HW 4

Monday, February 6, 2023 12:36 PM

1. (9, 11, 14, 15, 16, 20, 22, 23, 31, 32, 34, 35, 40, 45, 46, 55) $\boxed{\text{* Ideal Gas Law : IGL}}$

**1.9** $V$ of $n=1$ of air, $T=300K$ & $P=1atm=1.013\times10^5 Pa$

$\Rightarrow PV=nRT \Rightarrow V=\frac{nRT}{P}=\frac{(1mol)(8.31 J mol^{-1}K^{-1})(300K)}{1.013\times10^5 N m^{-2}}=\boxed{0.0246 m^3}$ (Using IGL)

**1.11** $V_a=V_b$, $T_a>T_b$, $P_a=P_b\approx 1atm$ (Using IGL)

$\rightarrow PV=nRT=NkT=nN_AkT=\frac{m}{\mu}N_AkT=Const.$

$\therefore \frac{m_a}{\mu}N_AkT_a=\frac{m_b}{\mu}N_AkT_b \Rightarrow m_aT_a=m_bT_b \Rightarrow \frac{m_a}{m_b}=\frac{T_b}{T_a}$, b/c $T_a>T_b$, $\boxed{m_b>m_a}$

**1.14** $N_2(.78)$, $O_2(.21)$, $Ar(.01)$, $m$ of 1 mol? Where $m=\mu n$ (remembered from chemistry)

$\rightarrow \mu_{da}=\mu_{N_2}(.78)+\mu_{O_2}(.21)+\mu_{Ar}(.01)=28.0134(.78)\frac{g}{mol}+31.998(.21)\frac{g}{mol}+39.948(.01)\frac{g}{mol}=\underline{28.9695\ g/mol}$

$\therefore m_{da}=\mu_{da}n=28.9695\frac{g}{mol}\cdot 1mol=\boxed{28.9695g}$

**1.15** $T$?, If $m_T=500kg$, $m_a$?, Assuming $P=1atm$ & $V=\frac{4}{3}\pi r^3=\frac{4}{3}\pi(8m)^3=2144.66m^3$ ($V$ of a sphere)

a) $\rho=\frac{m}{V}$, $V=\frac{nRT}{P}$, $=\frac{Pm}{nRT}=\frac{P\mu}{RT}$

To keep pressure const, there needs to be a buoyant force equal to the weight

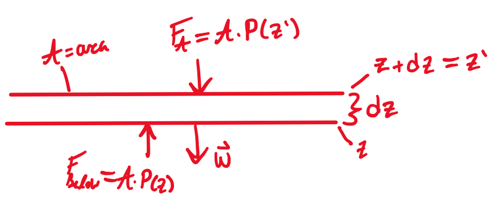
$\therefore \Delta\rho=-\frac{m_T}{V} \Rightarrow \rho_0-\rho=\frac{m_T}{V} \Rightarrow \frac{P\mu}{RT_0}-\frac{P\mu}{RT}=\frac{m_T}{V} \Rightarrow \frac{1}{T_0}-\frac{1}{T}=\frac{Rm}{P\mu V}$ $\therefore \frac{1}{T}=\frac{1}{T_0}-\frac{Rm_T}{P\mu V}$, assuming air Temp ($T_0$) is $\sim 23C=296K$

$\Rightarrow \frac{1}{T}=\frac{1}{296K}-\frac{(500kg)(8.31 J/K)}{(.0289kg)(1.013\times10^5 Pa)(2144.66m^3)}=\frac{1}{296K}-\frac{1}{1511.12K}=\frac{1}{368K}$ $\therefore \boxed{T\approx 368K}$

b) $PV=nRT$, $n=\frac{m}{\mu}$, $=\frac{m}{\mu}RT$ $\therefore m=\frac{PV\mu}{RT}=\frac{(1.013\times10^5Pa)(2144.66m^3)(.0289kg)}{(8.31J/K)(368K)}=\boxed{2053.13kg}$ (Using IGL)

$\rightarrow$ Which is over 4 times the mass of payload & unfilled balloon, if the assumptions are right.

