CH 421 Homework 1 I pledge my honor that I have not violated the Stevens Honor System

Focus 1B.

1(a) $v_{mean} = \left(8RT/\pi M\right)^{1/2}$

$v_{mean,H_2} = \left(\frac{8RT}{\pi M_{H_2}}\right)^{1/2} = \left(\frac{8(8.3145\ J K^{-1} mol^{-1}) \times (20+273)K}{\pi \cdot (0.002016\ kg\ mol^{-1})}\right)^{1/2}$

$= 1754.19\ m/s.$

$v_{mean,Hg} = \left(\frac{8RT}{\pi M_{Hg}}\right)^{1/2} = \left(\frac{8(8.3145 J K^{-1} mol^{-1}) \times (20+273)K}{\pi \cdot (0.20059\ kg/mol)}\right)^{1/2}$

$= 175.860\ m/s$

(i) ratio of mean speeds $= 1754.19/175.860 = 9.97$

$KE = \frac{1}{2} m v^2$

$KE_{mean,H_2} = \frac{1}{2} M_{H_2} v^2_{mean,H_2} = \frac{1}{2}\ 0.002016\ (kg/mol)\ (1754.19)^2\ (m/s)^2$

$= 3101.8\ J/mol\ H_2$

$KE_{mean,Hg} = \frac{1}{2} M_{Hg} v^2_{mean,Hg} = \frac{1}{2} (0.20059\ kg/mol)\ (175.860\ m/s)^2$

$= 3101.8\ J/mol\ Hg$

(i) ratio of mean kinetic energy $= 3101.8/3101.8 = 1$

2(a) $v_{rms} = \left(\frac{3RT}{M}\right)^{1/2}$

$v_{rms,H_2} = \left(\frac{3(8.3145\ J K^{-1} mol^{-1})(20+273\ K)}{0.002016\ kg\ mol^{-1}}\right)^{1/2} = 1.90 \times 10^3\ m/s$

$v_{rms,O_2} = \left(\frac{3(8.3145\ J K^{-1} mol^{-1})(20+273 K)}{0.03199\ kg/mol}\right)^{1/2} = 478\ m/s$

$M_{O_2} = 0.04401\ kg/mol$

5a. $v_{mp} = \left(\frac{2RT}{M}\right)^{1/2}$ $v_{mean} = \left(\frac{8RT}{\pi M}\right)^{1/2}$

$$v_{mp,O_2} = \left(\frac{2(8.3145\ J K^{-1} mol^{-1})(20+273K)}{0.04401\ kg/mol}\right)^{1/2}$$

$$= 333\ m/s$$

$$v_{mean,O_2} = \left(\frac{8(8.3145\ J K^{-1} mol^{-1})(20+273K)}{\pi\ (0.04401\ kg/mol)}\right)^{1/2}$$

$$= 375\ m/s$$

$v_{rel} = \left(\frac{8kT}{\pi\mu}\right)^{1/2}$ $\mu = \frac{M_A M_B}{M_A + M_B}$

$= \sqrt{2}\, v_{mean} = 531\ m/s$

6a. $Z = \frac{\sigma v_{rel} P}{kT}$, $\sigma = \pi d^2$

Table 18.1 $= \sigma_{H_2} \approx 0.27\ nm^2$

$v_{rel} = \sqrt{2} v_{mean} = \sqrt{2}\left(\frac{8(8.3145\ J K^{-1} mol^{-1})(25+273K)}{\pi\ (0.002016\ kg/mol)}\right)^{1/2}$

$= 2501\ m/s$

$$Z = \frac{(0.27 \times 10^{-18}\ m^2)(2501\ m/s)(1.01 \times 10^5\ Pa)}{1.381 \times 10^{-23}\ J/K\ (25+273K)}$$

$= 1.6 \times 10^{10}\ s^{-1}$

7a. (i) $v_{mean} = \left(\frac{8RT}{\pi m}\right)^{1/2}$ $M_{N_2} = 0.02801\ kg/mol$

$= \left(\frac{8(8.3145\ J K^{-1} mol^{-1})(25+273K)}{\pi (0.02801\ kg/mol)}\right)^{1/2}$

$= 475\ m/s$

(ii) $\lambda = \frac{kT}{\sigma p} = \frac{(1.381\times10^{-23}\ J/K)(25+273K)}{4.90\times10^{-19}\ m^2 \cdot (1.01\times10^5\ Pa)}$

