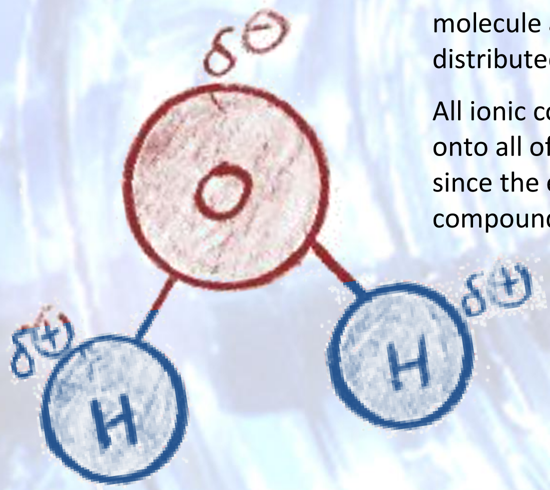
Chemistry Help Guide: **Polarity**

What is polarity in a molecule?

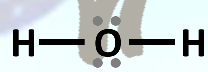
The term "polarity" refers to whether or not the electrons are evenly distributed all around the molecule. In a molecule, if one element is more electronegative than another, it will "steal" away the electrons from the other atoms. This means there will be more negative charge concentrated in one area of a molecule as compared to the rest of it. The more unevenly the electrons are distributed, the more polar a molecule will be.

All ionic compounds are polar since they will always have 1 element holding onto all of the electrons. Polarity does not play a role in metallic compounds since the electrons are already free to move around as they please. Covalent compounds can be highly polar, slightly polar, or nonpolar.



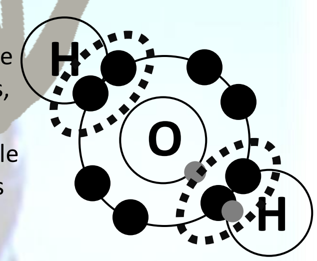
H_2O (water) is a polar molecule because its oxygen atom is so much more electronegative than the two hydrogen atoms it is bonded to. That means that the oxygen atom is going to "steal" away the electrons it is sharing with the hydrogen atoms. If the hydrogen atoms have lost their only electrons, they will have a positive charge (like a cation); since the oxygen has "grabbed onto" some extra electrons, it will have a negative charge (like an anion).

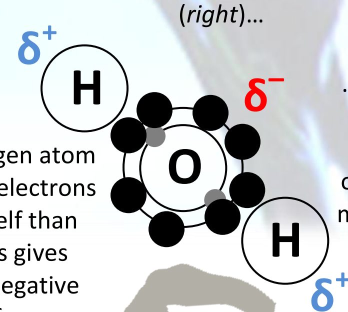
The **δ** (like a fancy lowercase "d") is called a "*delta*." It is a Greek letter that is used as a symbol in math and science to represent numerical changes. Here, you can think of it as a "sort of charge." The **δ^-** on the oxygen means that this end of the molecule will behave like it has a negative charge; the **δ^+** on the hydrogens means that their end will behave like it has a positive charge. This "sort of positive" and "sort of negative" make the molecule less stable and more reactive.



Lewis diagram of water

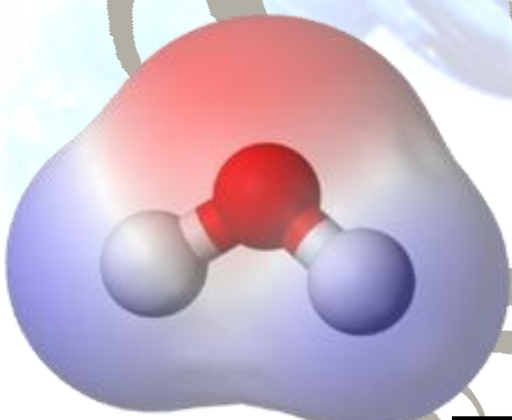
If we think about the sharing of electrons, we might imagine that a water molecule would look like this (*right*)…





Notice that the oxygen atom is holding all of the electrons much closer to itself than hydrogen is… This gives oxygen a slightly negative charge (**δ^-**) and forces hydrogen to have a slightly positive charge (δ^+).

…But, because of the high electronegativity difference between oxygen and hydrogen, the molecule would really look more like this (*left*) …



This three-dimensional diagram shows color-coded regions of **electropositivity** and **electronegativity**. The large red area in the middle shows oxygen's **negative charge** and the two blue areas on the outer edges show hydrogen's **positive charge**.

As much as 60% of the human body is made of water. It covers more than 70% of the world's surface. Water's polarity is one of the keys to why it is so important to like on earth. One of the most necessary uses of water in the functions of life is its ability to dissolve the vast majority of natural substances on earth.

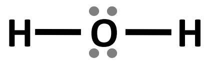
The ability to dissolve another substance is based on polarity. Polar substances, like water, are able to dissolve other polar substances. (Think "Like dissolves like.") Since most materials on earth are polar, water is able to dissolve almost anything in its way. This is why water is often called the "universal solvent."

