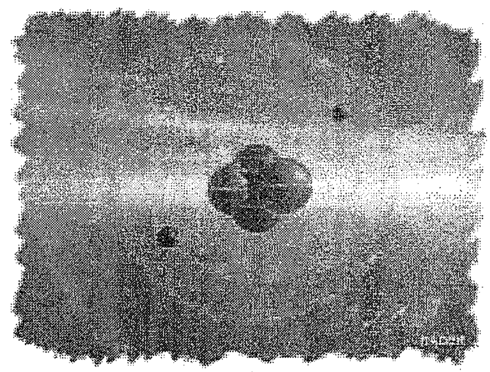
Atoms Around Us

If you want to have a language, you will need an alphabet. If you want to build proteins, you will need amino acids. Other examples in chemistry are not any different. If you want to build molecules, you will need **elements**. Each element is a little bit different from the rest. Those elements are the alphabet to the language of molecules.

Why are we talking about elements? This is the section on atoms.

Let's stretch the idea a bit. If you read a book, you will read a language. Letters make up that language. But what makes those letters possible? Ummm... Ink? Yes! You need ink to crate the letters. And for each letter, it is the same type of ink.



ATOMS HAVE THREE BASIC PARTS... PROTONS, NEUTRONS, AND ELECTRONS.

Confused? Don't be. Elements are like those letters. They have something in common. That's where atoms come in. All elements are made of atoms. While the atoms may have different weights and organization, they are all built in the same way. Electrons, protons, and neutrons make the universe go.

If you want to do a little more thinking, start with particles of matter. Matter, the stuff around us, is used to create atoms. Atoms are used to create the elements. Elements are used to create molecules. It just goes on. Everything you see is built by using something else.

You could start really small...
- Particles of matter
- Atoms
- Elements
- Molecules
- Macromolecules
- Cell organelles
- Cells
- Tissues
- Organs
- Systems
- Organisms

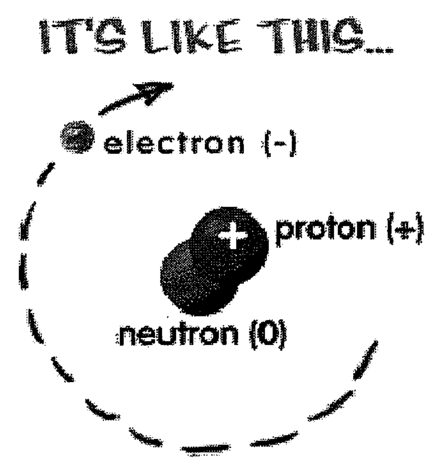
- Populations
- Ecosystems
- Biospheres
- Planets
- Planetary Systems with Stars
- Galaxies
- The Universe

.And finish really big.

Wow. All of that is possible because of atoms.

ATOMS = BUILDING BLOCKS

Atoms are the basis of chemistry. They are the basis for everything in the Universe. You should start by remembering that matter is composed of atoms. Atoms and the study of atoms are a world unto themselves. We're going to cover basics like atomic structure and bonding between atoms. As you learn more, you can move to the biochemistry tutorials and see how atoms form compounds that help the biological world survive.

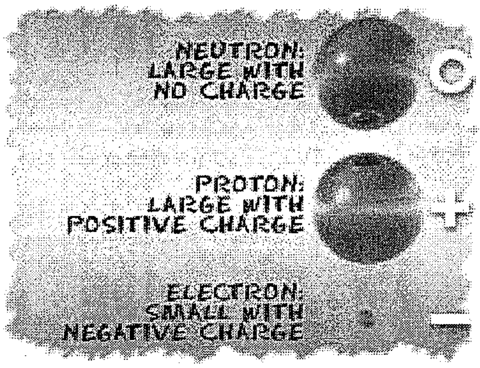


SMALLER THAN ATOMS?

