Quantum Physics (II): Homework 7
Due: June 4, 2021

Ex.1 10% List the spectroscopic states (in the form ${}^{2S+1}L_J$) that can arise from combining (1) $S = 1/2, L = 3$ (2)$S = 2, L = 1$ (3)$S_1 = 1/2$, $S_2 = 1$, $L = 4$ (4) $S_1 = 1, S_2 = 1, L = 3$. Which states are excluded, among the two-spin questions, if the particles are identical?

Ex.2 10%Consider the following states ${}^1D$, ${}^2P$, ${}^4F$, ${}^3G$, ${}^2D$, ${}^3H$. What are possible J values associated with each?

Ex.3 10%Consider the states ${}^1D$, ${}^3P$, ${}^3S$, ${}^5G$, ${}^5P$, ${}^3H$. Given that in each one the state consists of two identical particles in their largest possible spin state, which of the states are disallowed by the exclusion principle?

Ex.4 10% Use Hund's rules to find the spectroscopic description of the ground states of the following atoms: $N(Z = 7)$, $K(Z = 19)$, $Sc(Z = 21)$, $Co(Z = 27)$. Figure out the electronic configurations as far as you are able to.

Ex.5 8%Consider the following electron configurations of the helium atom: $(1s)^2$, (1s)(2s), (1s)(3d), and $(2p)^2$. Find the corresponding possible states of the helium atom using the spectroscopic notation ${}^{2S+1}L_J$.

Ex.6 Consider an atom with Z electrons. Suppose that we want to model this atom without considering the Pauli exclusion principle. It is then reasonable to assume that all electrons are in the same single particle state. In this single particle state, the average distance between the neucleus and the electron is R. Furthermore, by using the uncertain principle, $p = \Delta p = \hbar/R$, one can express the kinetic energy in terms of R. In addition to the above interaction, there are Coulomb repulsions between electrons so that we can assume the average distance between any two electrons is fR, where f is an electron-electron avoidance parameter. **(a)5%**Find the total energy of this atom in terms of f, R and Z. **(b)5%**By minimizing the total energy with respect to R, express the ground state energy of this atom in terms of Z and the ground state energy (ε_0)of the hydrogen atom. **(c)8%**It is found that the ground state energy of the Helium atom is $5.8\varepsilon_0$. From this, find f and calculate the ionization energy (the energy for removing one electron from the atom) in terms of Z and ε_0. Does it agree with experimental data? Note that there are two solutions for f, which one should be chosen? why?