

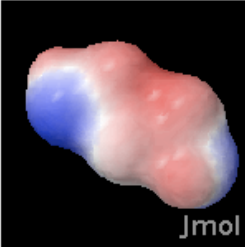



Intermolecular Attractions

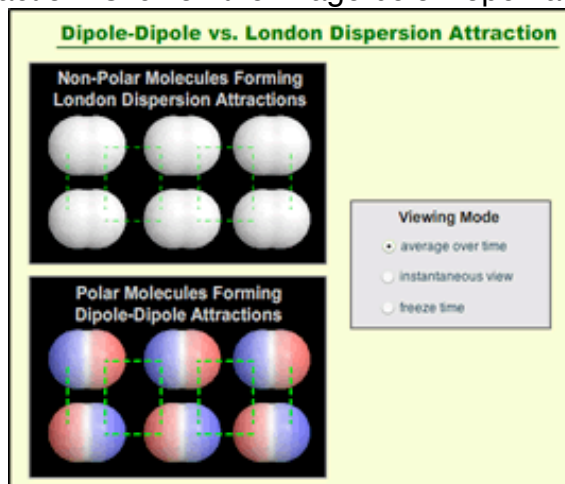
1. Handout: Intermolecular Attractions Notes
2. Handout: Using Jmol Guide
3. States of Matter
 1. Representation of solid, liquid, and gas from Ohio State
 2. Computer Lab: Macro/Micro connection for States of Matter (How to run this?)
 3. Computer Lab: Phase Change and van der Waals attractions (How to run this?)
 4. Demo: Liquid Nitrogen and Phase Changes
 5. Homework: Basic van der Waals Attractions and Phase Change
4. Weak Bonds (van der Waals attractions)
 1. Computer Lab: Experiment with "feeling" the difference between the types of bonds.
 2. Dipole-Dipole and Hydrogen Bonds
 1. Some molecules form areas of positive and negative charge formed through an uneven sharing of electrons (polar covalent bonding). Water is formed with polar covalent bonds between hydrogen and oxygen. Below is water.
 2. Because part of the molecule is partially positive (not as positive as an ion with a +1 charge) there are attractions between the negative portion of one molecule and the positive portion of another molecule. This attraction forms weak bonds between molecules
 3. When hydrogen is one of the atoms within a molecule that is attracted to the dipole on another molecule, this somewhat stronger dipole-dipole attraction is called a hydrogen bond. The hydrogen bond is the attraction between molecules, not the covalent bond which is formed between hydrogen and an atom from its own molecule. Below are some examples of hydrogen bonding.
 1. Click on the image below to see hydrogen bonds represented as dotted lines in this computer model.
 2. To see a 3D view of water and it's hydrogen bonds in motion go to: <http://cps.bu.edu/education/vmdl/software/water.html> and follow the instructions for installing the software. (Windows only.)
 3. Hydrogen bonding is also an important factor in helping to shape the structure of larger molecules. DNA is an excellent example.

4. A molecule can have more than one polar region, so the more polar regions a molecule has, the greater two molecules of this kind will attract to each other.

Name	Propane	1-Propanol	1,3-Propanediol
Boiling Point	-42°C	97°C	214°C
Structural Formula	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$	$\begin{array}{c} \text{H} & \text{H} & \text{H} \\ & & \\ \text{H}-\text{O}-\text{C}-\text{C}-\text{C}-\text{O}-\text{H} \\ & & \\ \text{H} & \text{H} & \text{H} \end{array}$
Surface Charges	 <p>electrostatic potential translucent potential</p>	 <p>electrostatic potential translucent potential</p>	 <p>electrostatic potential translucent potential</p>
	 <p>negative neutral positive</p>		

1. Homework: Finding Polar Bonds
 2. Demo: Viscosity
 3. Demo: Polar and non-polar streams of liquid deflected (or not) by charged rod.
 4. See the molecules in the viscosity demo.
 5. Lab: Making Silly Putty
 6. Dipole Attractions in Homemade Silly Putty
3. London Dispersion Attraction
1. Even when atoms are sharing electrons equally, the electrons are not static objects. They are constantly in motion. Sometimes due to their random movement between the two atoms in covalent bond they just happen to be more on one side than another.
 2. A fleeting instantaneous dipole (region of positive and negative charge) can be formed by the random distribution of electrons at any particular moment.

3. This instantaneous dipole can induce a dipole in another nearby non-polar molecule. They can then attract to each other in a similar way as the dipole-dipole attraction. However, the London dispersion force is much weaker than a dipole-dipole attraction. Click on the image below open a dynamic model of this.



