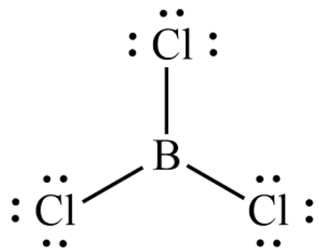
Microscopic world II

Non-Octet Structures

The octet rule states there is a strong tendency for all atoms to attain the stable electronic arrangement of the nearest noble gas (i.e. 8 electrons in the outermost shell). However, Some molecules can exist even if the central atom does not obey the octet rule.

Less than 8 outermost shell electrons:

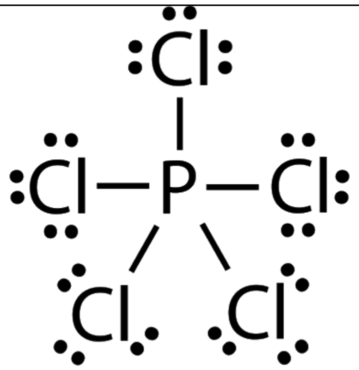
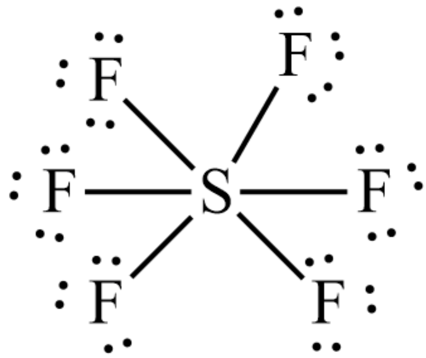
BCl_3



How many outermost shell electron does B have?

There is a possibility for BCl_3 to form a dative covalent bond with an atom from another molecule given that the atom has a vacant lone pair of electrons.

More than 8 outermost shell electrons:

PCl_5	SF_6
	

Question for thinking: If PCl_5 and SF_6 are stable molecules, can NCl_5 and OF_6 exist as well?

Such type of non-octet structure requires the central atom to be an element from period 3 or beyond, so that they can have more than 8 outermost shell electrons when forming some of its compounds.

Shape of molecules

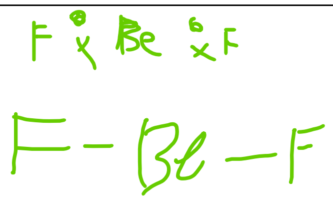
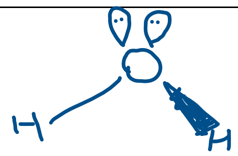
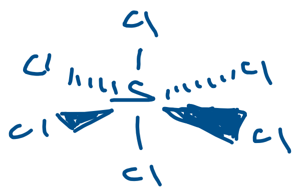
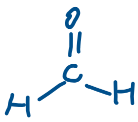
The simplest way to determine the shape of a molecule is to remember the principle that all atoms don't want to get too close to one another. Below is a more concrete method:

1. Draw the electronic arrangement diagram (you can draw it without circles to save time)
2. Count the number of atoms bonded to the central atom
3. Count the number of lone pairs in the central atom
4. Use the following chart (which you should memorize)

Atoms bonded → Lone pairs ↓	1	2	3	4	5	6
0	Linear	Linear	Trigonal planar	Tetrahedral	Trigonal bipyramidal	Octahedral
1		V-Shaped	Trigonal pyramidal	Seesaw	Square pyramidal	
2		V-Shaped	T-Shape	Square planar		

Grayed out: Not assessed.

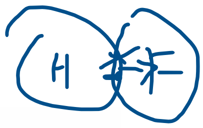
Example: State the molecular shape of the following molecules and draw their 3-D diagram, indicating lone pairs of electrons of the central atom

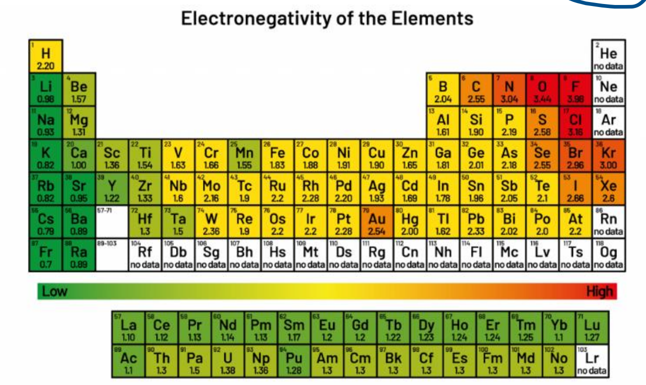
BeF_2	NCl_3	H_2O
 Linear		
PF_5	SCl_6	CH_2Cl
	 Octahedral	
HCHO (Formaldehyde)	SO_2	CO_2
 Trigonal planar		

Polarity of covalent bonds

When there is a difference in the electronegativity between two the elements of the two atoms linked together by a covalent bond, the covalent bond is described as a polar bond. Typically, all bonds between different elements are polar since different elements have different electronegativities. However, if the difference between the electronegativities are small (most commonly used for C-H bonds), then the bond is non-polar.