Are there pieces of matter that are smaller than atoms? Sure there are. You'll soon be learning that atoms are composed of pieces like neutrons, electrons, and protons. But guess what? There are even smaller particles moving around in atoms. These super-small particles can be found inside the protons and neutrons. Scientists have many names for those pieces, but you may have heard of **nucleons** and **quarks**. Nuclear chemists and physicists work together with particle accelerators to discover the presence of these tiny, tiny, tiny pieces of matter.

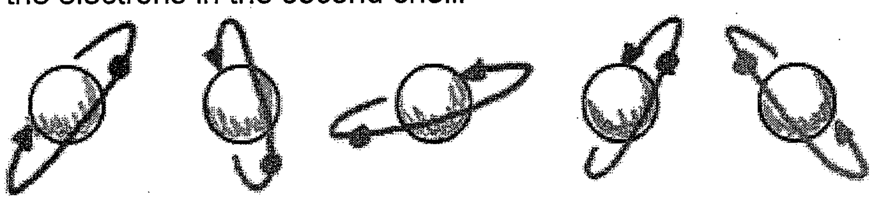
Even though those super tiny atomic particles exist, there are three basic parts of an atom. The parts are the **electrons**, **protons**, and **neutrons**. What are electrons, protons, and neutrons? A picture works best. You have a basic atom. There are three pieces to an atom. There are electrons, protons, and neutrons. That's all you have to remember. Three things! As you know, there are over 100 elements in the **periodic table**. The thing that makes each of those elements different is the number of electrons, protons, and neutrons. The protons and neutrons are always in the center of the atom. Scientists call the center of the atom the **nucleus**. The electrons are always found

whizzing around the center in areas called orbitals.



You can also see that each piece has either a "+", "-", or a "0." That symbol refers to the charge of the particle. You know when you get a shock from a socket, static electricity, or lightning? Those are all different types of electric charges. There are even charges in tiny particles of matter like atoms. The electron always has a "-" or negative charge. The proton always has a "+" or positive charge. If the charge of an entire atom is "0", that means there are equal numbers of positive and negative pieces, equal numbers of electrons and protons. The third particle is the neutron. It has a neutral charge (a charge of zero).

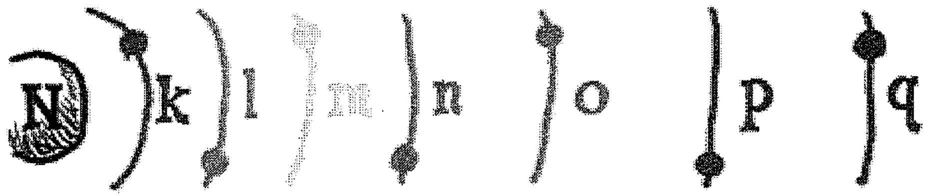
As you know, electrons are always moving. They spin very quickly around the nucleus of an atom. As the electrons spin, they can move in any direction, as long as they stay in their shell. Any direction you can imagine - upwards, downwards, or sidewards - electrons can do it. The atomic shell or orbital is the distance from the nucleus that the electron spins. If you are an electron in the first shell you are always closer to the nucleus than the electrons in the second shell.



ORBITAL BASICS

Let's cover some basics of atomic **orbitals**.
1. A shell is sometimes called an orbital or **energy level**.
2. Shells are areas that surround the center of an atom.
3. The center of the atom is called the nucleus.
4. Electrons live in something called shells.
5. Each of those shells has a name.

There are a couple of ways that atomic orbitals are named. You may have heard of the SPDF system before. Chemists also use letters to name the orbitals around a nucleus. They use the letters "k,l,m,n,o,p, and q". The "k" shell is the one closest to the nucleus and "q" is the farthest away.

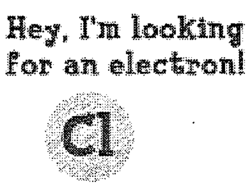


Not all shells hold the same number of electrons. For the first eighteen elements, there are some easy rules. The k-shell only holds two electrons. The l-shell only holds eight electrons. The m-shell only holds eight electrons (for the first eighteen elements). The m-shell can actually hold up to 18 electrons as you move farther along the periodic table. The maximum number of electrons you will find in any shell is 32.

