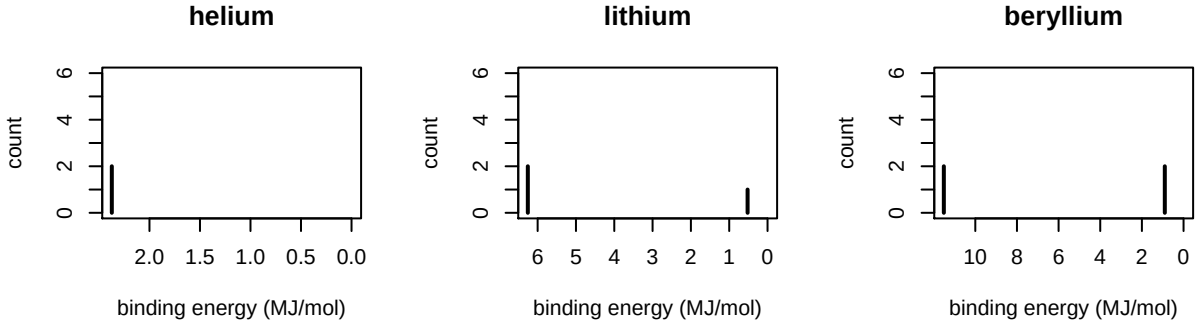
Photoelectron Spectroscopy Worksheet

The data we have examined thus far is limited to a single valence electron; that is, we considered data for an atom's first ionization energy only. Another experimental approach is photoelectron spectroscopy (PES) in which we bombard an element in the gas phase with high-energy X-rays. Although each atom absorbs one photon and ejects one electron, when we bombard a large sample of atoms with a large supply of high energy photons, we eject electrons from all possible shells in an amount proportional to the number of electrons in that shell. The photoelectron spectra below are for He, Li, and Be.



Our current model for the atom places electrons in shells described by a number, n, that takes on values of $1, 2, 3, \ldots$. The first three shells can accomodate 2, 8, and 8 electrons respectively.

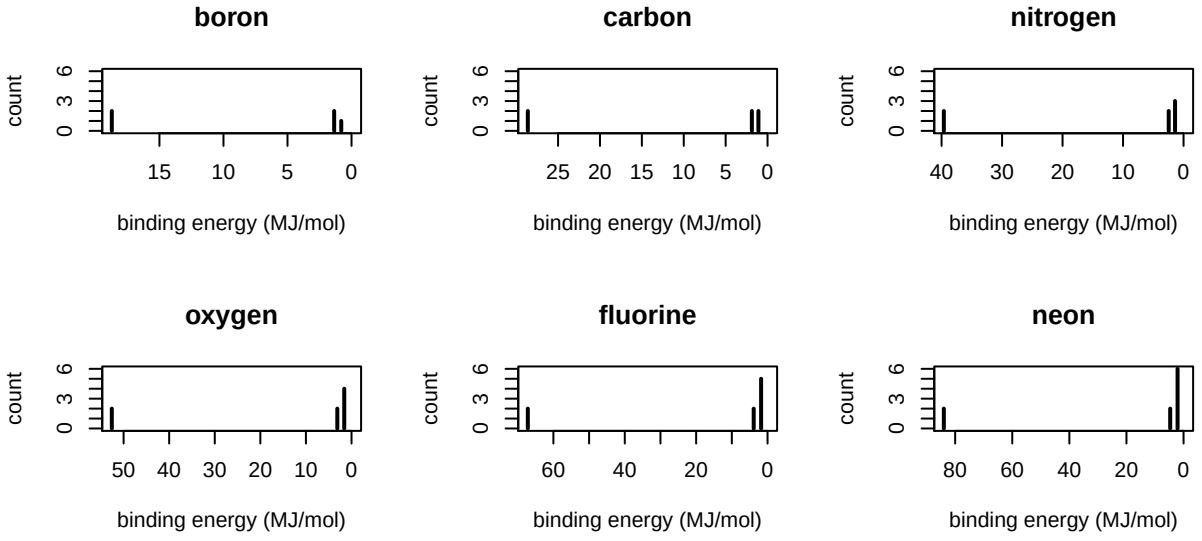
For each of the three spectra above, label each peak with its value for n. For lithium and for beryllium, which have two peaks each, how did you decide which peak has $n = 1$ and which peak has $n = 2$?

- For He, there is one peak, which has $n = 1$
- For Li and Be, there are two peaks, which, from left-to-right, are for $n = 1$ and $n = 2$. We know this is the order because binding energies decrease as n increases.

For each of the three spectra above, draw a circle around the peak that corresponds to the valence electrons. How did you decide which electrons qualify as valence?

- The valence electrons are those from the shell with the largest value of n; thus, you should circle the right-most peak in each spectrum.

The photoelectron spectra below are for the elements B $\longrightarrow$ Ne, which completes the second row of the periodic table.



Examine these spectra? In what way(s) are they similiar to the spectra for the lithium, and beryllium, which also are in the second row? In what way(s) are they different?

- One similarity is that there is significant gap between the electron with the largest binding energy and the electron with the smallest binding energy.
- One difference is that these elements have three peaks in their photoelectron spectra, which suggests three different types of electrons instead of the two types of electrons we see for Li and Be.

The spectra for the elements B $\longrightarrow$ Ne create a dilemma for our current model of the atom as they show three peaks—and, therefore, three types of electrons—when the simple shell model suggests there are two types of electrons: those with $n = 1$ and those with $n = 2$. We are faced with two choices

> stick with the simple shell model and assume that the three peaks are, from left-to-right, for the $n = 1$, $n = 2$, and $n = 3$, or
>
> abandon the simple shell model and assume that the $n = 2$ shell is split into two subshells that differ slightly in energy

Explain why the second possibility makes more sense given the ionization energies.

- From the evidence we've seen, we expect a large decrease in an electron's binding energy when we move from a shell closer to the nucleus $n = 1$ to a shell further from the nucleus $n = 2$. The small difference in the binding energy for the two lowest energy electron's in B $\longrightarrow$ Ne makes more sense if they are in the same shell. Why they differ in energy is not clear given our current model.

We identify subshells by adding a letter to the shell number. For $n = 1$ there is a single subshell, which we identify as $1s$; for $n = 2$ there are two subshells, which we identify as $2s$ and as $2p$. This allows us to write an electron configuration that describes an element's electrons. Given that these electron configuration for lithium is $1s^2 2s^1$, write the electron configuration for fluorine. Given the data available to you, how many electrons can a shell labeled s hold? p?

- The electron configuration is $1s^2 2s^2 2p^5$. A shell labeled s can hold two electrons and one labeled p can hold six electrons.