**1.16**




a) $F_y=A\cdot P(z')-A\cdot P(z)=-mg \Rightarrow P(z')-P(z)=-\frac{m}{A}g=-\rho\cdot dz\cdot g$ (From Newton's 2nd Law)

$\therefore \frac{P(z')-P(z)}{dz}=-\rho g=\frac{dP}{dz}$

b) Using $PV=nRT=NkT$ (Using IGL)

$\rightarrow \frac{dP}{dz}=-\frac{m}{V}g=-\frac{mg}{NkT}P$, $\mu=\frac{m}{N}=\frac{m}{n\cdot N_A}=\frac{m}{N_A}$, $=\boxed{\frac{-\mu g}{kT}P}$

c) Isothermal from b):

$\rightarrow \frac{dP}{dz}\cdot dz=\frac{-\mu g}{kT}P\,dz \Rightarrow \int_{P_0}^{P}\frac{1}{P}dP=\frac{-\mu g}{kT}\int_0^z dz \Rightarrow \ln\left(\frac{P}{P_0}\right)=\frac{-\mu gz}{kT} \Rightarrow e^{\ln(P/P_0)}=e^{\left(\frac{-\mu gz}{kT}\right)}$

$\therefore P(z)=P_0e^{\left(\frac{-\mu gz}{kT}\right)}$, where $P_0$ is at $z=0$

d) $z_1=1430m$, $z_2=3070m$, $z_3=4420m$, $z_4=8840m$, $P_0=1atm$ & $\bar{T}\approx 290K$ for all regions, $\frac{\mu g}{kT}\approx\frac{mg}{RT}$, $m=.0289kg$ & $R=8.31\frac{J}{K}$, $=\frac{.0289kg\cdot 9.8m/s^2}{8.31J/K\cdot 290K}=1.1752\times10^{-4}\frac{N}{N\cdot m}=1.1752\times10^{-4}m^{-1}$, from c)

$\rightarrow P_1(z)=1\cdot e^{(-1.1752\times10^{-4}\cdot 1430)}=\boxed{.8453\ atm}$, $P_2(z)=e^{(-1.1752\times10^{-4}\cdot 3070)}=\boxed{0.695\ atm}$, $P_3(z)=\boxed{0.5948\ atm}$, & $P_4(z)=\boxed{0.3538\ atm}$ $\therefore$ Higher you go, pressure decreases

**1.20** $T\approx 300K$, $V_{rms}=\left(\frac{3kT}{m}\right)^{1/2}$ (eq. 1.21), $k=\frac{R}{N_A}$ (eq. 1.6) & $m=\mu n=\mu\frac{N}{N_A}$ (from chemistry), $=\left(\frac{3RT}{\mu\frac{N}{N_A}\cdot N_A}\right)^{1/2}=\left(\frac{3RT}{\mu N}\right)^{1/2}$, assuming $N=1$

- For 238: $\mu=\mu_F\cdot 6+\mu_U=114+238=352g$, $V_{rms}=\left(\frac{3(8.31J/K)(300K)}{.352kg}\right)^{1/2}=\boxed{145.76\ m/s}$
- For 235: $\mu=114+235=349g$, $V_{rms}=\left(\frac{3(8.31J/K)(300K)}{.349kg}\right)^{1/2}=\boxed{146.39\ m/s}$

$\therefore$ for $\mu_{238}>\mu_{235}$, $(V_{rms})_{235}>(V_{rms})_{238}$ by a factor of 1.0043

**1.22** Effusion: gas leaking out of a small hole

a) Show: $N=\frac{PA\Delta t}{2m\bar{v}_x}$ (Using IGL)

