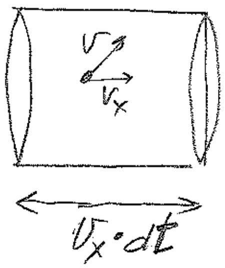
Homework #8

Pr #1.

From the principle of detailed balance the number of moleculer of water leaving the surface is equal to the number of water moleculer striking the surface. We can estimate the later using the following arguments.



A dN - number of molecule striking the surface of area A during the time interval dt is

$$dN = \underbrace{v_x \cdot dt \cdot A \cdot n}_{\text{total number of moleculer in the volume } (v_x dt)\cdot A} \cdot \frac{1}{2} \quad ; \; n - \text{concentration}$$

$\frac{1}{2}$ – the factor account for the fact that half of the moleculer move to the right.

We can choose the time of observation be so small ~~that~~ moleculer do not have any scattering when they move towards the wall.

$$PV = NkT \qquad P = nkT \qquad n = \frac{P}{kT}$$

$$\frac{1}{2} m v_x = \frac{1}{2} kT \qquad v_x = \sqrt{\frac{kT}{m}}$$

$$F = \frac{dN}{A\,dt} = F = \frac{1}{2} v_x n = \frac{1}{2} \frac{P}{kT} \sqrt{\frac{kT}{m}} = \frac{1}{2} \frac{P}{\sqrt{kTm}}$$

$$\frac{1}{2} \frac{23.8 \cdot \frac{1}{760} \cdot 10^5}{\sqrt{1.38 \cdot 10^{-23} \cdot \frac{1}{6 \cdot 10^{23}} \; 10^{-3} \cdot 18 \cdot 300}} = 1.4 \cdot 10^{26} \frac{1}{s \cdot m^2}.$$

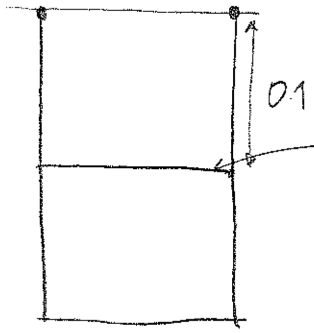
On the firs glance this number seems to be to high. For example if we assume that this number gives us the effective rate of evaporation then the glass of water will evaporate in time t_2

$$t_2 = \frac{A \cdot h \cdot \rho}{A \cdot F} \frac{N_A}{\mu} = \frac{0.1 \cdot 1000 \cdot 6 \cdot 10^{23}}{1.4 \cdot 10^{+26} \cdot 10^{-3} \cdot 18} = 0.0024 \text{ s.} \, !$$

$h = 10\text{ cm} = 0.1\text{ m}$

The part that is missing in the above estimate is that. most of the molecules escaping the surface are scattered back in water. So we need to take into account diffusion. of water molecules out of the surface.

$n = 0$. – concentration of water vapor is 0.



n – concentration of water vapor corresponds to the equilibrium pressure.

diffusion equation

$$j = -D \cdot \frac{dn}{dx} \quad D - \text{diffusion coefficient.}$$

$D = \frac{1}{3}\langle v \rangle l$ $\quad l$ – mean free path, the average length a molecule travels between scattering.

$$l = \frac{1}{2a^2 n_0} \approx 2.5 \times 10^{-5}\,\text{cm} \qquad v \sim 300\ \text{m/s}$$

$$= 2.5 \cdot 10^{-7}\,\text{m}.$$

$$D = \frac{1}{3} \cdot 300 \cdot 2.5 \cdot 10^{-7} = 2.5 \cdot 10^{-5}\ \frac{m^2}{s}$$

$$\frac{dn}{dx} = \frac{n}{x} = \frac{\frac{P}{kT}}{0.1m} = 7.56 \times 10^{24}.$$

$$j = 7.56 * 10^{24} * 2.5 \cdot 10^{-7} = 20 \cdot 10^{-17} = 2 \cdot 10^{-18}.$$

