15.3.1: Electronic Configuration

Often, but not always, the periodic table will include one or two sets of symbols intended to convey information about the ground state of the atom's electron cloud. The one seen more rarely includes information about the spin, orbital, and total angular momentum of the atom. In the NIST entry for Aluminum above, you can see this information in the upper right as ${}^2\mathrm{P}^{\mathrm{O}}_{1/2}$. The letter in the middle represents the total orbital angular momentum of all of the electrons the atom put together; S means $l=0$, P means $l=1$, D means $l=2$, and F means $l=3$. For Hydrogen, the single electron is in the $1s$ orbital, which has no orbital angular momentum, so that letter is S. For Aluminum, the letter is P. This results from the single electron in the $3p$ state. There are two electrons in each of the $1s, 2s$, and $3s$ states, and none of them have any orbital angular momentum. However, for Aluminum, there are also six electrons in the $2p$ state. But, because that shell is filled, there will be as many electrons with z-angular momentum of $+\hbar$ as there are with $-\hbar$ (two each, in this case), so all of their orbital angular momentum cancels out.

The superscripted number before the letter tells you about the electron spin state. It is equal to $2s+1$, where s is the net electron spin divided by $\hbar$. For Hydrogen, this is ${}^2S_{1/2}$. In Hydrogen, the net electron spin is 1/2, because there is just one electron that has spin $+\hbar/2$, so $2s=1$. In Helium, that number is 1, because the two electrons have spins in the opposite directions, so $s=0$. For aluminum, the net electron spin is the result of a single electron in the $2p$ state (as all of the filled states will have as many spin up as spin down electrons, thereby cancelling out each other's angular momentum). Thus, the net electron spin is 1/2 (as always in units of $\hbar$), so the number we see in the example above is (2)(1/2) + 1 = 2. Finally, the subscripted number after the letter is J, the quantum number associated with the total electronic angular momentum of the atom. J represents a combination of orbital and spin angular momentum for the electrons. For Hydrogen, $J=1/2$, because the angular momentum is entirely in the spin of the electron; for Aluminum, it's also $J=1/2$, but the reason is more complicated. Both the spin and orbit of the $3p$ electron contribute, but it would have been possible for them to combine yielding either $J=1/2$ or $J=3/2$. For Helium $J=0$ because there is no net angular momentum: there's no orbital angular momentum for two electrons in the $1s$ state, and the two spins cancel each other out. (As a caution, adding angular momenta in quantum mechanics can become complicated for cases with higher numbers than these examples.[1]) Similar to what we see with orbital angular momentum, the physical amount of angular momentum for an atom with total orbital quantum number J is $\hbar\sqrt{J(J+1)}$.

(The superscripted O— it's a capital O, not a zero— on the notation you see for Aluminum indicates that Aluminum has "odd parity". Parity is another quantum property that you don't need to worry about here.)

You may also see a series of letters and numbers that tell you how many electrons there are in each orbital. For Hydrogen, this is $1s^1$. That is, there is but a single electron in the $1s$ orbital. For Helium, it's $1s^2$: there are two electrons in the $1s$ orbital. For Nitrogen, it's $1s^22s^22p^3$. The $1s$ and $1s$ orbitals are filled, and the $2p$ orbital is half-filled. For periods after the second, it's often conventional not to list the full state, but to list the noble gas that has the same configuration as the inner core of electrons, and then just the states of the electrons outside of that. In our example of Aluminum above, the configuration is $[\mathrm{Ne}]3s^23p$ It's got all the electrons that Neon does— $1s^22s^22p^6$ — plus an additional two electrons in the $3s$ state and one in the 3p state.

The number at the very bottom of the box for Aluminum, 5.9858, is the ionization potential in eV for Aluminum. Many periodic tables will not include this number. This is the amount of energy it takes to remove one electron from the atom, forming a positive ion.

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[1]For example, with Aluminum, it turns out that for the total spin+orbit angular momentum of the $3p$ electron to be in a definite state $J=1/2$, neither the orbital z component nor the spin z component may individually be in definite states. If we write the state of the $3p$ electron as $|m, s_z\rangle$, for an Aluminum atom to have $J=1/2$ and $J_z=1/2$ (i.e. we've specified the orientation as well as the total angular momentum of our Aluminum atom), then the angular momentum state of the outermost electron would be

$$\sqrt{\tfrac{2}{3}}|+1,-1/2\rangle-\sqrt{\tfrac{1}{3}}|0,+1/2\rangle$$