$\rightarrow PV=nRT=NkT=Nm\bar{v}_x^2=P.AL \Rightarrow PA=Nm\frac{\bar{v}_x^2}{L}$, $\Delta t=\frac{2L}{\bar{v}_x}$ (eq. 1.10), $=\frac{2Nm}{\Delta t}\bar{v}_x$ $\therefore N=\frac{PA}{2m}\frac{\Delta t}{\bar{v}_x}=\frac{PA\Delta t}{2m\bar{v}_x}$

b) $\rightarrow PV=NkT=Nm\bar{v}_x^2$ $\therefore NkT=Nm\bar{v}_x^2 \Rightarrow \bar{v}_x^2=\frac{kT}{m}$

c) From a) & b) $\rightarrow N=\Delta N=\frac{-PA\Delta t}{2m}\left(\frac{m}{kT}\right)^{1/2}$, $P=\frac{NkT}{V}$, $\Rightarrow \frac{\Delta N}{\Delta t}=\frac{-NkT}{V}\cdot\frac{A}{2m}\cdot\left(\frac{m}{kT}\right)^{1/2}=\frac{-NA}{2V}\left(\frac{k^2T^2m}{m^2kT}\right)^{1/2}=\frac{-NA}{2V}\left(\frac{kT}{m}\right)^{1/2}$

$\therefore$ For small changes: $\frac{dN}{dt}=\frac{-A}{2V}\left(\frac{kT}{m}\right)^{1/2}N \Rightarrow \int_{N_0}^{N_1}\frac{1}{N}dN=\frac{-A}{2V}\left(\frac{kT}{m}\right)^{1/2}\int_0^t dt$, For Isothermal, $\Rightarrow \ln|N/N_0|=\frac{-At}{2V}\left(\frac{kT}{m}\right)^{1/2}=\frac{-t}{\tau}$

$\therefore N(t)=N_0e^{-t/\tau}$

d) $\tau$?

$V=1L=10^{-3}m^3$, $A=10^{-6}m^2$, $T=300K$ (Assuming Room Temp), Assuming gas is air

$\rightarrow \frac{1}{\tau}=\frac{A}{2V}\left(\frac{kT}{m}\right)^{1/2}=\frac{A}{2V}\left(\frac{RT}{\mu}\right)^{1/2}=\frac{10^{-6}m^2}{2\times10^{-3}m^3}\left(\frac{8.31\frac{J}{K mol}\cdot 300K}{.0289kg/mol}\right)^{1/2}=.14685s^{-1}$ $\therefore \boxed{\tau=6.81s}$

e) flat w/in an hour (3600s), size of hole?

Stretching the bike's tube, we can assume it's a cylinder, $\therefore V=\pi r^2 l$, Assuming $r=.04m$ & $l=2m$, $=.01m^3$

$\rightarrow \tau=\frac{2V}{A}\left(\frac{m}{kT}\right)^{1/2} \Rightarrow A=\frac{2(.01m^3)}{3600s}\left(\frac{(.0289kg/mol)}{8.31\frac{J}{K mol}\cdot 300K}\right)^{1/2}=\boxed{1.902\times10^{-8}m^2}$

f) Most def. NOT! There is no pressure in the Vacuum of Space, So if you open a hatch from a ship in space, the ship being pressurized, you will be blown out into space b/c the pressure from inside the ship is forcing it open. Which is why the door would open towards the outside, not inside, so it's easier to open. Hence the name Vacuum of Space b/c it acts as a vacuum does, sucking everything out

Assuming $V$ of spacecraft is $30m^3$, Area of the hatch is $2m^2$, & breathable air inside:

$\rightarrow \tau=\frac{2V}{A}\left(\frac{\mu}{RT}\right)^{1/2}=30\left(\frac{.0289}{8.31\cdot 300}\right)^{1/2}=\boxed{0.102s}$ $\therefore$ No human can act this fast to throw a dog's corpse into space

