Polarity Notes

<u>What is polarity?</u>

Polarity is a word that describes a molecule's electrical balance. If there is an imbalance with electrical charge, then a molecule is polar. If the electrical charge is the same strength on all sides of the molecule, then it is nonpolar. If you think of a magnet that has a north and a south pole, that magnet is polar. If you just have some iron whose domains are disorganized, then it has no north or south pole and essentially is nonpolar. Polarity in chemistry is similar with respect to the idea that different parts of the molecule can have an attraction or repulsion for another molecule because of its electrical charge.

<u>How is polarity determined?</u>

Polarity is determined by the electronegativity scale. Differences in electronegativity between two elements is calculated. The resulting number indicates if the bond between the two elements is nonpolar, moderately polar, very polar, or ionic. After each bond is calculated, the entire molecule is analyzed. If the entire molecule is symmetric and the polar bonds are equally balanced, then the overall molecule is nonpolar. If there is asymmetry, then the molecule is polar.

<u>Some definitions:</u>

<u>Nonpolar covalent</u>: the electrons are shared equally between the two elements. The electrons are not considered to be located closer to one element or the other. Electronegativity differences 0.0 - 0.4.

<u>Moderately polar covalent</u>: the electrons are not shared equally, they are slightly closer to one element. Electronegativity differences 0.4 – 1.0.

<u>Very polar covalent</u>: the electrons are not shared equally, they are very much closer to one element, but the atoms have not ionized. Electronegativity differences 1.0 – 2.0.

Ionic: electrons left one atom and joined the other to make ions. In this case, the electrons are NOT shared. Electronegativity differences > or = 2.0.

Examples:

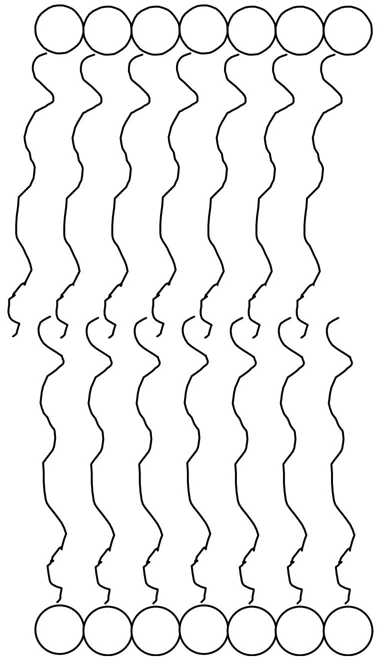
CF_4 has four polar C-F bonds. But since the shape of the molecule is a tetrahedron and the shift of electrons is equal on all sides of the molecule, CF_4 is nonpolar. $CClF_3$, however, is not symmetric and would be polar.

Although technically not a part of the definition, if the molecule has a lone pair of electrons, it will be polar. Lone pairs of electrons cause bends in molecules. These bends result in asymmetric molecules. For example, H_2O and NH_3 have lone pairs on the central atom. Both are polar because the shift of electrons away from the H toward the O or the N is not symmetrical in 3-dimensions.

Polarity is responsible for many behaviors you see happening in nature. One main concept is that "Like dissolves like." For example, salt dissolves in water because it is charged and water is polar (has an imbalance of its charge.) Things with charges on them can dissolve in water. Oil, on the other hand, is nonpolar. It does not dissolve in water, but it will dissolve in another nonpolar liquid. In general, long hydrocarbon chains like those found in oil, are nonpolar.

Another example where polarity is important is the plasma membrane. Remember what surrounds each animal cell? A phospholipid bilayer membrane. Each layer in the bilayer is made of molecules that have polar heads and nonpolar tails. The polar heads go toward the liquid part of the cell and the nonpolar tails are hydrophobic (water fearing) so they go away from the liquid part of the cell. This polar and nonpolar structure helps keep water in the cell yet allows the membrane to still be semi-permeable.

