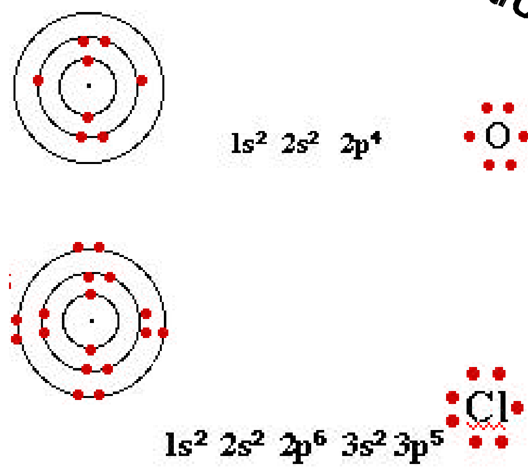
Section 4.6 Periodic Trends of the Elements

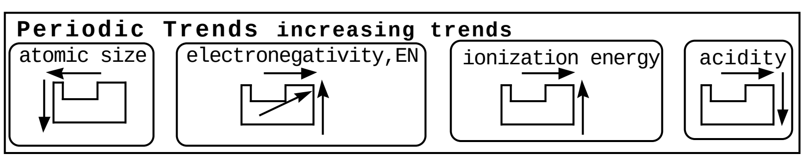
Periodic Trends as experimental evidence to support electron filling



Section 4.6 Periodic Trends of the Elements

Supplemental packet page 58

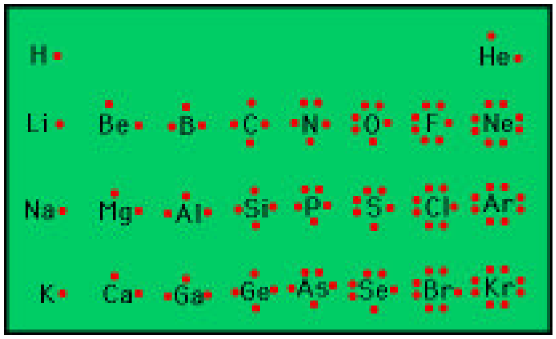
Periodic Trends to memorize



Supplemental packet page 29

Lewis Electron-dot Symbols - A Periodic Trend

G.N. Lewis, at the University of California at Berkeley devised a simple way to understand the nature of the chemical bond in both ionic and molecular compounds. His method rests upon focusing on the valence electrons of the elements. He represents these valence electrons as "dots" around the four sides of the elemental symbol.

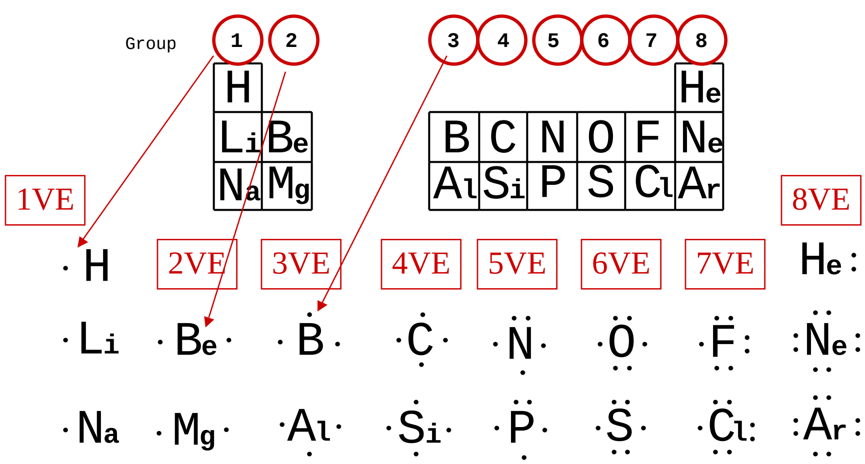


It is the valence electrons (outermost electrons) that are involved in most chemical reactions. Therefore, these Lewis electron-dot symbols should help us understand the chemical properties of these elements. Recall, for these representative elements, group number equals the number of valence electrons, except of helium.

Supplemental packet page 29

Electron Dot Structure = Group Number = Valence Electron (outermost)

Lewis Dot Structures

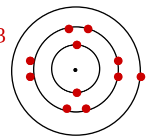


Outermost valence electrons provide chemical reactivity

Supplemental packet page 49

Atomic Structure

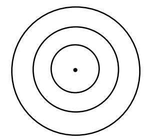
Atomic Number: **11**
Name: sodium-23
Symbol: $^{23}_{11}Na$



mass # **23**
p 11
n 12
e 11
Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^1$

Physical Properties: soft metal, conducts e-
Chemical Properties: reacts w/ H_2O
Lewis Dot: **Na•**

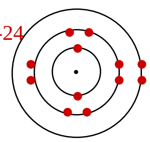
Atomic Number: **17**
Name:
Symbol:



mass # **35**
p ______
n ______
e ______
Electronic Configuration:

Physical Properties:
Chemical Properties:
Lewis Dot:

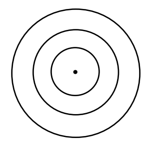
Atomic Number: **12**
Name: magnesium-24
Symbol: $^{24}_{12}Mg$



mass # **24**
p 12
n 12
e 12
Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2$

Physical Properties: ductile metal, conducts e-
Chemical Properties: burns in O_2
Lewis Dot: **• Mg•**

Atomic Number: **8**
Name:
Symbol:



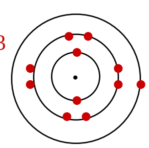
mass # **16**
p ______
n ______
e ______
Electronic Configuration:

Physical Properties:
Chemical Properties:
Lewis Dot:

Supplemental packet page 49

Atomic Structure

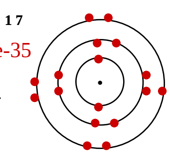
Atomic Number: **11**
Name: sodium-23
Symbol: $^{23}_{11}Na$



mass # **23**
p 11
n 12
e 11
Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^1$

Physical Properties: soft metal, conducts e-
Chemical Properties: reacts w/ H_2O
Lewis Dot: **Na•**

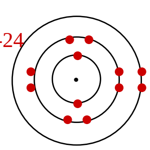
Atomic Number: **17**
Name: chlorine-35
Symbol: $^{35}_{17}Cl$



mass # **35**
p 17
n 18
e 17
Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Physical Properties: yellow gas, nonconductor
Chemical Properties: reacts w/ Na(s)
Lewis Dot: $:\ddot{\underset{\cdot\cdot}{Cl}}\cdot$

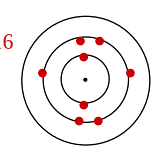
Atomic Number: **12**
Name: magnesium-24
Symbol: $^{24}_{12}Mg$



mass # **24**
p 12
n 12
e 12
Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2$

Physical Properties: ductile metal, conducts e-
Chemical Properties: burns in O_2
Lewis Dot: **• Mg •**

Atomic Number: **8**
Name: oxygen-16
Symbol: $^{16}_{8}O$

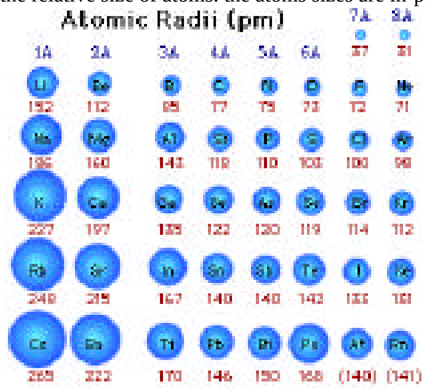


mass # **16**
p 8
n 8
e 8
Electronic Configuration: $1s^2\ 2s^2\ 2p^4$

Physical Properties: colorless gas, nonconductor
Chemical Properties: supports combustion
Lewis Dot: $\cdot\ddot{\underset{\cdot\cdot}{O}}\cdot$

Atomic Radii Supplemental packet page 59

Below is a diagram showing the relative size of atoms. the atoms sizes are in picometers (1 pm = 1EE-12 m).



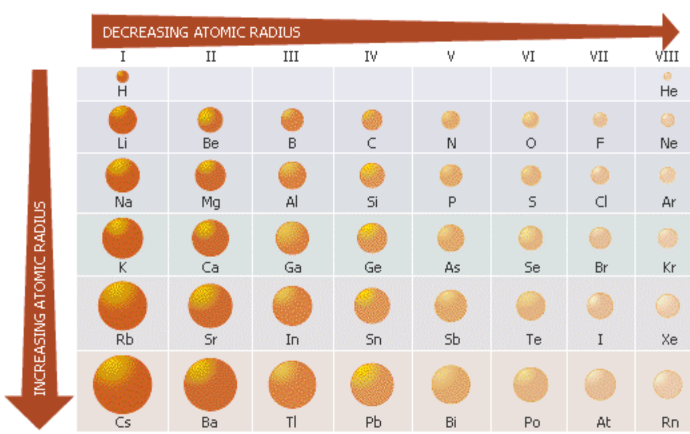
• Two factors must be taken into consideration in explaining this periodic trend

(1) Increasing nuclear charge, Z, which is related to the number of increasing protons with a nucleus.
• Along a period (left to right) the the atomic number increases while the valence electrons remain in the same shell. Thus due to the increasing nuclear charge (pulling electrons closer to the nucleus) the radii of the atoms decrease left to right.

(2) Increasing number of shells, which is related to increasing principal quantum number n, where an element's row number equals its total number of electrons shells.
• Top to bottom along a group the atomic number continues to increase. However the shell increases from shell 1 to shell 2 etc.. The atomic orbitals for each successive shell get larger and larger - more than compensating for the increased nuclear charge. The result is atomic radii increase top to bottom along a group.