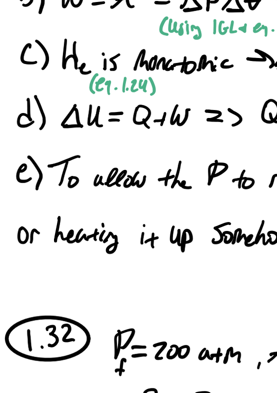
**1.23** $T=300K$, $P=1atm=1.013\times10^5Pa$ (eq. 1.23)

a) $1L=.001m^3$ of He $\rightarrow U_{Th}=Nf\frac{1}{2}kT=nf\frac{1}{2}RT=\frac{f}{2}PV$, He is monatomic $\therefore f=3$, $=\frac{3}{2}(1.013\times10^5Pa)(.001m^3)=\boxed{151.95J}$

b) $.001m^3$ of air (which is a diatomic gas b/c it's mostly $N_2+O_2$) $\rightarrow U_{Th}=\frac{5}{2}PV=\frac{5}{2}(1.013\times10^5Pa)(.001m^3)=\boxed{253.25J}$

**1.31** $V_0=1L$, $P_0=1atm$, $V_f=3L$ & $P_f=3atm$

a) P-$V$ Diagram:




(eq. 1.28)

b) $W=A=-\Delta P\Delta V=-(3\cdot 1.013\times10^5-1.013\times10^5)(3\cdot 0.001-.001)=\boxed{-405.2J}$ * Negative b/c pressure increases w/ Volume, meaning work being done by

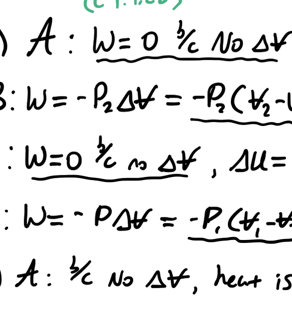
c) He is Monatomic $\rightarrow \Delta U=\frac{3}{2}\Delta(PV)$ (Using IGL & eq. 1.23) $=\frac{3}{2}(P_fV_f-P_0V_0)=\frac{3}{2}(3\cdot 3-1)=\frac{24}{2}=12L\cdot atm(1.013\times10^5Pa\cdot .001m^3)=\boxed{1215.6J}$

d) $\Delta U=Q+W$ (eq. 1.24) $\Rightarrow Q=\Delta U-W=1215.6J+405.2J=\boxed{1620.8J}$ * Positive b/c heat was added

e) To allow the P to rise w/ $V$, you'd need an increase in T, meaning holding the piston in a furnace or heating it up somehow.

**1.32** $P_f=200atm$, Assuming $P_0=1atm$, $V_0=1L$, $V_f=.99V_0=.99L$

P-$V$ Diagram:




$W=-\bar{P}\Delta V$, instead of $\Delta P$ we assume avg $P(\bar{P})$ which is $\frac{P_f}{2}$, $=-(100atm)(.99-1)L=1\cdot 1.013\times10^5Pa\cdot .001m^3=\boxed{101.3J}$ (eq. 1.28)

**1.34** Using Fig 1.10b, diatomic gas $f=5$, quasistatic

a) A: $W=0$ b/c No $\Delta V$ (eq. 1.28), $\Delta U=\frac{5}{2}\Delta(PV)=\frac{5}{2}(P_2-P_1)V_1$ (eq. 1.23) & $Q=\Delta U-W=\frac{5}{2}(P_2-P_1)V_1$ (eq. 1.24) $\rightarrow$ 1st Law of Thermo

B: $W=-P_2\Delta V=-P_2(V_2-V_1)$, $\Delta U=\frac{5}{2}P\Delta V=\frac{5}{2}P_2(V_2-V_1)$, $Q=\Delta U-W=P_2\Delta V(\frac{5}{2}+\frac{2}{2})=\frac{7}{2}P_2(V_2-V_1)$

C: $W=0$ b/c no $\Delta V$, $\Delta U=\frac{5}{2}\Delta PV_2=\frac{5}{2}(P_1-P_2)V_2$, $Q=\Delta U-W=\frac{5}{2}(P_1-P_2)V_2$

D: $W=-P\Delta V=-P_1(V_1-V_2)$, $\Delta U=\frac{5}{2}P_1\Delta V=\frac{5}{2}P_1(V_1-V_2)$, $Q=\Delta U-W=\frac{7}{2}P_1(V_1-V_2)$

b) A: b/c No $\Delta V$, heat is being applied increasing the P but not $V$

B: $\Delta V$ is positive, so expansion is happening but at a rate for heat to still be applied w/ P being constant