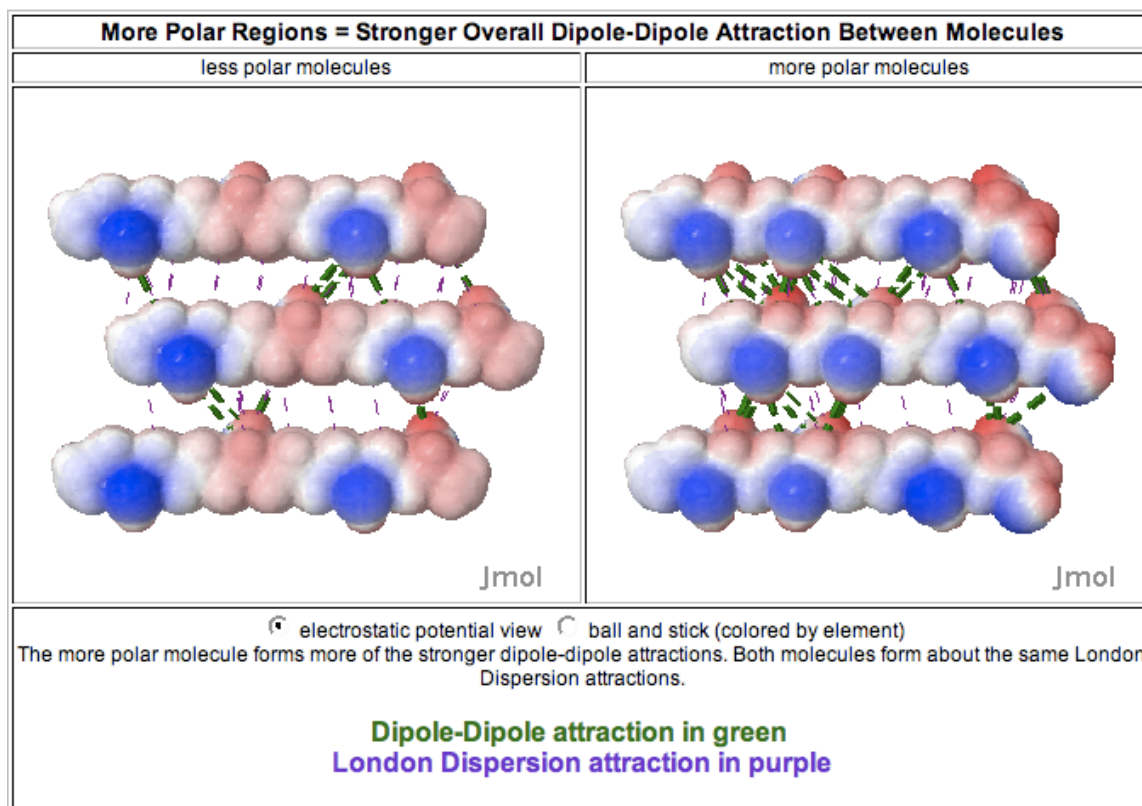
4. The size of a molecule can affect the London dispersion force between two molecules. The more surface area there is on a molecule the greater chance there will be at least one instantaneous dipole at any particular moment. Therefore, the greater the surface area (generally this means the bigger the molecule) the stronger the attraction between two molecules of this type due to London dispersion forces.

Name	Propane	Butane	Pentane
Boiling Point	-42°C	0°C	36°C
Structural Formula	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $

4. Factors Affecting the Strength of van der Waals attractions

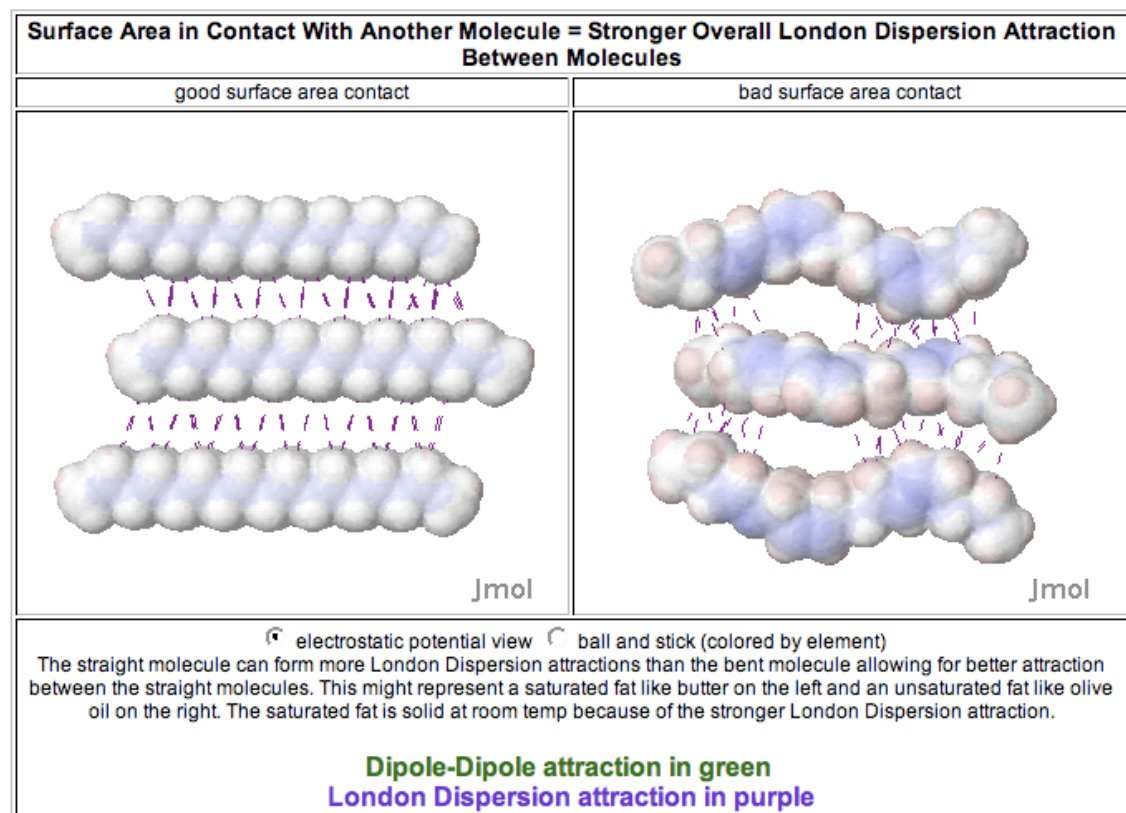
1. Polarity of Molecules

1. The more polar a molecule is the stronger it will be able to attract to other molecules.
2. The most common way for a molecule to be more polar is to have more polar covalent bonds, creating more polar regions where dipole-dipole attractions can occur.



2. Shape/Surface Area of Molecules

1. The more surface area a molecule has the stronger it will be able to attract to other molecules.
2. However, just having a large surface area is not enough. The shape of the molecule must allow it to come in close contact with the surface of another molecule.



5. Computer Lab: Weak Intermolecular Attractions (How to run this?)

6. Homework: van der Waals Bonds Sheet

7. Why Substances Dissolve (or Don't)

1. During previous units we learned that some substances are polar:

1. Ionic substances

2. Molecular substances that have molecules with one or more polar covalent bonds joining atoms together and forming a dipole (region of positive and negative charge) on a molecule.

2. Substance which are polar tend to dissolve in water because water is polar. The positive and negative charges on the polar substances attract to water's own dipoles allowing them to form a solution.

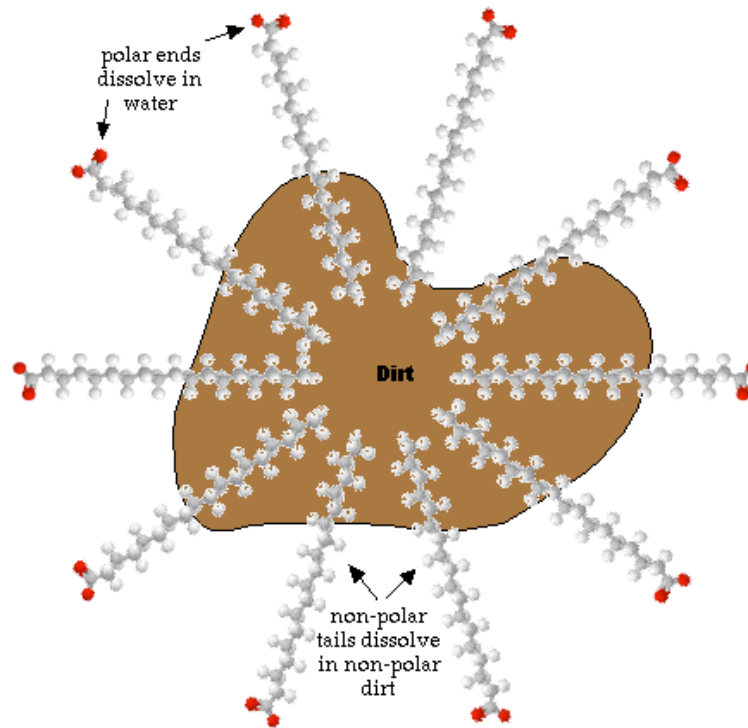
1. Film: See How Ionic Substances Dissolve in Water

