Ground state term symbols

The procedure is to, from the spectroscopic notation of an element (i) determine the possible term symbols using the Russel-Saunders coupling scheme ($J = L + S$), (ii) determine which of these term symbols is consistent with the fact that the electron wave function must be anti-symmetric (Pauli principle), then (iii) apply Hund's rules to identify the ground-state term symbol.

a) Na ($Z=11$) ; $3s^1$; $s = \frac{1}{2}$; $l = 0$; ${}^{2S+1}L_J$ = $\boxed{{}^2S_{1/2}}$

$j_{max} = \frac{1}{2} + 0$; $j_{min} = \frac{1}{2} - 0$; $j = \frac{1}{2}$

b) Mg ($Z=12$) ; $3s^2$; $S_{max} = \frac{1}{2} + \frac{1}{2}$; $S_{min} = \frac{1}{2} - \frac{1}{2}$;

$S = 1, 0$; $l = 0$; $j_{max} = 1 + 0$; $j_{min} = 1 - 0$, for $S = 1$

$j_{max} = 0 + 0$; $j_{min} = 0 - 0$, for $S = 0$

term symbols: ~~${}^3S_1$~~ ; ${}^1S_0$

(${}^3S_1$) forbidden by Pauli Principle. Therefore $\boxed{{}^1S_0}$

c) Al (Z=13) ; $3s^2 3p^1$; $\ell=1$;

adding 2 spins: $S_{max} = \frac{1}{2} + \frac{1}{2} = 1$, $S_{min} = \frac{1}{2} - \frac{1}{2} = 0 \Rightarrow S = 1$ or 0

adding third spin: $S=1$: $S_{max} = 1 + \frac{1}{2}$, $S_{min} = 1 - \frac{1}{2} \Rightarrow \frac{3}{2}, \frac{1}{2}$

$S=0$: $S_{max} = 0 + \frac{1}{2}$, $S_{min} = |0 - \frac{1}{2}| \Rightarrow \frac{1}{2}$ } allowed S

finding j: $S = \frac{3}{2} \Rightarrow j_{max} = \frac{3}{2} + 1$, $\frac{3}{2} - 1 \Rightarrow j = \frac{5}{2}, \frac{3}{2}, \frac{1}{2}$

$S = \frac{1}{2} \Rightarrow j_{max} = \frac{1}{2} + 1$, $|\frac{1}{2} - 1| \Rightarrow j = \frac{3}{2}, \frac{1}{2}$ (allowed j)

term symbols:

$S = \frac{3}{2}, L = 1$: ${}^4P_{5/2,\,3/2,\,1/2}$ ← These are forbidden by Pauli Principle

$S = \frac{1}{2}, L = 1$: ${}^2P_{3/2,\,1/2}$

Allowed term symbols. Now use Hund's rules: 1st two rules don't distinguish these term symbols. Last hund rule requires smallest j. Thus

$$\boxed{{}^2P_{1/2}}$$

d) Si (Z = 14). $3s^2 3p^2$

- I'll just look up the term symbols that are consistent w/ Pauli Principle:

$$^3P_{2,1,0}\ ,\ ^1D_2\ ,\ ^1S_0$$

- Now Hunds rules require (i) highest multiplicity ($2S+1 = 3$) and then (iii) smallest j ($j = 0$). So

$$\boxed{^3P_0}$$

e) Phosphorus P (Z = 15) $[Ne]3s^2 3p^3$

- Allowed symbols: only S (not P, D or F)

So $L = 0$, Maximize multiplicity: $S = \frac{3}{2}$, ~~$\frac{1}{2}$~~

Thus $j = \frac{3}{2}$.

$$\boxed{^4S_{3/2}}$$

f) Sulfur S(Z = 16) $[Ne]3s^2 3p^4$. Only ^1S, ^1D, ^3P

allowed by symmetry / Pauli principle.

(i) maximum multiplicity: ^3P

(iii) largest j: must have $S = 1$ and $L = 1$, $j_{max} = 1 + 1 = 2$

$$\boxed{^3P_2}$$

g) Chlorine Cl $(Z=17)$ $[Ne]3s^2 3p^5$

Allowed term symbols: ~~^2P~~ ^2P

Therefore since $2S+1 = 2$, $S = \frac{1}{2}$,

since $\mathcal{L} = P$, $L = 1$

Need to maximize j: $j = 3/2$

$$^2P_{3/2}$$

h) Argon A $(Z=18)$ $[Ne]\ 3s^2 3p^6$

$S=0,\ L=0$, $j_{max}=0$

$$^1S_0$$