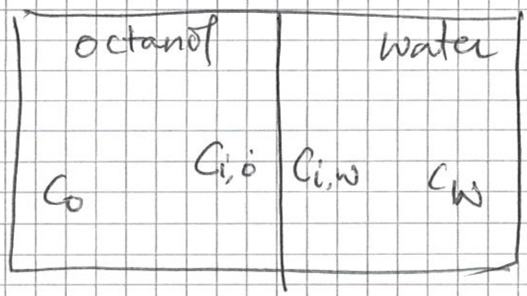
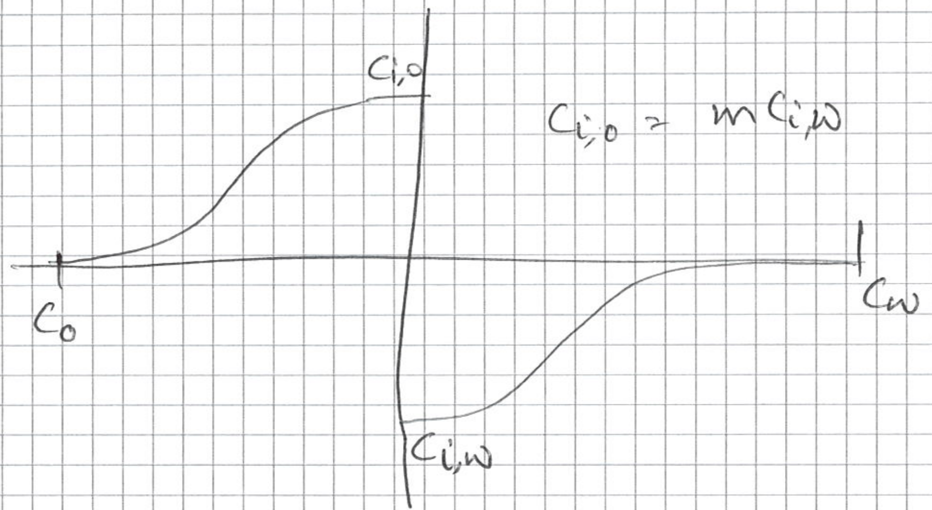
(1) Given that octanol prefers water and bulk concentration are same, the flux will be from the water phase to the octanol phase.




$C_{i,o} = m C_{i,w}$ where $m = 100$

Flux in water phase $= J_w = k_w (C_w - C_{i,w})$ — (1)

Flux in octanol phase $= J_o = k_o (C_{i,o} - C_o)$ — (2)

$J_w = J_o$ ~~$k_w = k_o$~~ at steady state $\Rightarrow$ $J = J_w = J_o$

From (1) and (2)

$$\frac{J_w}{k_w} = C_w - C_{i,w}, \quad \text{— (3)} \qquad \frac{J_o}{k_o} = C_{i,o} - C_o \quad \text{— (4)}$$

Multiply (3) by $m$ and add to (4)

$$\frac{m J_w}{k_w} + \frac{J_o}{k_o} = m C_w - \cancel{m C_{i,w}} + \cancel{C_{i,o}} - C_o$$

$$= m C_w - C_o$$

$$\Rightarrow \quad J = \frac{m C_w - C_o}{\left( \frac{m}{k_w} + \frac{1}{k_o} \right)} \quad \text{— (5)}$$

$k_w$ is obtained from surface renewal theory

$$k_w = \sqrt{\frac{D}{\tau}} = \frac{10^{-3}}{\sqrt{3}} \frac{cm}{s}$$

$k_o$ is obtained from film theory

$$\Rightarrow k_o = \frac{D}{l} = \frac{10^{-6}}{10^{-2}} \frac{cm}{s} = 10^{-4} \frac{cm}{s}$$

$\Rightarrow$ Plugging values in eqⁿ 5, we get

$$J = \frac{[m C_w - C_o]}{\left(\frac{m}{10^{-3}}\sqrt{3} + 10^{4}\right)} \frac{[M]}{\left(1/\frac{cm}{s}\right)}$$

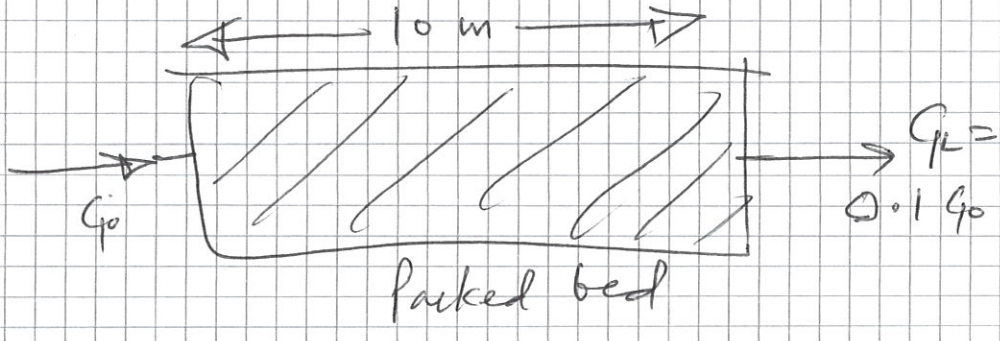
$$= \frac{\left(1000 \times 0.001 - 0.001\right)}{\left(\sqrt{3}\times 10^{6} + 10^{4}\right)} \frac{\frac{mol}{liter}}{\left(1/\frac{cm}{s}\right)}$$