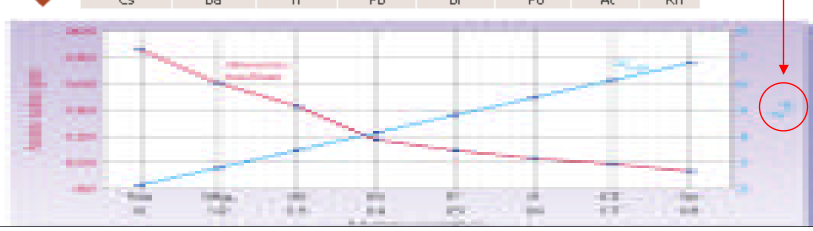
Supplemental packet page 59

Atomic Radius Variation in the Periodic Table



Z=nuclear charge
Z increases from left to right within a row

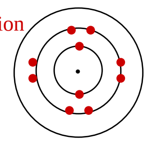
Note: atomic size decreases within a row as Z increases see graph



Supplemental packet page 50

Ionic Structure

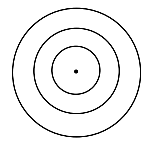
Atomic Number: 11
Name: sodium-23 ion
Symbol: $^{23}_{11}Na^{1+}$
mass # 23
p 11
n 12
e 10
More protons than electrons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^0$

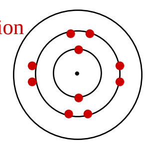
Physical Properties: metal cation, positive ion, 1+ charge
Chemical Properties: combines w/ anions
Lewis Dot: $[Na]^{1+}$

Atomic Number: 17
Name:
Symbol:
mass # 35
p ______
n ______
e ______
Electronic Configuration:



Physical Properties:
Chemical Properties:
Lewis Dot:

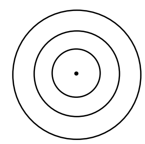
Atomic Number: 12
Name: magnesium-24 ion
Symbol: $^{24}_{12}Mg^{2+}$
mass # 24
p 12
n 12
e 10
More protons than electrons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^0$

Physical Properties: metal cation, positive ion, 2+ charge
Chemical Properties: combines w/ anions
Lewis Dot: $[Mg]^{2+}$

Atomic Number: 8
Name:
Symbol:
mass # 16
p ______
n ______
e ______
Electronic Configuration:

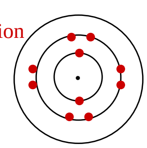


Physical Properties:
Chemical Properties:
Lewis Dot:

Supplemental packet page 50

Ionic Structure

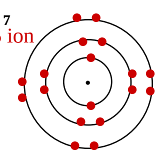
Atomic Number: 11
Name: sodium-23 ion
Symbol: $^{23}_{11}Na^{1+}$
mass # 23
p 11
n 12
e 10
More protons than electrons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^0$

Physical Properties: metal cation, positive ion, 1+ charge
Chemical Properties: combines w/ anions
Lewis Dot: $[Na]^{1+}$

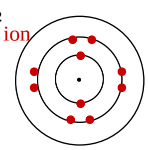
Atomic Number: 17
Name: chloride-35 ion
Symbol: $^{35}_{17}Cl^{1-}$
mass # 35
p 17
n 18
e 18
More electrons than protons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Physical Properties: nonmetal anion, negative ion, 1- charge
Chemical Properties: combines w/ cations
Lewis Dot: [:Cl:] 1-

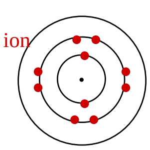
Atomic Number: 12
Name: magnesium-24 ion
Symbol: $^{24}_{12}Mg^{2+}$
mass # 24
p 12
n 12
e 10
More protons than electrons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^2$

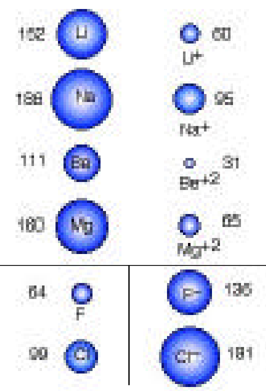
Physical Properties: metal cation, positive ion, 2+ charge
Chemical Properties: combines w/ anions
Lewis Dot: $[Mg]^{2+}$

Atomic Number: 8
Name: oxygen-16 ion
Symbol: $^{16}_{8}O^{2-}$
mass # 16
p 8
n 8
e 10
More electrons than protons



Electronic Configuration: $1s^2\ 2s^2\ 2p^6\ 3s^0$

Physical Properties: nonmetal anion, negative ion, 2- charge
Chemical Properties: combines w/ cations
Lewis Dot: [:O:] 2-



Radius of some representative atoms and their ions in picometers

Anions: The reverse occurs when a negative ion is formed by gaining an electron. The electron added is in the same energy level as the other valence electrons but the effective nuclear charge, Z_{eff}, is lower in comparison to the number of valence electrons. The attraction of the nucleus for each electron is less than before and the negative ion has a larger radius than the neutral atom. Forming -2 and -3 ions increases the size of the ion even more.

