9.24

(1) 根据玻耳兹曼分布律：

$$E_p = -(\delta g \cdot \frac{4}{3}\pi a^3 - mg)h$$

$$n = n_0 e^{-E_p/kT} = n_0 e^{(\delta g \cdot \frac{4}{3}\pi a^3 - mg)h/kT}$$

代入等式左侧

$$\frac{RT}{N_A}\ln\frac{n_0}{n} = \frac{RT}{N_A} \cdot \frac{4}{3}\pi a^3 g(\Delta - \delta) \cdot \frac{h}{kT}$$

$$= \frac{4}{3}\pi a^3 (\Delta - \delta) g h$$

(2) 验证：$\frac{886}{1620} \simeq \frac{1620}{3360} \simeq \frac{3360}{7160} \simeq 0.5$

$$\frac{R\times(20+273.15)}{N_A} \times \ln\frac{7160}{3360} = \frac{4}{3}\pi \times (0.212\times10^{-6})^3 \times (0.2067\times10^3) \times 9.8 \times 3\times10^{-3}$$

$$\Rightarrow N_A = 7.6\times10^{23}\ mol^{-1}$$

9.25

(1) $$n = \frac{N_A}{V_m} = 2.0\times10^{19}\ cm^{-3}$$

(2) $$f = \frac{1}{4}n\bar{v} = \frac{1}{4}n\sqrt{\frac{8RT}{\pi M}} = 3.3\times10^{27}\ m^{-2}\cdot s^{-1} = 3.3\times10^{23}\ cm^{-2}\cdot s^{-1}$$

(3) $3.3\times10^{23}\ cm^{-2}\cdot s^{-1}$

(4) 1 atm

9.26

$$\left(P+\frac{m^2}{M^2}\frac{a}{V^2}\right)\left(V-\frac{m}{M}b\right)=\frac{m}{M}RT \Rightarrow P=2.57\times10^6\ Pa$$

$$P'V=\frac{m}{M}RT \Rightarrow P'=2.97\times10^6\ Pa$$

$$P_{ab}=P'-P=5.7\times10^5\ Pa$$

9.28

(1) $\eta=\frac{1}{3}\bar{v}n\cdot m\bar{\lambda}=\frac{1}{3}\bar{v}\cdot\bar{\lambda}\cdot\frac{M}{V_m}$

$\Rightarrow \bar{\lambda}=2.65\times10^{-7}\ m$

(2) $\bar{\lambda}=\frac{1}{\sqrt{2}\pi d^2 n}$

$$\Rightarrow d^2=\frac{1}{\sqrt{2}\pi\bar{\lambda}n}=\frac{1}{\sqrt{2}\pi\bar{\lambda}\cdot\frac{P_0}{KT}}=\frac{KT}{\sqrt{2}\pi\bar{\lambda}P_0}=1.78\times10^{-10}\ m$$

9.29

$$K=\frac{1}{3}nm\bar{v}\bar{\lambda}C_V$$

$$=\frac{1}{3}nm\bar{v}C_V\cdot\frac{1}{\sqrt{2}\pi d^2 n}$$

$$=\frac{m\bar{v}C_V}{3\sqrt{2}\pi d^2}\quad \alpha\ \bar{v}=\sqrt{\frac{8RT}{\pi M}}\ \alpha\ \sqrt{T}\ \text{与}p\text{无关}$$

若 $\bar{\lambda}=l=\frac{1}{\sqrt{2}\pi d^2 n}=\frac{KT}{\sqrt{2}\pi d^2 p}$

$$\Rightarrow p=\frac{KT}{\sqrt{2}\pi d^2 l}=1.7\ Pa$$

9.30

(1) $\frac{dm}{dt} = -D\frac{d\rho}{dr}\cdot 4\pi r^2$

$\frac{d\rho}{dr} = \frac{c}{r^2} \Rightarrow d\rho = \frac{c}{r^2}dr \Rightarrow \rho_\infty - \rho = -\frac{c}{r}\Big|_R^\infty = \frac{c}{R}$

$\Rightarrow \frac{d\rho}{dr} = \frac{R(\rho_\infty - \rho)}{r^2}$

$\Rightarrow \frac{dm}{dt} = 4\pi D r^2 \cdot \frac{R}{r^2}(\rho - \rho_\infty)$

$= 4\pi DR(\rho - \rho_\infty) = W$

(2) $\frac{dm}{dt} = \frac{d(\frac{4}{3}\pi R^3 \rho_w)}{dt} = 4\pi DR(\rho - \rho_\infty)$

