Exercise problem 1

Helium/Argon mixture is diffusing through a 100 nm pore at 1 bar and 25 ºC. Report $D_{molecular}$, D_K and D_{vis} for helium at 1 bar and 10 bar. Calculate D_{total} at 1 and 10 bar pressures.

$D_{He,Ar} = 0.7\ cm^2 s^{-1}$ at 1 bar

$$D_K = \sqrt{\frac{8k_BTd^2}{9\pi m}}$$

$$D_{vis} = \frac{d^2}{32\eta_1}P_1$$

$$\eta_{He} = 2 * 10^{-5}\ \text{Pa s}$$

At 1 bar,

$$D_{molecular} = 0.7\ cm^2/s$$

$$D_K = \sqrt{\frac{8 * 1.38 * 10^{-23} * 298 * (100 * 10^{-9})^2}{9 * 3.14 * 0.004/(6.022 * 10^{23})}} = 0.419\ cm^2/s$$

$$D_{vis} = \frac{(100 * 10^{-9})^2}{32 * 2 * 10^{-5}} * 10^5 = 0.016\ cm^2/s$$

$$1/D = 1/D_K + 1/D_{molecular} \Rightarrow D = 0.262\ cm^2/s$$

$$D_{Total} = D + D_{vis} = 0.278\ cm^2/s$$

At 10 bar,

$$D_{molecular} = 0.7/10 = 0.07\ cm^2/s$$

$$D_K = 0.419\ cm^2/s$$

$$D_{vis} = 0.016 * 10 = 0.16\ cm^2/s$$

$$1/D = 1/D_K + 1/D_{molecular} \Rightarrow D = 0.06\ cm^2/s$$

$$D_{Total} = D + D_{vis} = 0.22\ cm^2/s$$

Exercise problem 2: Capillary condensation

Water at 25 °C and 1 bar has a vapor pressure of 23.8 torr. Calculate the equilibrium vapor pressure in a capillary with diameter of 2 nm.

$$\gamma_{lv} = \text{surface tension} = 0.072\ \text{N/m}$$

$$\theta = \text{contact angle} = 30\ \text{degree}$$

$$V_l = \text{molar volume} = 0.018/1000\ \text{m}^3/\text{mole}$$

$$P_{sat,curved} = P_{sat,flat} \exp\left(- \frac{2 V_l \gamma_{lv}}{(r/\cos\theta) RT} \right)$$

$$= 9.6\ \text{torr}$$

40% of the P_{sat} for flat interface

EPFL

Exercise problem 3

An electrochemical cell is composed of an ion-selective membrane which separates two well-mixed compartments filled with electrolytes. You are working as a process engineer, and need to screen a newly launch membrane. To do this you decide to place the membrane in cell such that:

$$t = 0,\ c_{F0} = 1\ \mathrm{M}$$
$$c_{P0} = 0\ \mathrm{M}$$

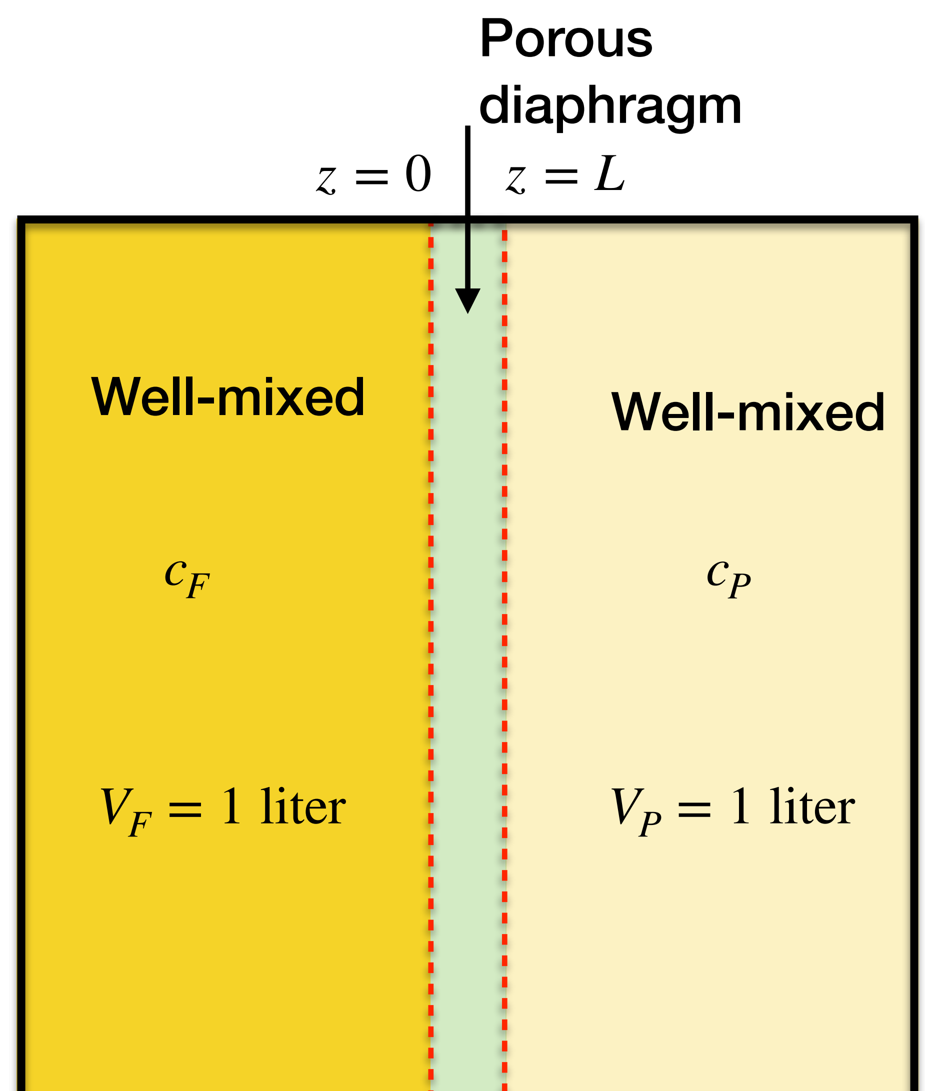
Calculate the diffusion coefficient for a membrane if

