Physics 3315 Exam 2 03/09/2000

(Show your work on attached sheets.)

Student Name:
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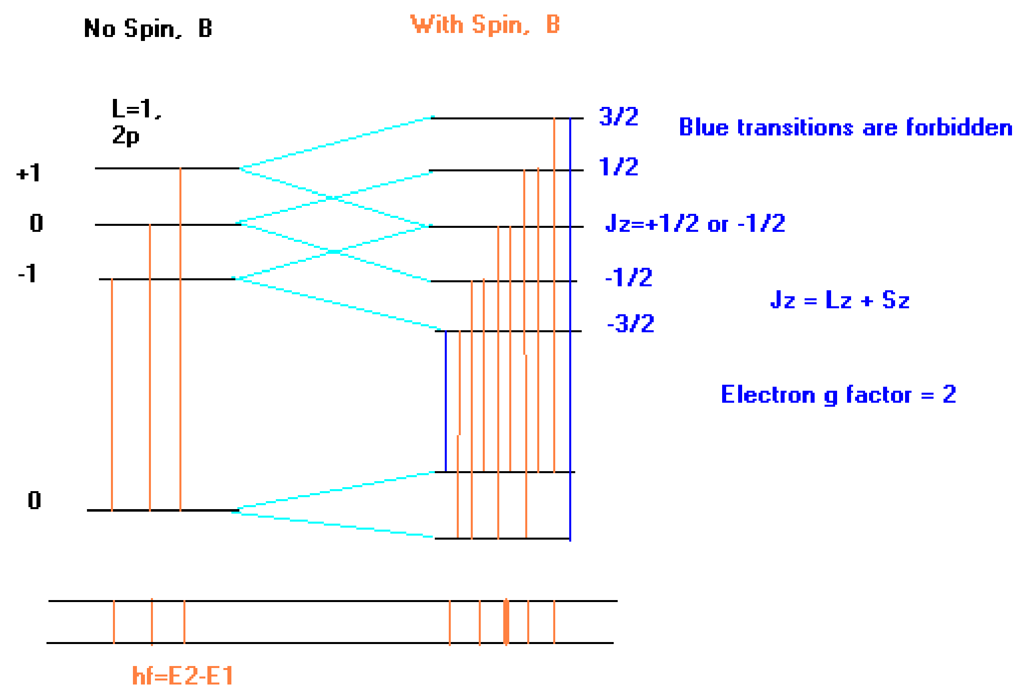
$m_e = 0.511 Mev$
$c = 3 \times 10^8$ m/s
hc = 1240 eV nm
e = 1.6 x 10^{-19} *Coulombs*
$E_{0hydrogen} = 13.68 eV$

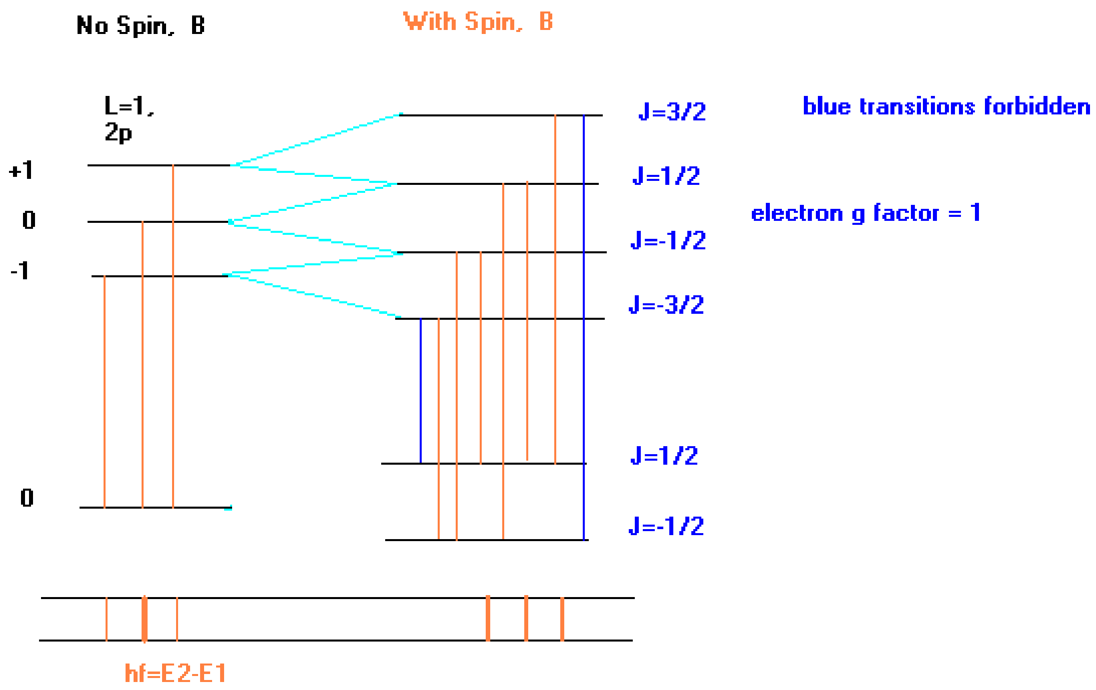
Problem 1

Compute the wavelengths of the 2p-1s transitions (including spin) in hydrogen when placed in a 3 Tesla B field.