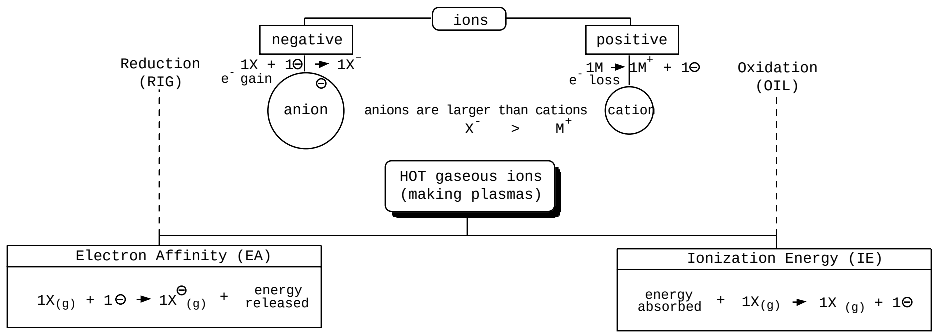
Compare the atomic and ionic radii for these selected atoms.

Cations **Anions**

Anions are larger than cations

Familiarize yourself with these ion trends

Plasmas (hot gaseous ions) - The Fourth State of Matter



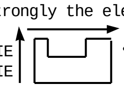
Ionization Energy

Ionization Energy (IE)

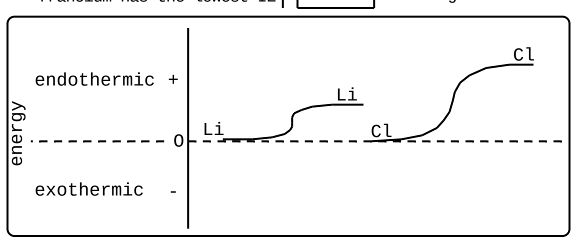
energy absorbed + $1X_{(g)} \rightarrow 1X^+_{(g)} + 1e^-$

Ionization energy is the energy required (absorbed)
to remove an electron from an atom in the gaseous state

- IE energies are always postive in numerical value
- the smaller the IE, the more easily an electron can be removed
- IE is a measure of how strongly the electrons are held by the nucleus
- direction of increasing IE
- francium has the lowest IE



- He has the highest IE



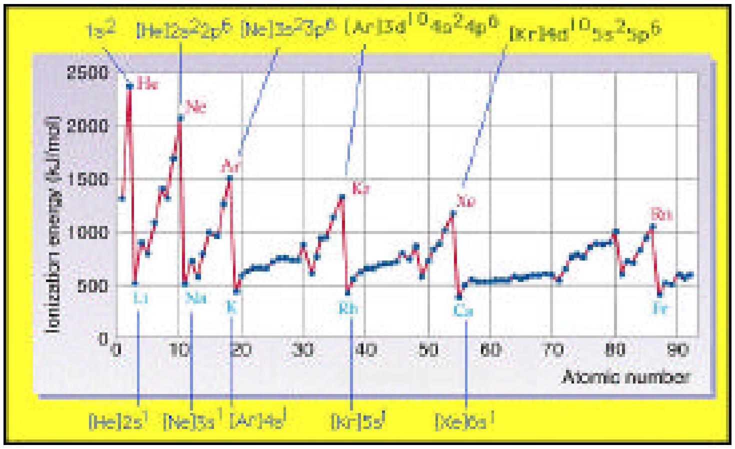
energy absorbed endothermic + $1X_{(g)} \rightarrow 1X_{(g)} + 1e^-$

Ionization Energy

Ionization energy is how much energy it takes to pull an electron away from each atom in the gaseous phase,

Ionization Energy (IE)
energy absorbed + $1X_{(g)} \rightarrow 1X^{+}_{(g)} + 1\ominus$

If we plot these ionization energies versus atomic number the resulting graph below emerges.

