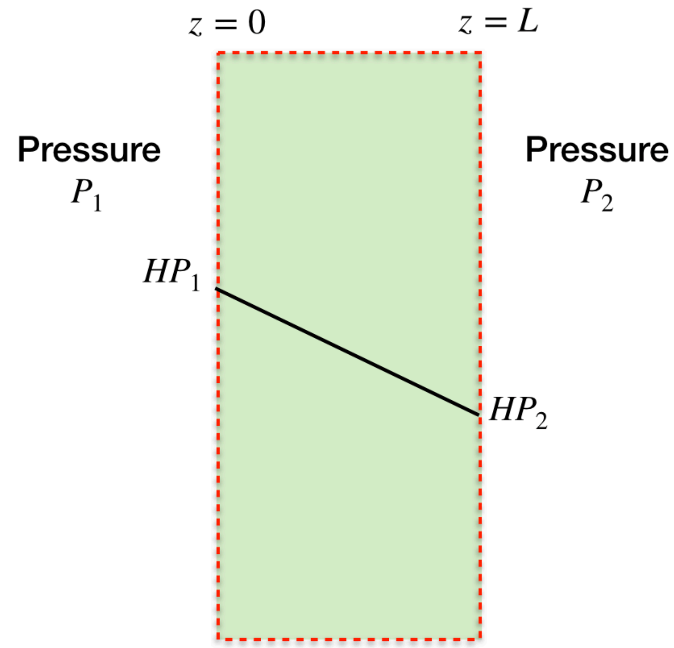
Exercise 1: steady-state diffusion across a thin membrane

A plastic bag is designed to increase the shelf life of bananas. It works by removing ethylene responsible for ripening bananas. The bag is made of 1 μm thick polymer film. Assuming that the concentration of ethylene outside the bag (in the room) is zero, and inside the bag is 1 mole%, calculate grams of ethylene that would be removed in 1 day from a bag made of 1 m² material. The pressure inside and outside the bag is 1 bar.

$$H = 0.1 \ \frac{mol}{liter\ bar}$$

$$D = 10^{-6}\ cm^2\ s^{-1}$$



Exercise 1 solution

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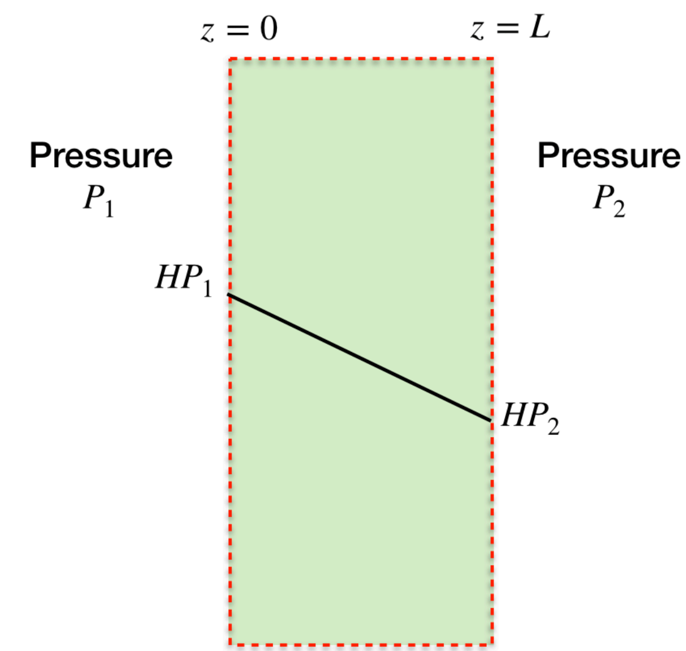


Inner wall of bag, ethylene concentration = $HP_1 \ = \ 0.1 * 0.01 \ = \ 0.001 \ \dfrac{mol}{liter}$

