Chemistry Lecture #33: Ionization Energy, Electron Affinity & Electronegativity

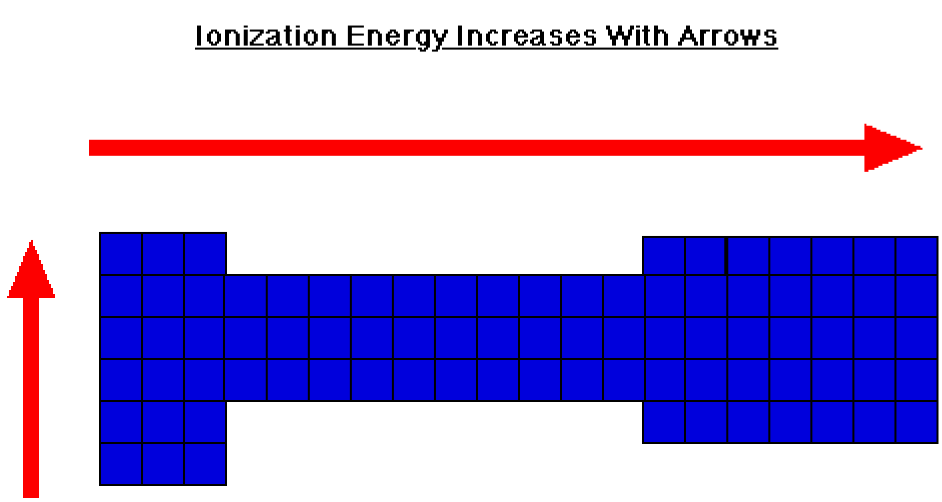
The energy required to remove an electron from an atom in the gaseous state is the ionization energy.

Atoms with small radii have larger ionization energies. A small radius indicates that the electrons are being held tightly. It takes more energy to remove an electron if it is held tightly.

Since the periodic chart can be used to predict trends in atomic radius, it can also be used to predict trends in ionization energy.

Atomic radius is inversely related to ionization energy. Thus, if you go up a column on the periodic chart, ionization energy increases since radius decreases.

Ionization energy also increases as you go from left to right across the chart since radius decreases.



Below is a chart showing the ionization energies of the period 2 elements. Notice the *general* trend of increasing energy as you go from left to right (from Li to Ne) across the chart. But you should also notice the energy occasionally *decreases* as we move from left to right. (Energies are expressed in kj/mole).

	*			*			
Li	Be	B	C	N	O	F	Ne
520	900	800	1090	1400	1310	1680	2080

Look at the ionization energy of Be. We would expect it to have a value between that of Li and B (between 520 and 800). Instead, Be has an ionization energy of 900, which is not between 520 and 800. Why is the energy Be elevated? It is because Be has a full s sublevel.

Be	↑↓	↑↓
	1s	2s

Remember that a full sublevel stabilizes or makes an atom less reactive. Thus, Be (and all the other elements in group 2A) will have an elevated ionization energy.

