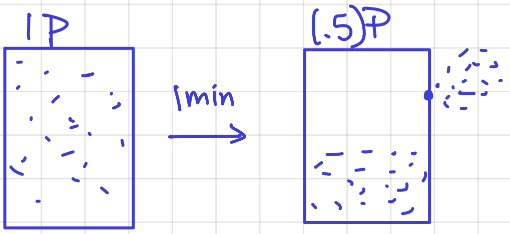
HW # 8

Chem 3321 homework #8 out of 50 marks – due April 17, 2023

Problem 1, 10 marks

A gaseous compound is placed in a rigid container of volume 10.0 L at temperature 300.0 K and at pressure 1.0 atm. The container is placed in an evacuated chamber and a small hole of area 2.65 mm^2 is made in one of the container walls. It takes 1.00 minutes for the gas pressure in the container to fall to half of its original value. Determine the molar mass of the gas.



what is molar mass of gas?

V = 10L
T = 300K
$a = 2.65mm^2$

$$\ln\left(\frac{P}{P_0}\right) = -\frac{a\,\overset{\text{mean speed } \langle v\rangle}{v_{mean}}\cdot t}{4\underset{\text{volume}}{V}}$$

and $v_{mean} = \cancel{(4\sqrt{\frac{k_BT}{2\pi m}}} = \sqrt{\frac{8RT}{\pi M}} = 4\sqrt{\frac{RT}{2\pi M}}$

$$\text{so, } \ln\left(\frac{.5}{1}\right) = \frac{-2.65\overset{\text{convert to m}}{\overset{\uparrow}{mm^2}}\cdot v_{mean}(60s)}{4(10\times10^{-3}m)}$$

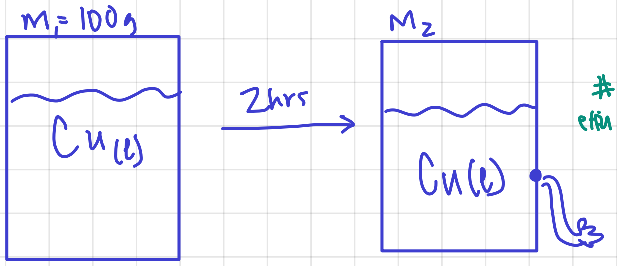
solve for v_{mean}

then plug value into $v_{mean} = 4\sqrt{\frac{RT}{2\pi M}}$ and solve for M (which is molar mass

Problem 2, 10 marks

100.0 g of liquid copper (molar mass 63.546 g/mol; melting point 1358 K; density 8.02 g/mL) is placed in a rigid container of volume 10.0 L at temperature 1508 K. The container is placed in an evacuated chamber and a small hole of area 3.23 mm^2 is made in the upper container wall. After 2.00 hours, the mass of copper in the container has decreased by 0.0168 g. Assuming the mass loss is due to effusion, calculate the vapor pressure of liquid copper at 1508 K.

Hint: because the liquid constantly evaporates, the pressure inside the container is constant.



Rate of effussion

\# of moleculer effussing ↖

$$\frac{dN}{dt} = \frac{Pa}{\sqrt{2\pi m k_B T}}$$

and, $N = n \cdot 6.022\times10^{23}$

and $m = \frac{N \cdot M}{6.022\times10^{23}}$

so, $N = \left(\frac{m}{M}\right)N_a$

$m = 100g$
$M = 63.546 g/mol$
$T_M = 1358 K$
$D = 8.02 g/mL$
$V_c = 10L$
$\boxed{T_c = 1508K}$
$a = 3.23mm^2$ (convert to m^2)
$\Delta P_c = 0$

$$\frac{dN}{dt} = \frac{d\left(\frac{m}{M}\cdot Na\right)}{dt}$$

$$\frac{Na}{M}\cdot\frac{dm}{dt} = \frac{Pa}{\sqrt{2\pi m k_B T}}$$

$$P = \frac{Na}{M}\left(\sqrt{2\pi m k_B T}\right)\frac{dm}{dt}$$

$$= \frac{Na}{M}\sqrt{2\pi\left(\frac{M}{Na}\right)\left(\frac{R}{Na}\right)(T)}\ \frac{dm}{dt}$$

$$= \left(\frac{Na}{M}\right)\left(\frac{1}{Na}\right)\sqrt{2\pi MRT}\ \frac{dm}{dt}$$

$$\therefore P = \frac{\sqrt{2\pi MRT}}{aM}\cdot\frac{dm}{dt}$$

→ 0.0168g

↘ time in seconds

plug in & solve

Problem 3, 10 marks

A space vehicle of internal volume 3.0 m^3 and internal temperature 298 K is struck by a meteor and a hole of radius 0.1 mm is formed.