$$@\,t = 1\ \mathrm{hr},\ (\mathrm{c_F} - \mathrm{c_P}) = 0.5\ \mathrm{M}$$

Compare above with the diffusion coefficient for another membrane when

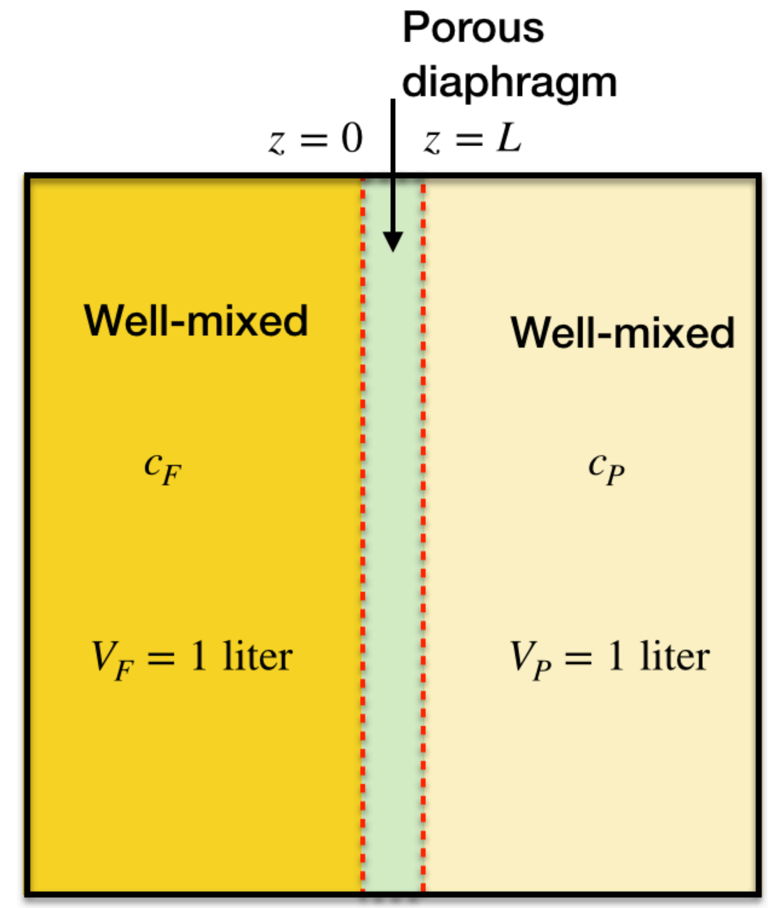
$$t = 1\ \mathrm{hr},\ (\mathrm{c_F} - \mathrm{c_P}) = 0.25\ \mathrm{M}$$

$$D = \frac{1}{\beta t} \ln\left(\frac{c_{F0} - c_{P0}}{c_F - c_P}\right) \qquad \beta = \frac{AH}{L}\left(\frac{1}{V_F} + \frac{1}{V_P}\right)$$



$$A = 1\ m^2 \qquad L = 100\ \mu m$$
$$H = 0.1\ \frac{M}{M}$$

$$\beta = \frac{AH}{L}\left(\frac{1}{V_F} + \frac{1}{V_P}\right) = \frac{1 * 0.1}{10^{-4}}\left(\frac{1}{10^{-3}} + \frac{1}{10^{-3}}\right) = 2 * 10^6$$



$$A = 1\ m^2$$

$$L = 100\ \mu m$$

$$H = 0.1\ \frac{M}{M}$$

Membrane 1

$$D = \frac{1}{\beta t}\ln\left(\frac{c_{F0} - c_{P0}}{c_F - c_P}\right) = \frac{1}{2 * 10^6 * 3600}\ln\left(\frac{1}{0.5}\right) = 9.6 * 10^{-11}\ \mathrm{m^2 s^{-1}}$$

Membrane 2

$$\frac{D_2}{D_1} = \frac{ln(1/0.25)}{ln(1/0.5)} = 2$$