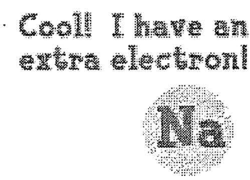
WHERE ARE THE ELECTRONS?

We've been telling you that electrons reside in specific shells or move in specific directions. We can't really tell you exactly where an electron is at any moment in time. We can only approximate, or guess, where an electron is located. According to something called **quantum theory**, an electron can be found anywhere around the nucleus. Using advanced math, scientists are able to approximate, or guess, that electrons are in general areas. These general areas are called the shells.

LOOKING AT IONS

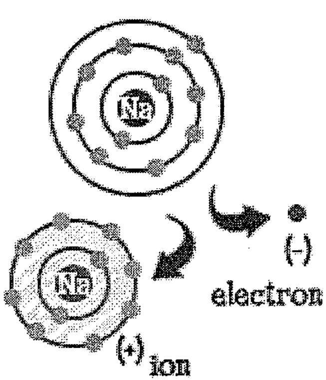


We've talked about ions before. Now it's time to get down to basics. Ions are atoms with either extra electrons or missing electrons. A normal atom is called a neutral atom. That term describes an atom with a number of electrons equal to the **atomic number**.



What do you do if you are a sodium (Na) atom? You have eleven electrons, one too many to have your shell filled. You need to find another element who will take that electron away from you. Bring in chlorine (Cl). Chlorine (Cl) will take that electron away and leave you with 10 electrons inside of two filled shells. You are a happy atom. Now you are also an ion and missing one electron. You are a sodium ion (Na+). You have one less electron than your atomic number.

ION CHARACTERISTICS



So now you've become a sodium ion (Na+). Now you have ten electrons. That's the same number as neon (Ne). But you aren't neon (Ne). Since you're missing an electron you aren't really a complete sodium (Na) atom either. You are now something completely new. An ion. Your whole goal as an atom was to become a "happy atom" with completely filled **electron orbitals**. Now you have those filled shells. You are stable.

What do you do that's so special now? Now that you have given up the electron, you are quite electrically attractive. Other electrically charged atoms (ions) are now looking at you and seeing a good partner to bond with. That's where chlorine comes in.

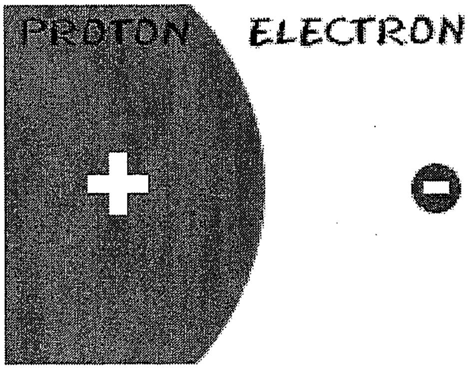
ELECTROVALENCE

Don't get worried about the big word. **Electrovalence** is just another word for something that has given up its electron and become an ion. If you look at the periodic table, you might notice that elements on the left side usually become positively charged ions and elements on the right side get a negative charge. That trend means the left side has a positive valence and the right side has a negative valence. Valence is a measure of how much an atom wants to bond with other atoms.

There are two main types of bonding, **covalent** and **electrovalent**. Scientists also call ionic bonds electrovalent bonds. **Ionic bonds** are just groups of charged ions held together by electric forces. Scientists call these groups ionic agglomerates. When in the presence of other ions, the electrovalent bonds are weaker because of outside electrical forces and attractions.

Look at sodium chloride (table salt) as an example. Salt is a very strong bond when it is sitting on your table. It would be nearly impossible to break those ionic bonds. However, if you put that salt into some water the bonds break very quickly. It happens easily because of the electrical attraction of the water. Now you have sodium ($Na+$) and chloride ($Cl-$) ions. Remember that ionic bonds are normally strong but very weak in water.

