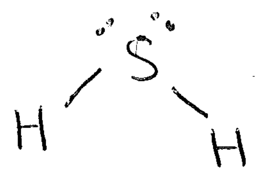
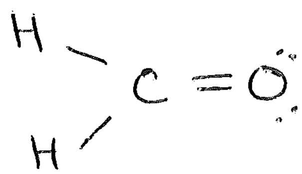
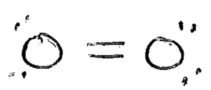
Problem Set 9.1 - Answer Key

a) 

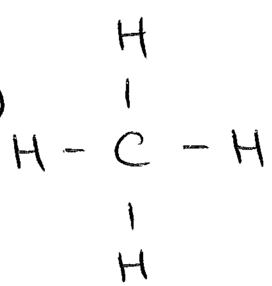
Bent/Angular — 104.5°

b) 

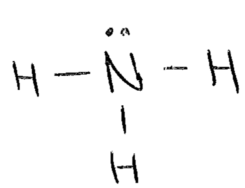
Trigonal Planar — 120°

c) 

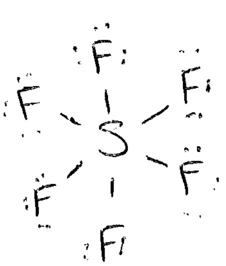
Linear — 180°

d) 

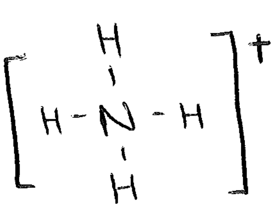
Tetrahedral — 109.5°

e) 

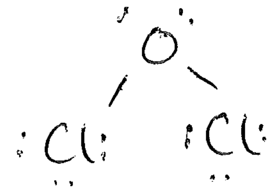
Trigonal Pyramidal — 107°

f) 

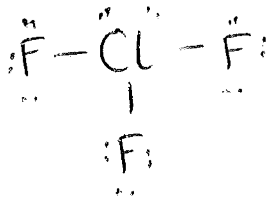
Octahedral — 90° & 180°

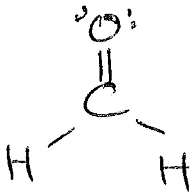
g) 

Tetrahedral — 109.5°

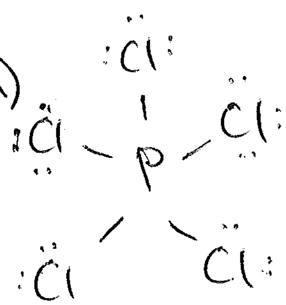
h)  Bent 104.5°

i) $O=C=O$ Linear 180°

j)  * Don't worry about this one!!

k)  Trigonal Planar 120°

l)  Bent 104.5°

m)  Trigonal Bipyramidal 90°, 120°, 180°

n) $H-C\equiv N:$ Linear 180°

Key

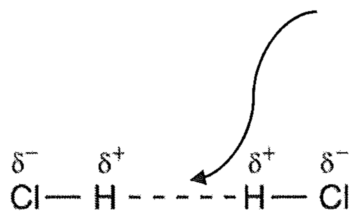
Problem Set 9.2: Intermolecular Forces

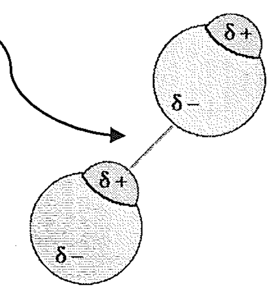
Chemical bonds within molecules are **intramolecular** forces ("Intra" means within). Attractive forces between molecules and between ions and molecules are called **intermolecular forces.** These occur in liquids and solids.

Below are a few types you will need to know!

A. Dipole-Dipole Forces = polar molecules

- Within any substance containing polar molecules, each molecule has a partial positive and partial negative pole (a molecular *dipole*).
- This arises when electronegative elements (O, N, halogens) are bonded to less electronegative species.
- This causes the molecules in a liquid or solid phase to orient themselves with the positive pole of one molecule being next to the negative pole of the next. This is called a DIPOLE-DIPOLE FORCE!

