NS F6 (G2) (pg 1 of 2) **Ionization Energy** Name______________________Per____

First Ionization Energy – **Amount of energy is needed to remove one e–**
which tells us how tightly those electrons are held.

Remember that atoms are neutral in charge. When an atom transfers electrons, that atom will take on a charge and become an ion. This happens naturally to atoms, as we will soon learn, however, in a laboratory, chemists can force any atom to lose an electron by "spanking" an atom with some form of energy such as heat, light, or electricity. Chemists do this in the laboratory in hopes of learning more about the atom. This measured quantity of energy is called ionization energy, and chemists have measured that amount of energy for most of the representative (group A) elements. The process can be shown by the chemical reaction shown below:

Ionization Energy (IE) *the amount of energy required to remove an electron from a specific atom.*

$$X + IE \rightarrow X^+ + e^-$$

As shown in the reaction above, the atom absorbs (endothermic) an amount of energy, which causes an electron to separate from the atom. This removed electron is shown as a separate particle on the product side of the reaction and the atom is changed into a positive ion.

The ionization energies of the elements display periodic trends. Observe the periodic chart below showing the elements listed with their ionization energy. Look for a general trend as you move across the chart, and look for a trend as you move down within a column.

First Ionization Energies (kJ/mole)

1	H 1311							He 2370	1
2	Li 521	Be 899	B 799	C 1087	N 1404	O 1314	F 1682	Ne 2080	2
3	Na 496	Mg 737	Al 576	Si 786	P 1052	S 1000	Cl 1245	Ar 1521	3
4	K 419	Ca 590	Ga 579	Ge 762	As 944	Se 941	Br 1140	Kr 1351	4
5	Rb 403	Sr 550	In 558	Sn 709	Sb 832	Te 869	I 1009	Xe 1170	5
6	Cs 376	Ba 503	Tl 589	Pb 716	Bi 703	Po 812	At 900	Rn 1037	6
7	Fr 370	Ra 500							

Ionization energy generally *increases* as you move *across a row* (or period) and ionization energy generally *decreases* as you move *down a column* (or group or family).

Why? Coulomb's Law of electrostatic attraction: $F = k\dfrac{Q^+Q^-}{d^2}$

- The IE **decreases** as we proceed **down a column** because the **size of the atoms increase** as we proceed down a column, due to more energy levels. The increased size means the electron being removed is further from the protons (in the nucleus) that are attracting that valence electron (Coulombs Law), thus making the removal of the electron "*cost" less energy*.
- The IE **increases** as we proceed across a period for a different reason. The number of **protons increases** (Q^+) across the row, attracting valence electrons **in the same energy level** resulting in a larger effective nuclear charge (ENC). This increased proton attractive force makes the removal of the electron "*cost" more energy*.

Notice that the units at the top of the chart are kJ (kilojoules) per mole of atoms.

Successive Ionization Energies – Amount of energy to remove a second, or third, or fourth…. e^-

Notice that the chart on the previous page is titled FIRST ionization energies. This is because those numbers represent the energy to remove only one electron. Chemists thought they might learn more about an atom by measuring how much energy would be required to remove more than just the first electron. The chart below lists the amount of energy required to remove successive electrons.

Equation to represent the second ionization energy process (for generic element X): $X^+ + 2^{nd}\text{ IE} \rightarrow X^{2+} + e^-$

Equation to represent the third ionization energy process (for generic element X): $X^{2+} + 3^{rd}\text{ IE} \rightarrow X^{3+} + e^-$

You will notice that the IE increases for each extra electron removed. This makes sense because as electrons are removed, the ion from which the next electron is to be removed is influenced by less valence electron repulsion, allowing the electron cloud to "skootch" closer to the nucleus, resulting in a smaller size and greater attractive force (Coulombs Law). Thus the more electrons removed, the valence electron repulsive force becomes smaller, and the resulting ion will hold tighter on to the remaining electrons.

You should also observe that the energy values that are in shaded and in ***bold italics*** are much higher than the energy immediately preceding it. This indicates that it is very difficult to pull off that particular electron. The extremely high increase (compared to the previous value) is due to the fact that the electron being removed is an energy level closer to the nucleus. When we look carefully at the number of valence electrons that an atom has, we will find that there is a very large increase in the successive ionization energy when attempting to remove one more electron than the number of valence electrons. This of course is because knocking off an electron that is **one whole level closer to the nucleus** requires a lot of energy.

Successive Ionization Energies kJ/mole

	1st	2nd	3rd	4th	5th	6th	7th	8th
H	1311							
He	***2370***	5220						
Li	521	***7304***	11752					
Be	899	1756	***14849***	20899				
B	799	2422	3657	***25019***	32660			
C	1087	2393	4622	6223	***37822***	46988		
N	1404	2856	4573	7468	9446	***53250***	63970	
O	1314	3396	5297	7468	10990	13325	***71312***	83652
F	1682	3367	6050	8423	11028	15167	17869	***91950***
Ne	***2080***	3946	6165	9301	12138	15148	19972	22963
Na	496	***4564***	6918	9542	13373	16644	20175	25501
Mg	737	1447	***7738***	10546	13624	18033	21767	25742
Al	576	1814	2750	***11578***	14820	18361	23465	27575
Si	786	1582	3232	4361	***16007***	19693	23658	29110
P	1052	1901	2914	4959	6272	***21516***	25858	30489
S	1000	2258	3387	4544	6947	8500	***27112***	31734
Cl	1245	2287	3850	5162	6542	9359	11028	***33442***
Ar	1521	2653	3927	5886	7526	8587	11964	13778

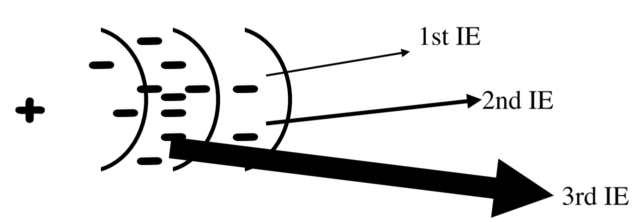
For Example

Mg has 12 electrons: 2 in the 1^{st} energy level, and 8 in the second energy level and 2 in the third energy level. Notice the cost to remove the first electron is 737 J. The energy requirement to remove the second electron is about double the first amount. To remove the third electron costs MUCH more (more than 5 times more) because the third electron to be removed is an energy level closer to the nucleus.

Model of Mg atom:

Thickness and length of the arrow to indicate the size of each IE.

For Mg it is the *third IE* that shows a very large increase.



The BIG increase occurs 1 more than the number of valence electrons, because that electron so MUCH closer to the nucleus.