Phospholipid bilayer membrane

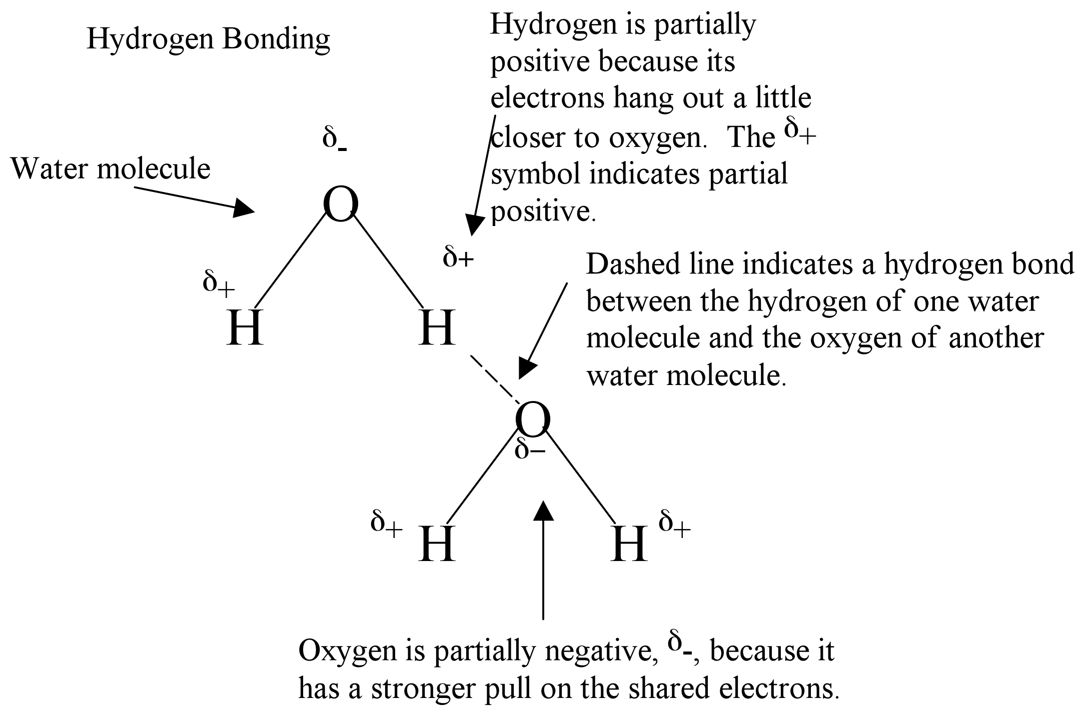


Proteins fit in the plasma membrane according to their polarity. The protein channels, which keep ion concentrations happy, are made of amino acids that have polar or nonpolar parts. If the amino acid is polar, it will be toward the edge of the membrane. If the amino acid is nonpolar, it will be toward the middle of the membrane. These proteins regulate what can go in or out of the cell.

By far the most important consequence of polarity is hydrogen bonding. Hydrogen bonding is responsible for all of water's special behaviors. It is also responsible for connecting the two branches in the DNA double helix as well as the funky shapes you can get from proteins.

<u>So, what is hydrogen bonding?</u>

Hydrogen bonding occurs when the hydrogen on one molecule is attracted to the oxygen or nitrogen of another molecule. Hydrogen will be partially positive and oxygen or nitrogen will be partially negative. These are not full positives or negatives because the electrons are still being shared, they are just shifted toward one atom more than another. These interactions are called <u>inter</u>molecular because they happen between molecules. Hydrogen bonding, while it involves positive and negative interactions, is much weaker than ionic bonding. Ionic bonding involves full charges, not partial ones.



Properties of water affected by hydrogen bonding:

1. higher boiling point: Not only do molecules have to acquire enough kinetic energy to leave the liquid phase, but they need to also get enough energy to break the intermolecular forces between the water molecules.
2. capillary action: because water molecules stick to each other, they can creep upwards against gravity in small spaces
3. adhesion: water can stick to other objects due to polar interactions
4. cohesion: water likes to stick to itself
5. lower density when frozen: the hydrogen bonding actually forces the water molecules to move further away from each other in the frozen state than when they are in the liquid state (thus the concept of the expansion of ice). Being more spread out, the volume is larger, thus less dense. This is why ice floats on liquid water.
6. high specific heat: hydrogen bonding makes the molecules more stable so they are able to hold heat longer than other molecules

What about large molecules?

Large molecules handle polarity a little differently. Parts of a large molecule can be polar whereas other parts can be nonpolar. The polar parts let the molecule stick to other charged things whereas the nonpolar part lets the molecule hang out with uncharged things. Soap molecules are an example. Like the molecules in the plasma membrane, soap molecules have polar heads and nonpolar tails. The nonpolar tails can trap dirt and grease while the polar heads dissolve in water, so that when the water flows down the drain, the dirt and grease goes with it. The structure formed when a bunch of soap molecules surround a grease particle is called a micelle. Inside the micelle is a nonpolar, uncharged environment, whereas outside the micelle is a charged, water-loving, environment.