Outer wall of bag, ethylene concentration = $HP_2 \ = \ 0 \ \dfrac{mol}{liter}$

$$J = -D\frac{dc}{dz} \ = \ D\frac{(HP_1 - HP_2)}{L} \ = \ \text{constant}$$

$$J = 10^{-10}\frac{(1-0)}{10^{-6}} \ = \ 10^{-4}\ \frac{mole}{m^2 s}$$

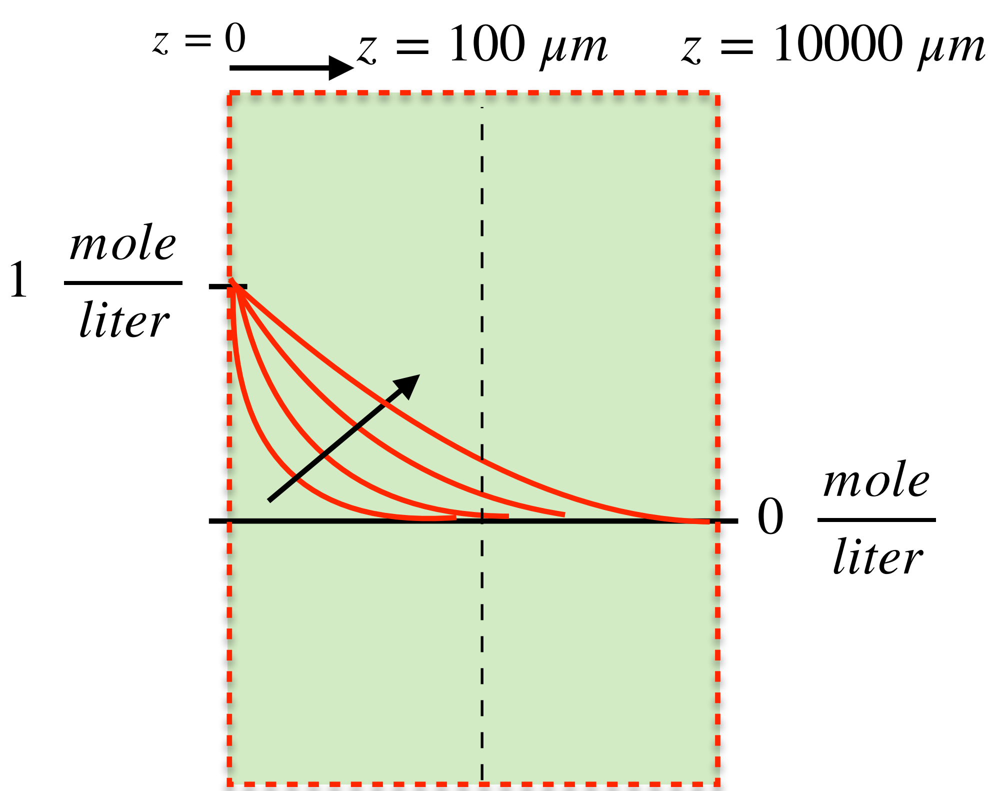
$$\text{moles removed} \ = \ 10^{-4} * 1 * 24 * 3600 = 8.64 \text{ mole}$$

$$\text{gram removed} \ = \ 8.64 * 28 \text{ g} = 241.9 \text{ gm}$$

Exercise 2: Compare the flux in transient vs. steady-state case

Calculate flux at z = 100 μm at t = 1 min in the case of transient and steady-state.

$$J = -D\frac{\partial c}{\partial z} = -\sqrt{\frac{D}{\pi t}}\,(c_\infty - c_S)\,\exp\left(-\frac{z^2}{4Dt}\right)$$



