In class problem:

Calculate velocity of component 1 at z = 0 and z = l

$$n_1 = \frac{D\bar{c}}{l}\ln\left(\frac{\bar{c}-c_1^l}{\bar{c}-c_1^0}\right)$$

$$\frac{\bar{c}-c_1}{\bar{c}-c_1^0} = \left(\frac{\bar{c}-c_1^l}{\bar{c}-c_1^0}\right)^{\frac{z}{l}}$$

$c_1^0 = 0.02$ mole/liter $\quad c_1^l = 0.1c_1^0$

$D = 1\ \mathrm{cm^2\ s^{-1}}$ $\quad l = 10$ cm

$\bar{V}_1 = \bar{V}_2 = \frac{1}{\bar{c}}$ **is constant (22.4 liter/mole) in vapor phase at 1 bar.**

$\bar{c} = 0.045$ mole/liter

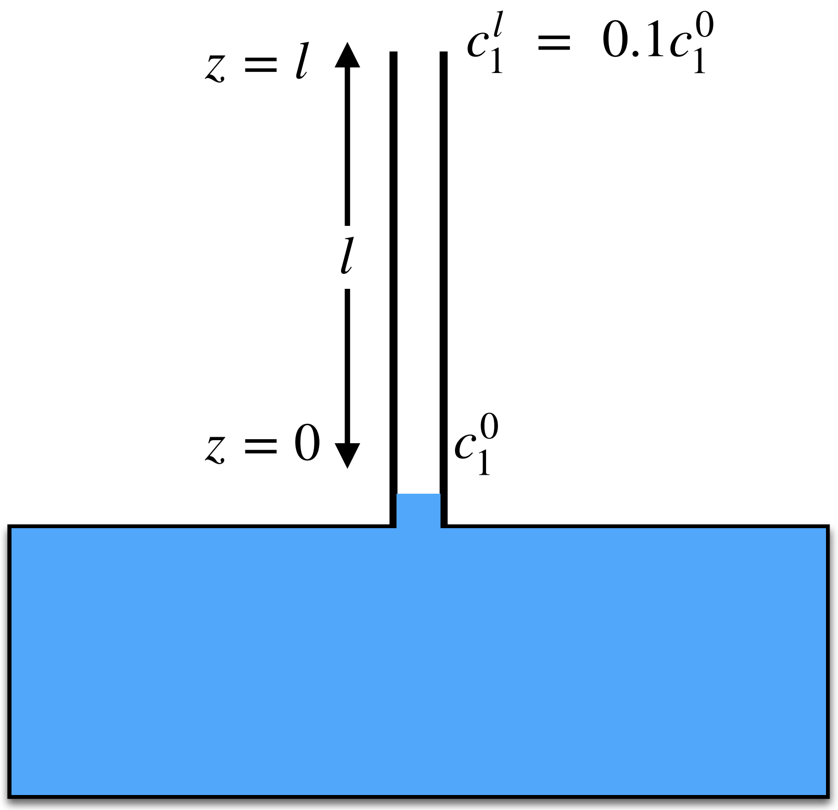
$$\text{velocity of component 1} = \mathrm{v}_1 = \frac{\mathrm{n}_1}{\mathrm{c}_1}$$

$$n_1 = \frac{10^{-4}*0.045*1000}{0.1}\ln\left(\frac{0.045-0.002}{0.045-0.02}\right)$$

$$= 2.44*10^{-2}\ \mathrm{mole\ m^{-2}\ s^{-1}}$$

$$v_1^0 = \frac{2.44*10^{-2}}{0.02*1000} = 1.22*10^{-3}\ m\ s^{-1}$$

$$v_1^l = \frac{2.44*10^{-2}}{0.002*1000} = 1.22*10^{-2}\ m\ s^{-1}$$



Liquid evaporation through a capillary

Exercise problem #1

Compare total flux when you consider convection and when you neglect convection (use thin film result without convection)