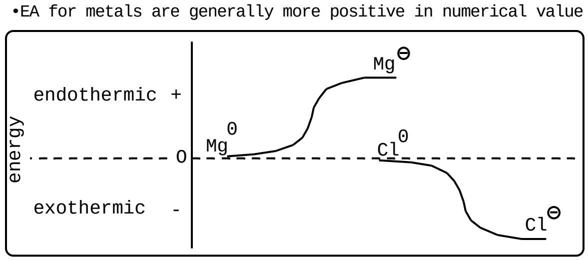


Electron Affinity

Electron Affinity (EA)
$1X_{(g)} + 1\ominus \rightarrow 1X^{-}_{(g)}$ + energy released

Electron affinity is the amount of energy released when an electron is accepted by an atom in the gaseous state

- EA measures the tendency to gain or retain electrons
- EA for nonmetals are generally negative in numerical value
- EA for metals are generally more positive in numerical value



$1X_{(g)} + 1\ominus \rightarrow 1X^{-}_{(g)}$ + energy released exothermic

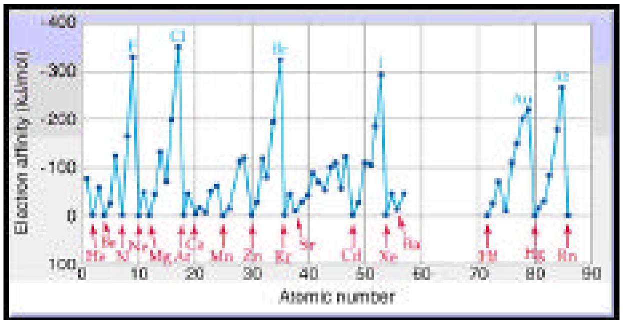
Electron Affinity

Electron affinity is, essentially the opposite of the ionization energy: Instead of removing an electron from the element we add an electron to the element to create an anion.

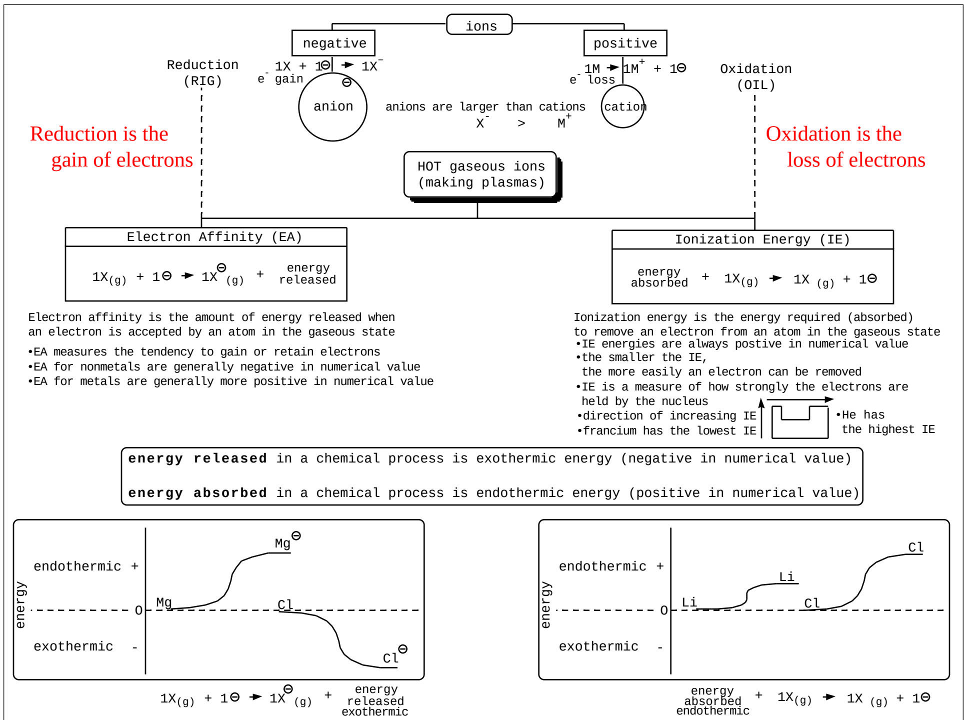
Electron Affinity (EA)

$$1X_{(g)} + 1e^{-} \rightarrow 1X^{-}_{(g)} + \text{energy released}$$

Generally, the energy that results from this process (the electron affinity) is negative or close to zero. The more negative this energy the more this process is favored. In the figure below we see the trends in the electron affinity for many of the elements.



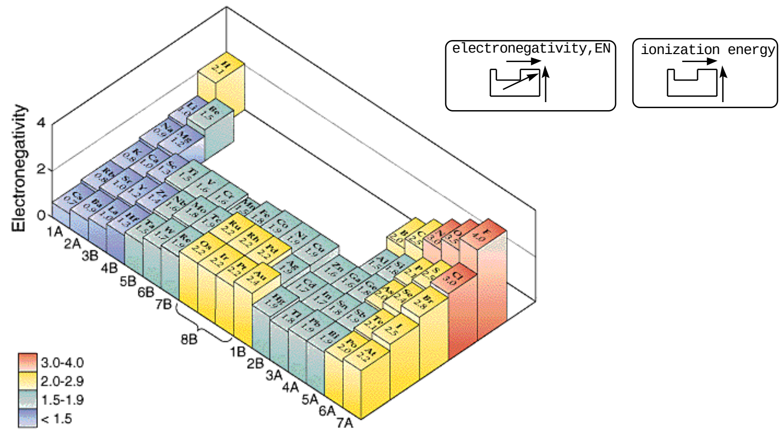
Note that the noble gases, alkali metals and alkali earth metals have E.A. close to zero - indicating that these groups of elements do not particularly like to become anions. However, the nonmetals and especially the halogens are highly negative and thus readily become anions. A periodic trend is evident, as was the case for the ionization energy. This periodic trend can be understood as a reflection of the underlying periodicity in the electronic configuration of the elements