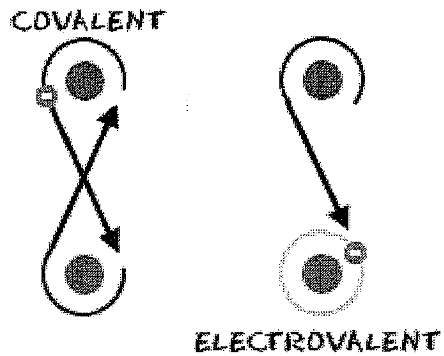
CHARGE IT!



Electrons are the negatively charged particles of atoms. Together, all of the electrons of an atom create a **negative charge** that balances the positive charge of the protons in the atomic nucleus. Electrons are extremely small compared to all of the other parts of the atom. The mass of an electron is almost 1,000 times smaller than the mass of a proton.

Electrons are found in clouds that surround the nucleus of an atom. Because electrons move so quickly, it is impossible to see where they are at a specific moment in time. After years

of experimentation, scientists discovered specific areas where electrons are likely to be found. These shells change depending on how many electrons an element has. The higher the atomic number, the more shells and electrons an atom will have.



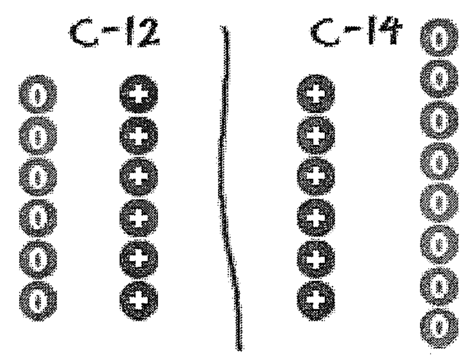
Electrons play a major role in many chemical bonds. There is one type of bonding called **electrovalent** bonding (ionic) where an ion from one atom is transferred to another atom. It is an even trade, creating two ions. The second type of bonding is called **covalent** bonding. Electrons are actually shared between two or more atoms in a cloud. Both types have specific advantages and weaknesses.

POWER UP

Electrons are very important in the world of electronics. The very small particles stream through wires and circuits creating currents of electricity. The electrons move from negatively charged parts to positively charged ones. The negatively charged pieces of any circuit have extra electrons while the positively charged pieces want more electrons. The electrons then jump from one area to another. When the electrons move, the current can flow through the system.

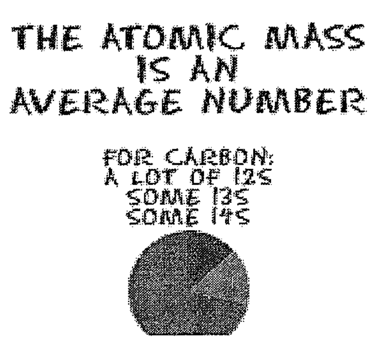
NEUTRON MADNESS

We have already learned that ions are atoms that are either missing or have extra electrons. Let's say an atom is missing a neutron or has an extra **neutron**. That type of atom is called an **isotope**. An atom is still the same element if it is missing an electron. The same goes for isotopes. They are still the same element. They are just a little different from every other atom of the same element.



There are a lot of carbon atoms in the universe. The normal ones are carbon-12. Those atoms have 6 neutrons. There are a few straggler atoms that don't have 6. Those odd ones may have 7 or even 8 neutrons. As you learn more chemistry, you will probably hear about carbon-14. Carbon-14 actually has 8 neutrons (2 extra). C-14 is considered an isotope of the element carbon.

MESSING WITH THE MASS



If you have looked at a periodic table you may have noticed that the atomic mass of an element is rarely an even number. That happens because of the isotopes. If you are an atom with an extra electron, it

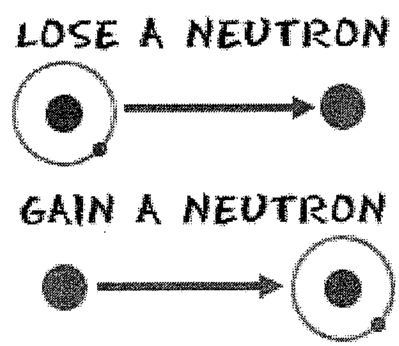
is no big deal. Electrons don't have much of a mass when compared to a neutron or proton.