$\boxed{\text{Clicker question: Is an F-F bond polar?}}$





Electronegativity typically means the tendency to attract the bond pair of electrons towards the atom of that element. F has the highest electronegativity. In an H-F bond, the bond pair of electrons will be strongly attracted towards the side of the F atom (since F is more electronegative than H).

There is no need to remember the electronegativity values of each element. It is only important to remember that N, O, F are highly electronegative elements (useful for hydrogen bond)

Determining polarity of molecules

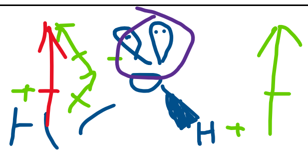
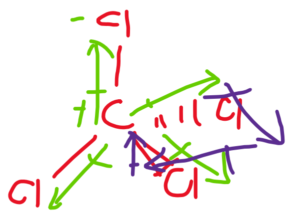
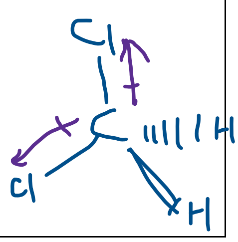
You only need to tell whether a molecule (e.g. HCl) is polar of non-polar.

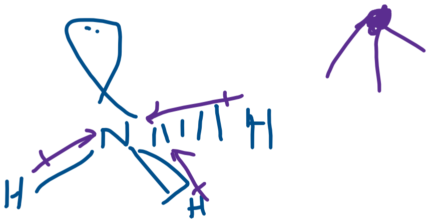
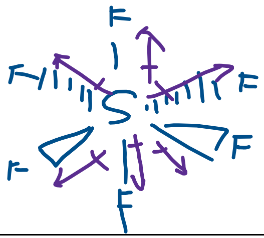
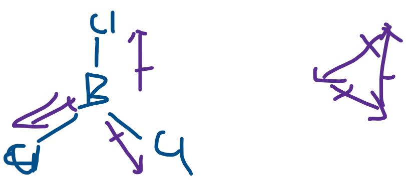
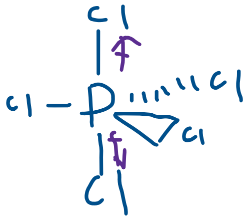
Process of thinking:

1. Draw 3-D diagram of the molecule.
2. Label the polar bonds.
3. "Add" the polar bonds together to see its net effect.

If you get used to this you can skip steps 1 and 2.

Example, draw the 3-D diagram of the following molecules and state whether the molecule is polar or not.

H_2O	CH_2Cl_2
	 

NH_3	SF_6
	
BCl_3	PCl_5
	

Intermolecular forces

Van der waals forces:

3 factors can affect the strength of the Van der waal's forces between molecules:

1. Most influential: Molecular size
   Larger molecules have stronger van der waal's forces between them.
2. Polarity of molecules
   The van der waal's forces between polar molecules are stronger than those between non-polar molecules.
3. Least influential: Area of contact
   A higher area of contact between molecules result in stronger van der waal's forces between them. This is usually used to describe the boiling point/melting point differences between straight-chain and branched-chain hydrocarbon compounds. Straight-chain hydrocarbon compounds have a larger surface area of contact (i.e. stronger van der waal's forces).

Example:

1. Explain why N_2 has a higher boiling point than H_2

   N_2 has a larger molecular size than H_2. (1)

   Hence the strength of the van der waal's forces between N_2 molecules are stronger than those between H_2 molecules, so N_2 has a higher boiling point. (1)