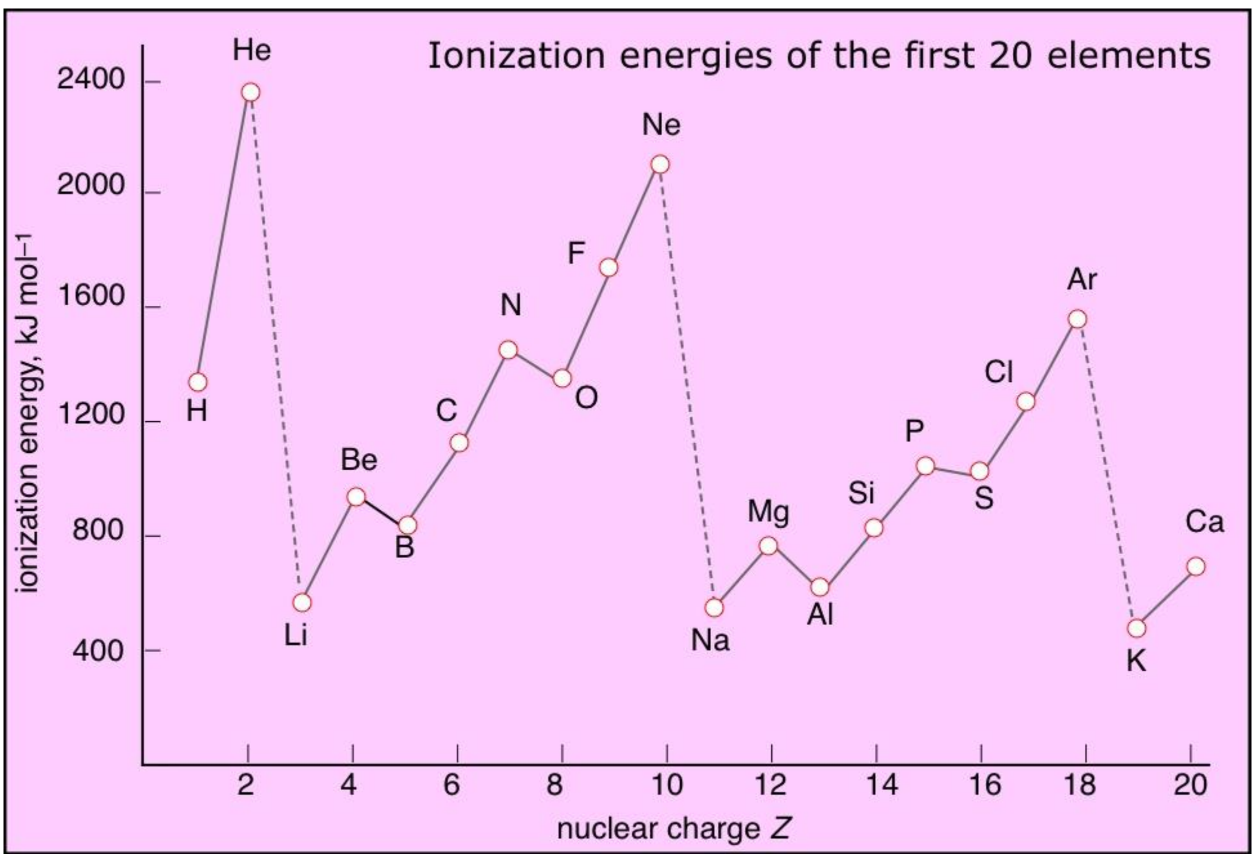
Nitrogen should have an ionization energy between that of carbon and oxygen (between 1090 and 1310). Instead, it has an energy of 1400. Nitrogen has an elevated ionization energy since it has a half filled p sublevel.

N: $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

1s 2s 2p

Having a half-filled p sublevel also stabilizes an atom. Thus, nitrogen and all the other elements in group 5A will have an elevated ionization energy.

Below is a graph showing the ionization energies of the first 20 elements.



Notice that the energy increases, reaches peaks at He, Ne, and Ar, then drops again. Why does it reach peaks at these elements?

It reaches peaks at He, Ne, and Ar because these are group 8A elements. Group 8A elements have the highest form of stability since all but helium have an octet, or 8 outer electrons. Argon, for example, has 8 electrons in its 3rd energy level.

Ar	↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑↓
	1s	2s	2p	3s	3p

Atoms are reluctant to give up an electron if they have an octet. Thus, having an octet will elevate ionization energy.

The energy required to remove the first electron from a neutral atom is the first ionization energy. The energy required to remove a 2nd electron is the 2nd ionization energy. Removal of the 3rd electron is the third ionization energy, and so on.

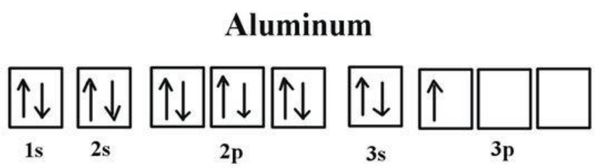
Ionization energy increases with the removal of each electron. Each time an electron is removed, the charge on the atom becomes more positive, causing the remaining electrons to be held more tightly and making the radius smaller.

