Chemistry Lecture #42: Polar and Nonpolar Molecules

An Ionic bond occurs when an electron is transferred from one atom to another. A covalent bond occurs when electrons are shared between atoms. We can use the difference in electronegativity between two atoms to determine if the bond formed between them is ionic or covalent. Below is a chart showing the electronegativity values of the elements.

H 2.20																	He
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne
Na 0.93	Mg 1.31											Al 1.61	Si 1.90	P 2.19	S 2.58	Cl 3.16	Ar
K 0.82	Ca 1.00	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr 3.00
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66	Xe 2.60
Cs 0.79	Ba 0.89	*	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.20	Pt 2.28	Au 2.54	Hg 2.00	Tl 1.62	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn 2.2
Fr 0.7	Ra 0.9	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
*	La 1.1	Ce 1.12	Pr 1.13	Nd 1.14	Pm 1.13	Sm 1.17	Eu 1.2	Gd 1.2	Tb 1.1	Dy 1.22	Ho 1.23	Er 1.24	Tm 1.25	Yb 1.1	Lu 1.27		
**	Ac 1.1	Th 1.3	Pa 1.5	U 1.38	Np 1.36	Pu 1.28	Am 1.13	Cm 1.28	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.3	Lr 1.3		

Periodic table of electronegativity using the Pauling scale

Electronegativity values range from 0.7 to 3.98. If the difference in electronegativity between atoms is relatively small, the bond will be covalent. For example, the difference in electronegativity between oxygen and nitrogen is 3.44 - 3.04 = 0.4. The difference in electronegativity is relatively small so the electrons will be equally shared between the two atoms, and the bond will be covalent.

If the difference in electronegativity is relatively large, the bond will be ionic. For example, the difference in electronegativity between F and Fr is 3.98 - 0.7 = 3.28, a relatively large difference. Thus, a bond between F and Fr will be ionic.

In reality, most bonds are neither entirely covalent nor ionic. Since electrons between atoms are in constant motion, there are times when the electrons are shared, and times when they are transferred. At best, we can say that a bond is mostly covalent or mostly ionic.

If the difference in electronegativity is less than 1.7, the bond is mostly covalent. If the difference is greater than 1.7, the bond is mostly ionic. If the difference is equal to 1.7, the bond is 50% covalent and 50% ionic.

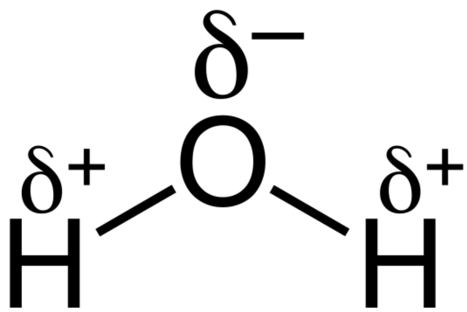
The only time a pure covalent bond occurs is when two identical atoms form a bond (such as an H_2 molecule). In this circumstance, the difference in electronegativity is zero since both atoms share the exact same electronegativity strength.

In covalent bonds, the electrons between the atoms will move closer to the atom with greater electronegativity. If the electrons spend a significant amount of time closer to one atom, it gives the atom a partial negative charge. When such electrons are shared unequally in a covalent bond, we say that it is a *polar covalent bond*. A bond will be polar covalent if the difference in electronegativity is greater than 0.4.

The unequal sharing of electrons in a covalent bond can create a *polar molecule*. A polar molecule has a negative charge on one side and a positive charge on another side. Polar molecules are also called *dipoles*.

Polar molecules are made when the molecule has polar covalent bonds, and when the molecule has the correct shape.

For example, H_2O has polar covalent bonds and a bent shape. In the picture below, oxygen is at the top and the hydrogens are on the bottom.

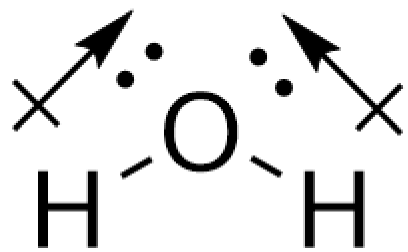


Electronegativity of oxygen: 3.44
Electronegativity of hydrogen: 2.20

The symbol above the oxygen means "partial negative charge." The symbols above the hydrogens mean "partial positive charge." The oxygen develops a partial negative charge because it has an electronegativity of 3.44, which is greater than that of the hydrogens (2.20). Thus, oxygen pulls the shared electrons away from the hydrogens and becomes partially negative. Likewise, when the electrons are pulled away from the hydrogens, they develop a partially positive charge.

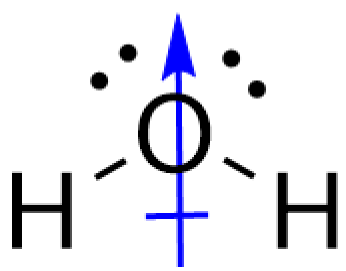
As a result, the water molecule is partially negative on the top oxygen side, and partially positive on the bottom hydrogen side. Water is therefore a polar molecule.

Sometimes we use arrows to show the location of the positive and negative charge on the molecule.



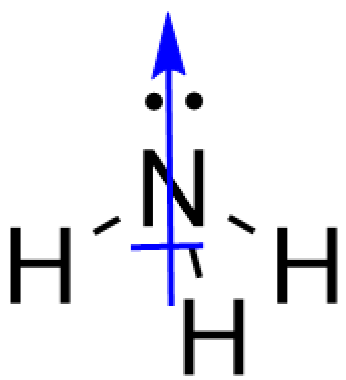
The bottom of the arrow is the plus side. The tip of the arrow is the negative side.

Other times, we draw a single arrow to show which side of the molecule is negative and which side is positive.



The way to determine if a molecule is polar is to figure out where the partial positive and negative charges develop. If it is possible to draw a straight line through the diagram and have all the positive charge on one side, and all the negative charge on the other side, then you have a polar molecule.

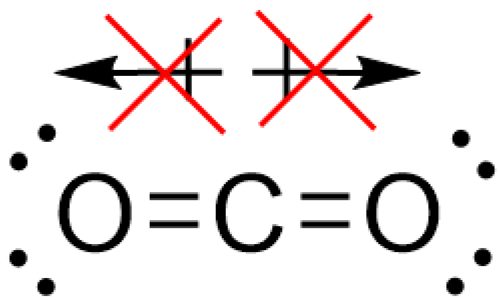
Is NH_3 a polar molecule? The central atom, N, has an unshared pair of electrons, and there are also three terminal atoms attached. Thus, it has a 3 dimensional, pyramidal shape. Nitrogen has an electronegativity of 3.04, while that of hydrogen is 2.20. Thus, the shared electrons will move closer to the nitrogen.



Nitrogen electronegativity: 3.04
Hydrogen electronegativity: 2.20

The top of the molecule is negative, and the bottom is positive. Thus, NH_3 is a polar molecule.

Is CO_2 a polar molecule? The central atom, C, has two terminal atoms attached. Thus, it has a linear shape. C has an electronegativity of 2.55 and O has a value of 3.44, so the electrons move closer to the oxygens.



Oxygen electronegativity: 3.44
Carbon electronegativity: 2.55

The positive charge is in the middle of the molecule. There is no way to draw a line through the molecule and have the positive charge on one side and the negative charge on the other side. The polarity arrows cancel each other. Thus, this is a nonpolar molecule.