Chemical Bonding

Now that we know what atoms "look" like …

A very small (less than 0.001% of the volume) and massive (more than 99.99% of the mass) nucleus with protons (+) and neutrons (neutral) and electrons in orbitals.

… it is time to consider how atoms combine or bond.

When atoms combine they form compounds.

Ionic Bonding

Ionic bonding occurs when metals and nonmetals "trade" one or more electrons and the resulting opposite charges attract each other.

Metals are on the left side of the periodic table.

Metals tend to lose electrons (they have a low ionization energy, a low electron affinity and a low electronegativity).

Ionic Bonding

Nonmetals are on the upper right side of the periodic table.

Nonmetals tend to gain electrons (except for the Noble Gases) because they have high ionization energy, high electron affinity and high electronegativity.

Metalloids (or semi metals) are elements with properties intermediate to metals and nonmetals. Sometimes they act as metals, sometimes they act as nonmetals.

Metal Properties

low ionization energy

low electron affinity

low electronegativity

tend to lose electrons in reactions

conduct heat and electricity

malleable

ductile

shiny

Nonmetal Properties

high ionization energy

high electron affinity

high electronegativity

tend to gain electrons in reactions

good insulators

brittle

dull

Noble Gases

Noble Gases are special elements.

Many of the Noble Gases have never formed a stable compound.

Some of the larger Noble Gases form compounds only under extreme conditions with highly electronegative elements.

Why?

Noble Gases have full energy levels.

The full energy levels provide a stable and unreactive element.

Noble Gas Configuration

Because the Noble Gas electron configuration is so stable other elements "want" to get to this same electron configuration.

(ending in p^6 except helium which is full with $1s^2$)

Metals will generally lose electrons until they achieve a Noble Gas electron configuration.

Nonmetals will generally gain electrons until they achieve a Noble Gas electron configuration.

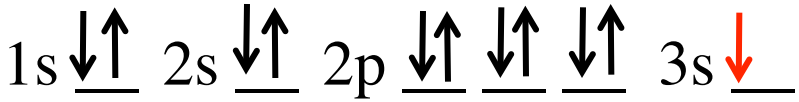
Ionic Compounds
“trading” of electrons

Consider common table salt, chemical name of sodium chloride.

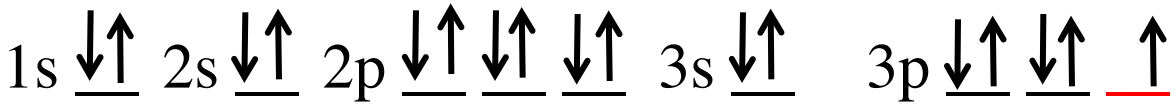
It is composed of the elements sodium and chlorine.

sodium chloride

sodium has 11 p^+ and 11 e^-



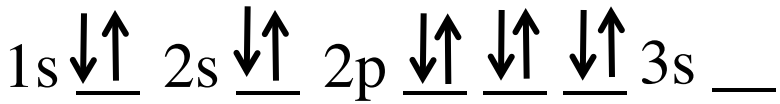
chlorine has 17 p^+ and 17 e^-



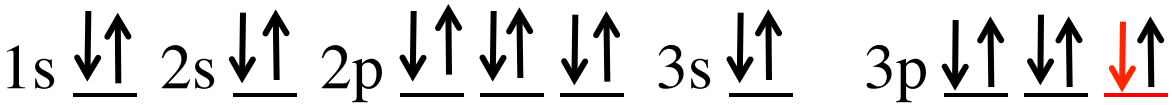
sodium has one electron in the outer energy level that it would be "happy" to lose and chlorine needs one more electron to have a full energy level.

sodium chloride

If sodium loses one electron it will have 11 p^+ and 10 e^- giving it a 1+ charge and a stable electron configuration that matches the Noble Gas neon.



If chlorine gains one electron it will have 17 p^+ and 18 e^- giving it a 1- charge and a stable electron configuration that matches the Noble Gas argon.



These opposite charged particles will attract each other.

Ions

An ion is any particle that is not neutral (it has a charge)

A cation is an ion with a positive charge. Metals usually form cations when they lose one or more electrons.

An anion is an ion with a negative charge. Nonmetals usually form anions when they gain one or more electrons.

Ionic Bond

These opposite charges from the cation and the anion will attract each other.

The attraction is called an ionic bond.

When multiple atoms form ions and attract each other the result is called an ionic compound.

When forming ionic bonds the law of conservation of matter still applies - electrons are not created or destroyed, only transferred from one atom to another.

Cations

Because metals "like" to lose electrons they often form cations.