Electronegativity FONClBrISCH

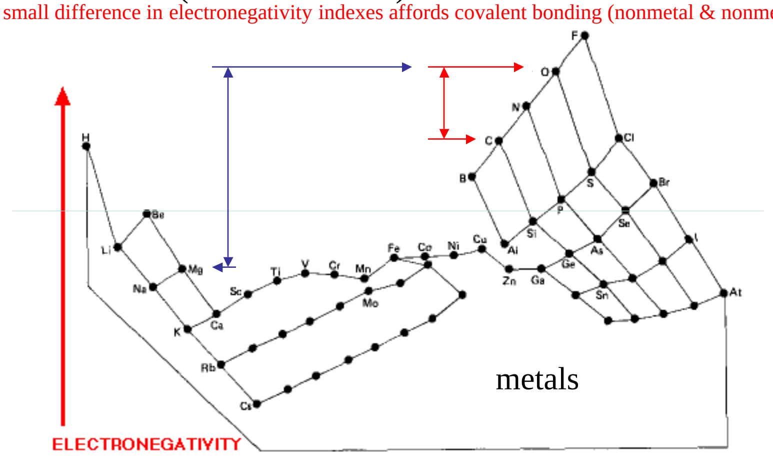
Electronegativity, EN, is an index that tells the relative attraction an element has for electrons in a bond. Electronegativity has a high value of 4.0 for F, fluorine. The lowest electronegativity value is about 0.7 for Cs, cesium. The table below shows the nonmetals have relatively high electronegativities. The metals have relatively low electronegativities. The electronegativities follow the same trends as ionization energies. The rare gases generally are not tabulated for EN values. The takehome messages is that do not need to remember electonegativity values only this trend for increasing EN for these nonmetals.

F > O > N > Cl > Br > I > S > C > H



nonmetals (FONCl BrISCH)

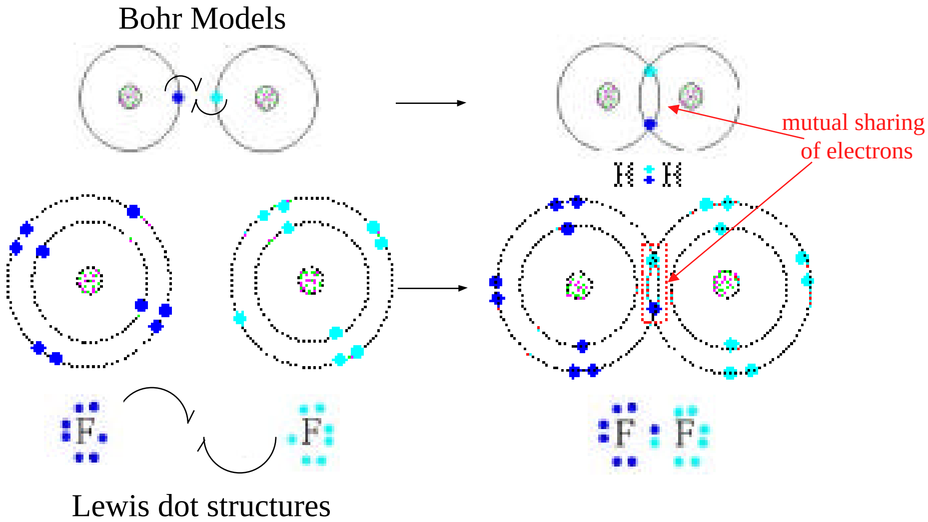
A small difference in electronegativity indexes affords covalent bonding (nonmetal & nonmetal)



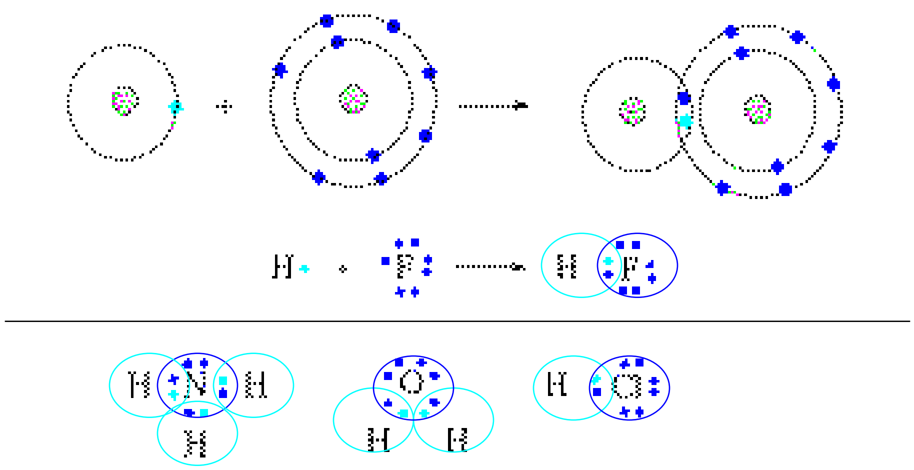
A large difference in electronegativity indexes affords ionic bonding (metal & nonmetal)

