

PROBLEM SET 6

Show **ALL WORK** to get full/partial credit. Begin each problem on a new page, and clearly label each part of the problem.

1) (5 pts) TextProblem 6.5

2) (10 pts) A system has three non-degenerate energy levels with energies 0, ϵ , and 2ϵ .

(*hint*: Set up similar to problem 6 of HW set 5. How many ways (microstates) can the particles populate the 3 energy levels such that the total energy is 2ϵ , then the entropy can be easily calculated)

a) Calculate the entropy of the system if the three levels are populated by two distinguishable particles such that the total energy is $U=2\epsilon$.

b) Calculate the entropy of the system if the three levels are populated by three distinguishable particles such that the total energy is $U=2\epsilon$.

3) (5 pts) TextProblem 6.12

(*hint*: Think of ratio of probability between 1st excited state and ground state, and note that 1st excited state has 3 degenerate states with the same energy. Also, note that the energy given is really a difference between 1st and ground)

4) (5 pts) TextProblem 6.13

(*hint*: Think of ratio of probabilities as the ratio of $P_{\text{neutron}}/P_{\text{proton}}$, you are also told how to calculate the total energy difference. Also keep in mind that $P_{\text{neutron}} + P_{\text{proton}} = 1$)

5) (25 pts) Consider a system with two non-degenerate energy levels with energies $\epsilon_1 = 0$ and $\epsilon_2 = \epsilon$. Suppose that the system contains N distinguishable particles at temperature T .

a) Determine the partition function of the system and the occupancies N_1 and N_2 of the two levels.

b) Find the average energy per particle given by $\langle u \rangle = U/N$, where U is the total internal energy of the system and N the total number of particles.

c) Show that at very small temperatures, $\langle u \rangle \approx \epsilon e^{-\alpha}$, where $\alpha = \frac{\epsilon}{k_B T}$,
and that as the temperature becomes very large, $\langle u \rangle \rightarrow \frac{1}{2}\epsilon$

d) Show that the volume heat capacity per particle is given by
 $C/N = k_B \alpha^2 e^{-\alpha} / (1 + e^{-\alpha})^2$

6) **(20 pts) Text Problem 6.31** – to perform the required integrals, make a change of variable and then carry out an integration by parts.

7) **(5 pts) Text Problem 6.33** – evaluate the requested quantities at $T = 20^\circ \text{C}$. (*Hint: Careful with the units, convert to K first*)

8) **(5 pts)** Calculate the average energy (in eV) and rms velocity of an electron at the temperatures $T_1 = 10^3 \text{ K}$ and $T_2 = 10^5 \text{ K}$

9) **(20 pts)** Suppose that instead of the Maxwell-Boltzmann distribution, the distribution of molecular speeds in a gas was given by the expression $N(v) = A v e^{-v/v_0}$, where A and v_0 are constants.

a) Determine the constant A so that the total number of molecules in the gas is N .

b) In terms of v_0 , find the average speed, the rms speed, and the most likely speed of the molecules in the gas.