$$1 \frac{mol}{liter} = \frac{1}{1000} \frac{mol}{cm^3}$$

$$= \frac{0.999}{10^{4} \times \cancel{173} \; 174.4} \frac{mol}{cm^3} \cdot \frac{cm}{s} \times \frac{1}{1000}$$

$$= \frac{0.999 \times 10^{-7}}{174.4} \frac{mol}{cm^2 \cdot s} = 5.72 \times 10^{-10} \frac{mol}{cm^2 \cdot s}$$

(2)




We should calculate enhancement factor for each case of packing and then see if a given packing is sufficient to achieve $C_L \leq 0.1\, C_0$

$$E = \sqrt{\frac{k}{D}}\, l \;\coth\left(\sqrt{\frac{k}{D}}\, l\right) = \frac{\sqrt{kD}}{k^0} \coth\left(\frac{\sqrt{kD}}{k^0}\right)$$

$k = 10\, s^{-1}$

$$E = \left(\frac{\sqrt{10\, s^{-1} \times 10^{-5}\, cm^2/s}}{10^{-3}\, cm/s}\right) \coth\left(\frac{\sqrt{10 \times 10^{-5}}}{10^{-3}}\right)$$

$$= 10 \coth 10$$

$\simeq$ ~~100~~ 10 (also makes sense from the plot we discussed in the class)

(i) $a = 10\, cm^{-1}$, (ii) $a = 50\, cm^{-1}$, (iii) $a = 250\, cm^{-1}$
(iv) $a = 500\, cm^{-1}$

$K = k^0 E = 10^{-2}\, cm/s = 10^{-4}\, m/s$

| a (cm$^{-1}$) | a (m$^{-1}$) | $C_{1L} = C_{10} \exp\left(-\frac{KaL}{v}\right)$ |
|---|---|---|
| 10 | 1000 | $0.37\, C_{10}$ |
| 50 | 5000 | $0.007\, C_{10}$ |
| 250 | 25000 | $10^{-11}\, C_{10}$ |
| 500 | 50000 | $10^{-22}\, C_{10}$ |

$L = 10\, m$
$v = 1\, m/s$

(ii) $\Rightarrow$ $a \geq 50$ will work. The right packing is $50\, cm^{-1}$ as this is lowest cost.

(3) We have diffusion controlled regime when

$$k = \sqrt{KD}$$

To operate outside this regime, we need $k$ such that

$$k > \sqrt{KD}$$

$$\Rightarrow k > 0.1 \text{ cm/s}$$

Plugging $k = 0.1$ cm/s in the mass transfer correlation, we get

$$\frac{kd}{D} = 0.13 \left( \frac{(P/V) d^4}{\rho \nu^3} \right)^{1/4} \left( \frac{\nu}{D} \right)^{1/3}$$

$$\Rightarrow \frac{0.1 \times 0.1}{10^{-6}} = 0.13 \left( \frac{(P/V)\,(0.1)^4}{1 \times 10^{-24}} \right)^{1/4} \times \left( \frac{10^{-8}}{10^{-6}} \right)^{1/3}$$

$$\Rightarrow 10^4 = \frac{0.13 \times 0.1}{10^{-6}} \times 10^{-2/3} \left[ \frac{P}{V} \right]^{1/4}$$

$$\Rightarrow \left[ \frac{P}{V} \right]^{1/4} = \frac{10^4 \times 10^{-6}}{0.013 \times 10^{-2/3}} = \frac{10^{-2}}{0.013 \times 10^{-2/3}}$$

$$\Rightarrow \frac{P}{V} = \left[ \frac{1}{1.3 \times 10^{-2/3}} \right]^4 = 162 \ \frac{g}{cm} \cdot s^{-3}$$

$\cancel{= 162}$

$\frac{P}{V}$ in SI unit is $\frac{\text{Watt}}{m^3} \sim \frac{Kg}{m} s^{-3} = \frac{1000}{100} \cdot \frac{g}{cm} s^{-3}$

$$= 10 \ g/cm \ s^{-3}$$

$$\Rightarrow \quad \frac{P}{V} = 162 \frac{g}{cm} s^{-3} = 16.2 \frac{Watt}{m^3}$$

$$= 16.2 \times 10^{-3} \frac{Watt}{liter}$$