Make an energy level diagram to describe the processes. The followiing diagram is based on the assumption that the g factor for the electron spin is 1/2. The magnetic energy is
$-\mu \circ B = (e/2m)(Lz + gSz)B$



The following diagram wold hold if the g factor for the electron were 1.



The transitions with zero B correspond to the energy difference between the n=2 and n=1 states E2-E1=$13.6 \times 3/4 = 10.2$ eV

The effect of the magnetic field is to add small energy increments due to the interaction of the magnetic moment and the orienting B field. The magnetic Energy split between neighboring lines is of the order of $-\mu \circ B = (e/2m)(Lz + gSz)B \approx (9.27 \times 10^{-24})(3) = 2.781 \times 10^{-23} Joules = 2.781 \times 10^{-23}/(1.6 \times 10^{-19}) = 1.7381 \times 10^{-4}$ eV.

Note that this magnetic energy shift (times 0,$\pm$1,$\pm$2) is very small compared to the energy difference between the states 2p and 1s.

Problem 2

Consider a carbon atom (Z=6) that has been stripped of all but 1 electron.

(a) What frequency is required to strip the last electron and completely ionize the atom?

Use the Bohr formula $E = 13.6(Z^2) = 13.6 \times 36 = 489.6$ eV

$f = Ec/hc = 489.6 \times 3 \times 10^8/(1240 \times 10^{-9}) = 1.1845 \times 10^{17}$ hertz

(b) What is the frequency of radiation require to raise an electron from the ground state to the second excited state?

Use the Bohr formula again n=1 to n=3

$E = 13.6(Z^2)(1/1 - 1/9) = 13.6 \times 36 \times 8/9 = 435.2$ eV

$f = Ec/hc = 435.2 \times 3 \times 10^8/(1240 \times 10^{-9}) = 1.0529 \times 10^{17}$ Hertz

Problem 3

Find the total orbital and spin quantum numbers for Nitrogen (Z=7).

Nitrogen has three 2p electrons each with l=1 outside of closed subshells. All 3 electrons cannot exist in the l=2 state, but 2 can (spin up and spin down) hence L=2,1,0. The spin quantum numbers can range from when all 3 electrons have parallel spins (3/2) to when two have spin up and the other has spin down. What you have to do is place 3 electrons in the triplet p state levels= 1,0,-1 levels spin up and spin down and use the Pauli principle that each electron must have a different quantum number.

Three electrons cannot coexist in any of the p state levels, so that L = l1 + l2 + l3 = 3 is excluded by the Pauli principle. The possibilities turn out to be $\{L = \pm 2, S = \pm 1/2\}, \{L = \pm 1, S = \pm 1/2\}, L = \{0, S = \pm 3/2, \pm 1/2\}$

Anothe way is to enumerate the possibilities: Take three electrons and put 2 spin up and spin down in the top of the triplet level. Put the third electorn spin up or spin down in the middle triplet level, or in the lower triplet level (4 possibilities). Next put the pair in the middle level and try all combinations in the other levels (4 more possibilites). Finally put the pair in the lower level and the third in other combinations (4 more possibilities). The try all combinations of three electrons, 1 in each of the p levels.

Then add up the ml and ms to obtain the L and the S possibilities.

The Hund rules give the Ground State configuration - not all possibilites.

Problem 4

In three dimensions, discuss the meaning of deneracies, and discuss the degeneracy differences between the hydrogen atom, and the three dimensional square well.

Degeneracies are when there is more than one configuration state for a given energy. The ground state is not degenerate. Excited states are often degenerate. Interactions with the evironment often ”remove” the degeneracies by introducing a spread in the energy eigenvalues due to the ineraction. The classic example is the Zeeman splitting of an atom in a magnetic field.

In the 3D square well, the energy states are given by the formula

$E(nx, ny, nz) = Const\{(nx)^2 + (ny)^2 + (nz)^2\}$. Choose various integer values for nx, ny, nz to determine E.

Then count the number of permutation possibilities to give the number of degeneracies. For example, E(1,1,2)=E(1,2,1)=E(2,1,1) all have the same energies. The degenerac is 3 for this energy state.

In the Bohr formula (mod spin) the energy levels are given by the formulas

$E(n, l, m_l) = Const(1/n^2)$

with 1+(2l+1)+... (2(n-1)+1) degeneracies due to different angular momentum configurations.

The lowest energy state in the H atom has l=0, n=1, no degeneracies.. E = const $1/n^2$

The first excited state in the Square well has nx=2,ny=1,nz=1, or nz=1 with three permutations giving

E=Const 6.

The first excited state in hydrogen has n=2, but an l=0 state and 3 l=1 states for a total of 4 degeneracies.

The second excited state in hydrogen has n=3, but an l=0 state, 3 l=1 states, and 5 l=2 states for a total of 9 degeneracies..