**Periodic Table**

First few elements:

<table>
<thead>
<tr>
<th>Element</th>
<th>Configuration</th>
<th>Spin Multiplicity (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>1s(^1)</td>
<td>1</td>
</tr>
<tr>
<td>He</td>
<td>1s(^2)</td>
<td>1</td>
</tr>
<tr>
<td>Li</td>
<td>2s(^2)2p(^1)</td>
<td>1</td>
</tr>
<tr>
<td>Be</td>
<td>2s(^2)2p(^2)</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>2s(^2)2p(^1)</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>2s(^2)2p(^2)</td>
<td>2</td>
</tr>
<tr>
<td>N</td>
<td>2s(^2)2p(^3)</td>
<td>2</td>
</tr>
<tr>
<td>O</td>
<td>2s(^2)2p(^4)</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>2s(^2)2p(^5)</td>
<td>1</td>
</tr>
<tr>
<td>Ne</td>
<td>2s(^2)2p(^6)</td>
<td>1</td>
</tr>
</tbody>
</table>

**Ground state determination**

What is \(^{2S+1}L_J\) of ground state?  

- **Hund's rule** (higher multiplicity tends to have lower energy)  
- **LS coupling** \(\Sigma L_i \pm \Sigma S_i\)  
- **Heavier atoms** \(j^{-j}\)  

**Hund's rules:**

1. Coupled the valence electrons (or holes) to give maximum total spin  
2. Choose state of max \(L\) (subject to Pauli)  
3. If the shell less than half-full \(\Rightarrow\) lowest \(J = |L-S|\)  
   Otherwise \(\Rightarrow\) highest \(J = L+S\)

**Justification**

**Rule 1 & 2** minimize Coulomb interaction between e\(^-\)'s

- **Max spin state** \(\Rightarrow\) symmetric spin part of \(Ψ\) ground
- **Max L** \(\Rightarrow\) antisymmetric spatial part

\(\overset{e^-}{e^-} \rightarrow \text{less Coulomb inter.} \text{ less energy}\)

\(\text{Higher } L \rightarrow \text{electrons "meet" less frequent} \Rightarrow \text{less Coulomb b/w e^-'s}\)

**Rule 3** minimize \(V_{So} \propto \langle \hat{L} \cdot \hat{S} \rangle \propto \frac{J(J+1)}{L(L+1)} - S(S+1) \)

\(\overset{\text{minimize } J}{\text{if } < \text{half-full}}\)

**Ex.** \(B\ (Z=5)\)

- \(\{1s^2\ 2s^2\ 2p^1\}\) valence e\(^-\)

<table>
<thead>
<tr>
<th>(m_e)</th>
<th>(L)</th>
<th>(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>(\frac{1}{2})</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>(\frac{1}{2})</td>
</tr>
<tr>
<td>-1</td>
<td>1</td>
<td>(\frac{1}{2})</td>
</tr>
</tbody>
</table>

\(S = \Sigma m_e = \frac{1}{2}\)  
\(L = \Sigma m_e = 1\)  
\(J = \frac{1}{2} \Rightarrow 2p_{1/2}\)

**C\ (Z=6)\)**

- \(\{1s^2\ 2s^2\ 2p^2\}\)

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<tr>
<th>(m_e)</th>
<th>(L)</th>
<th>(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>-1</td>
<td>0</td>
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</tr>
</tbody>
</table>

\(S = \Sigma m_e = 1\)  
\(L = \Sigma m_e = 1\)  
\(J = 0 \Rightarrow 3p_0\)
\[
\begin{array}{ccc}
\text{N}(z=7) & \text{O}(z=8) & \text{F}(z=9) \\
\{3s^2 \ 3p^3\} & \{3s^2 \ 3p^4\} & \{3s^2 \ 3p^5\} \\
\text{Mr} & \text{Mr} & \text{Mr} \\
1 & 1 & 1 \\
1 & 1 & 1 \\
1 & 1 & 1 \\
S = 3/2 & S = 1 & S = 1/2 \\
L = 0 & L = 1 & L = 1 \\
J = 3/2 & J = 2 \ (\text{max}) & J = 3/2 \ (\text{max}) \\
\Rightarrow \ ^4S_{3/2} & \Rightarrow \ ^3P_{2} \ (\text{max}) & \Rightarrow \ ^2P_{1/2} \ (\text{hole}) \\
\end{array}
\]

Selectron rules (light emission)

- \(\Delta J = 0, \pm 1\)
- \(J = 0 \rightarrow 0\) always forbidden
- \(\Delta M_J = 0, \pm 1\)
- Parity of states must change

**Elements zoo**

\[
\begin{array}{c}
\text{max } e^-'s \\
S & p & d & f \\
2 & 6 & 10 & 14 \\
\end{array}
\]

\[
\begin{array}{c}
\text{width } 18 \\
\end{array}
\]

**Group**

- noble gases (18)
  - He Ne Ar Kr Xe
  - [filled shells]
  - \(J=L=S=0\)
  - Smallest atoms
  - Self-sufficient ( inert)

- alkali metals (1)
  - Li Na K Rb Cs ...
  - [filled shell] + \(\text{ns}^1\) electron
  - Weakly bound
  - + e\(^-\) giver! (strongly electropositive)
  - + largest atoms / soft
  - + lowest work function

- halogens (17)
  - F Cl Br I ...
  - [\(\text{NG}\)] + 1 hole (-e\(^-\) electron)
  - + e\(^-\) thief! (strongly electronegative)
alkaline earth metals (2)
Be Mg Ca Sr Ba ...
[NG] + nS^2
* like "watered down" version of alkalies
(except Be)

transition metals (3-12)
* outer (valence) shell nS^1 or nS^2 electrons (free)
* subshells 3d, 4d, 5d, ... being partially filled
(d-d transitions, give vibrant colors to salts)
* many oxidation states: FeO, Fe_3O_4, Fe_2O_3

poor metals (13-16)
Al Ga In Sn Te Pb Bi
* valence nS^2 + np^1,2,3
* higher electronegativity than
  transition metals
* soft, worse conductors

metalloids (13-16)
B Si Ge As Sb Te
* half-filled outer shell
* weird m-between elements
* semiconductors

other non-metals (14-16)
C N O P S Se
* most abundant in earth's crust
* life stuff!

Lanthanides (rare earth)
15 each
* filling 4f-subshell
* many hi-tech uses

Actinides
* filling 5f-subshell
* nuclear bomb!