70 points total assignment

problem set 2 solution

[

10 points total

1.23 He has 3 degrees of freedom (translation) 2 points: f = 3

so $U = 3N \frac{1}{2} kT = \frac{3}{2} PV$

3 points numerical U

for $P = 10^5\ N/m^2$ & $V = 10^{-3}\ m^3$, $PV = 100\ J \Rightarrow U = 150\ J$

2 points: f = 5

for air there are 5 degrees of freedom (3 translation & 2 rotation) $\Rightarrow U = \frac{5}{2} PV = 250\ J$ 3 points: numerical U

Schroeder 5 points total

1.29 The $5°C$ increase in tempurature requires an energy input of $\Delta U = 1 \frac{\text{cal}}{\text{g}\cdot°\text{C}} \times 5°\text{C} \times 200\text{g}$

5 points: ΔU = W+Q means you can't tell how energy is attributed to W and Q

$= 10^3$ cal

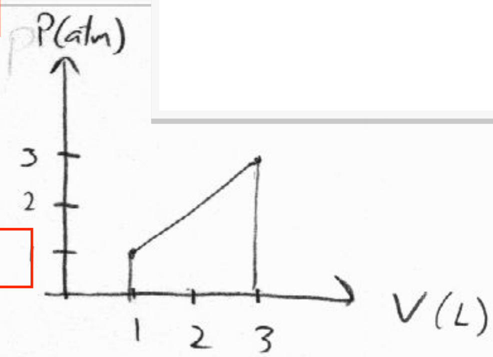
But $\Delta U = Q + W$. There's no way to know if ΔU was from heat, work, or both.

12 points total

1.31

a)

2 points



b) $W = -\text{Area} = -(10^5\,\text{Pa} \times 2\times 10^{-3}\,\text{m}^3) - \frac{1}{2}(2\times 10^5\,\text{Pa} \times 2\times 10^{-3}\,\text{m}^3)$

3 points

$= -400\,\text{J}$ < 0 so work done <u>by</u> gas on environment

c) He atom has 3 DOF, $U = \frac{3}{2}NkT = \frac{3}{2}PV$

3 points

$\Delta U = \frac{3}{2}\left[P_f V_f - P_i V_i\right] = \frac{3}{2}\left[3\,\text{atm}\cdot 3\,L - 1\,\text{atm}\cdot 1\,L\right]$

$= 12\ L\cdot\text{atm} = 1200\,\text{J}$

1.31 (cont.)

2 points

d) $Q = \Delta U - W = 1200\,J - (-400\,J) = 1600\,J$

this The heat <u>entering</u> the gas

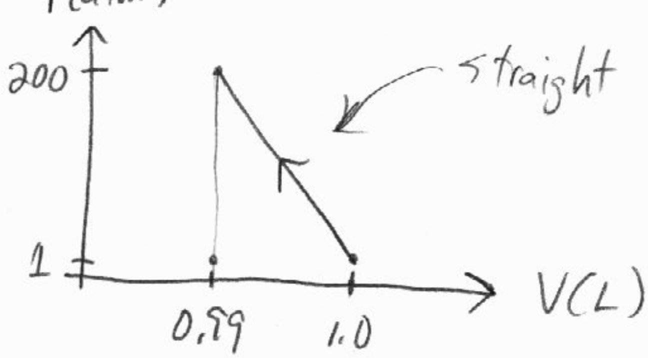
2 points

e) To cause an increase in P & T as the gas expands requires heat input.

1.32

7 points total

2 points



straight line is an approximation

3 points

$$W = \int -P\,dV = -(1\,atm)(-0.01\,L) - \tfrac{1}{2}(199\,atm)(-0.01\,L)$$

$$= -1.005\ atm\cdot L = 100\,J$$

or $W \hat{\approx} -\bar{P}\cdot\Delta V \approx -(100\,atm)(-0.01\,L) = 1\,atm\,L = 100\,J$

2 points

This isn't much - the same as lifting 10 kg by 1 m

That's because the water isn't very compressible, so ΔV is small.

