Intermolecular Forces: (forces present between molecules)

- Attractive intermolecular forces:
  - i) Hydrogen bonding – strongest on per atom basis (e.g. base recognition in forming DNA helix) (also in RNA)
  - ii) Dipole-dipole interaction (Intermediate strength)
  - iii) London forces (temporary dipole; hydrophobic bonding) – weakest on per atom basis – distortion of inner shells.

Electronegativity:

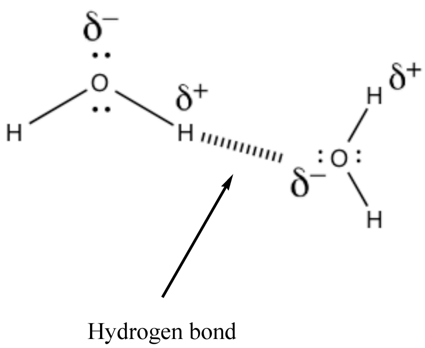
- An atom's desire for electrons (negative charge).
- On the periodic table, electronegativity increases as you go from left to right (up to inert gases, which are not electronegative) and as you go from down to up
- Halogens (F, Cl, Br, I) are highly electonegative
  -
  - i.e. Fluorine is the most electronegative atom (wants to gain the inert gas configuration of Ne) and is small (has few electrons)
- It influences acidity of H's attached, as well as the intermolecular forces between molecules.

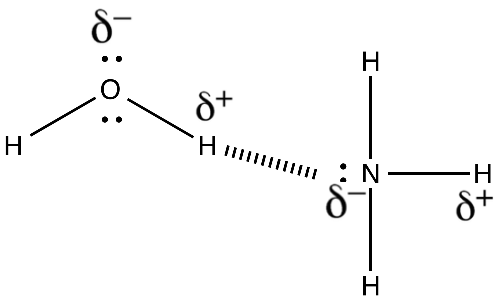
Hydrogen Bonding:

- Strongest intermolecular attractive force
- Need H directly attached to a very electronegative atom (N, O, F, Cl, Br, I)
  - Known as **donors**
- Very electronegative atom needs a lone pair of electrons (N, O, F, Cl, Br, I)
  - Known as **acceptors**

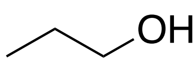
e.g. H-O-H (water)

- Oxygen is electronegative and it is sp^3 hybridized
- The partial positive charge on H and the partial negative charge on O lead to their attraction
- Results in high boiling point (100 C) and high melting point by self-association
- HF, H_2O and NH_3 form hydrogen bonds



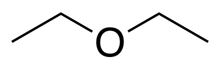


1. Water is a liquid at RT while ammonia is a gas
2. Oxygen is more e-neg than nitrogen, so the protons on water have a higher positive partial charge than the protons on ammonia
3. In an ammonia solution, water would be the hydrogen bond donor and ammonia would be the acceptor
4. Water dissolves ammonia very well – up to 18M



n-Propanol
(1-Propanol)

- Can hydrogen bond to itself
  - Has H directly attached to oxygen
- Has a high boiling points relative to its size due to hydrogen bonding
- Can dissolve in water very well

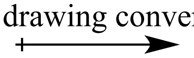


Diethyl Ether

- Cannot hydrogen bond to itself
  - Has no H directly attached to oxygen (No donor)
  - Can H-bond to water because it has an acceptor
- Has a low boiling point
- Will not dissolve in water very well (although a little bit will be dissolved)

Dipole-Dipole Interactions:

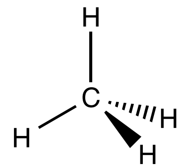
Dipole drawing convention:



δ^+ δ^-

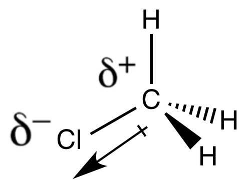
Partial positive charge is the "plus" end, partial negative charge is the arrow head

1. Methane; CH_4



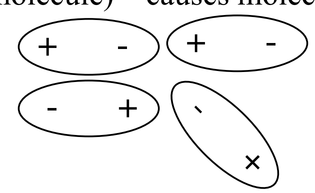
- C and H have ~same electronegativity
- Non-polar (net-zero ~dipole)
- Gaseous
- Low BP -164 °C (this is relatively low compared to water at 100°C)
- Low MP -182 °C

2. Chloromethane, methyl chloride; CH_3Cl

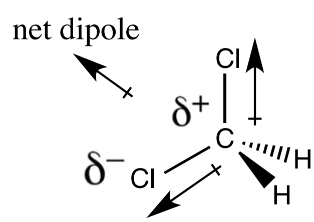


- H and C have similar electronegativity values (non-polar bond)
- Cl is very electronegative due to the fact that it only needs one electron to get inert gas configuration.
- Electron density is pulled toward the chlorine atom, creating a net dipole toward chlorine atom. A net dipole is the vector sum of individual bond dipoles.

Dipoles in different molecules tend to line-up temporarily with each other (partial positive / negative charge on the molecule) – causes molecules to "stick" to each other



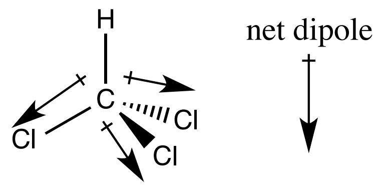
3. Dichloromethane, methylene chloride; CH_2Cl_2



- Liquid at room temperature BP 40 °C MP – 95 °C
- More polar than chloromethane

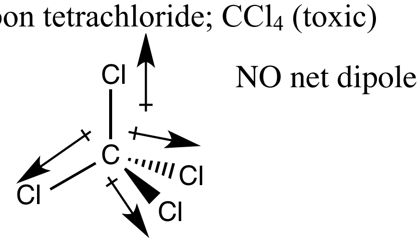
- Not miscible with water

4. Trichloromethane, chloroform; $CHCl_3$



- More polar than methylene chloride   BP 61 ^{o}C   MP – 64 ^{o}C

5. Tetrachloromethane, carbon tetrachloride; CCl_4 (toxic)

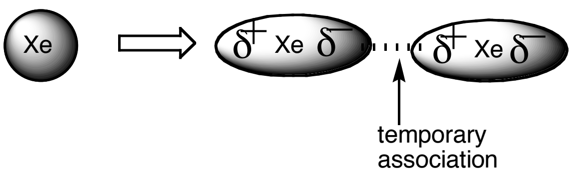


- Non-polar molecule (net-zero dipole)
- Has temporary dipoles since chlorine is polarizable (see below), BP ~77
- Historically used as a dry cleaning fluid

London Forces:

- Also know as dispersion forces
- Weakest attractive force
- Distortion of filled outer shell electrons
- Principal effect in hydrophobic interactions

Atoms	Boiling Point	
He	-269 ^{o}C	Small atom/ Low polarizability
Ne	-246 ^{o}C	
Ar	-186 ^{o}C	
Kr	-153 ^{o}C	
Xe	-108 ^{o}C	Large atom/ High polarizability



- The larger the atom (expanded electron density), the easier the formation of temporary dipoles

This is the reason why CH_4 associates with CH_4, due to London forces

C_5H_{12} hydrophobic bonding:

$H_3C-CH_2-CH_2\cdot CH_2-CH_3$ n-pentane