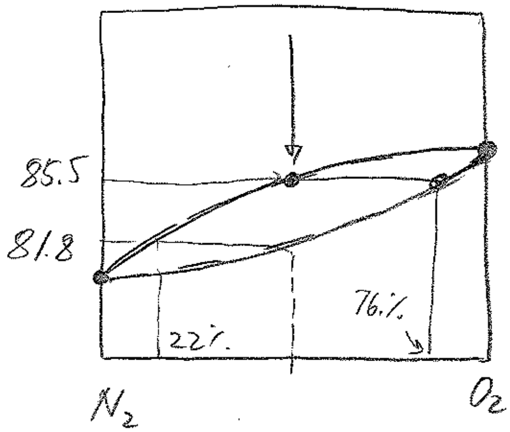
10^8 – difference with our other estimate.

The gram of water than will evaporate in.

$$2.4 \cdot 10^{-3} \cdot 10^{8} = 2.4 \cdot 10^{5}\,s. \approx 100 \text{ hours}.$$

HW # 8

Pe # 2. (5.59 text book)



Consulting the figure in the textbook we can conclude that for the 50% nitrogen 50% oxygen mixture ; ~~to~~

1) the gas is stable until the temperature reaches ≈ 85.5°C

2) as the T is lowered further: a liquid begins to condense, initally composed of 76% of O_2.

3) The condensation reduces the percentage of O_2 in the gas so its composition moves downward to the left, along the upper curve of the diagram.

4) When the temperature reaches 81.8K, the composition of the liquid is 50% oxygen, so there can't be. any gas left; just before this, the last remaining gaz has a composition 22% ~~of~~ oxygen.

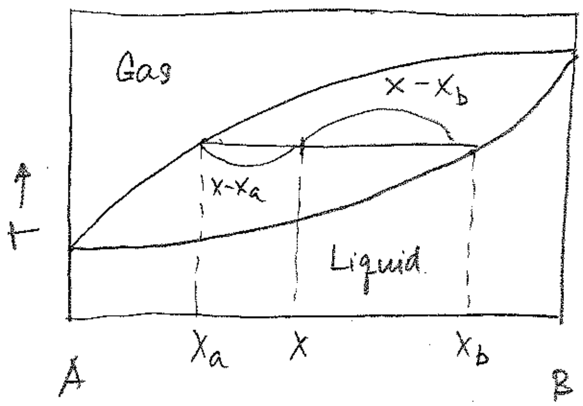
HW # 8

problem N 5.62

N_A, N_B $\frac{N_B}{N} = \frac{N_B}{N_B + N_A} = x$.

N_g - total number of molecule in gas phase

N_L - total number of molecules in the liquid phase.



xN - total number of B molecule.

$x_a N_g$ - number of B molecules in gas phase

$x_b N_L$ number of B molecule in liquid phase

$$x_a N_g + x_b N_L = x(N_g + N_L)$$

$$x_a \frac{N_g}{N_L} + x_B = x \frac{N_g}{N_L} + x \quad \text{or} \quad \frac{N_g}{N_L} = \frac{x - x_b}{x_a - x} = \frac{x_b - x}{x - x_a}$$

Problem # 4 HW #8 extra credit.

Boiling process of any liquid at normal conditions means the saturated vapor of this liquid has reached the value 1 atm.

The saturated vapor of $H_2O - CCl_4$ mixture is composed of both H_2O and CCl_4 molecules. Partial pressure of water molecules at 65.5 °C is the same as saturated vapor pressure at this themperature $P_{H_2O} = 25.6\,kPa = 0.25\,atm$.

The rest $(1\,atm - P_{H_2O})$ is CCl_4 gas.

Molar evaporation ratio is equal to the ratio of saturated pressures. $\frac{P_{H_2O}}{P_{CCl_4}} = \frac{1}{3}$