1. Low-lying states of Mg are linear combinations of product states formed from \(3s\), \(3p\) and \(3d\) orbitals. In \(jj\) coupling the orbitals \((nlj n'l'j')\) 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 \textit{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 \textit{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: \(2.69 \times 10^{-12}\) s.)

4. Determine the dominant decay mode (E1, M1, E2), the decay channels \((I \rightarrow F)\), and the wavelengths in Å of transitions from each of the following initial states \(I\).
   
   (a) H 3\(p\) state
   (b) Al\(^{2+}\) 3\(p\) (Na-like) state
   (c) Al 3\(p_{3/2}\) state
   (d) Ba\(^+\) 5\(d_{3/2}\) state

   You can determine wavelengths from the NIST database or from the tables \textit{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 2\(s\) state, He \((1s2s)^1S_0\) state, He \((1s2s)^3S_1\) state.