Practice Problems (Ch 5 and Ch 6)

1. The viscosity of argon at 0°C and atmospheric pressure has been measured as $2.096*10^{-5}$ kg/(m.s) [M=40 kg/kmol]

(a) Calculate the molecular diameter

$$\sqrt{\frac{RT}{\pi M}} = \sqrt{\frac{8314 \times 273.15}{3.1416 \times 40}} = 134.431 \text{ m/s}$$

$$\sigma^2 = \frac{M}{N_A \pi \mu} \cdot \sqrt{\frac{RT}{\pi M}} = \frac{40}{6.023\times10^{26} \times 3.1416 \times 2.096\times10^{-5}} * 134.431$$

$$= 9.49 \times 10^{-20}$$

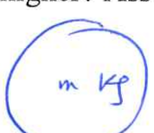
$$\sigma \simeq 3.68 \times 10^{-10} \text{ m} \simeq \boxed{3.68 \text{ Å}}$$

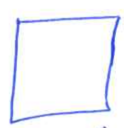
(b) Predict the viscosity of argon at 400°C and atmospheric pressure

$$\frac{\mu_2}{\mu_1} = \sqrt{\frac{T_2}{T_1}} \Rightarrow \mu_2 = 2.095 \times \sqrt{\frac{673.15}{273.15}} = \boxed{3.289 \times 10^{-5} \frac{kg}{m \cdot s}}$$

$$\left[\text{Note: } Pa \cdot s = \frac{N \cdot s}{m^2} = \frac{kg \cdot m/s^2 \cdot s}{m} = \frac{kg}{m \cdot s}\right]$$

2. (a) There is m kg of nitrogen gas in a spherical container at temperature T. In another cylindrical container (height = radius), there is 2m kg of nitrogen at the same temperature. In which container pressure is higher? Assume radius of sphere is equal to the radius of cylinder.





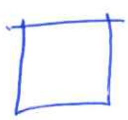
$m/M = n$

$$P_{sph}\,(4/3\,\pi r^3) = nRT \quad -(1)$$

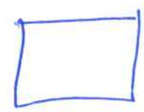
$$P_{cyl} * (\pi r^2 * r) = 2nRT \quad -(2)$$

$$(2) \div (1) \Rightarrow P_{cyl} = 2.667\, P_{sph} \qquad \text{So, } \boxed{P_{cyl} > P_{sp}}$$

(b) Two vessels A and B are of equal volumes and are in equal temperatrue. Vessel A contains n mole of gas X at temperature T and at 1 atm pressure. Vessel B contains n mole of gas X and some amount of Y at a pressure of 2 atm. What is the mole fraction of Y in vessel B?



T, V, 1 atm
n mole X



T, V, 2 atm
n mole X + n' mole Y

IG: $1 \times V = nRT \quad -(1)$

IG: $2 * V = (n+n')RT \quad -(2)$

$$(2) \div (1) \Rightarrow 2 = \frac{n+n'}{n} \Rightarrow n' = n$$

Then, mole fracti. $Y = \frac{n'}{2n'} = \boxed{\frac{1}{2}}$ A.

3. The b parameter of a mixture of gases X and Y is 0.03 (m^3/mol). The value of b for pure X and Y are 0.05 and 0.01 m^3/kmol, respectively. What is the mole fraction of gas X in the mixture?

$$b_{mix} = y_1 b_1 + y_2 b_2$$

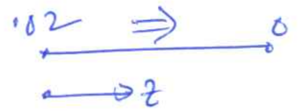
$$0.03 = y_1(.05) + (1-y_1)(.01)$$

$$\Rightarrow \boxed{y_1 = 1/2}$$

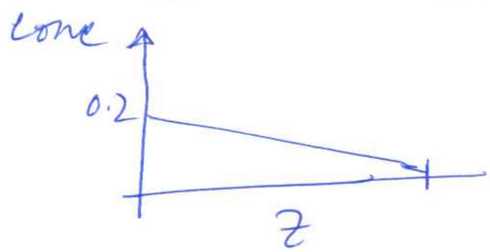
4. (a)If the steady state concentration of a chemical in a room at the window is 0 and at a location 5 m far away from the open window is 0.2 mol/m^3, what is the steady state concentration gradient? Sketch the concentration profile.

(b) Consider heat transfer from a metal plate at 400 K through a gas to another plate which is 1 m away and at 300K. If thermal conductivities of air at 400 K, 350 K and 300 K are .03, .025 and 0.02 W/(m.K), respectively, find (a) concentration gradient, and (b) heat flux

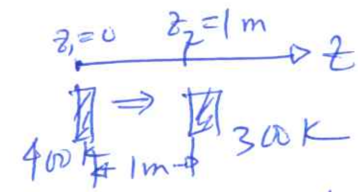
(a)



$$\frac{dc}{dz} = -0.04 \ \frac{mol}{m^4}$$



(b)



(a) Temp grad $= \frac{dT}{dz} = -100$ K/m

Flux, $Q/A = (-k)\left(\frac{dT}{dz}\right)$

$= (-.025)(-100)$

K at an avg temp 350K

$= 2.5$ W/m^2

5. Calculate the compressibility factor of n-butane at 479.65 K and 39.45 atm using vdW equation of state. Do two iteration only. [a = 13.7 atm (lit/mol)^2, b =0.1163 m^3/kmol]

$$V_m^{Id} = \frac{RT}{P} = 1 \ m^3/kmol$$

vdw: $V_m^3 - 1.116 V_m^2 + 0.347 V_m - .0404 = 0$

$$\Rightarrow V_m^{(i+1)} = 1.116 - \frac{.347}{V_m^{(i)}} + \frac{.0404}{V_m^{(i)2}}$$

i=0 Initial guess: $V_m^{(0)} = V_m^{Id} = 1$ m^3/kmol

i=1 First iteration: $V_m^{(1)} = 0.81$

i=2: $V_m^{(2)} = .75$ m^3/kmol

[True value $V_m = .7$ m^3/kmol]