P1

19-3 $P_i V_i = nRT_i$ Assume ideal gas

$nR = \frac{P_i V_i}{T_i}$ with $P_i = 1.01 \times 10^5$ Pa

$V_i = \frac{1000}{10^6}$ m^3

$T_i = 40.0 + 272$ K.

$P_f V_f = nRT_f$

$P_f V_f = \left(\frac{P_i V_i}{T_i}\right) T_f$

$T_f = \frac{P_f V_f}{P_i V_i} T_i$

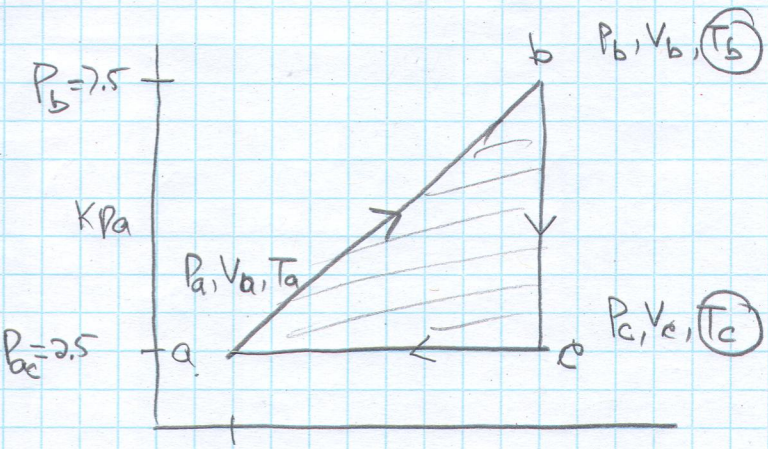
with $P_f = 1.06 \times 10^5$ Pa

$V_f = \frac{1500}{10^6}$ m^3

19-B

Given $P_{ac} = P_a = P_c = 2.5\ KPa$

$P_b = 7.5\ KPa$



To Find # of moles of gas n

use ideal gas law and assume the gas behave as ideal gas

(a) $PV = nRT$

$$n = \frac{PV}{RT} = \frac{P_{ac}V_a}{RT_a}$$

with $V_a = 1\ m^3$

$T_a = 200\ K$

$P_{ac} = 2.5 \times 10^3\ pa$

(b) To find T_b.

$PV = nRT$

$$T_b = \frac{PV}{nR} = \frac{P_bV_b}{nR} = \frac{P_bV_b}{\left(\frac{P_{ac}V_a}{RT_a}\right)R} = \frac{P_bV_bT_a}{P_{ac}V_a}$$

(c) $$T_c = \frac{P_cV_c}{nR} = \frac{P_cV_c}{P_{ac}V_a}T_a = \frac{V_c}{V_a}T_a$$

use the 1st law of T.D

$\Delta Q = \Delta E_i + \Delta W$ where ΔQ is heat added to system during cyclic process i.e abca.

$\Delta E_i = 0$ since the process starting from a ending at a. Internal energy does not change.

ΔE_i is the change in internal energy of completing one cycle

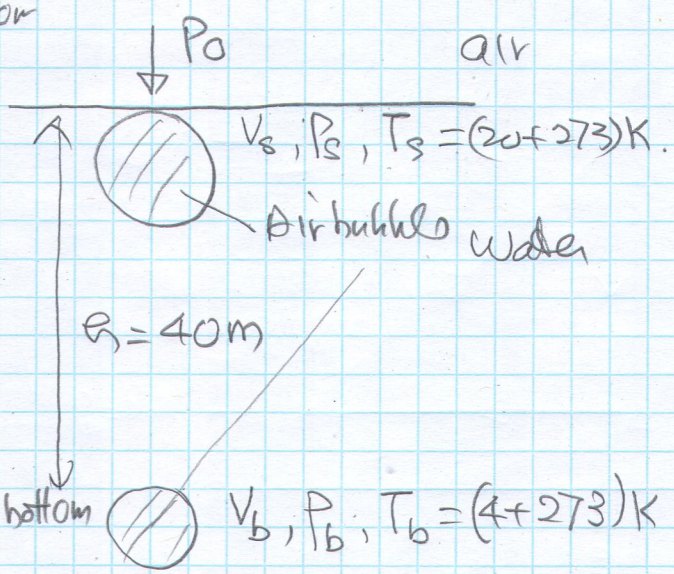
ΔW is the work done by the system when the heat is added to the system