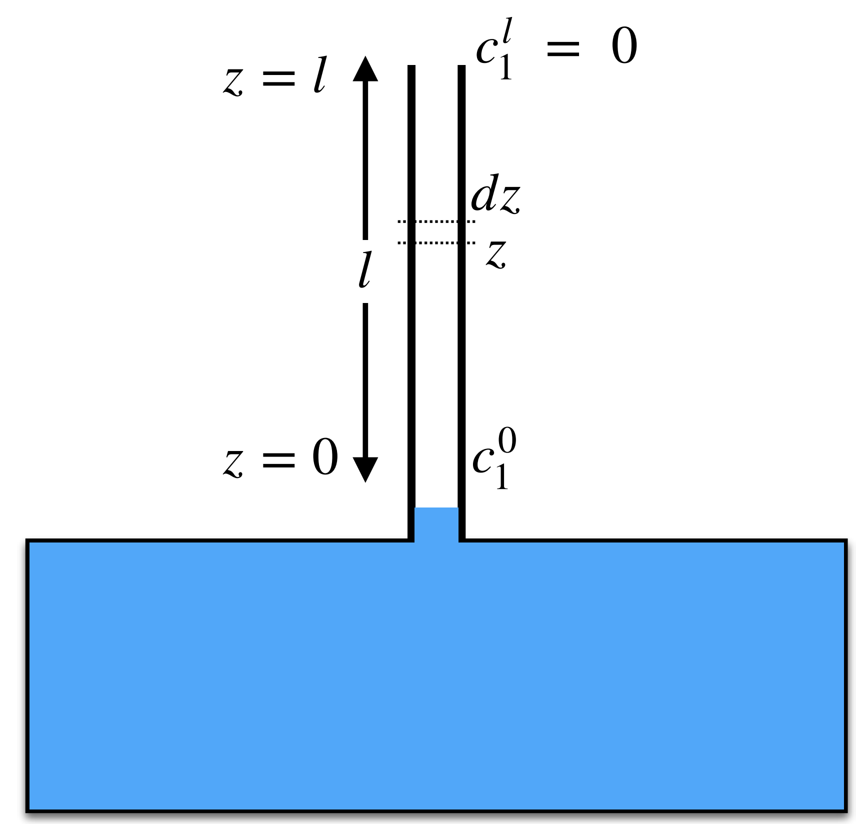
Consider two cases (stagnant air):

Benzene evaporating at 6 °C and 78 °C, Total pressure = 1 atm

T (°C)	P^{sat} (atm)
6	0.049
78	0.934

$c_1^l = 0$ **D = 0.01 cm²/s; l = 1 m**

$$\bar{c} = \frac{P}{RT} \qquad c_1^0 = \frac{P^{sat}}{RT}$$



Liquid evaporation through a capillary

T (°C)	Psat	$P \ln\left(\frac{P}{P - P^{sat}}\right)$	% Convection
6	0.049		
78	0.934		

Solution to exercise problem #1

Compare total flux when you consider convection and when you neglect convection (use thin film result without convection)

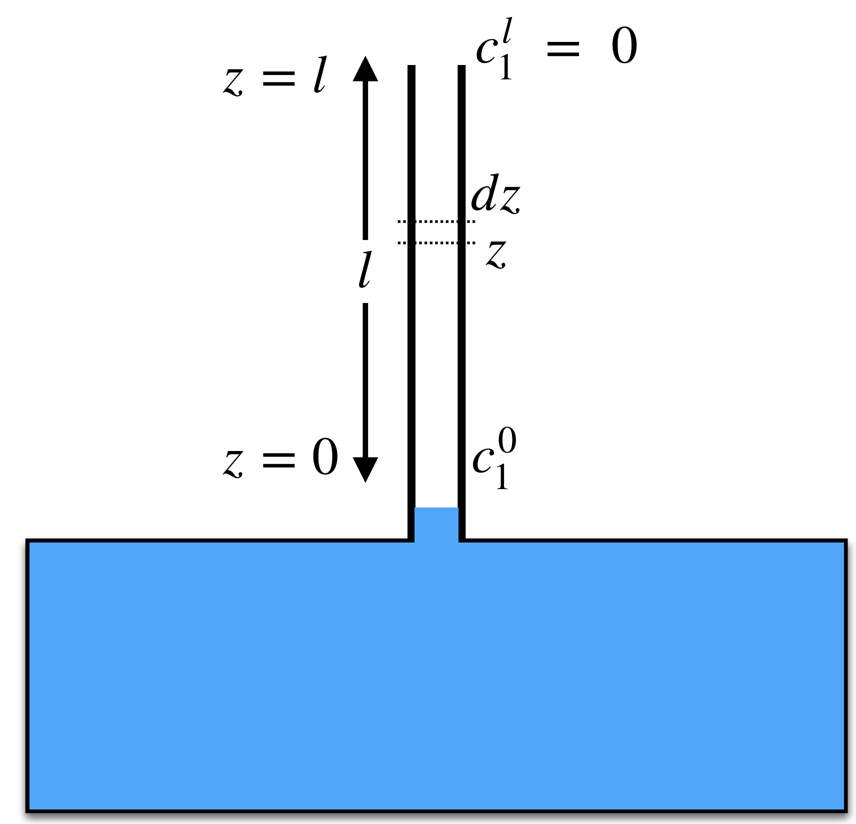
Consider two cases (stagnant air):