Below are the ionization energies for aluminum in kj/mole

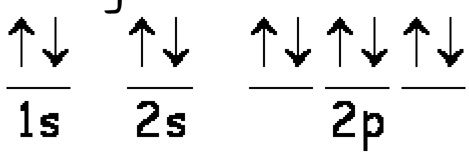
	1st	2nd	3rd	4th	5th	6th
Al	578	1810	2750	11,580	14,820	18,360

As expected, the energies increase each time an electron is removed. But notice that there is sudden leap in energy from the 3rd ionization energy to the 4th. Why is the 4th ionization energy suddenly so much larger?

When aluminum loses 3 electrons, it will have 10 electrons remaining. Neon, a group 8A element, has 10 electrons. Thus, after aluminum loses 3 electrons, it will have the octet configuration of neon. Having an octet makes the aluminum more resistant to change. Therefore, it will take more energy to remove the 4th electron from aluminum.



Configuration of neon or aluminum missing 3 electrons

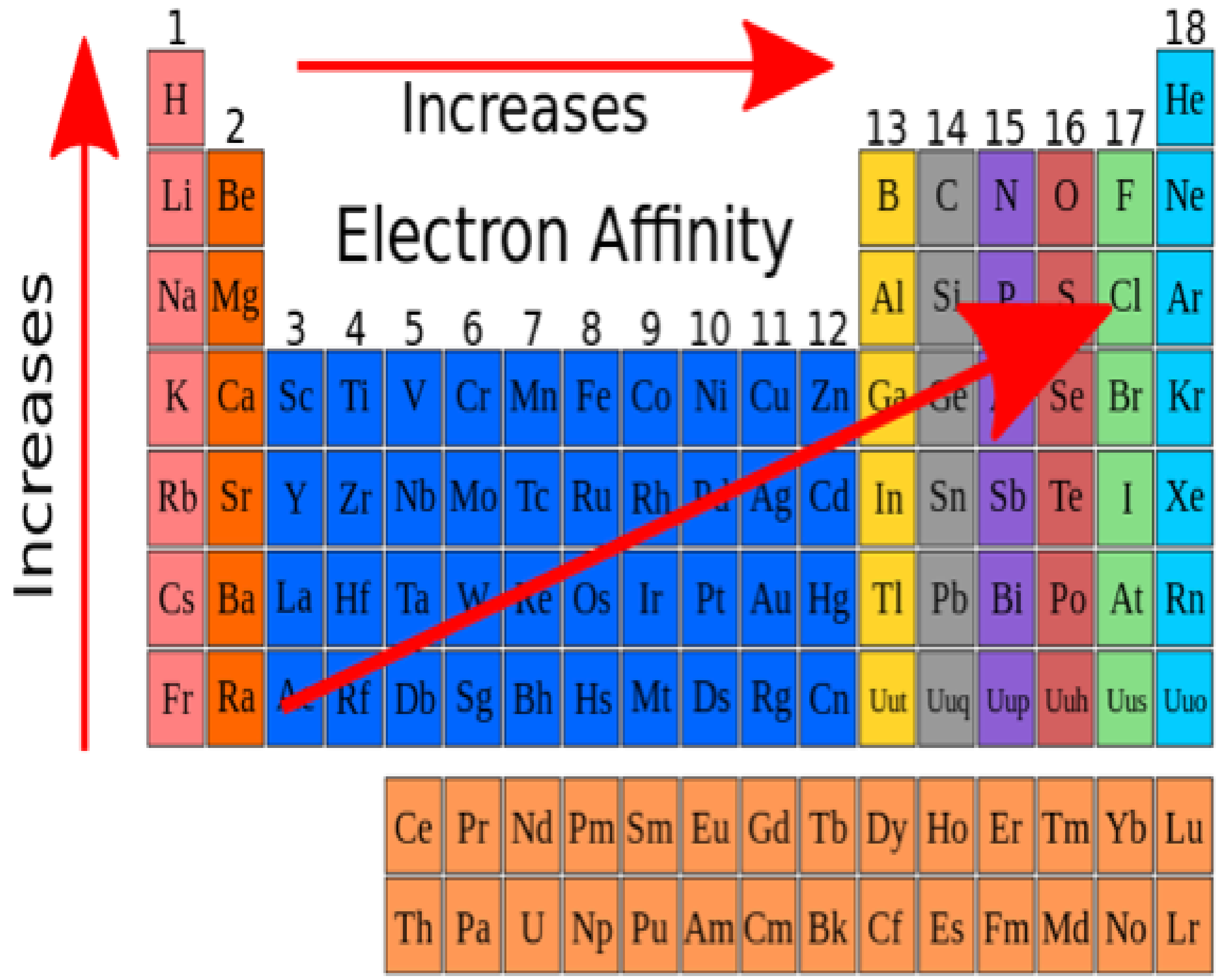


To summarize, the factors affecting ionization energy include:

- Radius
- Octet rule
- Filled sublevel
- ½ filled sublevel

Closely related to ionization energy is electron affinity. Electron affinity is the attraction of an atom for an electron. It is a measure of the atom's ability to acquire additional electrons.

Like ionization energy, electron affinity increases with decreasing atomic radius. If you go from left to right across the chart, affinity increases. If you go up a column, affinity increases.