2. Explain why NCl_3 has a higher boiling point than BCl_3

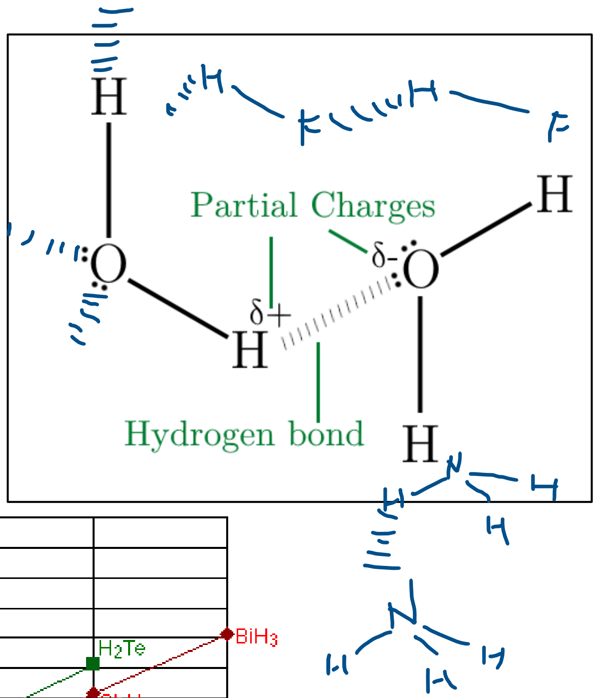
NCl_3 is a polar molecule while BCl_3 is non-polar. (1) The strength of the van der waal's forces between NCl_3 are stronger than those between BCl_3, so NCl_3 has a higher boiling point.

3. Explain why pentane has a higher boiling point than dimethylpropane

Pentane has a larger surface area of contact than dimethylpropane, the strength of the van der waal's forces between pentane molecules are stronger than those between dimethylpropane molecules.

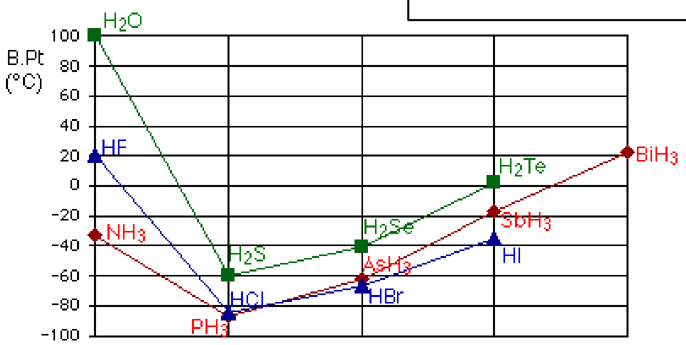
Hydrogen bonding

Hydrogen bonding can form between an H atom of one molecule and **a vacant lone pair an N, O or F atom of another molecule.** This is because N, O, F are highly electronegative and they are of the second period while H is in the first period, this combination creates a surprising strong bond.



Common examples of hydrogen bonding:

H_2O, NH_3, HF, CH_3OH, CH_3COOH



Example: Refer to the graph above and answer the following questions.

a. Why does HF have a higher boiling point than HCl?

HF molecules are held together by both hydrogen bonding and van der waal's force while HCl molecules are only held together by van der waal's forces. The strength of the hydrogens bonds between HF are stronger than the van der waal's forces between HCl molecules, so HF has a higher boiling point.

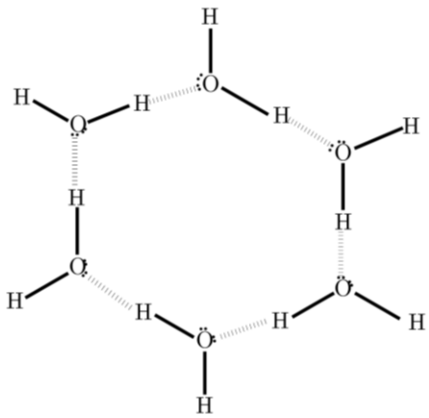
b. Why does H_2O have a higher boiling point than both HF and NH_3?

All three molecules are held together by both hydrogen bonding and van der waal's forces. The hydrogen bonding between H_2O molecules is more **extensive** than that between HF molecules and NH_3 molecules. The intermolecular forces between H_2O are stronger than those between HF and NH_3 molecules. H_2O has the higher boiling point out of the three.

Structure of ice

Typically solids are *denser* than their liquid counterparts, meaning that solids of a substance will sink to the bottom of its liquid. However, ice *floats* on water, which is quite the anomaly, why is this so? The answer is that ice is *less dense* than water.

In ice, water molecules are arranged in an open structure. H_2O molecules are held together by hydrogen bonds and van der waal's forces. when ice melts into water, the open structure collapses and H_2O molecules become closer to one another, resulting in increased density.



Open structure of ice

Solubility

To dissolve in a solvent: Solute-solvent attraction has to be stronger than or comparable to solute-solute attraction and solvent-solvent attraction.

Another rule of thumb when dealing with water: If the molecule can form hydrogen bonds with water, then it most likely dissolves/is miscible in water.

Example:

With the aid of a diagram, explain why methanoic acid(HCOOH) is miscible with water.

Methanoic acid can form hydrogen bonds with water, so it is miscible with water.