$\rho_w \frac{4}{3}\pi \cdot 3R^2 \frac{dR}{dt} = 4\pi DR(\rho - \rho_\infty)$

$\Rightarrow \rho_w \frac{dR}{dt} = \frac{D}{R}(\rho - \rho_\infty)$

$\rho_w \int_0^R R\,dR = \int_0^t dt\, D(\rho - \rho_\infty)$

$\Rightarrow \frac{\rho_w}{2}R^2 = Dt(\rho - \rho_\infty)$

$\Rightarrow t = \frac{\rho_w R^2}{2D(\rho - \rho_\infty)}$

10.1

(1) $T_B = \frac{V_B}{V_A} \cdot T_A = 600K$

$T_C = T_B = 600K$

$T_D = \frac{V_D}{V_C} T_C = 300K$

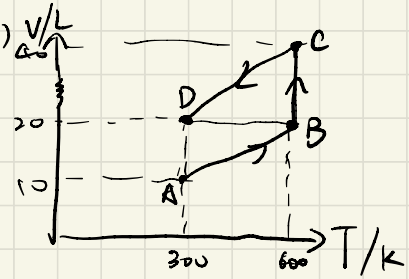
(2)

$A = A_{AB} + A_{BC} + A_{CD}$

$= p_A(V_B - V_A) + p_B V_B \cdot \ln\frac{V_C}{V_B} + p_C(V_D - V_C)$

$= 2.81 \times 10^3 J$

(3)



10.2

(1) $E_b - E_a = (560 - 356)J = 204J$

$Q_{adb} = E_b - E_a + A_{adb} = (204 + 220)J = 424J$

(2)

$Q_{ba} = E_a - E_b = A_{ba} = [-204 + (-282)]J = -486J$

10.5

(1) $Q = \nu C_{p,m} \Delta T = \nu \cdot \frac{7}{2} R \Delta T$

$\Rightarrow \nu = \frac{2Q}{7R\Delta T} = 41.3mol$

(2) $\Delta E = \nu C_{V,m} \Delta T = \nu \cdot \frac{5}{2} R \Delta T = \frac{5}{7} Q = 4.29 \times 10^4 J$

(3) $A = Q - \Delta E = 1.71 \times 10^4 J$

(4) $Q' = \Delta E = 4.29 \times 10^4 J$ (等体)

泄流中速率平均值推导：

$$g(v_x)=\left(\frac{m}{2\pi kT}\right)^{\frac{1}{2}}e^{-\frac{mv_x^2}{2kT}}$$

$$G(\vec{v})=\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}}e^{-\frac{mv^2}{2kT}}$$

$$\bar{v}_{泄}=\frac{\iiint v_z\cdot v\,G(\vec{v})\,dv_x\,dv_y\,dv_z}{\int_0^{+\infty}v_z g(v_z)\,dv_z}$$

$$\int_0^{+\infty}v_z g(v_z)\,dv_z=\frac{kT}{m}\left(\frac{m}{2\pi kT}\right)^{\frac{1}{2}}=\sqrt{\frac{kT}{2\pi m}}$$

$$dv_x\,dv_y\,dv_z=v^2\sin\theta\,dv\,d\theta\,d\varphi$$

$$=\frac{m}{kT}\left(\frac{m}{2\pi kT}\right)^{1}\iiint v_z\cdot v\cdot e^{-\frac{mv^2}{2kT}}dv_x\,dv_y\,dv_z$$

$$=\frac{m^2}{2\pi k^2T^2}\iiint v^2\cos\theta\cdot e^{-\frac{mv^2}{2kT}}\,v^2\sin\theta\,dv\,d\theta\,d\varphi$$

$$=\frac{m^2}{2\pi k^2T^2}\int_0^{2\pi}d\varphi\int_0^{\frac{\pi}{2}}\sin\theta\cos\theta\,d\theta\Big|_0^{+\infty}v^4e^{-\frac{mv^2}{2kT}}dv$$

$$=\frac{m^2}{k^2T^2}\int_0^{+\infty}v^4e^{-\frac{mv^2}{2kT}}dv$$

$$=\frac{m^2}{k^2T^2}\left(\frac{3\sqrt{\pi}}{8}\times\left(\frac{m}{2kT}\right)^{-\frac{5}{2}}\right)$$

$$=\left(\frac{3\sqrt{\pi}}{8}\times2^{\frac{5}{2}}\right)\times\left(\frac{m^2}{k^2T^2}\times\left(\frac{kT}{m}\right)^{\frac{5}{2}}\right)$$

$$=\frac{3\sqrt{\pi}}{\sqrt{2}}\sqrt{\frac{kT}{m}}$$

$$=\sqrt{\frac{9\pi RT}{2\mu}}$$