C: No $\Delta V$ w/ a decrease in P, meaning heat is being taken out, meaning T is decreasing

D: $\Delta V$ is negative meaning compression is happening, but at a rate for T to be decreasing w/ constant P

c) $\Sigma W=W_A+W_B+W_C+W_D=0-P_2(V_2-V_1)+0-P_1(V_1-V_2)=-P_2\Delta V+P_1\Delta V=(P_1-P_2)(V_2-V_1)=\boxed{-\Delta P\Delta V}$ * The Work done by the gas is positive b/c higher P when gas is expanding & lower when compressed

$\Sigma\Delta U=\frac{5}{2}V_1\Delta P+\frac{5}{2}P_2\Delta V-\frac{5}{2}V_2\Delta P-\frac{5}{2}P_1\Delta V=\frac{5}{2}(\Delta P\Delta V-\Delta P\Delta V)=\boxed{0}$ * b/c it's a closed loop, the cycle ends where it starts $\therefore \Delta U=0$

$\Sigma Q=\frac{5}{2}V_1\Delta P+\frac{7}{2}P_2\Delta V-\frac{5}{2}V_2\Delta P-\frac{7}{2}P_1\Delta V=\frac{-5}{2}(\Delta V\Delta P)+\frac{7}{2}(\Delta V\Delta P)=\frac{5}{2}\Delta V\Delta P+\Delta V\Delta P-\frac{5}{2}\Delta V\Delta P=\boxed{\Delta V\Delta P}$ * $Q=\Delta U-W=\Delta V\Delta P$, defined by 1st Law of Thermo, which it is

**1.35** Derive $V^{\gamma}P=Const$ from $VT^{f/2}=Const$ (eq. 1.39), for $\gamma=\frac{f+2}{f}$ $\rightarrow$ adiabatic exponent

$\rightarrow V\left(\frac{VP}{nR}\right)^{f/2}=V\cdot V^{f/2}\left(\frac{P}{nR}\right)^{f/2}=V^{\frac{f}{2}+1}\left(\frac{P}{nR}\right)^{f/2}=\left[V^{\frac{f+2}{2}}\left(\frac{P}{nR}\right)^{f/2}\right]^{\frac{2}{f}}=V^{\frac{f+2}{2}\cdot\frac{2}{f}}\frac{P}{nR} \Rightarrow V^{\frac{f+2}{f}}\cdot P=\underbrace{nR}_{const}$

$\therefore V^{\gamma}P=Const.$ (eq. 1.40)

**1.40** Adiabatic $\rightarrow Q=0$ $\therefore \Delta U=W$ (eq. 1.24)

$\rightarrow dU=W=-PdV$ (eq. 1.28) & $U=\frac{f}{2}nRT$ $\therefore \frac{f}{2}nRdT=-PdV \rightarrow d(PV)=nRdT=VdP+PdV=nRdT \Rightarrow PdV=nRdT-VdP=nRdT-\frac{nRT}{P}dP$

Plugging in: $\frac{f}{2}nRdT=\frac{nRT}{P}dP-nRdT \Rightarrow \frac{f}{2}dT+dT=\frac{T}{P}dP \Rightarrow dT(\frac{f}{2}+1)=\frac{T}{P}dP$ $\therefore \frac{dT}{dP}=\frac{2}{(f+2)}\frac{T}{P}$

b) From 1.16b) $\frac{dP}{dz}=\frac{-\mu g}{kT}P$, from a) $dP=\frac{P}{T}\frac{f+2}{2}dT$ $\therefore \frac{R}{K}\frac{f+2}{2}\frac{dT}{dz}=-\frac{\mu g}{kK}R \Rightarrow \frac{dT}{dz}=\frac{-2\mu g}{k(f+2)}=\frac{m}{N}\cdot\frac{-2g}{(f+2)}\cdot\frac{N}{R}=\frac{-2mg}{R(f+2)}$, air is diatomic, $=\frac{-2(.0289kg)(9.8m/s^2)}{7\cdot 8.31\frac{J}{mol K}}=\frac{-.566}{58.31}\frac{K}{m}=-.00974\frac{K}{m}=\boxed{-9.74\frac{K}{km}}$