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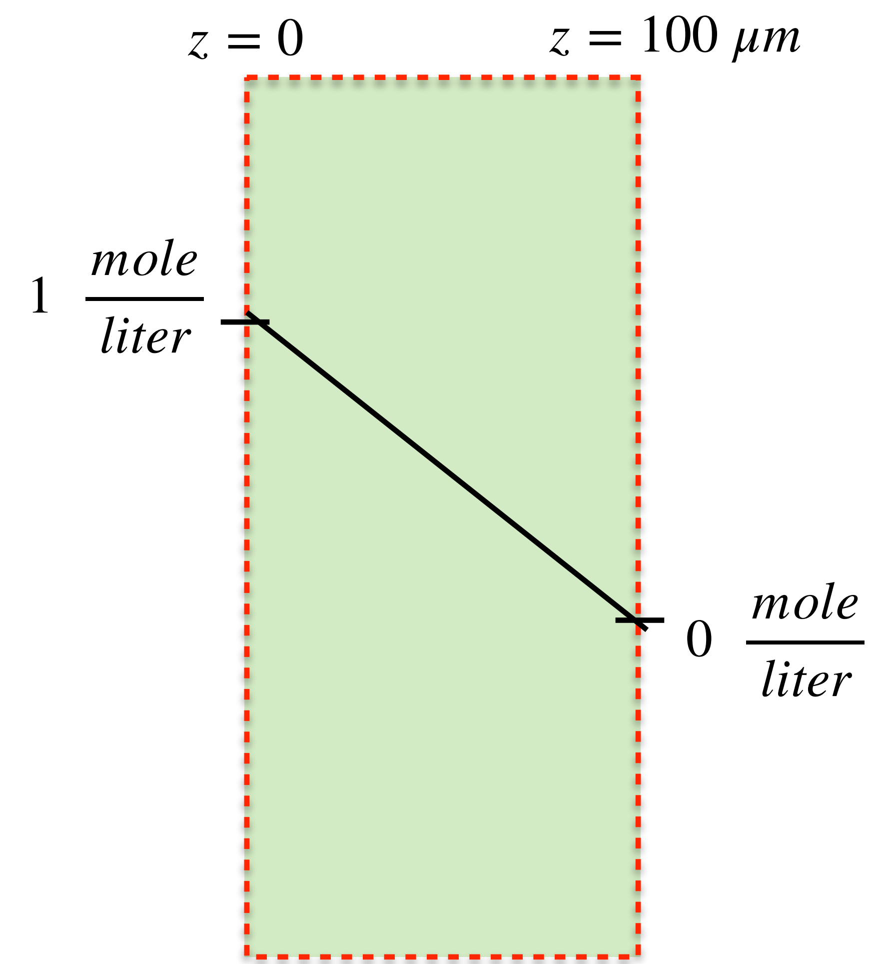


$D = 10^{-6}\ cm^2\ s^{-1}$

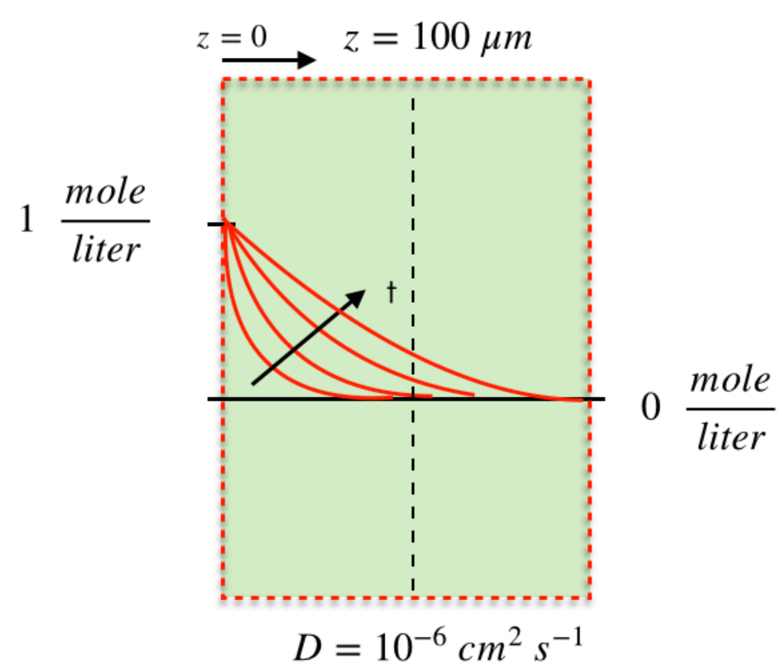
Exercise 2 solution:

Calculate flux at z = 100 μm at t = 1 min in the case of transient and steady-state.

$$J = -\sqrt{\frac{D}{\pi t}}\ (c_\infty\ -\ c_S)\ \exp\left(-\frac{z^2}{4Dt}\right)$$

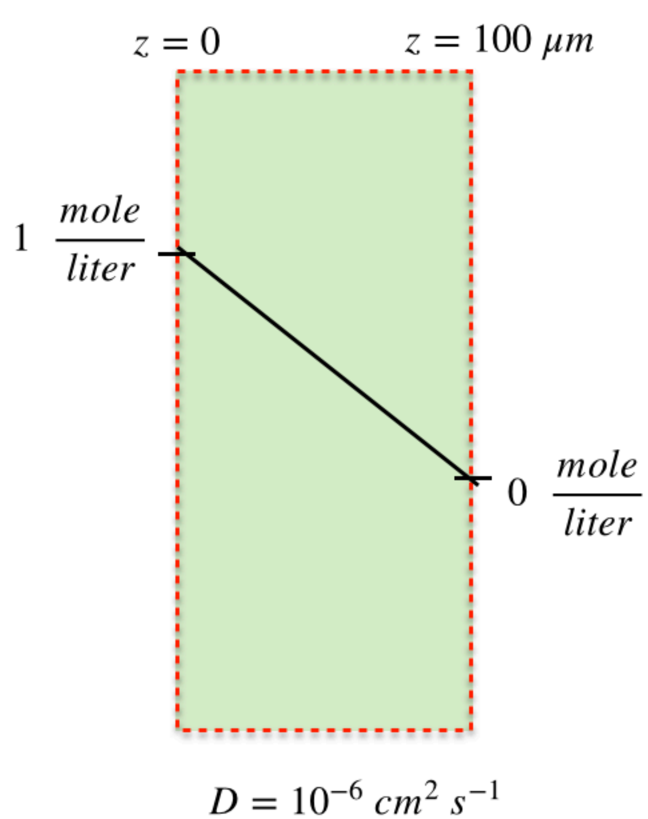
$$J\ = -\sqrt{\frac{10^{-10}}{\pi 60}}\ (0\ -\ 1000)\ \exp\left(-\frac{10^{-8}}{4 * 10^{-10}\ 60}\right)$$

$$=\ 4.8 * 10^{-4}\ \frac{mole}{m^2 s}$$



$$J = -D\frac{dc}{dz} = D\frac{(c_0 - c_L)}{L}\ =\ \text{constant}$$

$$J = 10^{-10}\frac{(1000 - 0)}{10^{-4}}\ =\ 10^{-3}\ \frac{mole}{m^2 s}$$



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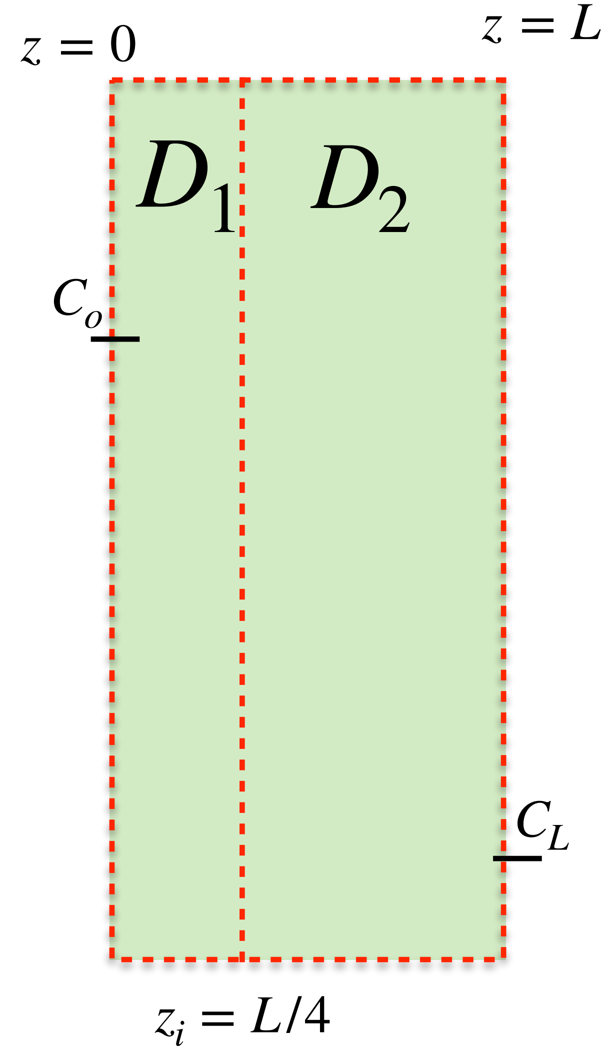
Exercise 3