Section 6.2 - Covalent Bonds & Electron-Dot Formulas

1) Covalent compounds consist of nonmetals (e.g., F O N Cl Br I S C H)
2) Unlike ionic salts, covalent compounds share electrons between atoms to achieve extra stability associated with 8 valence electrons.



Section 6.2 - Covalent Bonds & Electron-Dot Formulas



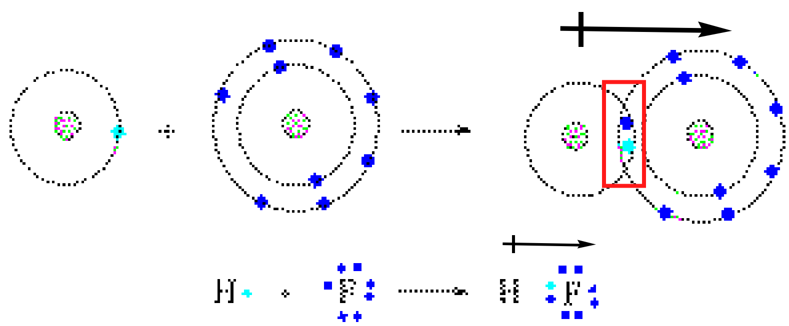
Note: Hydrogen wants a duet and the other nonmetals want an "octet."

Section 6.6 - Bond of Polarity

Bond Polarity is all about UNEQUAL SHARING of electrons in a covalent bond. Our analysis of bond polarity will be based upon an electronegativity trend. The definition of electronegativity is, “the ability for atom to pull electrons toward itself in a covalent bond.” This may cause an UNEQUAL SHARING of the electrons between atoms. An electronegativity trend, F O N Cl Br I S C H, can be used for determining **bond polarity** between two **nonmetal** atoms. Fluorine has been experimentally determine to be the most electronegative element of all the elements. It is small, has only two electron shells and has high effective nuclear charge. Memorize the trend and on the next slide will we see how to apply it in determining bond polarity.

F O N Cl Br I S C H

1. The elements of F O N Cl Br I S C H are all nonmetals.
2. F is the most electronegative element, hydrogen is the least in this trend



Large difference in electronegativity between H—F most polar bond

F is more electronegative than H

F O N Cl Br I S C H

between C—F very polar bond

F O N Cl Br I S C H

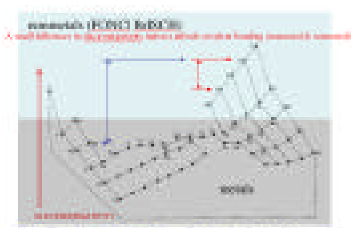
Little difference in electronegativity values produces a less polar bond

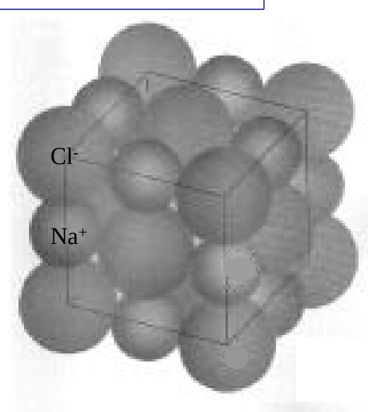
Equal Sharing between identical atoms, H-H, C-C, F-F

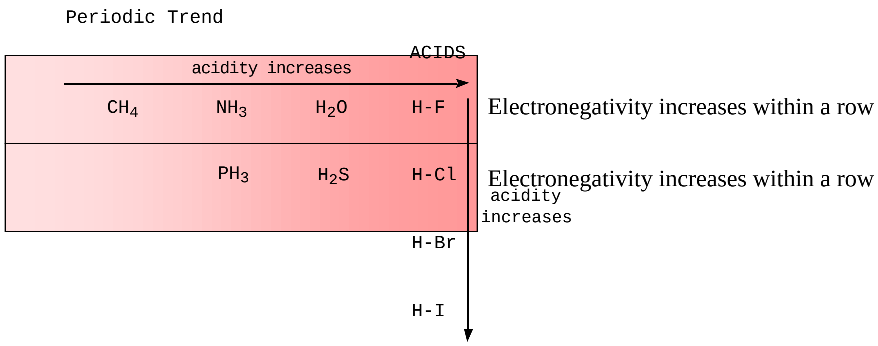
Equal sharing of electrons between two atoms produces a <u>nonpolar bond</u>

When EN differences are great, then electrons are transferred; not shared. This transfer of electrons produces ions that are involved in ionic bonding; bonds between cations and anions held together by electrostatics.