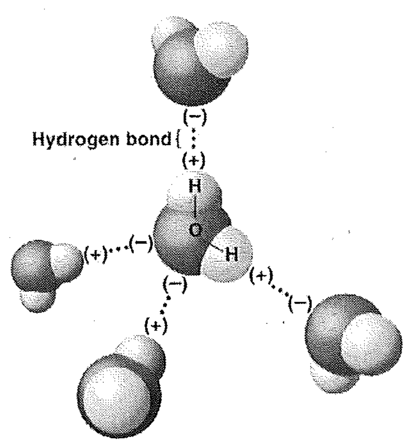




Ex. Two HCl molecules interacting

B. Hydrogen Bonds (special dipole-dipole forces) = H bonded to F, O, or N

- There is one type of dipole-dipole interaction which is especially strong. It is called a hydrogen bond (H-bond).
- The partial negative charge (δ-) comes from one of the electronegative elements **F, O or N**. The atoms of these second period elements are small, highly electronegative, and have lone electron pairs. These are called H-bond acceptors.
- The partial positive charge (δ+) comes from an **H** bonded directly to one of these elements (O-H, N-H, F-H). These are called H-bond donors.
- Both a donor and an acceptor are needed to form an H-bond. These are stronger IMF than dipole-dipole interactions.



Ex. A diagram showing 4 hydrogen bonds between water molecules

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C. London Dispersion Forces (LDF) = all molecules, including non-polar

- For a molecular substance to exist as a liquid or solid, the molecules must be close together. This means some kind of intermolecular attractive force must exist between those molecules (even non-polar molecules!).
- In all molecules the electrons are constantly moving around, which sometimes causes more electron density on one side of the atom than the other. This slight imbalance results in an **instantaneous dipole moment**.
- All atoms and molecules possess LDF, which increase with the size and the number of electrons in the molecule.
- These are very small, very short-lived charges.

Practice Problems

1) Using your knowledge of molecular structure, identify the main intermolecular force in the following compounds. You may find it useful to draw Lewis structures to find your answer.

a) PF_3 dipole - dipole

b) H_2CO dipole - dipole

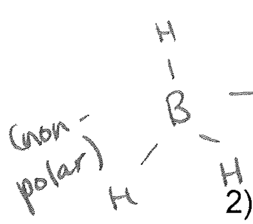
c) HF hydrogen bond

d) CH_4 LDF (non-polar molecule)

e) NH_3 hydrogen bond

f) H_2S dipole - dipole

g) N_2H_2 hydrogen bond



h) BH_3 LDF

2) Explain how dipole-dipole forces cause molecules to be attracted to one another.

Polar molecules have partially (+) & (−) sides (which correspond to the side that is more or less electronegative). Because opposite charges attract one another, these molecules stick electrostatically.

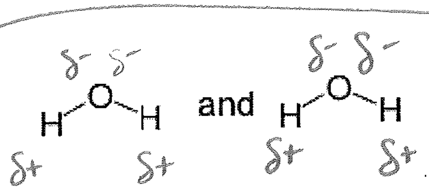
3) Explain why nonpolar molecules usually have much lower surface tension than polar ones.

B/c the molecules aren't attracted to each other as much as in polar molecules, so the force is easier to break.

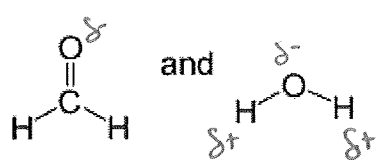
4) Which of the following pairs of compounds can form H-bonds? For those that can, mark the position of the partial positive (δ+) and negative (δ-) charges in the molecules and indicate where the H-bonds will form. For those that can't form H-bonds, describe the strongest Intermolecular Force available to that pair of compounds.

a) 

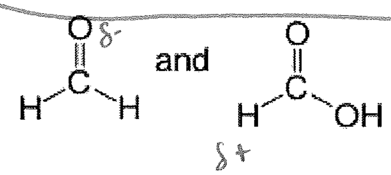
NO... H_2 has no δ+ or δ- side

b) 

Yes → H-bond forms btwn O & H on neighbouring molecules

c) 

Yes → H from H_2O donates to O in other molecule

d) 

Yes → H from CH_2O_2 donates to O in CH_2O.

5. Identify two examples of how hydrogen bonding between water molecules makes life on earth possible (you may need to do some research for this one!).

- responsible for ice being less dense than water, ∴ oceans don't freeze solid
- allows it to act as a universal solvent (can easily dissolve other polar molecules)
- high specific heat capacity
- surface tension / adhesion / cohesion....