Final Exam

P555

May 10, 2022

SHOW ALL YOUR WORK TO GET FULL CREDIT!

Submit a pdf file with your work not later than May 14 at 11:59PM.

Problem 1: In the periodic table we see that the Te atom has an electronic structure given by $4d^{10}5s^25p^4$.

a) Use Hund rules to obtain S, L, and J for the ground state of the Te atom. Draw the energy levels in the relevant shells and indicate the electronic placement. Provide your final result using spectroscopic notation: ${}^{2S+1}L_J$. (5 points)

b) What is the degeneracy of the ground state of Te? (5 points)

c) Calculate the Landé factor g for the Te atom. (5 points)

d) What is the energy splitting ΔE linear in the magnetic field B for the ground state of a Te atom placed in a magnetic field B? Provide the energy of each energy level as a function of B. (5 points)

e) What is the magnetization $\mathbf{M}$ of a sample of Te that contains N atoms in a volume V? (5 points)

f) Provide the value of the magnetization $\mathbf{M}$ calculated in (e) when $kT \gg \mu_B B$ and when $kT \ll \mu_B B$. (5 points)

Problem 2: In the second midterm you found that in a two-dimensional solid made of N atoms with one atom at each point of the Bravais lattice, the phonon density of states in the Einstein approximation is given by

$$D_E(\omega) = \frac{2N}{A}\delta(\omega - \omega_E), \tag{1}$$

where ω_E is the Einstein frequency and A is the area of the sample, while in the Debye approximation the phonon density of states is given by

$$D_D(\omega) = \frac{\omega}{\pi c^2}\Theta(\omega - \omega_D), \tag{2}$$

where c is the angular average of the speed of sound in the material and Θ is the Heaviside function.

a) Calculate the heat capacity C_E of the material in the Einstein approximation. (5 points)

b) Provide an expression for C_E when $T \to \infty$ and when $T \to 0$. (5 points)

c) Calculate the heat capacity C_D of the material in the Debye approximation. (5 points)

d) Provide an expression for C_D when $T \to \infty$ and when $T \to 0$. (5 points)