Atomic Physics I 80301 Exam II Nov. 4, 2005

Return exam in class on Nov. 7

1. Low-lying states of Mg are linear combinations of product states formed from $3s$, $3p$ and $3d$ orbitals. In jj coupling the orbitals $(nl_j\, n'l'_{j'})$ are coupled to form states of angular momentum J such as $(3s_{1/2}3p_{3/2})[1]$ while in LS coupling, the orbitals $(nl\sigma\, n'l'\sigma')$ are coupled to form states such as $(3p)^2\ {}^3P$. Give the spectroscopic designation of all possible low-lying *even parity* states in the jj and LS coupling schemes. Show that the total number of jj and LS states (including magnetic substates) is identical.

2. Evaluate the *excitation* energies of the $(1s2p)^1P$ and $(1s2p)^3P$ states of heliumlike boron ($Z = 5$). Assume that the $1s$ and $2p$ states are described by Coulomb wave functions with $Z_{\text{eff}} = (Z-5/16)$ and $Z-1$, respectively. Compare your calculated energies with values from the NIST website.

3. Determine the lifetime of the $(1s2p)^1P$ state of heliumlike boron using the approximate Coulomb wave functions of Prob.(**??**) and NIST wavelengths (Experimental lifetime: 2.69×10^{-12} s.)

4. Determine the dominant decay mode (E1, M1, E2), the decay channels ($I \to F$), and the wavelengths in Å of transitions from each of the following initial states I.

   (a) H $3p$ state

   (b) Al^{2+} $3p$ (Na-like) state

   (c) Al $3p_{3/2}$ state

   (d) Ba^{+} $5d_{3/2}$ state

   You can determine wavelengths from the NIST database or from the tables *Atomic Energy Levels NSRDS-NBS 35* on reserve in the physics-chemistry library.

5. Prove that following states are stable against single-photon decay in the non-relativistic approximation: H $2s$ state, He $(1s2s)\ {}^1S_0$ state, He $(1s2s)\ {}^3S_1$ state.