Physics 301

Homework due 21 September 2022

1) Stowe problem 7-6.

2) Stowe problem 7-9. Express your answer as a power of 10.

3) Stowe problem 7-12.

4) Stowe problem 8-3.

5) Stowe problem 8-18.

Physics 501

Answers to homework due 21 Sept 2022

(1) $m = 4.8 \times 10^{-26}$ kg

$V_r = 360\ m^3$

a) $\langle v \rangle = 300$ m/s

$$p = m\langle v \rangle = \left(4.8 \times 10^{-26}\ kg\right)\left(300\ \frac{m}{s}\right) = \boxed{1.44 \times 10^{-23}\ \frac{kg\ m}{s}}$$

b) $p_0 = 2m\langle v \rangle = 2.88 \times 10^{-23}\ \frac{kg\ m}{s}$

$$\text{Number of states} = \frac{V_p \cdot V_r}{h^3}$$

$$= \frac{\frac{4}{3}\pi p_0^3 \cdot V_r}{h^3}$$

$$= \frac{\frac{4}{3} \cdot \pi \left(2.88 \times 10^{-23}\ kg\ \frac{m}{s}\right)^3 \left(360\ m^3\right)}{\left(6.63 \times 10^{-34}\ J\text{-}s\right)^3}$$

$$= \boxed{1.24 \times 10^{35}}$$

c) $T = \frac{1}{2} m v^2$

$$= \frac{1}{2}\left(4.8 \times 10^{-26}\ kg\right)\left(300\ \frac{m}{s}\right)^2 = \boxed{2.16 \times 10^{-21}\ J}$$

d) $T_T = T \cdot N = \left(2.16 \times 10^{-21}\ J\right)\left(10^{28}\right) = \boxed{2.16 \times 10^{7}\ J}$

e) $V_p = \frac{4}{3}\pi p_0^3$

$$\frac{V_r V_p}{h^3} = 1$$

$$p_0 = \left(\frac{3 V_p}{4\pi}\right)^{1/3} = \left(\frac{3 h^3}{4\pi V_r}\right)^{1/3} = \left[\frac{3\left(6.63 \times 10^{-34}\ J\text{-}s\right)^3}{4\pi\ 360\ m^3}\right]^{1/3}$$

$$= \boxed{5.78 \times 10^{-35}\ \frac{kg\ m}{s}}$$

f) $T_0 = \frac{p_1^2}{2m} = \left(5.78\times10^{-35}\ kg\ m/s\right)^2 \cdot \frac{1}{2(4.8\times10^{-26}\ kg)}$

$$= \boxed{3.48\times10^{-44}\ J}$$

g) fraction $= \frac{3.48\times10^{-44}\ J}{2.16\times10^{7}\ J} = \boxed{1.6\times10^{51}}$

(2) Using Stowe Eq. 7.4,

$$\Omega_o = \prod_{i=1}^{N} \Omega_i$$

Here $N = 5$ and each $\Omega_i = 6$ (# faces)

So $\Omega_o = 6^5 = 7776$

Let $7776 = 10^x$, so

$$x = \log_{10}(7776) = 3.89$$

$$\boxed{\Omega_o = 10^{3.89} = 7776}$$

3) a) 1 cup is about 0.25 liter, or 250 g

$$\# \text{molecules} = \frac{6.02\times10^{23}}{\text{mole}} \times \frac{1\,\text{mole}}{18\,\text{g}} \times 250\,\text{g} = \boxed{8.4\times10^{24}}$$

b) 3 translational + 3 rotational $= \boxed{6}$

c) Kelvin = °Celsius + 273.15

Room temperature $\approx 25°C \cong 298\,K$

Boiling $= 100°C = 373\,K$

$E \propto kT$ so

fractional change in $E \propto$ fractional change in T

$$= \left(\frac{373}{298}\right) = \boxed{1.25}$$

d) $g(E) \propto E^{N/2}$ $\quad N = 6 \times 8.4\times10^{24} = 5.04\times10^{25}$

$$\frac{g(E(T=373))}{g(E(T=298))} = (1.25)^{5.04\times10^{25}/2} = (1.25)^{2.52\times10^{25}} = (1.75)^{10^{25}}$$

$$1.75 = 10^n$$

$$n = \log_{10}(1.75) = 0.244$$

$$= 10^{0.244\times10^{25}}$$

$$= \boxed{10^{2.4\times10^{24}}}$$

4) a)

E_1 $(N_1=4)$	E_2 $(N_2=5)$	E_3 $(N_3=6)$	$\Omega_1=E_1^{N_1/2}$	$\Omega_2=E_2^{N_2/2}$	$\Omega_3=E_3^{N_3/2}$	$\Omega_T=\Omega_1\cdot\Omega_2\cdot\Omega_3$
0	4	0	0	32	0	0
0	3	1	0	15.59	1	0
0	2	2	0	5.66	8	0
0	1	3	0	1	27	0
0	0	4	0	0	64	0
1	3	0	1	15.59	0	0
1	2	1	1	5.66	1	5.66
1	1	2	1	1	8	8
1	0	3	1	0	27	0
2	2	0	4	5.66	0	0
2	1	1	4	1	1	4
2	0	2	4	0	8	0
3	1	0	9	1	0	0
3	0	1	9	0	1	0
4	0	0	16	0	0	0
					TOTAL	17.66

b) most probable = $\boxed{(E_1=1,\ E_2=1,\ E_3=2)}$

Its probability is $\frac{8}{17.66} = \boxed{0.453}$

5 a) $\Omega_0 = \prod_{i=1}^{5} \Omega_i = (1)\cdot(2)\cdot(3)\cdot(4)\cdot(5) = \boxed{120}$

b) In general, $S_i = k \ln \Omega_i$; so

$S_1 = k \ln 1 = 0$
$S_2 = k \ln 2 = 0.693k$
$S_3 = k \ln 3 = 1.099k$
$S_4 = k \ln 4 = 1.386k$
$S_5 = k \ln 5 = 1.609k$

c) $S_0 = k \ln \Omega_0 = k \ln 120 = 4.787k$

—or—

$S_0 = \sum_{i=1}^{5} S_i = 4.787k$