Worksheet 9 Solutions

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1. (a) Consider helium in its ground electronic state. In what orbital will the electrons be found?
   The electrons are found in the $1s$ orbital.

   (b) What is the value of hte principle quantum number, n, for these electrons?
   $n = 1$

   (c) What is the value of the angular quantum number, l, for these electrons?
   $l = 0$

   (d) What is the value of the magnetic quantum number, m_l, for these electrons?
   $m_l = 0$

   (e) What is the value of the spin quantum number, m_s, for these electrons?
   $m_s = \frac{1}{2}, -\frac{1}{2}$

He: $1s^2$

Quantum Number	Electron 1	Electron 2	Total	
l	0	0	0	
m_l	0	0	0	M_L
m_s	$\frac{1}{2}$	$-\frac{1}{2}$	0	M_S

   (f) If we promote one electron in helium to an excited state, what will be the values of the four quantum numbers for the two electrons? $n = 1, 2$ $l = 0, 1$

Excited He: $1s^1 2s^1$

Quantum Number	Electron 1	Electron 2	Total	
l	0	0	0	
m_l	0	0	0	M_L
m_s	$\frac{1}{2}$	$\frac{1}{2}$	1	M_S
m_s	$\frac{1}{2}$	$-\frac{1}{2}$	0	M_S

   (g) What atomic states arise from this configuration?
   $^1S_0$, $^3S_1$

2. (a) What is the electron configuration of boron in its ground state?
   $1s^2 2s^2 2p^1$

   (b) Which electrons contribute to the boron atom states?
   $2p^1$

   (c) What are the atomic states arising from the boron ground state?
   $^2P_{\frac{1}{2}}$, $^2P_{\frac{2}{3}}$

3. (a) What is the electron configuration of fluorine in its ground state? $1s^2 2s^2 p^5$
   (b) Which electrons contribute to the fluorine atomic states? **If we use the missing electrons when the shell is over half-filled,** $2p^1$
   (c) What are the atomic states arising from the fluorine ground state?
   They are the same as boron's, $^2P_{\frac{1}{2}}$**,** $^2P_{\frac{2}{3}}$

4. (a) What is the electron configuration of carbon in its ground state? Which electrons contribute to the atomic states?
   $1s^2 2s^2 2p^2$**. Only the** $2p^2$ **electrons contribute.**
   (b) What is the principal quantum number, n, for the electrons in the valence shell? $n = 2$
   (c) What are the possible values of the angular quantum number, l, for the electrons in the valence shell?
   $l = 1$
   (d) What are the possible values of the magnetic quantum number, m_l, for the electrons in the valence shell?
   $m_l = -1, 0, 1$
   (e) What are the possible values of the spin quantum number, m_s, for the electrons in the valence shell?
   $m_s = \frac{1}{2}, -\frac{1}{2}$
   (f) Remembering that electrons in the atom must have unique quantum numbers, what are the possible combinations of m_l and m_s?

C: $1s^2 2s^2 2p^2$ Microstates

m_l				
+1	0	−1	M_L	M_S
↑	↑		1	1
↑		↑	0	1
	↑	↑	−1	1
↓	↓		1	−1
↓		↓	0	−1
	↓	↓	−1	−1
↑↓			2	0
↑	↓		1	0
↑		↓	0	0
↓	↑		1	0
↓		↑	0	0
	↑↓		0	0
	↓	↑	−1	0
	↑	↓	−1	0
		↑↓	−2	0

(g) If $l = 1$, what values are possible for m_l? $m_l = -1, 0, 1$

(h) If $L = 1$, what values are possible for M_L? $M_L = -1, 0, 1$

(i) If $s = 1$, what values are possible for m_s? $m_s = -1, 0, 1$

(j) If $S = 1$, what values are possible for M_S? $M_S = -1, 0, 1$

5. The following questions are answered more easily when we construct a table that organizes $M_S - M_L$ combinations:

$M_L - M_S$

Combinations

M_L	M_S		
	+1	0	−1
+2		1	
+1	1	2	1
0	1	3	1
−1	1	2	1
−2		1	

(a) What is the largest value of M_L in your table for carbon? What value of L can lead to that value of M_L?

The largest $M_L = 2$, which corresponds to $L = 2$.

(b) What is the value of M_S for this value of M_L? What value of S can lead to that value of M_S?

The largest M_S filled in with $M_L = 2$ the preceding table is $M_S = 0$, which corresponds to $S = 0$. This is how the first proceeding table is constructed.

(c) For this largest value of M_L and thus L, what other values of M_L must contribute to the state with this value of L?

The following states contribute: $M_L = -2, -1, 0, 1, 2$

(d) What atomic states will arise from this combinations of L and S?

For this case, using the definition of J, we find $J = 2$, so our term symbol should be $^1D_2$.

(e) What M_L and M_S values are left?

Ignoring the microstates we just considered, the remaining maximum values are $M_L = 1$, $M_S = 1$. These allows us to construct the second table below. Ignoring these, the only values, let alone maximum values, left will be $M_L = 0$, $M_S = 0$, which allows us to construct the final table.

We extract combinations of S and L (and therefore J) based on the range of the M_S and M_L values which we considered in the previous questions. We can cluster this information into the following tables:

$L = 2,\ S = 0$

$J = 2$

M_L	M_S
	0
+2	1
+1	1
0	1
−1	1
−2	1

$^1D_2$

$L = 1,\ S = 1$

$J = 0, 1, 2$

M_L	M_S		
	+1	0	−1
+1	1	1	1
0	1	1	1
−1	1	1	1

$^3P_2, ^3P_1, ^3P_0$

$L = 0,\ S = 0$

$J = 0$

M_L	M_S
	0
0	1

$^1S_0$