Benzene evaporating at 6 °C and 78 °C, Total pressure = 1 atm

$c_1^l = 0$ **D = 0.01 cm²/s; l = 1 m**

$$\bar{c} = \frac{P}{RT} \qquad c_1^0 = \frac{P^{sat}}{RT}$$

T (°C)	Psat (atm)
6	0.049
78	0.934



Liquid evaporation through a capillary

Considering convection

$$n_1 = \frac{D\bar{c}}{l}\ln\left(\frac{\bar{c}-c_1^l}{\bar{c}-c_1^0}\right) = \frac{D\bar{c}}{l}\ln\left(\frac{\bar{c}}{\bar{c}-c_1^0}\right) = \frac{D}{RTl}P\ln\left(\frac{P}{P-P^{sat}}\right)$$

Neglecting convection

$$j_1 = \frac{D}{l}(c_1^0 - c_1^l) = \frac{D}{l}(c_1^0) = \frac{D}{RTl}(P^{sat})$$

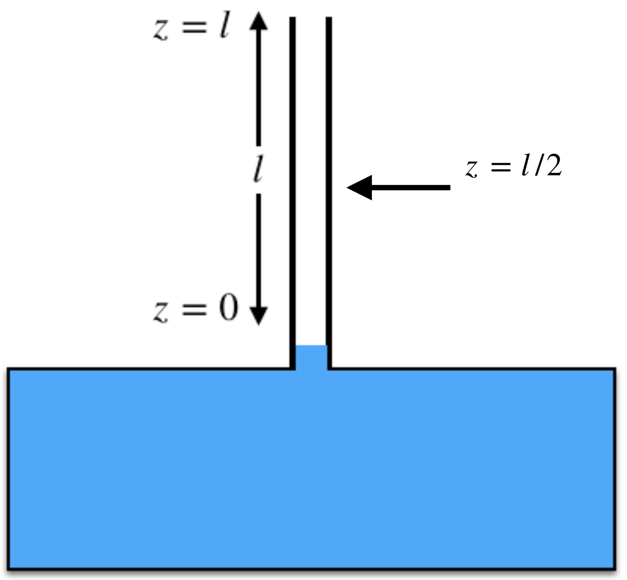
T (°C)	Psat	$P\ln\left(\frac{P}{P-P^{sat}}\right)$	% Convection
6	0.049	0.050	2.454
78	0.934	2.718	65.638

Exercise problem #2

We said the air was stagnant, can you calculate the diffusive and convective flux of air?

$$v_2 = 0 \qquad \Rightarrow n_2 = c_2 v_2 = 0$$

$$n_2 = j_2 + c_2 v^v \qquad \Rightarrow j_2 = -c_2 v^v$$



Liquid evaporation through a capillary

Average velocity of volume = v^v

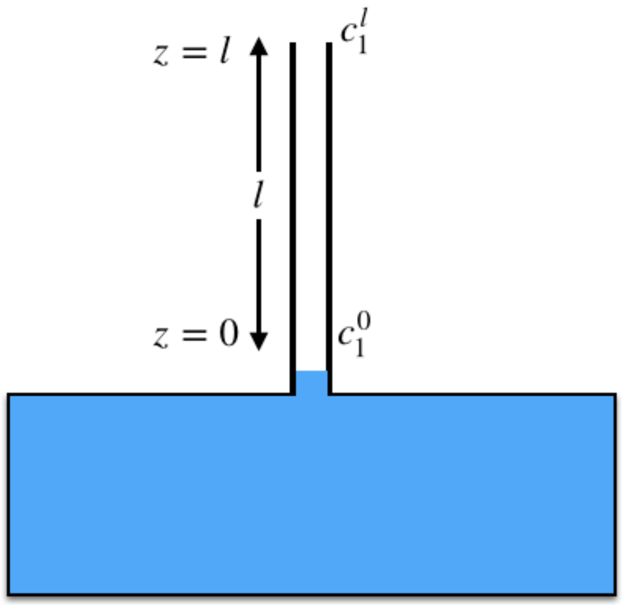
Solution to exercise problem #2

We said the air was stagnant, can you calculate the diffusive and convective flux of air?

$$v_2 = 0 \qquad \Rightarrow n_2 = c_2 v_2 = 0$$

$$n_2 = j_2 + c_2 v^v \qquad \Rightarrow j_2 = -\, c_2 v^v$$

Convective and diffusive flux of air will counter each other



Liquid evaporation through a capillary

Convective flux

$$c_2 v^v = c_2 \bar{V}_1 n_1 = \frac{c_2}{\bar{c}} n_1 \approx y_2 n_1$$

$$\frac{\bar{c} - c_1}{\bar{c} - c_1^0} = \left(\frac{\bar{c} - c_1^l}{\bar{c} - c_1^0}\right)^{\frac{z}{l}} \qquad \Rightarrow \frac{c_2}{c_2^0} = \left(\frac{c_2^l}{c_2^0}\right)^{\frac{z}{l}}$$

$$n_1 = \frac{D\bar{c}}{l} \ln\left(\frac{\bar{c} - c_1^l}{\bar{c} - c_1^0}\right) = \frac{D\bar{c}}{l} \ln\left(\frac{c_2^l}{c_2^0}\right) > 1$$