The root name of the cation stays the same but the word ion is added to indicate that it now has a charge.

The symbol of the element also changes to reflect this charge.

sodium atom - Na

sodium ion - Na^{1+} or Na^{+1} or Na^{+}

Anions

Because nonmetals "like" to gain electrons they often form anions.

The root name of a single atom anion gets changed to end in "ide" and the word ion is added to indicate that it now has a negative charge.

The symbol of the element also gets changed to reflect this charge

chlorine atom - Cl

chloride ion - Cl^{1-} or Cl^{-1} or Cl^{-}

Ionic Compounds

Ionic compounds are neutral. They have no net charge.

When formulas for ionic compounds are written they must be neutral. The charge of the cations must cancel the charge of the anions.

sodium chloride NaCl

Standard rules require the cation be written first and the anion written second.

Lewis Electron Dot Structures

Writing out the entire electron configuration becomes very cumbersome.

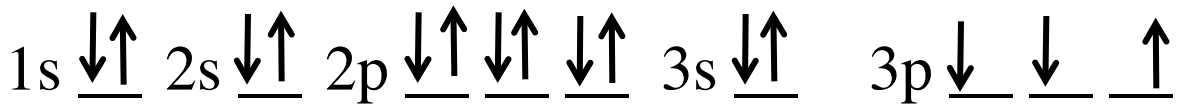
A shorter method of showing what happens to the electrons is called the Lewis electron Dot structure.

To write this structure "dots" (or sometimes *'s or x's) used to represent valence electrons are placed around the symbol of the element.

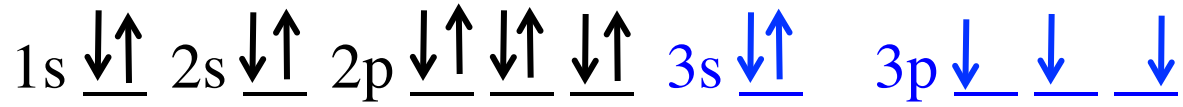
Valence electrons are the electrons in the highest occupied energy level of the atom.

Valence Electrons

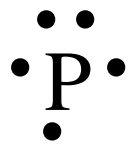
Consider phosphorous with 15 protons and 15 electrons.



The highest occupied energy level is n=3



There are 5 electrons in the third energy level so phosphorous has 5 valence electrons.



Group or Family Similarities

The reason elements are placed into a group (or family) on the periodic table is that they have similar properties.

The most important property is that of electron configuration.

The electron configuration determines most of the chemical properties of an element.

Elements with the same ending electron configuration (same number of valence electrons) are placed in the same group.

The Octet Rule

The Noble Gases have 8 valence electrons (except for helium that has a full energy level with 2).

This "rule of 8" valence electrons being stable is called the octet rule.

All of the elements "want" to get to 8 or 0 dots representing 8 or 0 valence electrons (except hydrogen which wants either 0 or 2).

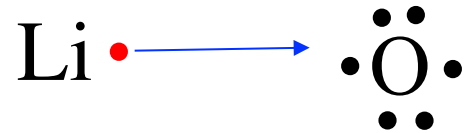
It is shorter to show the valence electrons as dots to indicate how electrons are transferred.

lithium and oxygen

Lithium has one valence electron.

Oxygen has six valence electrons.

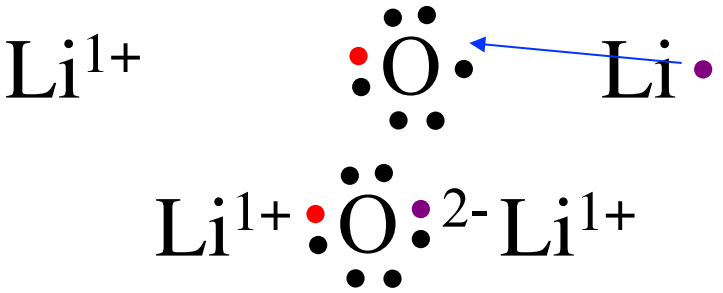
Lithium would like to give away the one valence electron to the oxygen.



This leaves oxygen still "wanting" one more electron.

lithium and oxygen

The oxygen will search for another lithium that will give it the other electron it "needs".



This gives a formula of Li_2O

The total charge is zero, no electrons were created or destroyed.

The cation is written first, the name becomes lithium oxide.

More Examples

Try writing the formula and the name for the compound that forms between the following elements.

calcium and fluorine

CaF_2 calcium fluoride

potassium and sulfur

K_2S potassium sulfide

aluminum and oxygen

Al_2O_3 aluminum oxide