Physics 4311: Thermal Physics - Homework 2

due date: Tuesday, Feb 11, 2025, please upload your solution as a pdf on Canvas

Problem 1: Boltzmann factors (10 points)

a) Compute the characteristic thermal energy $k_B T$ at room temperature.

b) Convert the result to electronvolts (eV)

c) The dissociation (binding) energy of a hydrogen molecule is about $4.5\,\text{eV}$. Do you expect hydrogen molecules to be appreciably dissociated at room temperature?

d) Estimate the temperature at which hydrogen molecules start dissociating appreciably!

e) Do you expect the rotational energy levels of a diatomic molecule to be excited at room temperature? (The excitation energies are about 10^{-4} eV.)

Problem 2: Impurity in solid (30 points)

An impurity atom in a solid can occupy two different lattice positions. In the first position, it has an energy $E_1 = \epsilon$. In the second position, its energy is $E_2 = 2\epsilon$. The solid and impurity are in thermal equilibrium at temperature T.

a) Compute the probability for the impurity atom to be in position 1.

b) Compute the probability for the impurity atom to be in position 2.

c) What is the average energy $\langle E \rangle$ of the impurity atom as function of the temperature?

d) Determine the limiting values of $\langle E \rangle$ for $T \to 0$ and $T \to \infty$.

e) Compute the heat capacity $C = d\langle E \rangle / dT$ as function of T.

f) Determine the limiting values of C for $T \to 0$ and $T \to \infty$.

g) Find the maximum of C. (This is called the Schottky anomaly.)

h) Sketch or plot the $\langle E \rangle$ vs. T and C vs. T curves. Qualitative hand sketches are OK, but they should reflect the features you found in parts d), f), and g).