$\Delta Q = \Delta W =$ work done in the cyclic process abca

$\Delta W = \Delta W_{ab} + \Delta W_{bc} + \Delta W_{ca}$ $\quad \Delta W_{bc} =$ zero since $dV = 0$

$= \Delta W_{ab} - \Delta W_{ac} =$ Area defined by a b and c.

19-16 Consider the gas at lake bottom



$P_b V_b = nRT_b$

$P_b = (P_0 + \rho g h)$

$\therefore nR = \dfrac{(P_0 + \rho g h) V_b}{T_b}$

At surface: $nR = \dfrac{P_s V_s}{T_s}$

$= \dfrac{P_0 V_s}{T_s}$

Assuming No change in gas molecules inside the bubbles

$$\frac{(P_0 + \rho g h) V_b}{T_b} = \frac{P_0 V_s}{T_s}$$

$$V_s = \frac{(P_0 + \rho g h) V_b T_s}{P_0 T_b} \quad (\text{in } cm^3)$$

$\rho = 10^3 kg/m^3$

$g = 9.81\ ms^{-2}$

$h = 40m$

$T_s = 293K$

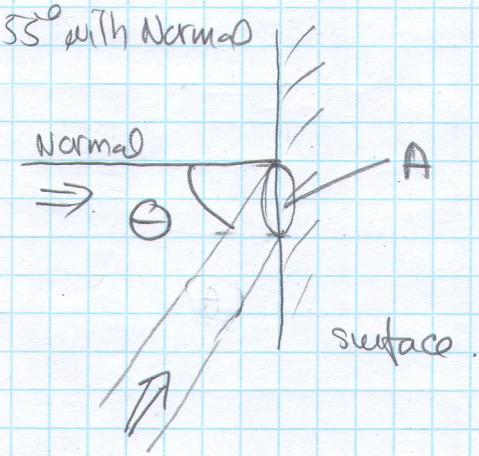
$T_b = 277K$

$P_0 = 1.01 \times 10^5 pa$

$V_b = 20\ cm^3$

IP-23. Beam of H_2 striking a surface @ $\theta = 55°$ with Normal

Find pressure on wall.



Force acts on surface by one molecule at Normal is

$$F_\perp = \frac{\Delta 2mV}{\Delta t} = 2V\frac{\Delta m}{\Delta t}$$

Force acts on surface by one molecule at θ is

$$F_\theta = 2V\frac{\Delta m}{\Delta t}\cos\theta$$

Total F_θ for N # of molecules each of mass m_i

$$F_\theta = 2V\frac{\Delta N m_i}{\Delta t}\cos\theta \qquad \frac{\Delta N}{\Delta t} = 10^{23} \text{ molecule/s}.$$

$$P = \frac{F_\theta}{A} = \frac{2V}{A}\left(\frac{\Delta N}{\Delta t}\right) m_i \cos\theta \quad (Pa) \;//$$

with $V = 10^3 ms^{-1}$ $\quad m_i = 3.3\times10^{-24}\times10^{-3}$ kg, $\quad A = \frac{2}{100^2}\ m^2$.

