Conceptual Questions Week 6

Oktober 6 2022

1. **Argue why the angular momentum's quantum number m_l can not effect the atom's emission spectrum.**
   Due to spherical symmetry m_l does not appear in H and thus the eigenvalues are independent of m_l.

$$(-\frac{\hbar^2}{2m_e}\frac{d^2}{dr^2} + V(r) - \frac{\hbar^2 l(l+1)}{2m_e r^2}\Big)u_{nl}(r) = E_{nl}\ u_{nl}(r) \tag{1}$$

   Does your reasoning under 1) also apply to the quantum number l? (Spoiler alert: see section 6.3 (2ed) or 7.3 (3ed) of the book, if you look closely enough at the spectral lines of atoms you will find they show very small differences.)
   We can introduce terms in the Hamiltonian for (hyper)fine-splitting

2. **Does applying both the raising and lowering operator to a state (in either order) result in the same state it was applied to? Think of a case where the difference between both outcomes is stark.** Only when you are not applying the raising (lowering) to the highest (lowest) states, do you return to the same state with some constants in front.

3. **What kind of process can change the angular momentum of the state an electron by one unit? And what can change its spin by a unit?**
   Emission of a photon from an excited state is accompanied by $\Delta l = \pm 1$ and $\Delta m = 0, \pm 1$.

4. **Which state is an eigenstate with respect to all three Cartesian components of angular momentum - is this possible?**
   The $l = 0$ case can be in an eigenstate of all L_i simultaneously without causing problems with the uncertainty principle, as all components vanish.

$$\sigma_{L_i}\sigma_{L_j} \geq \frac{\hbar}{2}\left|\langle L_k \rangle\right| \tag{2}$$

5. **A Deuterium atom is Hydrogen with one extra neutron. What is the total angular momentum of this system when the electron is in the ground state? Use both the arrow and number notation to express this. (You only have to consider the spin and the electron's angular momentum for this and the next question. You can find information on the notations in Chapter 4.4 of the book.)**

6. **When the electron is excited to the next energy level, what values can the total angular momentum of the system now take?**

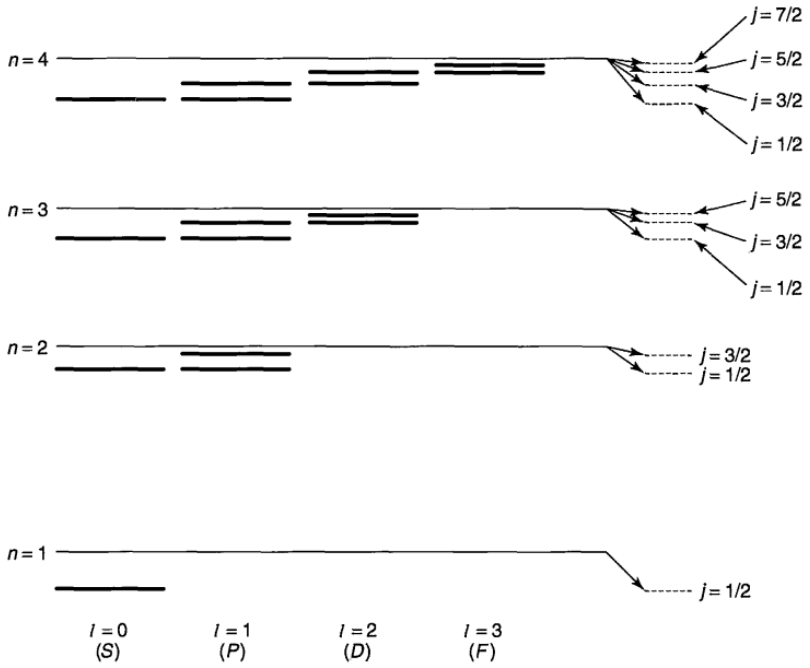

FIGURE 6.9: Energy levels of hydrogen, including fine structure (not to scale).

Figure 1: Fine structure of Hydrogen