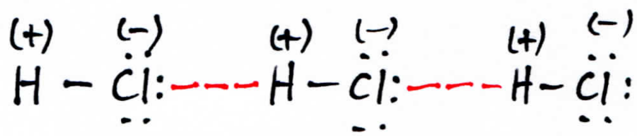
Chemistry Lecture #43: Intermolecular Forces

Atoms that are covalently bonded are called molecules. Molecules are capable of being attracted to each other. The bonds between molecules are not as strong as ionic or covalent bonds, but they can significantly affect the properties of molecular substances.

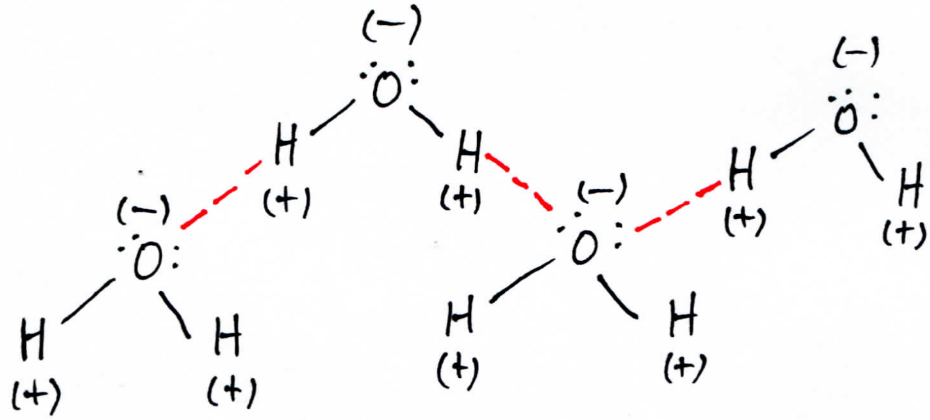
Intermolecular forces are forces between molecules that hold the molecules together. Intermolecular forces are also called *weak forces* or *van der Waals* forces. There are several types of intermolecular forces.

One type of intermolecular force is the *dipole-dipole* force. This occurs when the positive end of one polar molecule is attracted to the negative end of another molecule. For example, hydrogen chloride (HCl) in gaseous form is a polar molecule. The partially positive hydrogen will be attracted to the partially negative chlorine atom of another molecule.



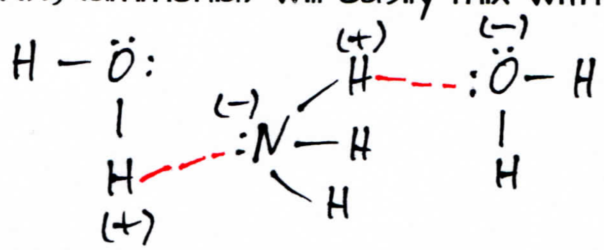
There is a special type of dipole-dipole force called a *hydrogen bond*. This occurs when hydrogen is attached to either a nitrogen, oxygen, or fluorine atom. When this occurs, the hydrogen has a partial positive charge that is larger than usual. This higher density of positive charge allows the hydrogen to form an even stronger bond with unpaired electrons on other dipoles.

H_2O molecules form hydrogen bonds with each other. The positive hydrogen will be attracted to the negative oxygen.

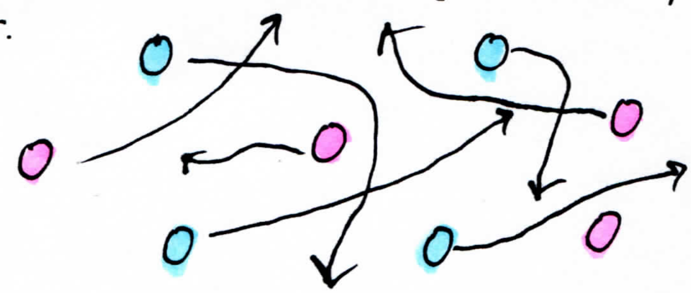


The strong attractive force between H_2O molecules is the reason why H_2O is a liquid instead of a gas at room temperature.

Different types of dipoles or polar molecules will easily mix with each other. The positive end of one type of molecule will be attracted to the negative end of another molecule. For example, NH_3 (ammonia) will easily mix with H_2O.



