**Tableau method for determining atomic terms illustrated for a $p^2$ electronic configuration**

As we have discussed in Chap. 2, if we have two electrons in any one of three 2*p* orbitals and two possible spin states, we have 15 different possibilities. We can create a tableau (fancy word for a table), in which these possible electron assignments are assigned to boxes corresponding to the projection of the total angular momentum

$$M_L = m_{l1} + m_{l2}$$

and to the projection of the total spin

$$M_S = m_{s1} + m_{s2}$$

Since $-1 \le m_l \le +1$, and $-1/2 \le m_s \le +1/2$ (both in integer steps), $M_L$ and $M_S$ are limited to $-2 \le M_L \le +2$ and $-1 \le M_S \le +1$.

Each box in the tableau contains all possible spin-orbital product wavefunctions that correspond to the values of $M_L$ and $M_S$ for the particular box. Allow *only* one entry for each combination; ordering does NOT create a different entry. (This is a consequence of indistiguishability). In additional entries must be consistent with the Pauli exclusion principle in that no spin-orbital can be repeated in a particular product.

For a $p^2$ electronic configuration the tableau is (bars designate $m_s = -1/2$)

| $M_S \setminus M_L$ | 2 | 1 | 0 | –1 | –2 |
|---|---|---|---|---|---|
| 1 | | $p_1 p_0$ | $p_1 p_{-1}$ | $p_{-1} p_0$ | |
| 0 | $p_1 \bar{p}_1$ | $p_1 \bar{p}_0$ $\bar{p}_1 p_0$ | $p_1 \bar{p}_{-1}$ $p_{-1} \bar{p}_1$ $p_0 \bar{p}_0$ | $p_{-1} \bar{p}_0$ $\bar{p}_{-1} p_0$ | $p_{-1} \bar{p}_{-1}$ |
| –1 | | $\bar{p}_1 \bar{p}_0$ | $\bar{p}_1 \bar{p}_{-1}$ | $\bar{p}_{-1} \bar{p}_0$ | |

1. Select the highest value of $M_S$. Here this is 1. There are entries in the $M_S$=1 box, so there must exist an *S*=1 (triplet) state. The highest value of $M_L$ in the $M_S$ =1 row is 1. Thus, there is an *S*=1 (triplet) state with L=1. This is called a *P* state (because *l*=1 for a single electron is called a *p* state). In fact it's a *triplet P* state, denoted $^3P$. The value of 2S+1 (the "multiplicity") is given as a leading superscript.

There will be nine components of this state, corresponding to the possible values of $M_L$ (+1, 0, and –1) and $M_S$ (+1, 0, and –1). Eliminate one product wavefunction (it doesn't matter which one) from each corresponding box

2. We are left with

| $M_S \setminus M_L$ | 2 | 1 | 0 | –1 | –2 |
|---|---|---|---|---|---|
| 1 | | | | | |
| 0 | $p_1 \bar{p}_1$ | $\bar{p}_1 p_0$ | $p_{-1} \bar{p}_1$ $p_0 \bar{p}_0$ | $\bar{p}_{-1} p_0$ | $p_{-1} \bar{p}_{-1}$ |
| –1 | | | | | |

3. Only $M_S = 0$ entries are left, thus all the remaining states are singlets. Select the highest value

of $M_L$. Here this is 2, thus there must be a $L = 2$ state ($D$). Thus the state is a $^1$D. There will be five components of this state. Eliminate one from each appropriate box.

4. We are then left with

| $M_S \setminus M_L$ | 2 | 1 | 0 | –1 | –2 |
|---|---|---|---|---|---|
| 1 | | | | | |
| 0 | | | $p_0\,\bar{p}_0$ | | |
| –1 | | | | | |

5. There is only one remaining component with $M_S = 0$ and $M_L = 0$. Thus, the remaining state is a $^1S$.

In conclusion, for an atom with a $p^2$ electron configuration (*e. g.* C, $N^+$, Si ...) the allowed electronic terms (states) are $^3P$, $^1D$, and $^1S$. Because the Hamiltonian is independent of the orientation of the $z$-axes (in both coordinate space and spin space), the 9 different components of the $^3P$ state are all degenerate, as are the 5 components of the $^1D$ state. The $^1S$ state has only one component, and hence is non-degenerate.