Calculate c_i at the steady–state if $D_2 = 6D_1$

$c_o = 10$ mole/L $c_L = 0$

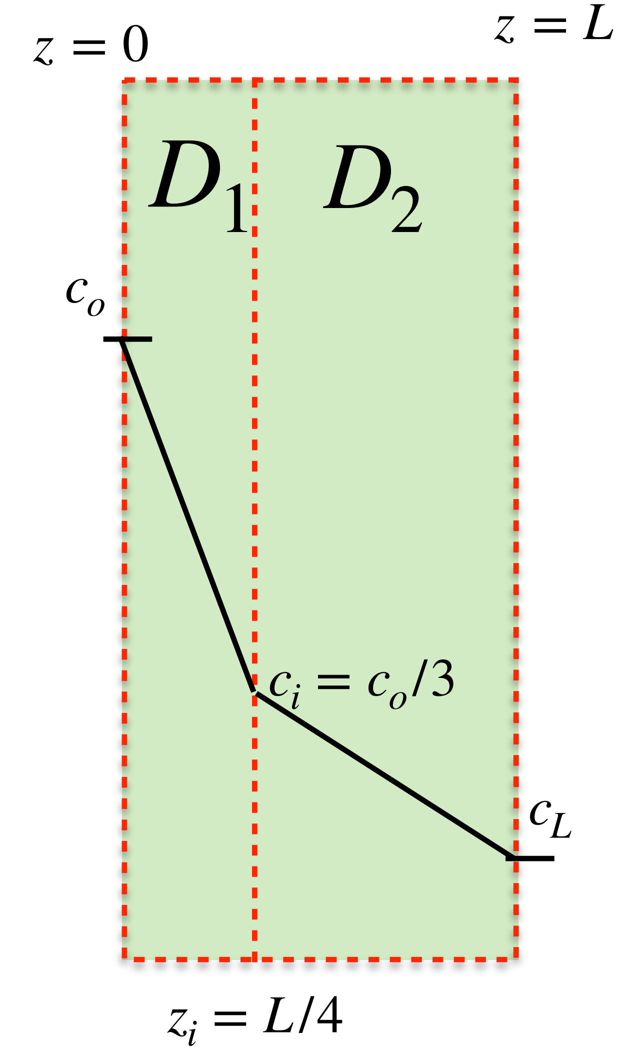
Draw the concentration profile



Exercise 3 solution

Calculate c_i at the steady–state if $D_2 = 6D_1$

$c_o = 10$ mole/L $c_L = 0$ **Draw the concentration profile**



$$J = J_{left} = J_{right}$$

$$-D_1 \frac{(c_0 - c_i)}{z_i} = -D_2 \frac{(c_i - c_L)}{z_L - z_i}$$

$$\Rightarrow c_0 - c_i = (c_i - c_L)\left(\frac{D_2}{D_1} \frac{z_i}{z_L - z_i}\right)$$

$$= (c_i - c_L)\left(\frac{D_2}{3D_1}\right) = 2(c_i - c_L)$$

$$\Rightarrow 3c_i = c_0 + 2c_L$$

$$\Rightarrow c_i = c_0/3 = 10/3 \text{ mole/L}$$

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