Physics 555	Fall 2007	HW 5

Due Wednesday October 24 (note: midterm exam is Friday October 26)

1. Curie Law. The figure is from S. Arajs and R. V. Colvin, J. Appl. Phys. **33**, 2517 (1962). Gd^{3+} has a $4f^7$ configuration, with approximately 7 Bohr magnetons of moment per ion. The data agree fairly well with the Curie Law. Derive the Curie Law.

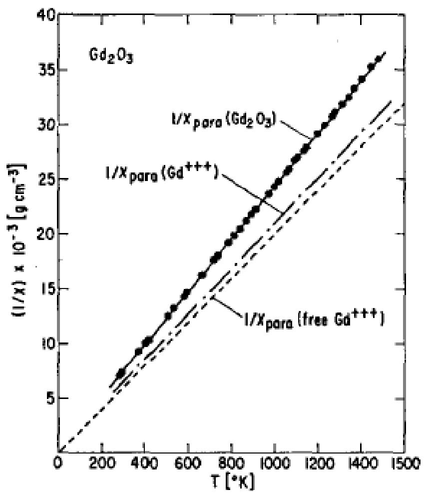
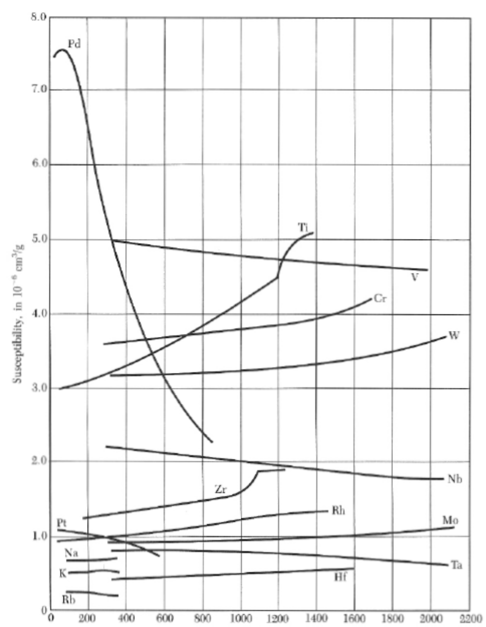


FIG. 1. Inverse magnetic susceptibility of Gd_2O_3 as a function of temperature.

2. The Curie law should work only when spins on neighboring ions don't interact. Quantum mechanics allows a strong exchange interaction which is apparently not important in Gd_2O_3. But there must always be a dipole-dipole classical interaction. As an estimate of the temperature below which the Curie law should fail, calculate the optimum attractive energy of (dipole-dipole) interaction of two Gd moments on nearest neighbor sites in Gd_2O_3. Estimate the spacing from the density $\rho = 8.33$ g/cm^3.

3. In metals with weak exchange interactions between spins, the susceptibility (as explained by Pauli) is smaller than the Curie law by the small factor $\sim k_BT/E_F$. Derive the Pauli susceptibility. Assume an ordinary metal with a density of states D(E) which varies slowly with E on a scale of k_BT.

4. Aluminum metal has a Pauli susceptibility which is quite close to the free electron value. Suppose you put a gram of Al near a strong magnet, in a region with B = 1 T and dB/dx = 100 T/m. How large is the force (compared with mg, for example.)? You may use the free electron approximation.



Note: The figure to the right is from C. Kittel, *Introduction to Solid State Physics* (6th edition, Ch 14 – J.Wiley & Sons, 1986). It shows the susceptibility of various metals to rather high T, with some mild deviations from the *T*-independent Pauli form, except for Pd which deviates fairly strongly. It is not accidental that Pd also has the largest low *T* value.