19-32 the equation for the mean free path is $\lambda = \frac{RT}{\sqrt{2}\, p \pi d^2}$ (5)

where R – Boltzman const
T – temp in Kelvin
p – pressure in Pa
d – m.
λ – m.

for Ar $\lambda_{Ar} = \frac{RT}{\sqrt{2}\, p \pi d_{Ar}^2}$

fa N_2 $\lambda_{N_2} = \frac{RT}{\sqrt{2}\, p \pi d_{N_2}^2}$

$$\frac{\lambda_{N_2}}{\lambda_{Ar}} = \frac{\frac{RT}{\sqrt{2}\, p \pi d_{N_2}^2}}{\frac{RT}{\sqrt{2}\, p \pi d_{Ar}^2}} = \frac{d_{Ar}^2}{d_{N_2}^2}$$

(a) $$\frac{d_{Ar}}{d_{N_2}} = \sqrt{\frac{\lambda_{N_2}}{\lambda_{Ar}}} = \sqrt{\frac{27.5 \times 10^{-6}}{9.9 \times 10^{-6}}} = \underline{\underline{1.67}}$$

(b) Find λ_{Ar_2} @ $T_2 = (20+273)K$, $P_2 = 150 \text{ torr} = \frac{150}{760} \times 1.01 \times 10^5 \text{ Pa}$

$$\lambda_{Ar_2} = \frac{RT_2}{(\sqrt{2})(P_2 \pi d_{Ar}^2)}$$

From: λ_{Ar_1} @ $T_1 = 293K$, $P_1 = 1.01 \times 10^5 \text{ Pa}$ is $9.9 \times 10^{-6} \times 10^{-3} \text{ m}$

$$d_{Ar}^2 = \frac{RT_1}{\lambda_{Ar_1}(\sqrt{2})(P_1 \pi)}$$

sub to $\lambda_{Ar_2} = \frac{RT_2}{(\sqrt{2})(P_2 \pi \frac{RT_1}{\lambda_{Ar_1} \sqrt{2} P_1 \pi})} = \frac{T_2}{T_1} \lambda_{Ar_1} \frac{P_1}{P_2}$

$= \frac{P_1}{P_2}(\lambda_{Ar_1})$ since $T_2 = T_1$

(c) $T_3 = (-40+273)K$, $P_3 = 750 \text{ torr} = \frac{750}{760} \times 1.01 \times 10^5 \text{ Pa}$

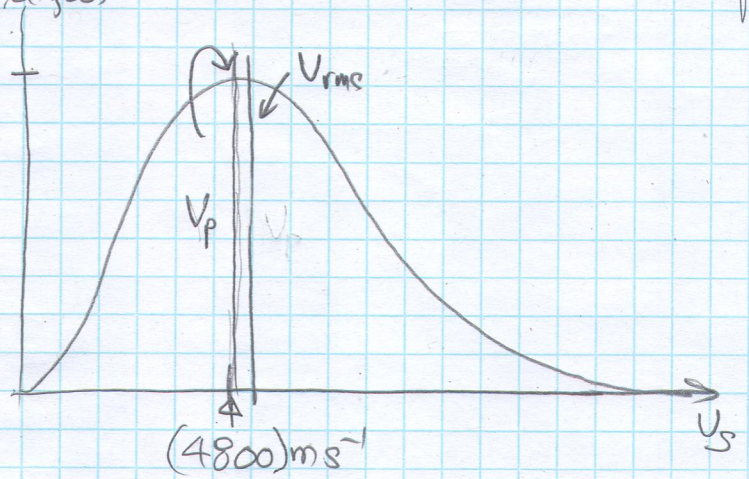
$$\lambda_{Ar_3} = \frac{T_3}{T_1} \frac{P_1}{P_3} \lambda_{Ar_1} \quad //$$

19—38 The most probable speed of a gas in thermal equilibrium obeys Maxwellian speed distribution

$$V_p = \sqrt{\frac{2RT}{M}}$$

and the root mean square V_{rms}

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$



Find T and V_{rms}

From graph. Eq(19-24) $V_p = 4800\ ms^{-1}$

using the equation for V_p

$$V_p^2 = \frac{2RT}{M}$$

$$T = \frac{mV_p^2}{2R} \quad //$$

where m is mass of N_2

R is universal gas const.