Recall, our graph of electonegativities showed





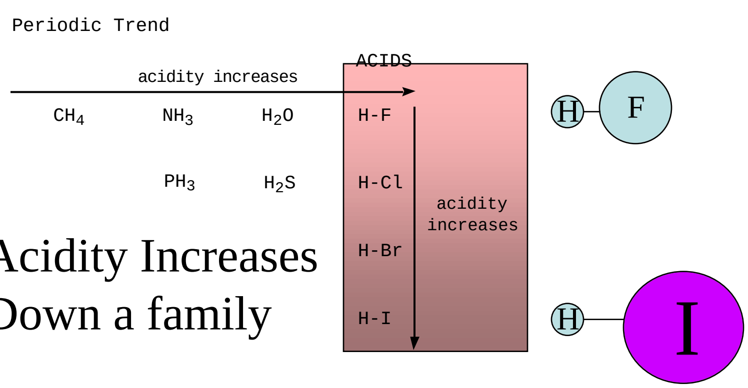


The more electronegative atom produces a <u>more</u> <u>polar</u> H-X bond

Electronegativity Trend

F > O > N > Cl > Br > I > S > C > H

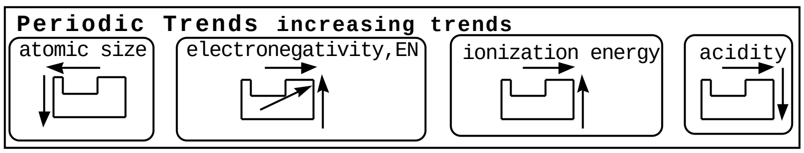
Foncl Brisch



Acidity Increases
Down a family

Atom size increases going down a family with in “n” shells.
A <u>larger</u> atoms afford <u>longer</u> H–X bond.
<u>Longer</u> covalent bonds are <u>more</u> <u>easily</u> <u>broken</u>.

Putting all together



Supplemental packet page 58

General Periodic Trends
Evidence to Support Wave Mechanical Atomic Orbital Theory

Atomic Size: (distance r between the nucleus and the outer most valence electrons)

low nuclear charge,Z, (Z=number of protons+)

high nuclear charge,Z

small atom size

atomic size

less e- shells

more e- shells

large atom size

Why are these FOUR increasing trends observed???

Ionic Size: (positive ions, negative ions, ions w/ multiple charge)

ionic size

less e- shells

Ion Charges

less e- smaller Period larger more e-

cations < anions

multiple charge Al^{3+} < Mg^{2+} < Na^{+} < F^{-} < O^{2-} < N^{3-} Same Row Elements Multiple Charge

family trend Li^{+} < Na^{+} < K^{+} < O^{2-} < S^{2-} < Se^{2-} Elements of the same family

more e- shells

smaller cation

larger anion

large ion size

Ionization Energy: A(g) ----> A^{+}(g) + 1e⁻

less e- shells

high nuclear charge,Z

ionization energy

Ionization Energy: Period

high ionization energy

Ionizing atoms in the gas phase (making plasmas) an endothermic (absorbed) energy process to remove an electron from an atom in the gas phase.

electronegativity

less e- shells

high nuclear charge,Z

Eletronegativity: Period

high electronegativity

The ability for an atom to attract electrons toward itself in a chemical bond FONCl BrISCH

Complete the following and check your answers — Supplemental packet page 61

Indentify Periodic Properties and Trends

Dr. Gergens - SD Mesa College

1. How many electrons are contained in the valence shell of the following?

K _1_ Aluminum _3_ Ca _2_

Germanium _4_ Si _4_ Barium 2__

2. How many electrons are allowed in:

an "s" subshell _2_ a "p" subshell _6_ a "d" subshell _10_

3. How many electrons are allowed in the:

second shell _8_ third shell _18_ fourth shell _32_

4. Give the electron dot structures for the following elements:

Ca Ne C O N Mg Al

Complete the following and check your answers — Supplemental packet page 61

5. Circle the member of each pair that has a larger atomic radius.

S or F   strontium or **cesium**   arsenic or **In**   C or **gallium**

6. Circle the member of each pair that has a larger ionic radius.

S^{2-} or F^- strontium or **cesium** Al^{3+} or **P^{3-}** Mg^{2+} or **K^+**

7. Circle the member of each pair that has a higher ionization energy.

O or **F**   **lithium** or potassium   **S** or selenium   **Ge** or lead

8. Circle the member of each pair that has the highest electronegativity.

S or **F**   **strontium** or cesium   **arsenic** or In   **C** or gallium