Periodic Trend: Electron Affinity

Below is a chart listing the electron affinities of some elements.

Table 12-4

Electron Affinities (in kilojoules per mole)

H							**He**
72.8							(−21.3)
Li	**Be**	**B**	**C**	**N**	**O**	**F**	**Ne**
59.8	(−241)	23.2	123	0	141	322	(−28.9)
Na	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
52.9	(−232)	44.4	120	74.3	200	349	(−34.7)
K							
49.0							

( ) indicates a calculated rather than an experimental value.

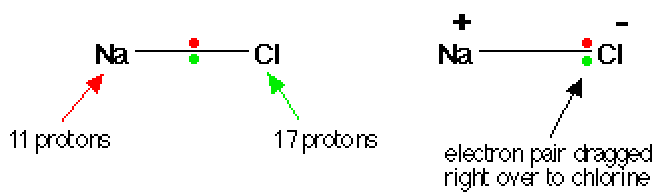
The deviations from periodic trends match those we see for ionization energy. For example, group 2A elements (Be, Mg) have negative affinities - they don't want to acquire electrons. This is because group 2A elements have a full s sublevel.

And group 8A elements like Ne and Ar also have negative affinities. This is because they have an octet, and also do not wish to acquire more electrons.

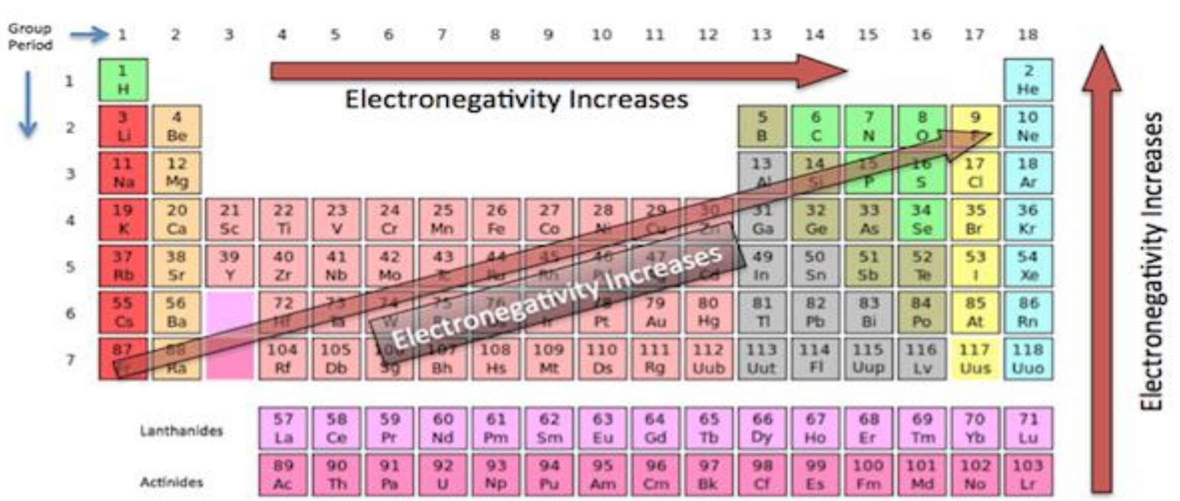
Finally, notice that nitrogen has a zero affinity. Remember that nitrogen is a group 5A element, which means it has a half-filled p sublevel. This reduces its likelihood of acquiring electrons. Phosphorus, also in group 5A, should have an affinity between that of Si and S (between 120 and 200). Instead, phosphorus has an affinity of 74.3, which is lower than expected.