**1.45** $W=xy$, $x=yz$

a) $W=x\cdot\frac{x}{z}=\boxed{\frac{x^2}{z}}$ & $W=\boxed{y^2z}$

b) $\frac{\partial W}{\partial x}=\frac{\partial}{\partial x}(x^2z^{-1})=\boxed{\frac{2x}{z}}$ & $\frac{\partial W}{\partial x}=\frac{\partial}{\partial x}(xy)=\boxed{y}$

$\rightarrow \left(\frac{\partial W}{\partial x}\right)_y\neq\left(\frac{\partial W}{\partial x}\right)_z \Rightarrow y\neq\frac{2x}{z} \Rightarrow \frac{x}{z}\neq\frac{2x}{z}$ $\therefore$ NOT an exact Equation

c) $\left(\frac{\partial W}{\partial y}\right)_x$, $\left(\frac{\partial W}{\partial y}\right)_z$, $\left(\frac{\partial W}{\partial z}\right)_x$, & $\left(\frac{\partial W}{\partial y}\right)_z$

$\rightarrow \frac{\partial}{\partial y}(xy)=\underline{x}$, $\frac{\partial}{\partial y}(y^2z)=\underline{2yz}$, $\frac{\partial}{\partial z}(x^2z^{-1})=-z^{-2}x^2=\underline{\frac{-x^2}{z^2}}$, $\frac{\partial}{\partial z}(y^2z)=\underline{y^2}$

Where $\left(\frac{\partial W}{\partial y}\right)_x\neq\left(\frac{\partial W}{\partial y}\right)_z$ & $\left(\frac{\partial W}{\partial z}\right)_x\neq\left(\frac{\partial W}{\partial z}\right)_y$ $\therefore$ None are exact Equations

**1.46**

a) Isobaric $\rightarrow \Delta V=\beta V\Delta T \Rightarrow dV_1=\beta VdT$, $\beta\equiv\frac{\Delta V/V}{\Delta T}$ (Volumetric expansion) (P. 1.7)

b) Isothermal $\rightarrow dV_2=\left(\frac{\partial V}{\partial T}\right)\frac{V}{V}dT=\partial V\left(\frac{nR}{V\partial P}\right)d\left(\frac{PV}{nR}\right)=\left(\frac{\partial V}{\partial P}\right)_T\frac{nR}{V}\cdot\frac{V}{nR}dP=\left(\frac{\partial V}{\partial P}\right)_T dP$

$\therefore dV_2=-\kappa_T VdP$

c) $\frac{dP}{dT}=\left(\frac{\partial P}{\partial T}\right)_V$, b/c $\Delta V=0$, $dV_2=-dV_1 \Rightarrow -\kappa_T VdP=-\beta VdT \Rightarrow \frac{dP}{dT}=\frac{\beta}{\kappa_T}$

In terms of $\beta$ & $\kappa_T$ $\rightarrow \frac{\beta}{\kappa_T}=\left(\frac{\partial P}{\partial T}\right)_V$ $\therefore -\frac{(\partial V/\partial T)_P}{(\partial V/\partial P)_T}=\left(\frac{\partial P}{\partial T}\right)_V$

d) $\beta=\frac{1}{V}\left(\frac{\partial}{\partial T}V\right)_P=\frac{1}{V}\frac{\partial}{\partial T}\left(\frac{NkT}{P}\right)=\frac{Nk}{VP}\frac{\partial}{\partial T}T==\boxed{\frac{1}{T}}$

$\kappa_T=-\frac{1}{V}\left(\frac{\partial}{\partial P}V\right)_T=-\frac{1}{V}\frac{\partial}{\partial P}\frac{NkT}{P}=\frac{-NkT}{V}\frac{\partial}{\partial P}P^{-1}=\frac{NkT}{V}\frac{1}{P^2}=\frac{P}{P^2}=\boxed{\frac{1}{P}}$