Convective flux of air goes upwards

Diffusive flux of air goes downwards

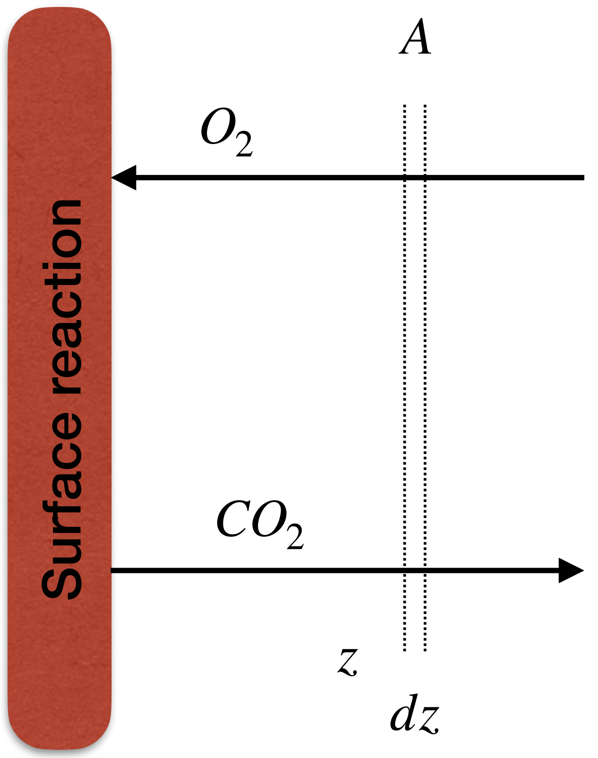
EPFL

Exercise problem #3

$$C + O_2 \;\rightarrow\; CO_2$$

Calculate concentration profile of O_2

Calculate velocity of CO_2 at $z = L$



$z = 0$

$c_1^0 = c_1^L/10$

$z = L$

$C_{O_2} = c_1^L$

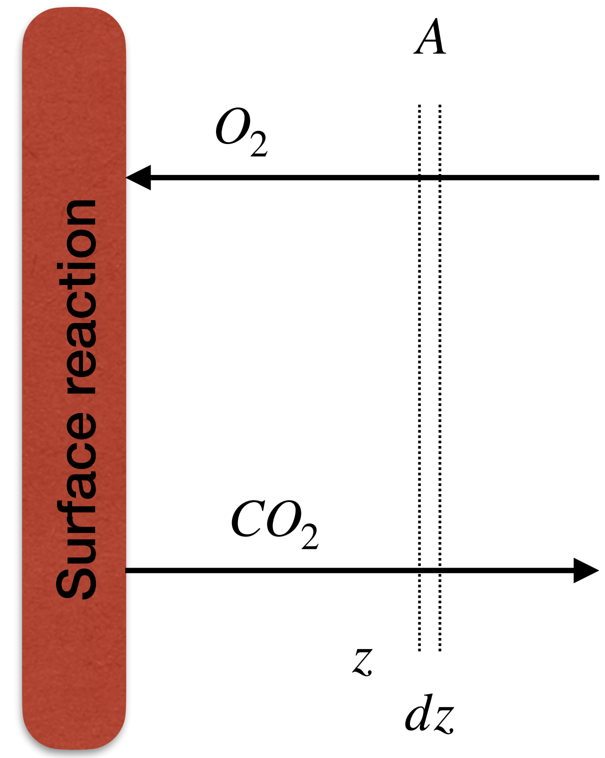
$C_{CO_2} = c_2^L$

Solution to exercise problem #3

$$C + O_2 \rightarrow CO_2$$

Calculate concentration profile of O_2

Calculate velocity of CO_2 at z = L



$z = 0$ $\qquad$ $z = L$

$c_1^0 = c_1^L/10$ $\qquad$ $C_{O_2} = c_1^L$

$C_{CO_2} = c_2^L$

n_1 is constant $\qquad$ n_2 is constant

Let's look at the boundary; z = 0

$$n_2 = -n_1$$

$$n = n_1 + n_2 = 0 = cv \qquad \Rightarrow v = 0$$

We can use mole average velocity because we are dealing with gases

$$v = y_1 v_1 + y_2 v_2 \qquad n_1 = -Dc\nabla y_1 + c_1 v$$

$$\Rightarrow \quad n_1 = j_1 = -Dc\nabla y_1$$

Convective part is zero

Linear concentration profile for both O_2 and CO_2

$$j_1 = -\frac{9D}{10L}c_1^L$$

$$j_2 = -j_1$$

$$v_2 = j_2/c_2 = \frac{9D}{10L}\frac{c_1^L}{c_2^L}$$

EPFL