

LECTURE 17. THEORY BEHIND INTERMOLECULAR FORCES

Intermolecular Forces – forces between molecules

- As we have just seen, there exists a correlation between the strength of the IMF and the magnitude of a property of a solution (ex. viscosity, boiling point, ΔH of vaporization, evaporation)

IMF	Strength
Instantaneous Dipoles	<1 kJ/mole
Permanent Dipoles	1-5 kJ/mole
Hydrogen Bonding	10-20 kJ/mole

Let's look more deeply at reasons for the magnitude of each of these kinds of intermolecular forces.

Permanent Dipoles

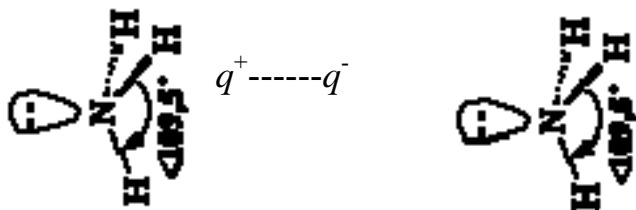
These occur in any molecule that is **not completely symmetrical**, thus, whose total electronegativity ($\sum \Delta EN$) is **not zero** (when the electronegativity values of all the species are added together).

CCl_4 does *not* have a permanent dipole; $\sum \Delta EN = 0$ and the molecule is symmetrical

CCl_3F does have a permanent dipole; $\sum \Delta EN \neq 0$ and the molecule is not symmetrical

Permanent dipoles cause intermolecular forces because each molecule possesses a q^- that has electron density and q^+ , that *lacks* electron density. As the dipoles align, $q^- \cdots q^+$, $q^- \cdots q^+$, $q^- \cdots q^+$, forces are created.

Example: NH₃



Instantaneous dipoles

Symmetrical molecules possess *weak* IMF! This is why He or N₂ can be a liquid. But why does any attraction at all? Because of instantaneous dipoles.

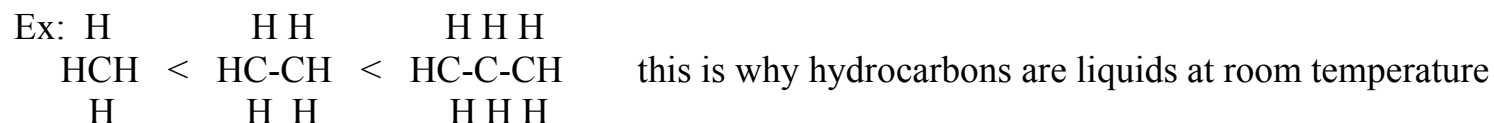
Note the 2 electrons in Helium over time:

1 st unit of time	2 nd unit of time	3 rd unit of time	4 th unit of time
e- ++	e- e- ++	 ++	e- ++
e-		e- e-	e-
Instantaneous dipole: none	Instantaneous dipole: ↑	Instantaneous dipole: ↓	Instantaneous dipole: none

So although $\sum \Delta EN = 0$ over time, *for an instant*, dipoles are created and a weak attraction occurs.

Important Facts about instantaneous dipoles:

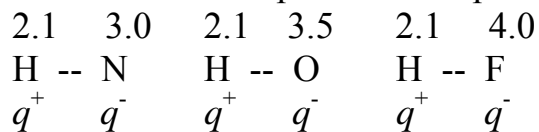
- 1) instantaneous dipoles are also known as London, dispersive, or Van der Waals forces
- 2) They are why noble gases form liquids and solids
- 3) Alone, they are mostly insignificant, but as the molecules increase in magnitude, dispersive forces can integrate and be quite substantial



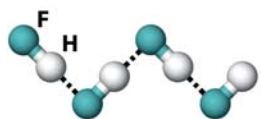
Permanent Dipole Special Case: Hydrogen Bonds

This is the strongest IMF, and is the rationale behind the phenomenon of H₂O (a molecule with a molecular weight of 18 that doesn't boil until 100° C)

In addition to the permanent dipole found in water, there is also an extremely electropositive H⁺ in the molecule.



*The electron density is increasingly removed from the H⁺, which results in a small, densely positive, charged region (a prime q⁺ for other molecules)

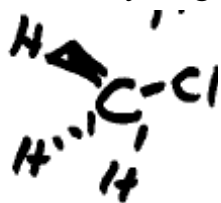


11 Hydrogen Fluoride, $(HF)_n$

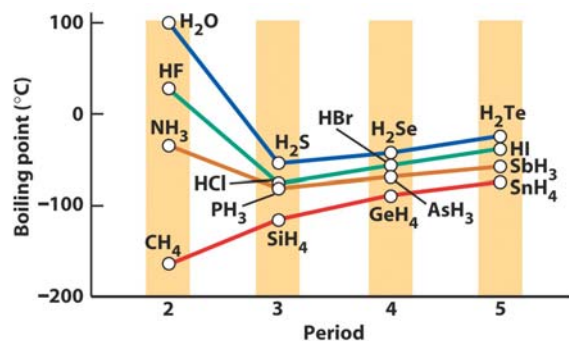
H-bonding is especially strong in the second row because of the high electronegativity values of Nitrogen, Oxygen, and Fluorine. This led to the definition of Hydrogen bonding as:

- 1) H must be involved
- 2) It must be attached to an EN atom such as N, O, F, or Cl

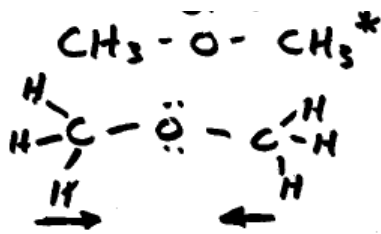
Thus, H_2O , HF , HCl , NH_3 have Hydrogen bonding but CH_3Cl *does not* because Chlorine is *not* attached to the Hydrogen atom



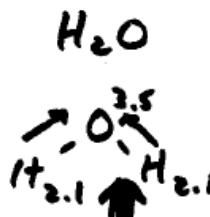
A more general definition is that Hydrogen bonding occurs for any H attached to another atom
Thus, H_2S , H_2Te , and PH_3 all exhibit hydrogen bonding, though it is very weak.



One final example: IMF and Solution Properties for Ether vs. Water



Small net dipole: $\sum \Delta EN \approx 0$; slightly polar



Net dipole $\sum \Delta EN = 0$; Very Polar

Comparison of Solution Properties

		Boiling Point	Vapor Pressure	ΔH vaporization
Ether	Nonpolar	36° C	440 torr	226 J/g
Water	Polar	100° C	18 torr	351 J/g

The H₂O molecule has H bonds so:

- 1) Boiling point is larger
- 2) Vapor pressure is lower
- 3) ΔH vaporization is higher