1.36

10 points total

3 points

a) $P_f V_f^{\gamma} = P_i V_i^{\gamma} \rightarrow V_f = V_i \left(\frac{P_i}{P_f}\right)^{1/\gamma} = (1\,L)\left(\frac{1\,atm}{7\,atm}\right)^{5/7} = 0.25\,L$

$\gamma = \frac{f+2}{f} = \frac{7}{5}$ for air @ room temp

1.36 (cont.)

b) $P(V) = C/V^{\gamma} = P_i V_i^{\gamma} / V^{\gamma}$.

$$\rightarrow W = -\int P\,dV = -P_i V_i^{\gamma} \int_{V_i}^{V_f} V^{-\gamma}\,dV = -P_i V_i^{\gamma} \left(\frac{V^{1-\gamma}}{1-\gamma} \right) \Bigg|_{V_i}^{V_f}$$

4 points

$$= \frac{P_i V_i^{\gamma}}{1-\gamma} \left(\frac{1}{V_f^{1-\gamma}} - \frac{1}{V_i^{1-\gamma}} \right) = \frac{P_i V_i}{\gamma - 1} \left[\left(\frac{V_i}{V_f} \right)^{\gamma-1} - 1 \right]$$

$$= \frac{1\ L\cdot atm}{2/5} \left[4^{2/5} - 1 \right] = 1.853\ L\cdot atm = 185\ L$$

c) using equ. 1.39 $\quad T_f = T_i \left(\frac{V_i}{V_f} \right)^{2/f} = (300\,K) \left(\frac{1\,L}{0.25\,L} \right)^{2/5} \approx 522\,K$

3 points

1.38

6 points total

The bubbles have the same number of molecules & end with the same pressure. $\Rightarrow$ $V = NkT/p$ will be larger for the bubble with the higher T

$U = \frac{f}{2} NkT$, so higher $T \rightarrow$ larger U.

2 points

As bubbles expand the do work and lose energy.

2 points

B absorbs heat to maintain constant T

$\Rightarrow$ B has larger U, higher T, larger V.

2 points

(BTW, what lake has seaweed?)

6 points total

1.49

3 points

Ignore the volume of the liquid water which is << volume of the vapor

$$W = PV = nRT = (1.5\,mol)(8.31\,\tfrac{J}{mol \cdot K})(298\,K)$$

$$\approx 4\,kJ$$

3 points

out of 286 kJ of heat only 4 kJ is from work done by the atmosphere. The other 282 kJ is from the chemical bonds

1.55

14 points total

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

PE: $U_p = \frac{G m^2}{2r}$

a)

apply F=ma to one mass $\left[\frac{G m^2}{(2r)^2} = m \frac{v^2}{r}\right] \times 2r$

3 points

$$\rightarrow \frac{G m^2}{2r} = 2 m v^2 = 2 U_K$$

$$\rightarrow U_p = -2 U_K$$

b) $U_{tot} = U_K + U_p = U_K - 2U_K = -U_K$

2 points

$\Rightarrow$ increasing U_{tot} decreases U_K

increasing U_{tot} towards zero is towards $v = 0$ at $U_{tot} = 0$

c) $U_{tot} = -U_K = -\frac{3}{2} NkT$, $C = \frac{dU_{tot}}{dT} = -3/2\, Nk$

negative!

3 points

1.55 (cont.)

d) U_p should depend on G, M & R (radius of star)

$[G] = \frac{N m^2}{Kg^2}$ M & R are in fundamental units.

$[M] = Kg \quad [R] = m$

We must multiply G by powers of M & R to get energy, $[E] = \text{Length} \times \text{Force}$

want $\left[G\, M^a R^b\right] = N \cdot m \qquad \frac{N m^2}{Kg^2}\, Kg^a\, m^b = N \cdot m$

3 points

$\rightarrow a = 2, \; b = -1$

So $U_p \propto G\, M^2/R$ & $U_p < 0$ to be attractive.

e) $U_K = \frac{3}{2} NkT$, using this plus the fact that $U_K = -\frac{1}{2} U_p$ we get $\frac{3}{2} NkT \approx -\frac{1}{2}\left(-\frac{GM^2}{r}\right) = \frac{2GM^2}{2R}$

3 points

$$\rightarrow T \approx \frac{GM^2}{3NkR} = \frac{GM}{3kR} \cdot \underbrace{\frac{M}{N}}_{\text{mass per particle}}$$

1.55
(cont.)

$\frac{M}{N}$ = mass per particle $\approx \frac{1}{2}(m_{proton} + m_{electron}) \approx \frac{1}{2} m_{proton}$

$\rightarrow T \approx 4 \times 10^6$ K

This is much higher than the $T \approx 6000$K of the Sun's surface. The core of the sun is $T \approx 10^7$ K, which is closer

2 points