Atomic masses are calculated by figuring out how many atoms of each type are out there in the universe. For carbon, there are a lot of C-12, a couple C-13, and a few C-14 atoms. When you average out all of the masses, you get a number that is a little bit higher than 12 (the weight of a C-12 atom). The mass for element is actually 12.011. Since you never really know which C atom you are using in calculations, you should use the mass of an average C atom.

RETURNING TO NORMAL

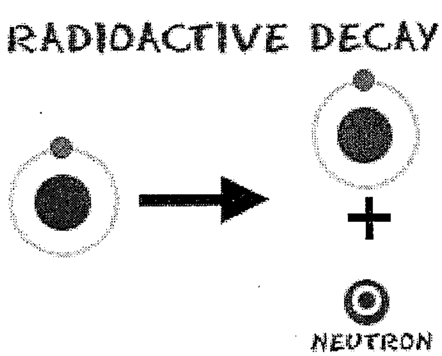
If we look at the C-14 atom one more time we can see that C-14 does not last forever. There is a point where it loses those extra neutrons and becomes C-12. That loss of the neutrons is called **radioactive decay**. That decay happens regularly like a clock. For carbon, the decay happens in a couple of thousand years. Some elements take longer and others have a decay that happens over a period of minutes.

NEITHER HERE NOR THERE



Neutrons are the particles on an atom that have a neutral charge. They aren't positive like protons. They aren't negative like electrons. But don't start thinking that they aren't important. Every piece of an atom has huge importance to the way the atom acts and behaves. Neutrons are no exception.

So if an atom has equal numbers of electrons and protons, the charges cancel each other out and the atom has a neutral charge. You could add a thousand neutrons into the mix and the charge will not change. However, if you add a thousand neutrons you will be creating one super-**radioactive** atom. Neutrons play a major role in the mass and radioactive properties of atoms. You may have just read about isotopes. **Isotopes** are created when you change the normal number of neutrons in an atom.



You know that neutrons are found in the nucleus of an atom. During **radioactive decay**, they may be knocked out of there. But under normal conditions, protons and neutrons stick together in the nucleus. Their numbers are able to change the mass of atoms because they weigh about as much as a proton and electron together.

ONE SPECIAL ELEMENT

Did we say that all atoms have neutrons? Ooops. All elements have atoms with neutrons except for one. A normal hydrogen (H) atom does not have any neutrons in its tiny nucleus. That tiny little atom (the tiniest of all) has only one electron and one proton. You can take away the electron and make an ion, but you can't take away any neutrons. That special structure becomes very important when you learn how hydrogen interacts with other elements in the periodic table.

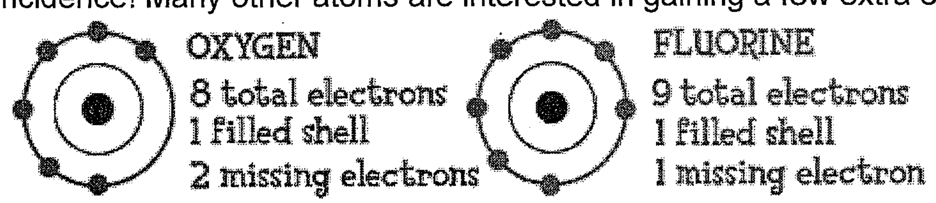
BONDING BASICS

You must first learn why atoms bond together. We use a concept called "Happy Atoms." We figure most atoms want to be happy, just like you. The idea behind Happy Atoms is that atomic shells like to be full. That's it. If you are an atom and you have a shell, you want your shell to be full. Some atoms have too many electrons (one or two extra). These atoms like to give up their electrons. Some atoms are really close to having a full shell. Those atoms go around looking for other atoms who want to give up an electron.

Let's take a look at some examples.