2. Film: See Another Video Clip of Ionic Substances Dissolving

4. Film: See How Polar Covalent Substances Dissolve in Water
3. Substances which are non-polar are attracted to polar water via London Dispersion forces and induced dipole-dipole attractions. However, the water molecules' attraction for themselves (dipole-dipole attraction) is much stronger than its attraction to the non-polar substance. This prevents the non-polar molecules from getting in between the water molecules.

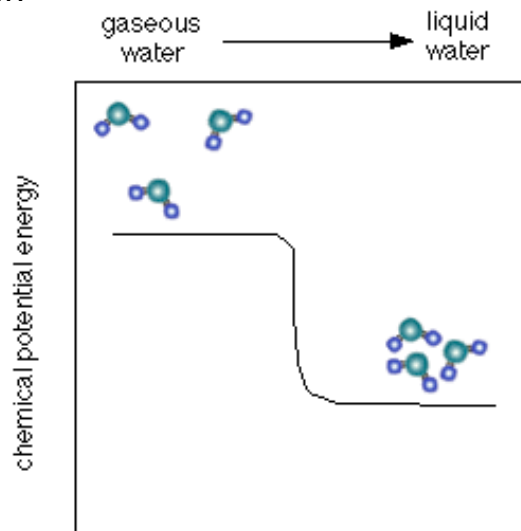
Why are some ionic compounds (which are very polar) insoluble in water?

4. When two non-polar substances are mixed together you get roughly equal attractions between the various molecules (weak because only via London Dispersion), so they can easily form a solution.
5. The general rule for how things dissolve is: Like dissolves like. (polar tends to dissolve polar and non-polar tends to dissolve non-polar)
6. [Click here to see how soaps use this property to clean.](#)
 1. There are two reasons why water doesn't clean well by itself. Both of these reasons have to do with water's high polarity.
 1. The strong surface tension of water prevents it from getting into small spaces.
 2. Most dirt is non-polar so it doesn't dissolve well in polar water.
 2. Sodium stearate is a common soap which solves both of the problems described above.
 1. Notice that one end is polar and the other end is non-polar. This makes sodium stearate a kind of schizophrenic molecule. It can dissolve in both polar and non-polar substances.
 4. To see how this breaks up water's surface tension: [Breaking up Surface Tension.](#)
 5. When soaps are dissolved in water the molecules arrange themselves into groups called micels. The non-polar ends will congregate together while the polar ends will interact with the water. Because dirt is mostly non-polar the dirt gets dissolved into the center of the micelle.



1. Lab: Dissolving Various Substances
2. Computer Lab: Dissolving(How to run this?)
3. Homework: Solubility Sheet
5. Phase Change and Latent Heat
 1. There is chemical potential energy in the weak van der Waals bonds as well as in the strong ionic and covalent bonds.
 2. Because the van der Waals bond/attraction is so much weaker there is much less chemical potential possible here, but it is a major factor in the energy of phase changes.
 3. As you can see below, the chemical potential energy of water is less than that of water vapor (or steam) which helps to explain why steam burns can be so severe. Not only is the steam hot, but it tends to condense into a liquid when it touches something. When forming a liquid the chemical potential energy that is released when the van der Waals bonds form can add substantial heat energy to the process of heat transfer from the water molecules to whatever they are condensing on.