But the truth is that this is not true… there are plenty of substances that water cannot dissolve, including anything that is nonpolar. Polarity is another example of why the way a molecule is bonded together determines the way it interacts with other substances around it.

Lewis diagrams tell us whether or not a covalent compound is polar.

Use the stability of the **central atom** to determine the polarity of a molecule.

For example: **Water, H_2O**

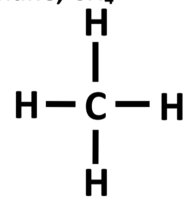


We already know that water is polar; but this is also shown by its Lewis diagram.

The central atom (**O**) has 2 unshared pairs of electrons. Unshared pairs are always less stable than shared pairs (like in a bond). This means that the oxygen atom is balancing much more electronegativity than the rest of the molecule, making it less stable. So, the molecule is polar.

Open electrons on the central atom always show that the molecule is polar.

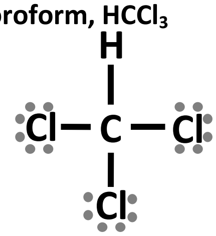
For example: **Methane, CH_4**



The central atom (**C**) has no unshared pairs of electrons. Since there are no open pairs of electrons on the central atom, the molecule is relatively stable. So, the molecule is nonpolar.

When there are no open electrons on the central atom, the molecule is most likely nonpolar.

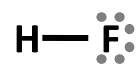
For example: **Chloroform, $HCCl_3$**



The central atom (**C**) has no unshared pairs of electrons. But there is a problem on the outside of this molecule. **Open electrons on the outer atom are not important to the polarity of a molecule.** Instead, the problem here is that the molecule is not symmetrical. If the central atom is forced to balance different atoms (with different electronegativity values) in different regions, the molecule is automatically less stable. So, this molecule is polar.

When the outside atoms are not symmetrical (even if the central atom has no open electrons), the molecule is most likely polar.

For example: **Hydrofluoric acid, HF** and **Nitrogen, N_2**



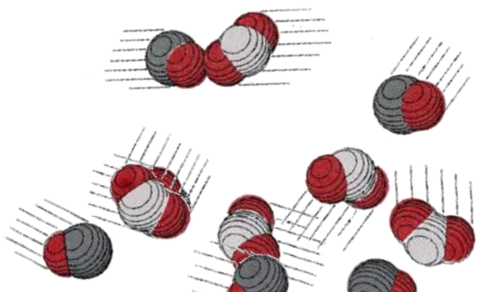
This molecule has no central atom. Instead, the two atoms are splitting the center. When there are only 2 atoms, symmetry becomes very important. Since the molecule is not symmetrical, and since there is such a huge electronegativity difference between H and F, this molecule is highly polar.

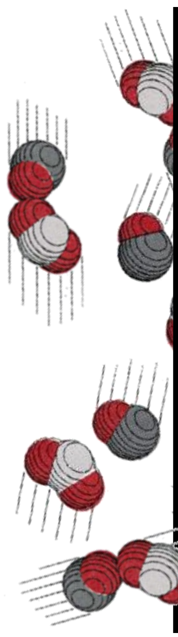
In elemental nitrogen, the bonds are being shared by the same element on both sides. Even though there are open electrons on both N atoms, this molecule is completely symmetrical. So, this molecule is nonpolar.

In diatomic molecules, if the same element is not sharing the bond, the molecule is polar. If the same element is sharing the bond, the molecule is nonpolar.

Chemistry Help Guide: **Molecular Geometry**

What is molecular geometry?





Geometry refers to the three-dimensional shape of an object. Even though scientists use flat drawings on paper to explain the way bonding occurs, these two-dimensional diagrams represent a wide range of shapes. These shapes play a very important role in the way substances interact with one another.

The molecular geometry of a substance comes from the way its atoms are bonded together. Electronegativity and polarity play an important role in how the atoms line up with one another, resulting in some strange "bends" and "stretches" in a molecule's shape. This bending and stretching is called VSEPR (pronounced "vesper"): valence shell electron pair repulsion.

The geometry of a molecule has the greatest impact on whether or not a chemical reaction between two substances will occur. Since reactions can only occur when the molecules collide with one another in the "right" way (called an "effective collision"), if their shapes don't line up, hitting each other right way is nearly impossible.

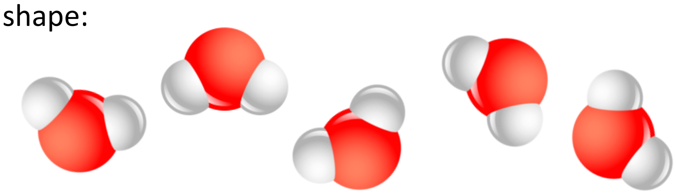
That's why bonding is so important! Chemical reactions can only happen if the two substances' structure matches one another in just the right way. The structure of a substance doesn't just control its stability… it controls everything!