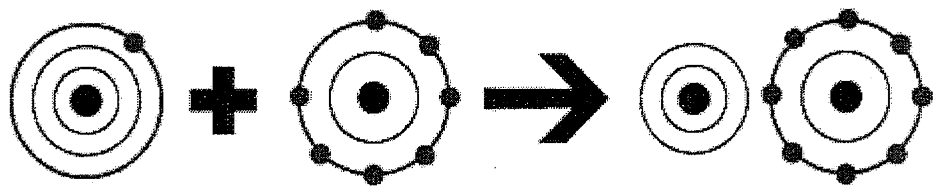
We should start with the atoms with atomic numbers between 1 and 18. There is a 2-8-8 rule for these elements. The first shell is filled with 2 electrons, the second is filled with 8 electrons, and the third is filled with 8. You can see that sodium (Na) and magnesium (Mg) have a couple of extra electrons. They, like all atoms, want to be happy. They have two possibilities. (1) They can try to get eight electrons to fill up their third shell. Or (2) they give up a few electrons and have a filled second shell. For them it's easier to give up a few electrons.

What a coincidence! Many other atoms are interested in gaining a few extra electrons.



Oxygen (O) and fluorine (F) are two good examples. Each of those elements is looking for a couple of electrons to make a filled shell. They have one filled shell with two electrons but their second shell wants to have eight. There are a couple of ways they can get the electrons. (1) They can share electrons, making a covalent bond. Or (2) they can just borrow them, and make an ionic bond (also called electrovalent bond).

So we've got a sodium (Na) atom that has an extra electron. We've also got a fluorine (F) atom that is looking for one.

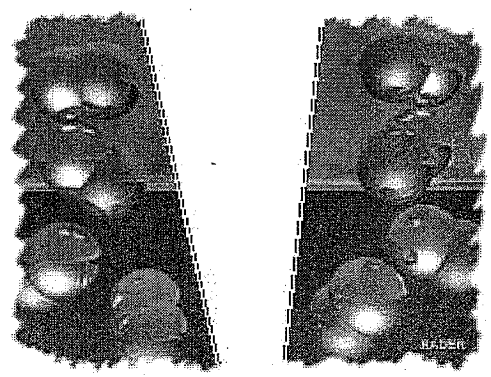


They wind up working together and both wind up happy! Sodium (Na) gives up its extra electron. The sodium (Na) has a full second shell and the fluorine (F) has a full second shell. Two happy atoms! That's one way things are able to bond together. They can give up or share electrons. The two elements have created an electrovalent bond.

COMPOUND BASICS

Compounds are groups of two or more elements that are bonded together. There are two main types of bonds that hold those atoms together, covalent and electrovalent/ionic bonds. **Covalent** compounds happen when the atoms share the electrons, and **ionic** compounds happen when electrons are donated from one atom to another.

We talked about compounds and molecules in the matter tutorials. When we discuss **phase changes** to matter, physical forces create the changes. When we talk about compounds, bonds are built and broken down by chemical forces. **Physical forces** (unless you're inside of the Sun or something extreme) cannot break down compounds. **Chemical forces** are forces caused by other compounds or molecules that act on substances.



A PHYSICAL FORCE WOULD CRACK A SOLID, BUT THE MOLECULES WOULD REMAIN.

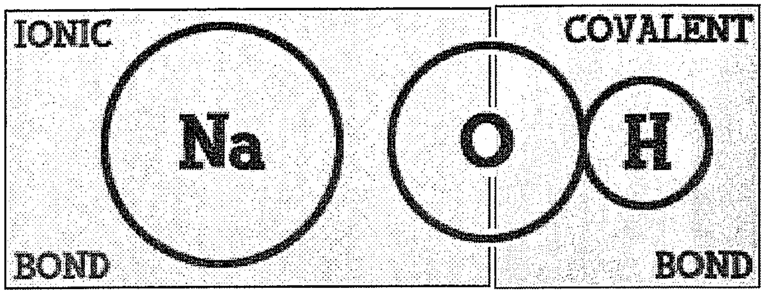
There are millions of different compounds around you. Chances are everything you can see is one type of compound or another. When elements join and become compounds, they lose their individual traits. Sodium alone is very reactive. But when sodium and chlorine combine, they form a non-reactive substance called sodium chloride (Salt, NaCl). The compound has none of the traits or the original elements. The new compound is not as reactive as the original elements. It has a new life of its own.

