Force of Attraction

rce of Attraction = FA

FA refers to the force (pull) that the nucleus (protons) exerts on the valence electrons. Before we get started with this we must define the difference between "core" versus "valence" electrons because the amount of force that the protons exert on the core electrons is different than the force that the protons exert on the valence. So lets look at the electron configuration of arbon. $^{6}C = 1s^2 2s^2 2p^2$ Remember that the valence electrons are the electrons found in the outermost energy level. In the case of carbon the electrons in $n=2$ are the valence which I now underline: $1s^2 \underline{2s^2 2p^2}$ we define the core electrons as the electrons found in all of the preceeding energy levels so the core is $1s^2$.

Examples of core vesus valence:

core

^{7}N $1s^2$ $2s^2 2p^3$

valence

core

^{11}Na $1s^2 2s^2 2p^6$ $3s^1$

valence

you should practice finding core versus valence for elements 1-36.

The FA is not the same for the core compared to the valence. Understand that the core e^- are closer to the protons and are held more tightly than the valence e^-.

we use a concept called effective nuclear charge (Z_{eff}) to evaluate the amount of positive charge available by the nucleus to "pull" on the core as compared to the valence. Z_{eff} is defined as $Z_{eff} = Z - \text{core } e^-$

the e^- preceeding the e^- of interest.

total # protons

amount of charge that can "pull" on the e^- of interest.

For carbon: ${}^{6}C$ $1s^2$ $2s^2 2p^2$

core — $1s^2$; valence — $2s^2 2p^2$

First we ask, "what is Zeff for C's valence?"

$1s^2$ core with $2e^-$

$$Z_{eff} = \underset{\#\text{ protons}}{6} - 2 = {}^{+}4$$

Second: Now we calculate Zeff for C's core:

there are <u>no</u> preceeding e^-

$$Z_{eff} = \underset{\#\text{protons}}{6} - 0 = {}^{+}6$$

Inspecting both numbers you can see that there is <u>more</u> charge pulling on the core than there is pulling on the valence. Thus, valence e^- are held <u>less</u> tightly than core. If you're observant, you'll also notice that C's Zeff for the valence e^- is equal to the group #. (what I need you to do now is to get out a periodic table.) Notice, based on group #'s for the <u>main group elements</u>, that Zeff increases moving left to right across any given period.

The increase in Z_{eff} from left to right across any period is true for all periods—even the transition metals.

Next we will use Z_{eff} to analyze what happens when moving <u>down</u> any group.

First let's look at $\overset{3}{Li}$: $\underbrace{1s^2}_{\text{core}}\underbrace{2s^1}_{\text{valence}}$

$$Z_{eff} = \underset{\substack{\uparrow \\ \#\text{ protons}}}{3} - \overset{\substack{\#\text{ core} \\ \downarrow}}{2} = +1$$

Second, let's look at $\overset{11}{Na}$: $\underbrace{1s^2 2s^2 2p^6}_{\text{core}}\underbrace{3s^1}_{\text{valence}}$

$$Z_{eff} = \underset{\substack{\uparrow \\ \#\text{ protons}}}{11} - \overset{\substack{\text{total core} \\ \downarrow}}{10} = +1$$

You can see that $Z_{eff\,Li} = Z_{eff\,Na}$ so Z_{eff} is constant down all groups. In other words, the amount of charge "pulling" on Li's valence is the same as the Z_{eff} pulling on Na's valence. Down any group the Z_{eff} is constant. So the amount of pull on the valence stays the same down any group.

There is another detail that is important to take into consideration and that is the distance that the valence e^-'s are from the protons.

To describe the distance issue moving left to right across any period I am going to use Period 2 as my example. Period 2 starts with Li and finishes with Ne. The EC for Li is $1s^2 2s^1$ and the EC for Ne is $1s^2 2s^2 2p^6$.

So you can see that moving from Li to Ne all of the incoming e^-'s are added to the same energy level ($n=2$) and are, therefore, the same distance from the protons. So distance of valence e^- is <u>constant</u> across any period.

However, moving down any group the distance of the valence electrons increases. Compare Li and Na: Li $1s^2 \underline{2s^1}$ Na $1s^2 2s^2 2p^6 \underline{3s^1}$ You can see that Na's valence is in $n=3$ and Li's valence is in $n=2$. So moving down any group the distance increases – the distance of the valence e^-'s from the protons becomes bigger.

Putting it all together: First I want to define FA more specifically:

FA is approximately equal to $\dfrac{\overset{(Z_{eff})}{\text{charge}}}{d^2}$

distance valence e^- from protons

approximate

$$FA \cong \frac{Z_{eff}}{d^2}$$

First the left → right issue: Z_{eff} increases but d^2 is constant. So FA increases L – R.

Second: Down any group: In this case, the Z_{eff} is constant but the d^2 increases so the FA decreases moving down the group.

Consequences of the FA Trend

L → R: Since FA increases, size of the element decreases and ionization energy increases. Remember that the size of an atom depends on the distance of the valence - the valence is the surface of the atom. Since e^- are held more tightly L-R, ionization energy increases.

Down Any Group: FA decreases, size of the atom increases and ionization energy decreases. The valence is held less tightly going down the group so that atoms expand in size. Since the valence is held less tightly its easier to remove an e^- and the ionization energy decreases.