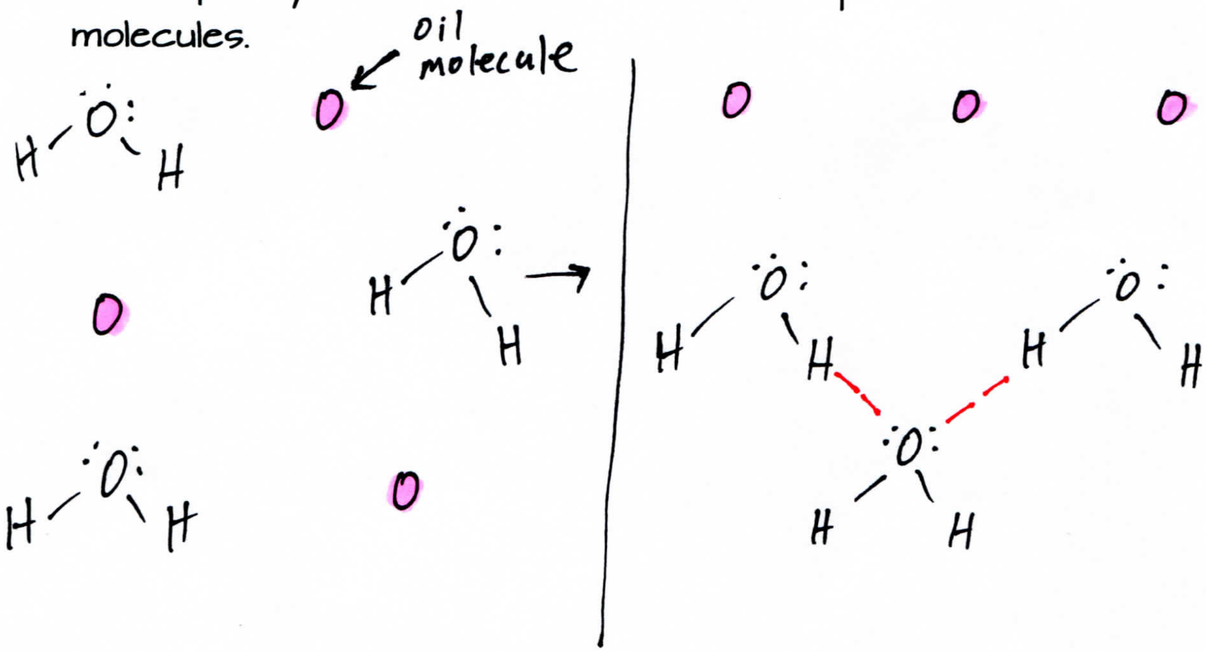
Nonpolar molecules will also easily mix each with other. If two different molecules are neither attracted nor repulsed to each other, there is nothing to stop them from moving close to each other. The molecules would just randomly move around each other.



Nonpolar molecules in random motion.

However, polar and nonpolar molecules will not mix together. For example, vinegar and vegetable oil will not mix. Vinegar is mostly water, a polar substance. Vegetable oil is made of fats, which is a nonpolar substance.

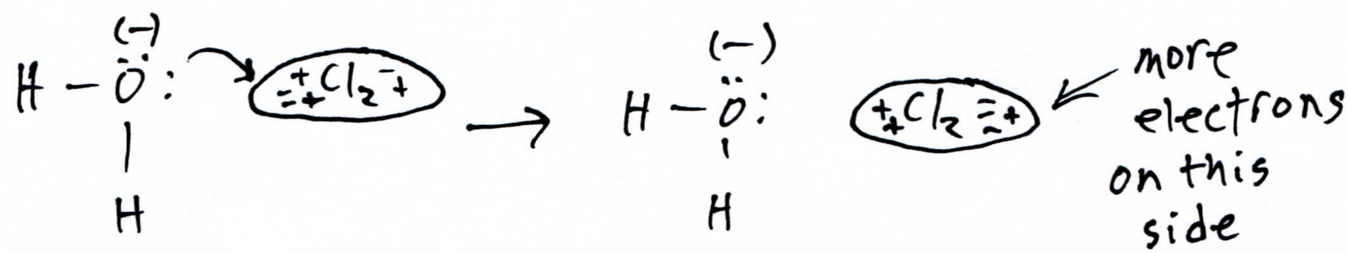
When the vinegar and vegetable oil are shaken together, they quickly separate after shaking. This occurs because the polar water molecules will be attracted to each other and clump together. The fat molecules do not have a positive and negative end, so they will not be attracted to the water molecules. Consequently, the water molecules will separate from the oil molecules.



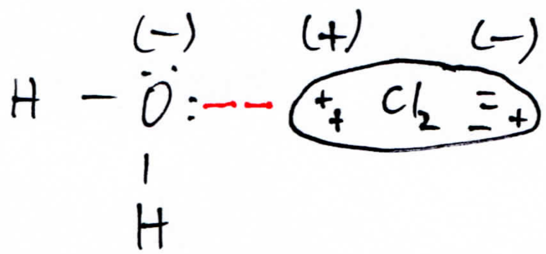
Thus, polar molecules will mix with polar molecules, nonpolar molecules will mix with nonpolar molecules, but polar and nonpolar molecules will not mix. A phrase that summarizes these ideas is "like dissolves like."