DIFFERENT BONDS ABOUND

Most compounds are made up of combinations of bonds. If you look at sodium chloride (NaCl), it is held together by one ionic bond. What about magnesium chloride (MgCl2)? One magnesium (Mg) and two chlorine (Cl) atoms. There are two ionic bonds. There's a compound called methane (CH_4). It is made up of one carbon (C) and four hydrogens (H). There are four bonds and they are all covalent. Those examples are very simple

compounds, but most compounds are combinations of ionic and covalent bonds.

Let's look at sodium hydroxide (Na-OH).



You can see that on the left is the sodium (Na) part and the right has the oxygen/hydrogen (-OH) part. The bond that binds the hydrogen (H) to the oxygen (O) is covalent. The sodium (Na) is bonded to the hydroxide part of the compound with an ionic bond. This is a very good example of how there can be different types of bonds within one compound.

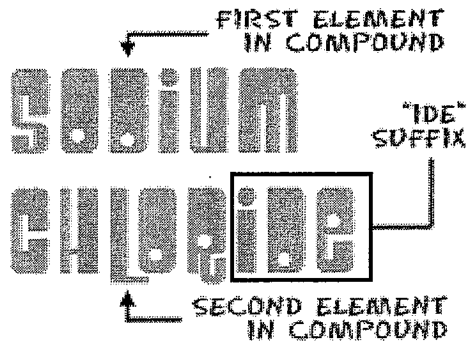
WHOLE LOTTA RULES GOING ON

The process is just a set of rules. We're going to show you some of the basics. There are some advanced ways of naming things that we're going to skip right now. Let's start with some basic rules. When you have two different **elements**, there are usually only two words in the compound name. The first word is the name of the first element. The second word tells you the second element and how many atoms there are in the compound. The second word also ends in IDE. That's the suffix. When you are working with non-metals like oxygen (O) and chlorine (Cl), the prefix (section at the beginning of the word) of the second element changes based on how many atoms there are in the compound. It's like this.

NUMBER	PREFIX	EXAMPLE
1	NONE	CHLORIDE
2	DI-	DICHLORIDE
3	TRI-	TRICHLORIDE
4	TETRA-	TETRACHLORIDE
5	PENTA-	PENTACHLORIDE
6	HEXA-	HEXACHLORIDE
7	HEPTA-	HEPTACHLORIDE
8	OCTA-	OCTACHLORIDE
9	NONA-	NONACHLORIDE
10	DECA-	DECACHLORIDE

Do you notice anything about the chalkboard? You can see that the prefixes are very

similar to the prefixes of geometric shapes. You know what a triangle is. Right? Well the prefix tri- means three. So when you have three chlorine (Cl) atoms, you would name it trichloride.



Look at the other names, too. You may know about a pentagon, a hexagon, or an octagon. The naming system in chemistry works the same way!

Let's put these ideas together! Remember, we're only talking about simple compounds with no metal elements. Most simple compounds only have two words in their names. Let's start with Carbon monoxide (CO). You have one carbon (C) atom and one oxygen (O) atom (you can also use the prefix MONO to say one atom). Remember that the second word ends in -ide. So...

(1) Carbon + (1) Oxygen = Carbon monoxide

Now we'll build on that example. What if you have one carbon (C) and two oxygen (O) atoms?

(1) Carbon + (2) Oxygen = Carbon dioxide

One last example and we'll call it quits. Now you have one carbon (C) and four chlorine (Cl) atoms.

(1) Carbon + (4) Chlorine = Carbon tetrachloride

You should be getting the idea now. The compound name can tell you how many atoms are inside. Take a look at some of the examples and see if you understand what is happening in the name.