use both the analytical equation and the chart.

$De = 5.31 \times 10^{-3}$ cm2/s
$ke = 0.18\ s^{-1}$

1st order rxn, calc eff factor for flat plate, cylinder, and sphere. For cylinder, use the chart. For flat plate and sphere, use both analytical equation and chart.

$De := 5.31 \cdot 10^{-3}\ \frac{cm^2}{s}$ $\quad$ $tplate := 2\ cm$ $\quad$ $Lplate := \frac{tplate}{2}$ $\quad$ $Lplate = 1\ cm$

$Rcyl := 2\ cm$

$ke := 0.18\ s^{-1}$ $\quad$ $Rsph := 2\ cm$ $\quad$ $Lcyl := \frac{Rcyl}{2}$ $\quad$ $Lcyl = 1\ cm$

$Lsph := \frac{Rsph}{3}$ $\quad$ $Lsph = 0.667\ cm$

CYLINDER

volume to surface area ratio for a cylinder = r/2

$$\phi cyl := \frac{Rcyl}{2} \cdot \sqrt{\frac{ke}{De}}$$

$\phi cyl = 5.822$

$\eta cyl := 0.18$ This value was obtained from Fig 18.6 of the text.

FLAT PLATE

$$mLplate := Lplate \cdot \sqrt{\frac{ke}{De}}$$

$mLplate = 5.822$

$\eta platechart1 := 0.18$

$$\eta plate1eqn := \frac{\tanh(mLplate)}{mLplate}$$

$\eta plate1eqn = 0.172$

These two values are reasonably close to one another.

SPHERE

$$\phi sph := \frac{Rsph}{3} \cdot \sqrt{\frac{ke}{De}}$$

$\phi sph = 3.881$

$\eta sphchart := 0.25$

$$\eta spheqn := \frac{1}{3 \cdot \phi sph^2} \cdot (3 \cdot \phi sph \cdot \coth(3 \cdot \phi sph) - 1)$$

$\eta spheqn = 0.236$

Problem 3.

A catalyzed chemical reaction (A->B) has an effective 1st order reaction constant ke = 0.2/sec. The effective diffusivity of A in the catalyst particle is 7.2×10^{-4} cm^2/sec. It has been proposed to use either spherical or cylindrical catalyst particles with a radius of 0.3 cm. Calculate the difference in effectiveness between these alternative catalyst particle shapes.

1st order rxn. Calculate the difference in effectiveness between spherical and cylindrical catalysts.

$ke2 := 0.2 \quad s^{-1}$

$De2 := 7.2 \cdot 10^{-4} \quad \frac{cm^2}{s}$

$R := 0.3 \quad cm$

SPHERE

$\phi sph2 := \frac{R}{3} \cdot \sqrt{\frac{ke}{De}}$ =1.66

$\eta sph2 := \frac{1}{3 \cdot \phi sph2^2} \cdot (3 \cdot \phi sph2 \cdot \coth(3 \cdot \phi sph2) - 1)$ =0.45

CYLINDER

$\phi cyl2 := \frac{R}{2} \cdot \sqrt{\frac{ke}{De}}$ =2.5

$\eta cyl2chart = 0.32$

$difference := \eta sph2 - \eta cyl2chart$ =0.45-0.32=0.13