In general, polar and nonpolar molecules do not stick together. However, temporary attractive forces between nonpolar molecules and polar molecules can be induced.

For example, when a polar water molecule approaches a nonpolar Cl_2 molecule, the negative end of the water molecule will repulse the electrons on the Cl_2 molecule. As a result, Cl_2 will be positive on one side and negative on the other side.

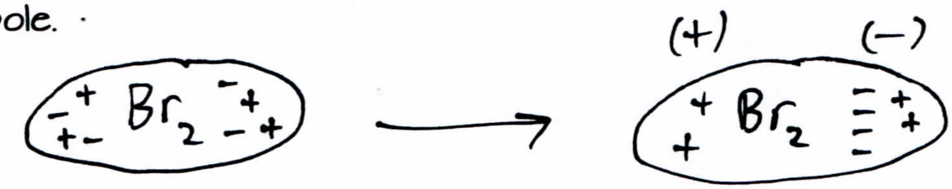


For a fleeting moment, Cl_2 will be a polar molecule. The positive end of Cl_2 will be attracted to the negative end of water.

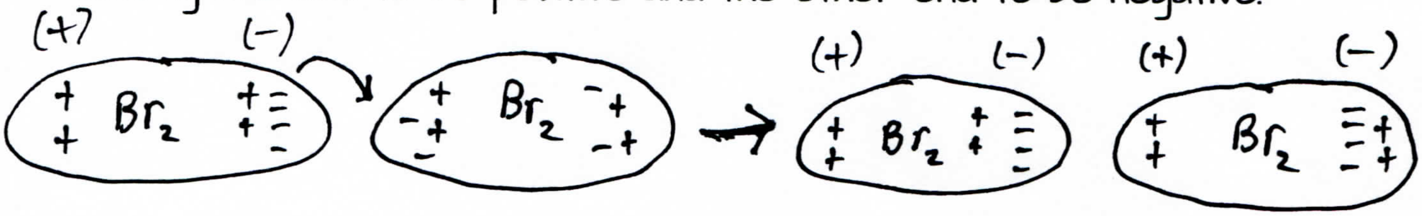


The force of attraction is called a *dipole-induced dipole force*. This force of attraction is very brief.

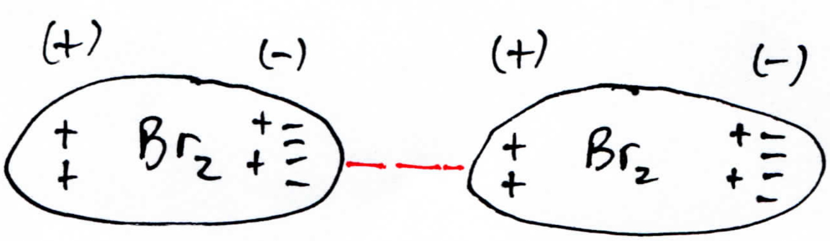
A nonpolar molecule, such as Br_2, can also spontaneously become a dipole. This occurs because the electrons in a molecule are in constant motion. For brief moments, there will be more electrons on one side of the molecule, causing one side to be positive and one side to be negative. It will become a temporary dipole.



When a Br_2 molecule becomes a temporary dipole, it can induce a polarity in an adjacent Br_2 molecule. The electrons on the adjacent molecule will be repelled by the negative end of the dipole, causing one end to be positive and the other end to be negative.



We now have two dipoles next to each other, and each is attracted to the other.



When nonpolar molecules are attracted to each other in this way, the attractive forces are called *dispersion forces* or *London forces*. Dispersion forces are strong enough to pull bromine molecules together to make bromine a liquid at room temperature. Dispersion forces also pull iodine molecules together to make iodine a solid.

Dipole-dipole forces, hydrogen bonding, dipole-induced dipole forces, and dispersion forces are all weak compared to ionic forces. The weak nature of intermolecular bonds makes molecular substances softer compared to ionic compounds. Molecular compounds also have lower melting and boiling points, while ionic compounds have very high melting and boiling points. In addition, molecular compounds do not conduct electricity, while ionic compounds will conduct electricity when dissolved in water and when heated to a molten state.

Both nonpolar and polar molecules will have lower melting and boiling points compared to ionic compounds, but there are differences between nonpolar and polar molecules. Nonpolar molecules will have lower melting and boiling points compared to polar molecules.

Ionic m.p. & b.p. > polar m.p. & b.p. > nonpolar m.p. & b.p.

Nonpolar molecules tend to be gases. Polar molecules have stronger intermolecular forces of attraction, so they tend to exist as solids.