To find V_{rms} sub T by $\frac{mV_p^2}{2R}$

$$V_{rms} = \sqrt{\frac{3R\cancel{m}V_p^2}{\cancel{m}\ 2R}} = \sqrt{\frac{3}{2}}\,V_p = \left(\sqrt{\frac{3}{2}}\right)(4800)\ ms^{-1}$$

19-43 $n = 3$ mol, diatomic gas.

$\Delta T = 40°C$ with $\Delta p = 0$

Consider 1st law $\Delta Q = \Delta E_i + \Delta W$

$$\Delta Q = nC_v\Delta T + \Delta W$$ where C_v is molar heat cap.

For const vol ie $\Delta V = 0$

$$\Delta Q = nC_v\Delta T$$

and const pressure

$$\Delta Q = nC_v\Delta T + p\,dV \qquad dV = \frac{nR\Delta T}{P}$$

$$= nC_v\Delta T + \cancel{P}\frac{nR\Delta T}{\cancel{P}}$$

$$\Delta Q = (nC_v + nR)\Delta T$$

Sing. $\Delta E_i = nC_v\Delta T$

$$= \frac{3}{2}nR\Delta T + \frac{2}{2}nR\Delta T$$

↑ translational ↑ rotational

$$nC_v\Delta T = \frac{5}{2}nR\Delta T$$

For constant pressure, $\Delta Q = (nC_v + nR)\Delta T$

$$= \left(\frac{5}{2}nR + nR\right)\Delta T$$

$$\Delta Q = \frac{7}{2}nR\Delta T$$

Heat Energy transfered $= \left(\frac{7}{2}nR\Delta T\right)$ $\Delta T = 40\,K$, $n = 3$

R universal gas const.

To calculate change in internal energy

$$\Delta E_i = nC_v\Delta T = \left(\frac{5}{2}\right)nR\Delta T$$

(b) Find ΔE_i

since $\Delta E_i = \frac{5}{2} nR\Delta T$ with $n=3$, $\Delta T = 40K$.

(c) What is work done by gas

use the 1st law of T.D.

$$\Delta Q_p = \Delta Q_V + \Delta W$$

$$\Delta W = \Delta Q_p - \Delta Q_V = n\left(\frac{7R}{2}\right)\Delta T - n\left(\frac{5}{2}R\right)\Delta T$$

$$= nR\Delta T$$

(d) What is the increase of rotational KE. of gas

Initial KE of rotation $= \frac{2}{2} nRT_i$

Final KE of rotation $= \frac{2}{2} nRT_f$

$$\Delta KE = nR(T_f - T_i) = nR\Delta T$$

$n = 3$
$R =$ ugas Const
$\Delta T = 40K$

$$= 997.25$$

$$\simeq 10^3 J.$$

19-52 Given O_2, mass = 12 g heated at const. atm pressure from $T_i = 25°C$ to $125°C$.

12 g of O_2 corresponds to $\frac{12}{32}$ mole of $O_2 = \frac{3}{8} = n$

$\Delta T = 100\,K$

(a) # of mole of O_2 is $n = \left(\frac{3}{8}\right)$

(b) $\Delta Q_p = nC_p\Delta T$ and $C_p = C_V + R$ with $C_V = \frac{3}{2}R + \frac{2}{2}R$

$= \frac{5}{2}R + R$

$= \frac{7}{2}R.$

$\Delta Q_p = (n)\left(\frac{7}{2}R\right)\Delta T$

$= \left(\frac{3}{8}\right)\left(\frac{7}{2}R\right)(100)$ //

(c) Fraction of heat ΔQ_V used raise E_i:

since $\Delta E_i = \Delta Q_V = \frac{5}{2}nR\Delta T$

$$\frac{\Delta E_i}{\Delta Q_p} = \frac{n\left(\frac{5}{2}\right)R(\Delta T)}{n\frac{7}{2}R(\Delta T)} = \frac{5}{7}$$

9-57 $V_i = 200\,L$ $V_f = 74.3\,L$

$P_i = 1\,atm$ $P_f = 4\,atm$

$T_i = 300\,K$ $T_f = ?$

Find T_f and n and γ.

