Physics 222 CID ____________

Homework 14

Score ________ / 30

1. (2 pts) Write down the multiplicity of the following spectroscopic terms: (a) $^1S_0$, (b) $^3P_1$, (c) $^3P_0$.

2. (3 pts) Consider a lithium ($Z = 3$) atom in a $^2P_{3/2}$ state. What are the possible electron configurations for which no electron is in a level with $n > 2$?

For the next three problems, we will consider a real-life application. In our lab we are using a "forbidden" transition in calcium to make an atom interferometer/atomic clock. Forbidden transitions are harder to drive, but they can have narrower linewidths (since the excited state can live for a long time). In these problems we will look at this forbidden transition. Before working these problems, skim the appendix to chapter 7, and note the LS selection rules. Also note that there is an additional selection rule not mentioned in the text - you can only make dipole allowed transitions between states of opposite parity (i.e. from an even to an odd or from an odd to an even). But to make our lives simple, for this class we will not worry about parity. We will pretend that we never heard of it. But I wanted to mention it because it will be important if you actually go and do experiments with real atoms some day.

3. (4 pts) What is the electron configuration and the spectroscopic term for the ground state of calcium?

4. (4 pts) Consider a calcium atom with an electron configuration which is the ground configuration of Argon plus $4s4p$. (a) What are the possible spectroscopic terms for this configuration? (Ignore parity because we haven't discussed how to find it.)

5. (5 pts) (a) Which of the terms that you found in the last problem can make a dipole-allowed transition to the ground state? (b) Remember that the three contributions to fine structure (spin-orbit coupling, a relativistic kinetic energy correction, and the "Darwin" term that accounts for other relativistic effects) result in states with lower j having lower energies. Which of the triplet states has the lowest energy? (c) In our experiment we are using an intercombination transition. This is one in which all of the selection rules are obeyed except that $\Delta s = \pm 1$. The transition we use is between the ground state and one of the terms you found in the last problem. Which one?

The rest of this assignment should be fairly easy, but the book kind of fell short in this chapter so you may need some help if you haven't seen this before. We will cover what you need to know in class, and you will be able to get help from the T.A. and from myself.

6. (3 pts) Use the table of electron configurations in table 7.4 or the periodic table to figure out what type of bonding (ionic or covalent) you would expect would be dominant in the following molecules: (a) FrCl, (b) N_2, (c) CH_4

7. (6 pts) (a) draw a sketch of the ground and first excited states of a system of two finite square wells which are separated by a long distance. (b) Now do the same sketch for two square wells which are close together. (c) Now do the same sketch for two square wells which are just touching to form a single well which is twice as wide as a single well.

8. (3 pts) In your own words, explain covalent bonding and "anti-bonding" occurs in terms of how "bent up" the wave functions are compared to the wave functions of a single isolated wells.

Extra problems I recommend you work (not to be turned in)

- Write down all of the possible spectroscopic terms for an atom with the following electron configurations: (a) $1s^2 2s^2 2p^6 3s^1$ (b) $1s^2 2s^2 2p^5 3s^1$ (c) $1s^2 2s^2 2p^4 3s^2$.
- Figure out what the ground state electron configuration and the ground state spectroscopic terms are for C, N, Ar, and Mg. Then check your answers at http://physics.nist.gov/PhysRefData/ASD/levels_form.html.

- Draw the ground and first *five* excited states for a system of two finite square wells which are close together. Describe how the energies of these energy eigenstates compare to the energies of a single finite square well.

- Draw the ground state and first two excited states for a system of three finite square wells in a line. Compare the energies of the three states to the ground state energy of a single finite square well.