(a) If the oxygen pressure within the vehicle is initially 100 kPa, how long will it take to fall to 20 kPa?

$\rightarrow O_2$

(b) Repeat the calculation using nitrogen as the gas.

$\rightarrow N_2$

a) $v_{mean} = \sqrt{\frac{8RT}{\pi M}}$ and $\ln\left(\frac{P_{(t)}}{P_0}\right) = -\frac{a\, v_{mean}\, t}{4V}$

$V = 3.0\ m^3$
$T = 298K$
$r = 0.1mm \rightarrow area = \pi r^2$
$P_1 = 100kPa$
$P_2 = 20kPa$

$t = \frac{-4V}{a}\sqrt{\frac{\pi M}{8RT}} \ln\left(\frac{P_{(t)}}{P_0}\right)$

plug in & solve

b) $t = \frac{-4V}{a}\sqrt{\frac{\pi M}{8RT}} \ln\left(\frac{P_{(t)}}{P_0}\right)$

$M_{N_2} = 28.02 \times 10^{-3}\ kg \cdot mol^{-1}$

Problem 4, 10 marks

On average what is the time between collisions of a xenon atom at 300 K and (a) one torr pressure; (b) one bar pressure.

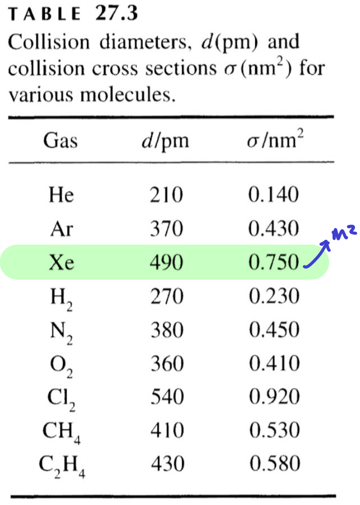


TABLE 27.3
Collision diameters, d(pm) and collision cross sections σ(nm^2) for various molecules.

Gas	d/pm	σ/nm^2
He	210	0.140
Ar	370	0.430
Xe	490	0.750 m^2
H_2	270	0.230
N_2	380	0.450
O_2	360	0.410
Cl_2	540	0.920
CH_4	410	0.530
C_2H_4	430	0.580

$$Z = \sqrt{2}\,\sigma\,\rho\,v_{mean} \quad \text{and} \quad v_{mean} = \sqrt{\frac{8RT}{\pi M}}$$

$$\rho = \frac{N}{V} = \frac{PN_A}{RT} = \frac{P}{k_B T}$$

$$k_B = \frac{R}{N_a}$$

$PV = nRT$

$PV = \left(\frac{N}{N_a}\right)RT$

$$\text{so,} \quad Z = \sqrt{2}\,\sigma_{Xe}\,\frac{P}{k_B T}\sqrt{\frac{8RT}{\pi M}}$$

$$Z = \left(\frac{\sigma_{Xe}}{k_B T}\right)\left(\sqrt{\frac{16RT}{\pi M}}\right)P \quad \text{in Pa} \quad \text{and} \quad t = \frac{1}{Z}$$

plug in and solve for a) and b)

Problem 5, 10 marks

Calculate the diffusion constant of argon ($\sigma = 0.43\ \text{nm}^2$ from Table 27.3) at 25 °C and (a) 100 kPa; (b) at 1.00 Pa.

(c) If a pressure gradient of 0.10 atm/cm is established in a pipe, what is the flow of the gas due to diffusion (use the diffusion constant from part a)?

$D = \frac{\lambda v_{mean}}{2}$ $\quad v_{mean} = \sqrt{\frac{8RT}{\pi M}}$

$\lambda = \frac{1}{\sqrt{2}\sigma\rho} = \frac{k_B T}{\sqrt{2}\sigma P}$ so, $D = \left(\frac{k_B T}{\sqrt{2}\sigma_{Ar} P}\right)\sqrt{\frac{8RT}{\pi M}}\left(\frac{1}{2}\right)$

a) $100\,kPa = 10^5\,kg/m\cdot s^2$ Plug in & Solve

b) plug in & solve

c)

$J_z = -D\frac{d\rho}{dz}$ and $\rho = \frac{N}{V} = \frac{P}{k_B T}$

so $J_z = \frac{-D}{k_B T}\frac{dP}{dz}$ and $\frac{dP}{dz} = 0.1\ atm/cm$

plug in D from part a and solve

$k_B = 1.38 \times 10^{-23}\ m^2$