For adiamatic process, $PV^\gamma = constant$ where γ is det by the degree of freedom of the gas.

monodatomic $\gamma = 5/3 = 1.667$

diatomic $\gamma = 7/5 = 1.40$

$P_i V_i^\gamma = P_f V_f^\gamma$

$\frac{P_i}{P_f} = \left(\frac{V_f}{V_i}\right)^\gamma$

$\ln\left(\frac{P_i}{P_f}\right) = \gamma \ln\left(\frac{V_f}{V_i}\right)$

(a) $\gamma = \frac{\ln\left(\frac{P_i}{P_f}\right)}{\ln\left(\frac{V_f}{V_i}\right)} = \frac{\ln\left(\frac{1}{4}\right)}{\ln\left(\frac{74.3}{200}\right)} = 1.4 \Rightarrow$ diatomic

(b) $T_f V_f^{(\gamma-1)} = T_i V_i^{(\gamma-1)}$

$T_f = \frac{T_i V_i^{(\gamma-1)}}{V_f^{(\gamma-1)}} = T_i \left(\frac{V_i}{V_f}\right)^{(\gamma-1)} = (300)\left(\frac{200}{74.3}\right)^{0.4} = \underline{445.8\,K}$

(c) $n = \frac{P_i V_i}{T_i R} = \frac{(1.01\times10^5)(200\times10^{-3}/10^6)\ pa\ m^3}{(300)(8.31\ J/mol K)\,K} = \underline{\underline{8.1\ mol}}$

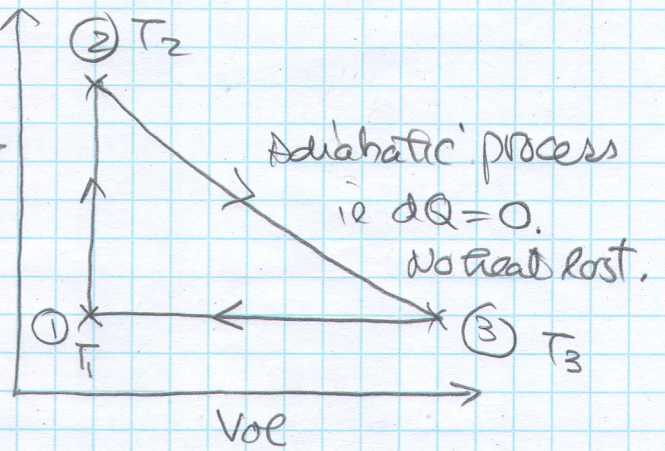
19-63

Given: $n = 1$ mole of gas, $N = nN_A = N_A$ with N_A = Avogadro number

gas: mono atomic

$KE/\text{molecule} = \frac{3}{2}RT$

$T_1 = 300\,K$
$T_2 = 600\,K$
$T_3 = 455\,K$



Find: ΔQ, ΔE_i, and ΔW in

(a)(b) and (c) ① → ② Isochoric, $\Delta V = 0$

1st law: $\Delta Q = \Delta E_i + \Delta W = \Delta E_i + \int p\,dV$ ($\int p\,dV \to 0$)

$\Delta Q = \Delta E_i$

Adding Real dQ to the system = increase in internal energy dE_i.