Electronegativity is similar to electron affinity. Electronegativity is the ability of an atom to draw electrons toward itself when electrons are shared between two atoms. Atoms sometimes fight each other for possession of electrons. The electronegativity tells you the strength of an atom in a tug of war over electrons.

For example, when Na and Cl come together, Cl will pull the electron from Na toward itself because it has a greater electronegativity.

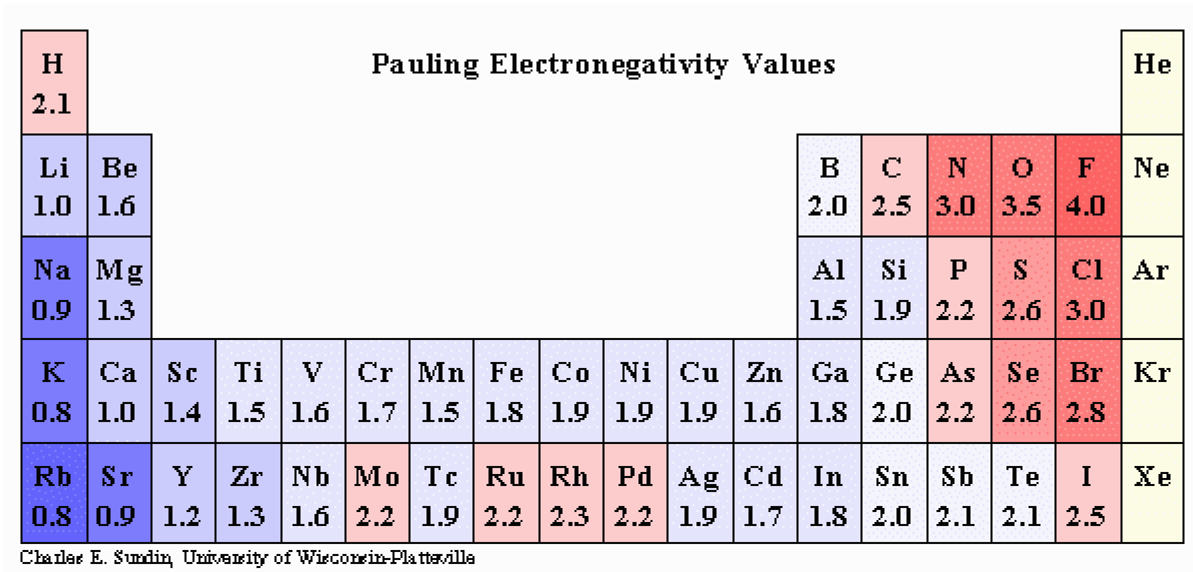


Like affinity, electronegativity strength follows periodic trends. As atomic radius decreases, electronegativity strength increases. Thus, electronegativity increases from left to right across the chart. It also increases as you go up the chart.



Electronegativity Trend

Here's a chart showing electronegativity values of some elements.



Rb at the lower left has the lowest value at 0.8, while F at the upper right has the highest value at 4.0

Notice that there are no values listed for the group 8A elements. Remember that these elements have an octet, and have no desire to pull additional electrons toward itself.