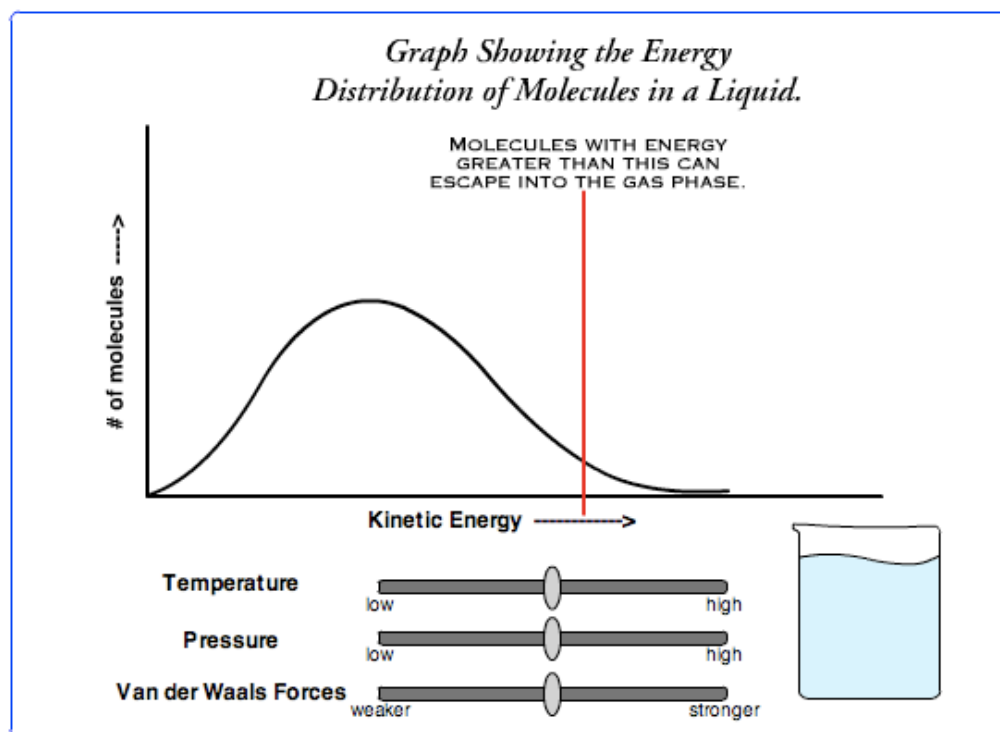
4. See a diagram of the energy below:



5. A process that releases chemical potential energy as heat is called exothermic.
6. A process that absorbs heat to increase chemical potential energy is called endothermic.
7. Whenever a change of state occurs energy is either absorbed or released
 1. An exothermic process releases heat (converting some of its chemical potential energy to heat energy).
 2. An endothermic process absorbs heat (converting some of the heat energy into chemical potential energy.)
8. Below is a table of common phase changes and their associated energy

Process	Name of phase change	Energy flow
solid -> liquid		
liquid -> solid		
liquid -> gas		
gas -> liquid		
solid -> gas		
gas -> solid		

9. In endothermic phase changes the heat energy is used to overcome the weak intermolecular bonds.
10. In exothermic phase changes some chemical potential energy is converted to heat energy when the weak intermolecular bonds form.
11. Latent Heat is the term describing the energy you get from exothermic phase changes. There are two phase changes where this heat energy is released:
 1. Condensation: When gas condenses to liquid the quantity of energy converted from chemical to heat is called the Heat of Vaporization or ΔH_v .
 2. Freezing: When a liquid freezes into a solid the quantity of energy converted from chemical to heat is called the Heat of Fusion or ΔH_f .
1. Computer Lab: Exploring chemical potential energy in phase changes. (How to run this?)
2. Handout: How Hungry is a Hurricane?
3. Homework: Questions for the above computer lab.
4. Lab: Sodium Thiosulfate Lab
5. Lab: Ice to Steam Lab
6. Homework: Chemical Potential Energy and Phase Changes
7. The nature of boiling
 1. Computer Lab: Maxwell Speed Distribution (How to run this?)
 2. Factors affecting the boiling point
 1. Boiling occurs when molecules have enough kinetic energy to separate from each other.
 2. Two forces hold molecules and atoms in a condensed state
 1. Pulling forces from the intermolecular attractions.
 2. Pushing forces from the pressure applied on all surfaces of the liquid (from both the container and the gas above the liquid)
 3. Below is an interactive graph that displays what happens when you alter the temperature, pressure, and type of substance with varying intermolecular forces. The red line depicts the amount of energy needed by a molecule to break free from the liquid state. See if you can demonstrate two distinctly different circumstances in which you have created the conditions for boiling. Sketch these graphs and describe the boiling environment.



6. The boiling point occurs when enough molecules have enough energy to break free from their intermolecular forces (van der Waals bonds) and the external pressure keeping them together. This can be achieved in several ways.
 1. You can heat the substance so that enough molecules break free.
 2. You can lower the pressure on a substance to make it easier for the molecules to break free with the energy they already possess.
 3. Some combination of either i or ii.
3. Lab: Warm water in syringe experiment
4. Demo: Low Pressure Boiling
5. Homework: Write up ideas of what is happening in the low pressure boiling demo
6. Lab: Butane Lab
7. Homework: Design a refrigerator based on your understanding of potential energy in phase changes.
6. Handout: Intermolecular Attractions Review Sheet