Ionization Energy

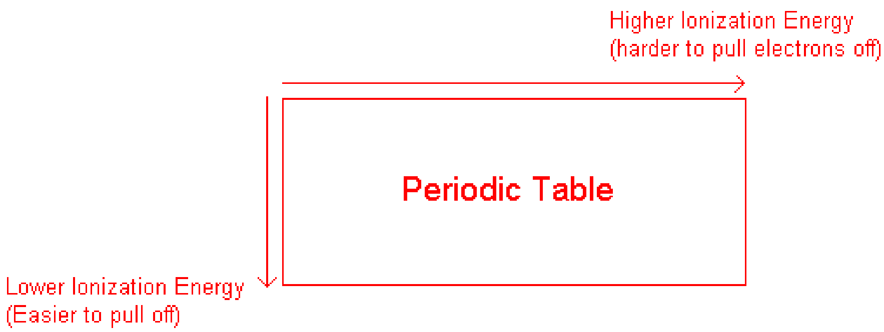
1. What is ionization energy?

The energy required to remove an electron from a gaseous atom/ion.

$$X_{(g)} \rightarrow X^{+}_{(g)} + e^{-}$$

These are endothermic processes.

2. General trend on the periodic table:



3. What can ionization energy tell us about core and valence electrons?

The trend in ionization energies can indicate when we have switched from pulling valence electrons to pulling core electrons.

For Example:

$Al_{(g)} \rightarrow Al^{+}_{(g)} + e^{-}$	$I_1 = 580$ kJ/mol
$Al^{+}_{(g)} \rightarrow Al^{2+}_{(g)} + e^{-}$	$I_2 = 1815$ kJ/mol
$Al^{2+}_{(g)} \rightarrow Al^{3+}_{(g)} + e^{-}$	$I_3 = 2740$ kJ/mol
$Al^{3+}_{(g)} \rightarrow Al^{4+}_{(g)} + e^{-}$	$I_4 = 11600$ kJ/mol

Why the jump from $I_3 \rightarrow I_4$?

Because $I_1 - I_3$ is the energy related to pulling off valence electrons. It gets successively larger because as the Al develops the positive charge the electrons are more and more attracted to the ion. The cause for the massive jump from $I_3 \rightarrow I_4$ is that I_4 represents the amount of energy required to pull off a core electron. Core electrons are much more tightly bound to the nucleus than are valence electrons.

4. Why does phosphorus have a first ionization energy of 1060 kJ/mol and sulfur have a first ionization energy of 1005 kJ/mol?

P: $[Ne]3s^23p^3$
S: $[Ne]3s^23p^4$

As you can see from the electron configuration of phosphorus and sulfur, the electrons in the phosphorus configuration are fully spread out over the 3p orbitals. In the sulfur, on the other hand, there would be some repulsion between the electrons sharing the orbital. Because of this repulsion is would be easier to pull the sulfur electron out.

5. Which configuration would have the highest 1st ionization energy and which would have the lowest 2nd ionization energy?

a. $1s^22s^22p^6$ – this would have the highest first ionization energy because the electrons are in a lower energy level and therefore – closer to the nucleus.

b. $1s^22s^22p^63s^1$

c. $1s^22s^22p^63s^2$ – this would have the lowest first ionization energy.

6. Which in each set has the smallest 1st ionization energy?

It is, generally, easiest (lowest ionization energy) to pull electrons off of bigger atoms and negatively charged ions. Though there are occasion where it may be necessary to look at the electron configurations to fully determine lowest first ionization energy.

a. Ca, Sr, Ba

Based on placement in the periodic table, the size ordering of the atoms of each element would be as follows:

Ca < Sr < Ba

Because Ba is the largest atom, it would be the easiest to pull an electron from, thus it would have the lowest first ionization energy.

b. N, O, F

Based on size: F < O < N, one would assume that N would have the lowest first ionization energy. However, it would be necessary to double check this by looking at the electron configurations:

N : $[He]2s^2 2p^3$ O: $[He]2s^2 2p^4$ F: $[He]2s^2 2p^5$

What do you notice about these configurations?

In the 2p orbital of nitrogen, the electrons are spread out over the 3 p orbitals. In the oxygen configuration there is one orbital (within 2p) that has a set of electrons together. In the fluorine configuration, there are 2 orbital (within the 2p) with electrons paired up. What can you glean from this… which atom has the most to gain from the removal of one electron?

Oxygen. If it loses one electron all the electrons in the 2p shell will be spread out – biog drop in energy because their will not be a shared pair of electrons that experience repulsion.

c. S^{2-}, S, S^{2+}

In this case we are focused on the charges - it is easiest to remove an electron from a negatively charged ion due to all the repulsion felt by the electron.

This means that S^{2-} would have the lowest first ionization energy.

7. To which family would the following element belong?

I_1=896 kJ/mol
I_2=1752 kJ/mol
The jump in energy occurs between 1 and 2
I_3=14807 kJ/mol
I_4=17948 kJ/mol

This jump means that the first 2 electrons that were removed valence and the 3 started pulling from core. This means that this substance has 2 valence electrons and therefore comes from group 2.