What's a VSEPR?

The Valence Shell Electron Pair Repulsion (VSEPR) theory explains that, since negative charges will always repel other negative charges, and since electrons all have negative charges, pairs of electrons around the same central atom will repel each other. Ok… So what does *that* mean?

Repelling means "spreading out." Electrons, whether they are shared in a bond or unshared in an open pair, don't like being close to one another. So they will always spread as far apart as they can. That "spreading out" ends up looking more like "stretching" or "bending."

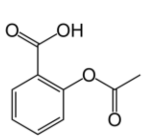
Due to VSEPR, even simple molecules will take on some very interested shapes. Water, for example, has tons of electrons crammed around the central atom (O). In order to remain stable, the water molecule has to spread out its bonds and open pairs so that they don't get too close to one another. So, water ends up with a "bent" shape:

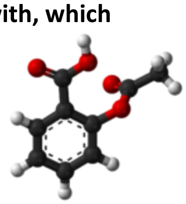


This special molecular geometry is actually responsible for a lot of the important roles water plays on earth. It helps water do its "job" as the "universal solvent;" it causes water form a special crystallized shape when it freezes which makes it the only natural substance on earth that is less dense as a solid than a liquid. (That's why life can exist under water even when the air temperature is below its freezing point!)

Aspirin and other drug or medicinal compounds are great examples of why the three-dimensional shape of a molecule is so important to its chemistry.

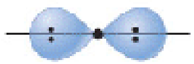
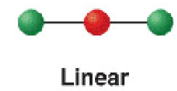
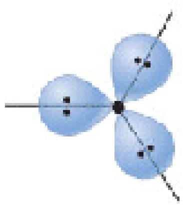
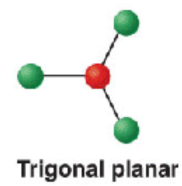
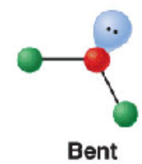
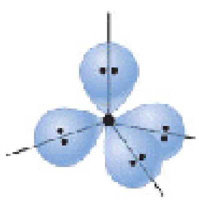
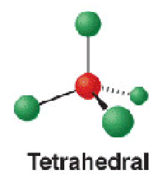
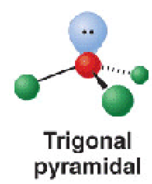
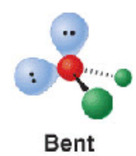
When a substance enters the human body, it will begin to interact with **protein receptors**. These receptors are responsible for communicating with the brain and other body systems in order to carry out **important biological functions**. When **a molecule's shape allows it to bind** onto one of these receptors, the molecule has the opportunity to **change the natural chemistry of the body** and manipulate the receptor's normal actions. This is how medicines treat symptoms in our body; it is also how illicit drugs carry out their influence on our brain and other body systems. **The shape of a molecule determines which receptors it can interact with, which determines its possible effects.** A drug can only influence our body based on which receptors its shape allows it to bind with.



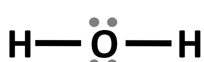


The **shape** (or **molecular geometry**) of a substance **determines how it will react** with other substances. This plays a huge role in **chemical reactions** in the environment, in engineering and research, and in our bodies!

Use this chart to determine the **molecular geometry** of covalent molecules:

Shape category (also called "electron pair geometry")	Number of bonding areas around the central atom (also called "bonding pairs")	Number of open electron pairs around the central atom (also called "nonbonding pairs")	Molecular geometry	Example Lewis diagram
Linear 	**2**	**0**		**Carbon dioxide, CO_2** and **Elemental nitrogen, N_2** (All diatomic molecules are linear.)
Trigonal planar 	**3**	**0**		**Boron trifluoride, BF_3**
	2	**1**		**Sulfur dioxide, SO_2**
Tetrahedral 	**4**	**0**		**Methane, CH_4**
	3	**1**		**Phosphorus trichloride, PCl_3**
	2	**2**		**Water, H_2O**

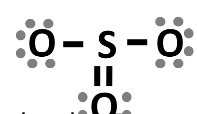
For example: **Water, H_2O**



The central atom (**O**) shares two bonding areas with the **H** atoms. The **O** also has two open pairs of electrons, making the molecule polar. This polarity forces the molecule to "stretch" in order to separate the two extra sets of negatively charged electrons. The stretching ends up "bending" the molecule out of its linear shape. So, water molecules have a tetrahedral "bent" shape.

The molecular geometry of water is bent.

For example: **Sulfur trioxide, SO_3**



SO_3 is a nonpolar molecule. The central atom (**S**) shares four total bonds with three **O** atoms, but two of these bonds fill just one bonding area. This makes three bonding areas. Since there are no open pairs of electrons around the central atom, sulfur trioxide molecules have flat shape; this is called "planar."

Double or triple bonds only count as one bonding area when determining molecular geometry. The molecular geometry of sulfur trioxide is trigonal planar.