Molecules: Intermolecular Forces: Student Review Notes

Here's a look at intermolecular forces -- The forces neighboring molecules exert upon one another.

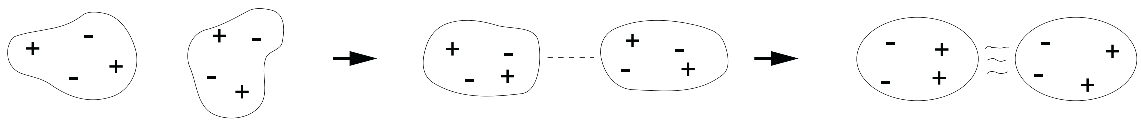
There are a couple of generalities you can depend on:

The higher the melting point and boiling point, the stronger the intermolecular forces

"**Like dissolves Like**", e.g., things held together by electrostatic attraction (ions, polar molecules) will be soluble in polar solvents

Dispersion Forces (Sometimes Called London Forces)

All substances have these weak interactions. They happen because you can induce dipoles in molecules. When two molecules get close to one another, they can influence each other in a local way. The molecules may be neutral or nonpolar, but locally if there is some + charge hanging around on a spot it will attract some - charge on the other molecule. The dipoles that are induced are temporary.



charge distribution on two nonpolar molecules | **"hey there"** | **temporarily induced dipoles**

How strong dispersion forces are depends upon how easily polarized the electrons are in each molecule. Usually the bigger the mass in the nucleus, the farther the electrons are from the nucleus and the easier they are to influence.

large molecule --> large molecular mass --> very polarizable --> stronger dispersion forces.

B. Dipole Forces

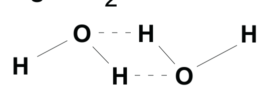
These are straight-up electrostatic interactions between polar molecules. The charges are at the ends of the dipole. So, the positive end of one polar molecule will be attracted to the negative part of another and so on.

$$\boxed{F = \frac{kq_1q_2}{r^2}}$$

C. Hydrogen Bonding

This is a special case of dipole forces in which the molecule is very polar (large electronegativity difference between bonded atoms in the molecule) and the molecules are constructed so they can get close to each other.

The classic example of hydrogen bonding is H_2O. We know water is a very polar molecule and it also fits together with itself very well.

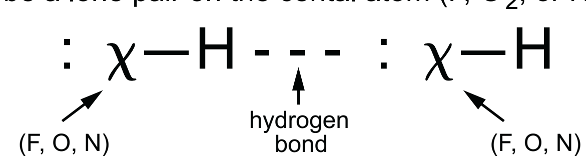


Because of water's polarity, all the H's and O's have strong electrostatic attractions. On top of that, the molecule fits together with itself very well.

Only a few molecules can hydrogen bond; you can tell from their properties because they will have abnormally high boiling points and melting points. --> You sort of expect these things (B.P and M.P.) to increase with molecular weight, so as you go down a group (V, VI, and VII) and look at the B.P. and M.P. of the hydrides you expect them to increase. But right at the beginning of the groups, NH_3, H_2O, HF the properties are way-high because of hydrogen bonding. CH_4 doesn't hydrogen bond so the properties of the Group IVA hydrides simply increase with molecular size.

Also use these rules to determine if hydrogen bonding will occur:

* H has to be bonded to F, O, N (big electronegativity differences induce molecular polarity). The positive and negative poles on the molecule, have to be able to get close together.
* There must also be a lone pair on the cental atom (F, O_2, or N) in the molecule under consideration.



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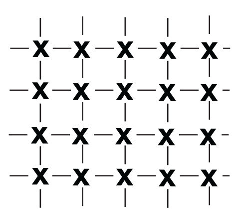
Type of Substance	Structural Unit	Force between Units	Properties	Example
Ionic	**ions** **m^+ x^- m^+ x^-** **x^- m^+ x^- m^+** **m^+ x^- m^+ x^-** **x^- m^+ x^- m^+**	Ionic Bonding (strong)	** High melting point ** Conducts electricity only when melted or dissolved ** Usually water soluble ** Insoluble in nonpolar solvents ("like dissolves like")	NaCl MgO
Molecular	**a) nonpolar molecules** } **covalent bonds**	**Dispersion Forces (weak)**	** Low melting point and boiling point ** Nonconducting, insoluble in H_2O ** Soluble in nonpolar solvents	H_2 CCl_4
	b) polar molecules **x- x x- x x-x** **x- x x- x x-x** **x- x x- x x-x** **x- x x- x x-x**	**Dispersion Forces** **Dipole Forces** **Hydrogen Bonding** **(Intermediate)**	** Higher melting point and boiling (higher than non-polar covalent solids) ** Nonconducting ** Likely to be soluble in H_2O	HCl NH_3 H_2O
Covalent Network Solids	**atoms** 	Covalent Bond (strong)	** Hard, solid ** VERY high melting point ** Nonconductors ** Insoluble in common solvents	C (diamond) SiO_2 (glass sand quartz) Si SiC
Metallic	**cations and mobile electrons** **m^+ e^- m^+ e^-** **e^- m^+ e^- m^+** **m^+ e^- m^+ e^-** **e^- m^+ e^- m^+**	Metallic Bond	** Variable melting points (Hg is liquid at room temp. vs. Mg that melts at ~650°C) ** Insoluble in common solvents ** Malleable, ductile ** Good conductors ** May react with H_2O	Na Hg Mg Fe

