Thoughts of the Day 11/09/10

Inter molecular forces (IMF)

Why are some things gases and other solids. It is the attractions of the molecules for each other (energy) and their tendency to spread out all over the universe (entropy) that governs this. The temperature determines the relative importance of each.

At T = 0 everything should be a solid
At T = infinity everything should be a gas

In the middle what matters is the magnitude of the intermolecular forces. Larger forces then you'll need a higher temperature to get from solid to liquid. Small forces you'll be a gas at very low temperatures.

What types of forces are there?

Ion-Ion

Very large. Bonding! Long range

Ion-ion force follow coloumb's law. What matters is the charges and the distance between the two molecules. These are the longest range forces falling off as 1/R

Dipole-Dipole
Much much smaller than ion-ion forces. These are also shorter range. The distance dependence falls of as $1/R^3$. What matters is how close the molecules can get and the magnitude of their dipoles. One way to rationalize the longer distance dependence is the fact that the polar molecule with a dipole is actually neutral. To "notice" the regions of different charge on the molecule you need to be able to be close enough to detect a difference.

In between these two are ion-dipole forces.

They have an intermediate distance dependence or $1/R^2$. Here what matters most is the charge density of the ion and the magnitude of the dipole. The smaller the ion the close it can get to the other molecule. The larger the charge the larger the interaction. Thus the charge density (charge per volume) takes both of these into effect.

You'll note that all of these interactions are electrostatics. That is interactions between charges. Thus why we have been so interested in molecular shape, differences in electronegativity, molecular orbitals,….

Finally we come to perhaps the most important IMF, London dispersion forces or Induced Dipole – Induced Dipole forces.

These are the shortest range (not the weakest). They are ubiquitous. Everything has them. They depend on the polarizability of the molecule. That is the ability of the electrons in the molecule to polarize (for a dipole) in response to a neighboring charge. As a general rule the more electrons the more polarizable. The farther the electrons are from the nucleus the more polarizable. And generally pi electrons are more polarizable than electrons in sigma bonds (as pi bonds are delocalized).

Dispersion forces fall off with a very short distance dependence of $1/R^6$.

As such F_2 is a gas, Cl_2 is a gas, Br_2 is a liquid, and I_2 as solid.
Why? I_2 has the most electrons and they are “far” from the nucleus (think 5p electrons). Thus I_2 is the most polarizable.

Gases

What is a gas.

Gases are substances for which the IMF are negligible (very small). Thus entropy is sending them wandering off to the far edges of the universe (or the container they are in).

How can we characterize a gas.

By its pressure, volume, and temperature.

We talked mostly about pressure.

Pressure = force/area. It has many units

Atm, bar, pounds per square inch (psi), mm Hg,…

We’ll try to stick with bar. 1 bar = 10^5 Pa
1 Pa = 1 N/m^2

1 bar is also approximately 1 atm. Thus the pressure outside today is likely to be approximately 1 bar.

Pressure can be measured in an old fashion device that examines the height of a column of liquid. If this is done, then the pressure is

$$P = \rho g h$$

The first term is the greek letter Rho which is the density of the fluid, g is the acceleration due to gravity, and h is the height of the column. Using units all in kg and meter this yields a pressure in Pa.