$\Delta Q = \Delta E_i$ with $\Delta W = 0$ //

$E_i = N\left(\frac{3}{2}RT_i\right)$ where $\frac{3}{2}RT$ is mean energy (gas) carried by an mono atomic

$N\left(\frac{3}{2}RT\right)$ is the mean energy carried by 1 mole of mono atomic gas or $nN_A = N_A = 6.02\times10^{23}$ molecule/mole.

$R = 1.380\times10^{-23}\,J/K$

$\Delta E_{12} = E_2 - E_1 = \frac{3}{2}NR(T_2 - T_1) = \frac{3}{2}N_AR(300)$ // with $\Delta T = 600 - 300 = 300\,K$

$\Delta Q_{12} = \Delta E_{12}$ //

(d)(e)(f) ② → ③ Adiabatic, $\Delta Q = 0$. //

$\Delta E_c + \Delta W = 0$

$\Delta E_{23} = N\left(\frac{3}{2}R\right)(T_3 - T_2) = \frac{3}{2}N_AR(455 - 600) = -\frac{3}{2}N_AR(145)$ //

the negative sign indicates that there is a decrease in internal energy

this lost of internal energy must be used to do external work ΔW

$\Delta W_{23} = +\frac{3}{2}N_AR(145)$ //

(g)(A)(i) ③ → ① Isobaric ie $\Delta p = 0$

1st law of T.D

$\Delta Q = \Delta E_i + \Delta W$ with $T_3 = 455$, $T_1 = 300$

and $\Delta E_{i_{31}} = N_A \frac{3}{2} R \Delta T_{13} = -\frac{3}{2} NR(155)$ //

$\Delta W = p\Delta V$ and since $pV = N_A RT$

$V = \frac{N_A RT}{p}$

$\Delta V_{31} = \frac{N_A R}{p}(T_1 - T_3) = \frac{N_A R}{p} \Delta T_{13}$

Sub to $p\Delta V$

$\Delta W_{31} = p_3 \frac{N_A R}{p_3}(\Delta T_{13}) = N_A R(300 - 455) = -N_A R(155)$ //

$\therefore \Delta Q_{31} = -\frac{3}{2} N_A R(155) - NR((155))$

$= -N_A R(155)\left(\frac{3}{2} + 1\right)$

$= -\frac{5 N_A R}{2}(155)$ -ve ΔQ_{31} ⇒ heat flows out of system

For full cycle ie ① → ② → ③

(j) $\Delta Q_{123} = \Delta Q_{12} + \Delta Q_{23} + \Delta Q_{31} = \frac{3}{2} N_A R(300) - \frac{5}{2} N_A R(155)$ //

($\Delta Q_{23} \to 0$)

(k) $\Delta E_{i_{123}} = 0$ //

(l) $\Delta W_{123} = \Delta W_{12} + \Delta W_{23} + \Delta W_{31}$

$= 0 + \frac{3}{2} N_A R(155) - NR(155)$ //

(m) To find the volume @ ② with p @ ① = $p_1 = 1.01 \times 10^5$ pa.

$pV = N_A RT$

$V_1 = \frac{N_A R T_{300}}{P_1}$ where $N_A = 6.023 \times 10^{23}$ molecules/mole, $R = 1.38 \times 10^{-23}$ J/K.

$P_1 = 1.01 \times 10^5$ pa. $T_{300} = 300$ K.

At ②, $P_2V_2 = N_A R T_2$

$P_1V_1 = N_A R T_1$

and $V_2 = V_1 = \frac{N_A R T_{300}}{P_1}$

(b) and $\frac{P_2}{P_1} = \frac{T_2}{T_1}$

$P_2 = \left(\frac{T_2}{T_1}\right)(P_1)$ //

$T_2 = 600K \quad T_1 = 300K.$

(c) At point ③, $V_3 = ?$, and $P_3 = ?$

$P_3 = P_1 = 1$ ~~Atm~~.

$V_3 = \frac{N_A R T_3}{P_3}$ //

$T_3 = 455$

$P_3 = 1.01 \times 10^5$ Pa