Homework 1

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1 Hund's rule and magnetic exchange as a result of Coulomb interactions

1.1 Why Coulomb interaction is stronger than magnetic dipole coupling?

1.2 The atomic ground state configuration of Cr^{3+}, Fe^{3+} and Gd^{3+}

The Hund's rules have their root in L-S coupling. After the occupation of each electron shell is determined, we apply the following rules one by one:

1. For each electron shell, make the total spin as large as possible.
2. After the total spin is determined, make the total orbital angular momentum as large as possible.
3. When S and L are already determined, if the shell is not yet half-filled, take $J = L + S$; otherwise $J = |L - S|$.
4. Now S, L, and J are all decided, and the Landé g-factor is

$$g_J = \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)}, \tag{1}$$

   and the total magnetic momentum is

$$\boldsymbol{\mu} = -g_J \mu_B \boldsymbol{J}, \tag{2}$$

   where $\hbar\boldsymbol{J}$ is the total angular momentum.

So for

2 Landau diamagnetism and Pauli paramagnetism

2.1 The physical origins of various magnetic responses in a solid

Pauli paramagnetism comes from the spin-magnetic field coupling: the external magnetic field splits the spin-↑ band and the spin-↓ band. Since the Fermi energy in the two bands is the same, when, say, the magnetic field is upward, we have less spin-↑ electrons than spin-↓ electrons, and we have an overall downward spin and therefore an overall upward magnetic moment, so there is a paramagnetic response.

Landau diamagnetism comes from the orbital angular momentum-magnetic field coupling.