Bonding Hierarchy

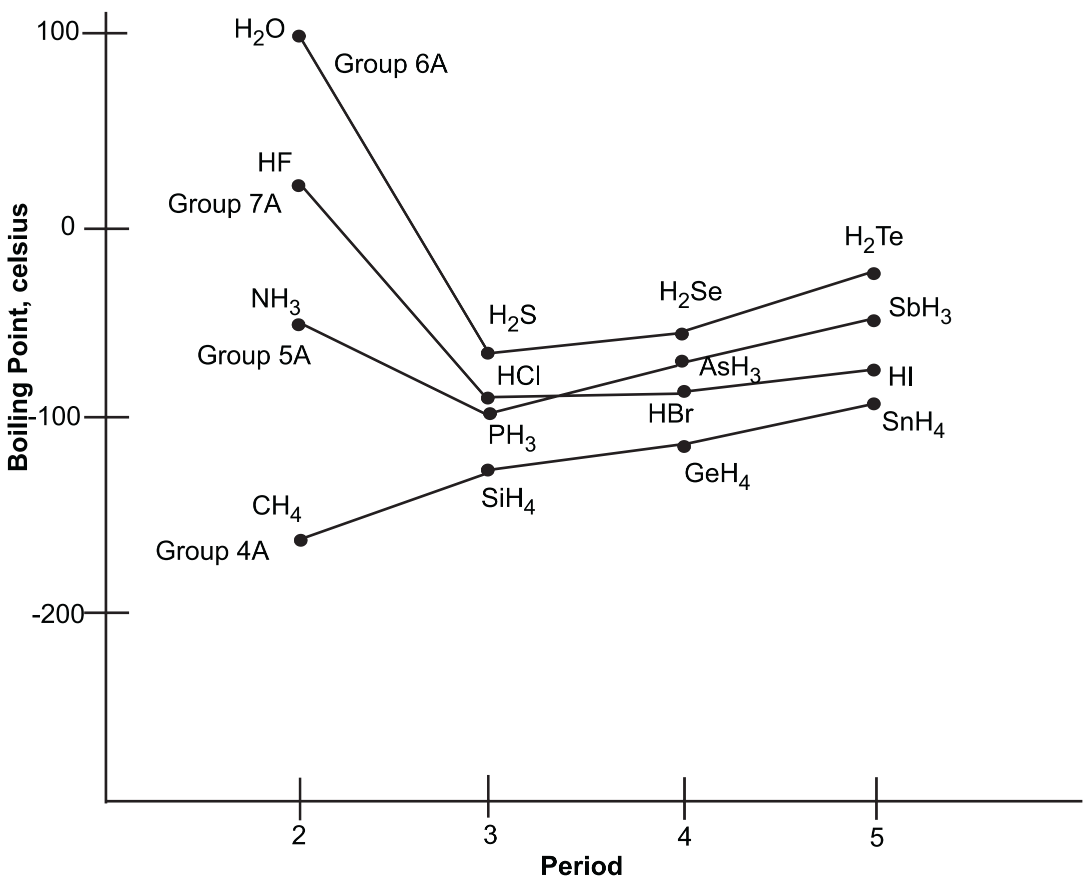
Weak ⟶ **Strong**

Dispersive	**Dipole**	**H bonding**	**Metallic ionic**	**Covalent bonds**
low MM ⟶ high MM	slightly polar ⟶ very polar	⟶ increases with more H atoms	⟶ large ions low charge ⟶ small ions high charge	

Boiling Point deviations and Hydrogen Bonding

You should understand that hydrogen bonding is the strongest type of dipole-dipole intermolecular force. Molecules like H_2O, NH_3, HF and alcohols hydrogen bond. Take a look at the influence this strong intermolecular force has on boiling point as hydrides of groups 4A, 5A, 6A, and 7A are compared for their period 2, 3, 4 and 5 elements. Remember that boiling is the phenomena that occurs when the vapor pressure exerted by the liquid is equal to the pressure above the liquid (typically atomospheric pressure). If it is difficult for molecules to escape from the liquid phase (strong intermolecular forces) you would expect a high boiling point. Get that? It takes more thermal energy to pop the molecules out of the liquid phase if the intermolecular forces are strong. Therefore it takes more energy (higher temperature) for the vapor pressure of the liquid (pressure exerted by the molecules going from the liquid to vapor phase) to equal that of the atmosphere.

Take a look (the numbers aren't exact):



Group 4A shows the expected trend for molecules of increasing molar mass with similar intermolecular forces

Aside from the period 2 hydrides, groups 5A, 6A, and 7A show the expected trend for molecules of increasing molar mass with similar intermolecular forces

The big jump in boiling point for the period 2 hydrides is due to hydrogen bonding. The high boiling points are a manifestation of the strong intermolecular forces.