$\sigma = \pi d^2 = \pi(3.795\times10^{-10}\ m)^2 = 4.90\times10^{-19}\ m^2$

$\lambda = 8.32\times10^{-8}\ m$

(iii) $\lambda = \frac{v_{rel}}{z} \Rightarrow z = \frac{v_{rel}}{\lambda} = \frac{\sqrt{2}\, v_{mean}}{\lambda} = \frac{\sqrt{2}(475\ m/s)}{8.32\times10^{-8}\ m}$

$= 5.71\times10^9\ s^{-1}$

Focus 6A

2a $D = \frac{1}{3}\lambda v_{mean}$ $P_1 = 1.00\ Pa$

(i) $D = \frac{1}{3}\frac{kT}{\sigma P_1}\left(\frac{8RT}{\pi m}\right)^{1/2}$

$D_1 = 1.48\ m^2/s$

$k = 1.381\times10^{-23}\ J/K$

$T = 20+273 = 293K$

$\sigma = 0.36\ nm^2$

$= 0.36\times10^{-18}\ m^2$

$m = 0.039948\ kg/mol$

$R = 8.3145\ J/K\cdot mol$

(ii) $P_2 = 100\times10^3\ Pa$

$D_2 = \frac{1}{3}\frac{kT}{\sigma P_2}\left(\frac{8RT}{\pi m}\right)^{1/2} = 1.48\times10^{-5}\ m^2/s$

(iii) $P_3 = 10.0\times10^6\ Pa$

$D_3 = \frac{1}{3}\frac{kT}{\sigma P_3}\left(\frac{8RT}{\pi m}\right)^{1/2} = 1.48\times10^{-7}\ m^2/s$

$$J = -D\frac{d[n]}{dz} = -D\frac{d(\frac{n}{V})}{dz} = -D\frac{d(\frac{P}{RT})}{dz}$$

$$= \frac{-D\frac{dP}{dz}}{RT}$$

$$J_1 = \frac{-1.48\ m^2/s \cdot 1.00\ \frac{bar}{m} \cdot 10^5\ \frac{Pa}{bar}}{8.3145\ J/K.mol \cdot 293K} = 60.6\ \frac{mol}{m^2 s}$$

$$J_2 = \frac{-1.48 \times 10^{-5}\ m^2/s \cdot 1.00\ \frac{bar}{m} \cdot 10^5\ \frac{Pa}{bar}}{8.3145\ J/K.mol \cdot 293K} = 6.06 \times 10^{-4}\ \frac{mol}{m^2 s}$$

$$J_3 = \frac{-1.48 \times 10^{-7}\ m^2/s \cdot 1.00\ bar \cdot 10^5\ \frac{Pa}{bar}}{8.3145\ J/K.mol \cdot 293K} = 6.06 \times 10^{-6}\ \frac{mol}{m^2 s}$$

7a) $\eta = \frac{1}{3} v_{mean} \lambda m N = \frac{\frac{1}{3} m \left(\frac{8RT}{M\pi}\right)^{1/2}}{\sigma}$

$M = 29.0\ g/mol = 0.0290\ kg/mol \quad R = 8.3145\ J/K.mol$

$m = \frac{0.0290\ kg/mol}{N_A} = 4.82 \times 10^{-26}\ kg \quad \sigma = 0.40\ nm^2 = 0.40 \times 10^{-18}\ m^2$

(i) $T_1 = 273K$

$$\eta_1 = \frac{\frac{1}{3} m \left(\frac{8RT_1}{M\pi}\right)^{1/2}}{\sigma} = 1.79 \times 10^{-5}\ kg\ m^{-1} s^{-1}$$

(ii) $T_2 = 298K$

$$\eta_2 = \frac{\frac{1}{3} m \left(\frac{8RT_2}{M\pi}\right)^{1/2}}{\sigma} = 1.87 \times 10^{-5}\ kg\ m^{-1} s^{-1}$$

(iii) $T_3 = 1000K$

$$\eta_3 = \frac{\frac{1}{3} m \left(\frac{8RT_3}{M\pi}\right)^{1/2}}{\sigma} = 3.43 \times 10^{-5}\ kg\ m^{-1} s^{-1}$$

8a $\eta = \frac{1/3\, m \left(\frac{8RT}{M\pi}\right)^{1/2}}{\sigma}$

$\sigma = \frac{1/3\, m \left(\frac{8RT}{M\pi}\right)^{1/2}}{\eta}$

$M = 0.0201797\ kg/mol$

$m = \frac{M}{N_A} = 3.35 \times 10^{-26}\ kg/molecule$

$R = 8.3145\ J/K \cdot mol$

$T = 273K$

$\eta = 166\ \mu P = 4.66 \times 10^{-5}\ kg\ m^{-1} s^{-1}$

$\sigma = 6.89 \times 10^{-19}\ m^2 = 0.689\ nm^2$