$\left(\frac{\partial}{\partial T}P\right)_V=\frac{\partial}{\partial T}\frac{NkT}{V}=\frac{Nk}{V}\frac{\partial}{\partial T}T=\boxed{\frac{P}{T}}$ $\therefore \frac{P}{T}=\frac{1/T}{1/P}=\frac{P}{T}$

e) @ 298K, $\beta=2.57\times10^{-4}K^{-1}$, $\kappa_T=4.52\times10^{-10}Pa^{-1}$ For Water:

- $dT=10K$, P? $\rightarrow$ from c) Since $P=const$: $\left(\frac{dP}{dT}\right)_V=\frac{\beta}{\kappa_T} \Rightarrow dP=\frac{\beta}{\kappa_T}dT=\frac{2.57\times10^{-4}K^{-1}\cdot 10K}{4.52\times10^{-10}Pa^{-1}}=5,685,840.71Pa=\boxed{56\ atm}$

@ 298K, $\beta=1.81\times10^{-4}K^{-1}$ & $\kappa_T=4.04\times10^{-11}Pa^{-1}$ For Mercury:

- $dT=10K$, P? $\rightarrow$ from c) & $P=const$: $dP=\frac{\beta}{\kappa_T}dT=\frac{1.81\times10^{-4}K^{-1}\,10K}{4.04\times10^{-11}Pa^{-1}}=44,801,980.2Pa=\boxed{442.3\ atm}$ ~ Dayum!!

~ I would most def want to keep it at const. P, so rather use $C_p$ so we don't deal w/ high pressures as shown

**1.55**

a) $m_1=m_2$ & eccentricity is 0 (Gravitational Potential energy)

$\rightarrow \overline{KE}=mv^2$ & $\bar{U}=-\frac{Gm_1m_2}{r_1+r_2}=-\frac{Gm^2}{2r}$, From Newton's 2nd Law: $F=ma=m\frac{v^2}{r}$

$\Rightarrow \frac{Gm^2}{(2r)^2}=\frac{mv^2}{r} \Rightarrow \frac{Gm^2}{4r^2}=\frac{mv^2}{r} \Rightarrow \frac{Gm^2}{2r}=\frac{2rmv^2}{r}=2\overline{KE}$ $\therefore \underline{\bar{U}=-2\overline{KE}}$

b) $\overline{KE}_T=\overline{KE}+\bar{U}=KE-2KE=-\overline{KE}$ $\therefore$ The $\overline{KE}_T$ is negative, thus decreases

c) $KE=KE+U=\frac{3}{2}kT-2KE=\frac{3}{2}kT-3kT=-\frac{3}{2}kT$ Since of star, multiple molecules $\therefore \underline{KE=-\frac{3}{2}NkT}$

$\rightarrow$ Heat Cap is defined as, $C=\frac{\partial U}{\partial T}$ (eq. 1.46) $=\frac{\partial KE}{\partial T}=-\frac{3}{2}Nk\,\partial T \Rightarrow \boxed{C=-\frac{3}{2}Nk}$

d) $J=N\cdot m \rightarrow \frac{Nm^2}{kg^2}\cdot\frac{kg^2}{m}=N\cdot m=J$, where $G=\frac{Nm^2}{kg^2}$, $m=kg$ & $R=m$

e) $KE=-\frac{3}{2}NkT=-\frac{Gm^2}{2r} \Rightarrow T=\frac{Gm^2}{3Nkr}=\frac{Gm}{3kr}\cdot\frac{m}{N}=\frac{Gm}{3kr}\cdot\mu$, $\mu$ is molar mass of proton, $=\frac{(6.67\times10^{-11}\frac{Nm^2}{kg^2})(2\times10^{30}kg)(1.67\times10^{-27}kg)}{3(1.38\times10^{-23}J/K)(7\times10^8m)}=\boxed{7.687\times10^6K}$

~ The book uses $\mu=\frac{\text{mass of proton}}{2}$, $=8.35\times10^{-28}kg$, but IDK why