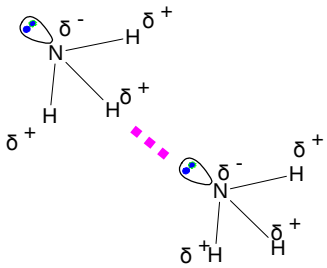
Intermolecular forces



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Intramolecular and Intermolecular Forces

Intramolecular forces are the forces within a molecule

i.e. covalent bonds which are strong.

These generally govern the chemical properties of a compound.

Intermolecular forces are the forces between molecules, and are generally weak.

These govern the physical properties such as bp, mp. viscosity.

There are three main types of intermolecular forces: Van der Waals, permanent dipole bonding, and hydrogen bonding.

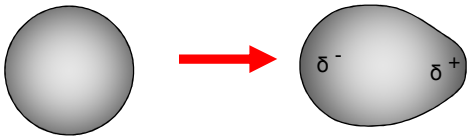
KEY

Van der Waals' Forces

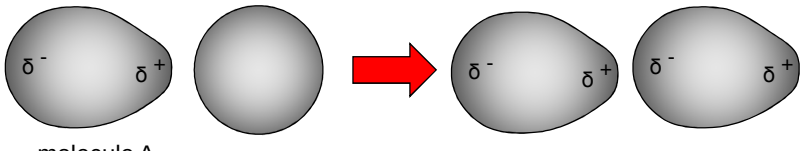
These are also called transient dipole-dipole interactions.
They occur between all simple covalent molecules and the separate atoms in noble gases.

How Van der Waals forces occur

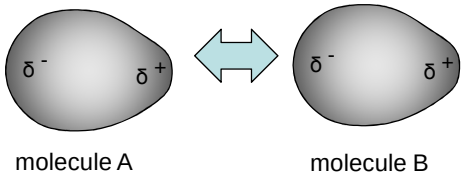
In any molecule the electrons are moving constantly and randomly. As this happens the electron density can fluctuate and parts of the molecule become more or less negative i.e small temporary or transient dipoles form.



2. These instantaneous dipoles can cause dipoles to form in neighbouring molecules. These are called induced dipoles. The induced dipole is always the opposite sign to the original one



3. A force of attraction forms between the dipoles in the different molecules, which is called the van der waals force.



Factors that control Van der Waals Forces

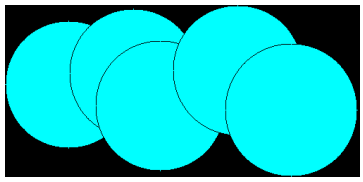
1. The **more electrons** there are in the molecule the higher the chance that temporary dipoles will form. This makes the van der waals forces **stronger between the molecules** and so boiling points will be greater.

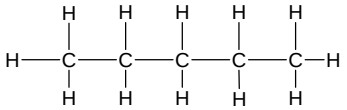
KEY

Element	No of electrons in molecule	Boiling Point (°C)	Physical State
Fluorine	18	-188	gas
Chlorine	34	-35	gas
Bromine	70	59	liquid
Iodine	106	184	solid

Don't use the word 'bond' to describe van der waals forces.

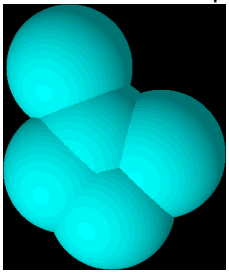
2 The shape of the molecule also has an effect on the size of the van der waals forces. Long chain molecules have a large surface area of interaction for the dipoles to form

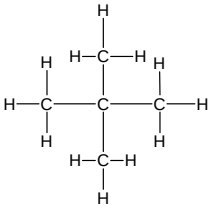




Pentane B.p.36 °C

Whereas a branched chain molecule is more spherical in shape and forms a smaller area of interaction.
The van der waals are therefore weaker between the molecules.





2,2 Dimethylpropane
B.p.10 °C

applied

What is wrong/insufficient in the following answers to why the boiling point of halogens increases down the group?

"In Bromine the van der waals forces between atoms are stronger than they are in chlorine so the bp is higher"

"The smaller molecules like fluorine have smaller van der waals forces and so the molecules are easier to break apart"

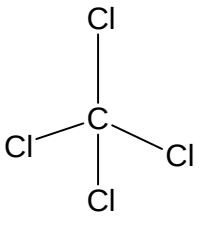
"Bromine is bigger than Chlorine so has larger van der waals. It therefore needs more energy to break the bonds in Bromine"

"Chlorine has more electrons than fluorine so has larger van der waals in its molecules"

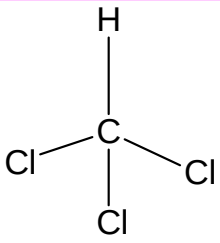
"Chlorine has more electrons than fluorine so has bigger van der waals force between its electrons and nucleus"

Permanent dipole bonding

- Polar molecules have a permanent dipole.
- Polar molecules are asymmetrical and have a bond where there is a significant difference in electronegativity between the atoms.



Non polar molecule.
All bonds equal- dipoles cancel



polar molecule.
Bonds different- dipole present on C-Cl bond

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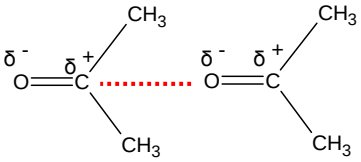
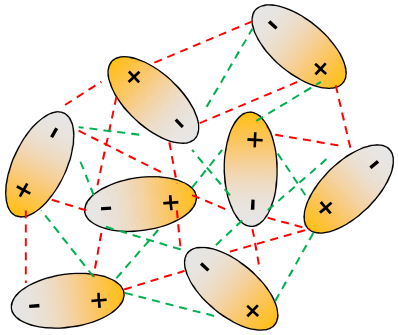
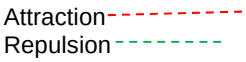


δ+ is over the less electronegative element.
δ- is over the more electronegative element.

Interaction on two polar molecules

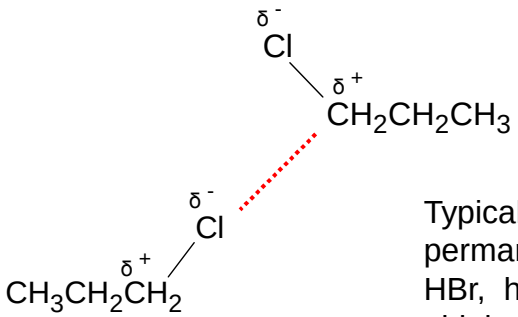




Interaction of many dipoles in a liquid.

These forces of attraction between molecules are stronger than van der waals and they occur in addition to van der waals.

E.g. in 1-chloro propane there are both van der waals and permanent dipole attractions, so its boiling point is higher than an alkane with similar numbers of electrons



Typical compounds that have permanent dipoles include HCl, HBr, halogenalkanes, ketones, aldehydes.

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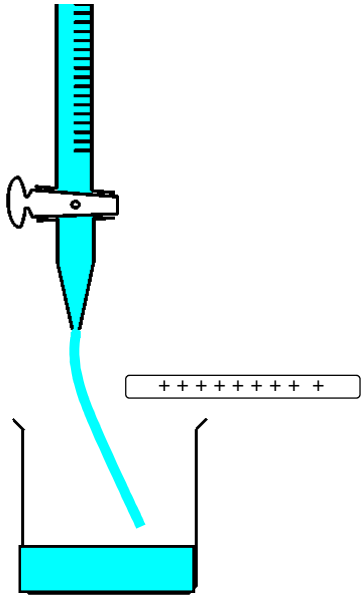
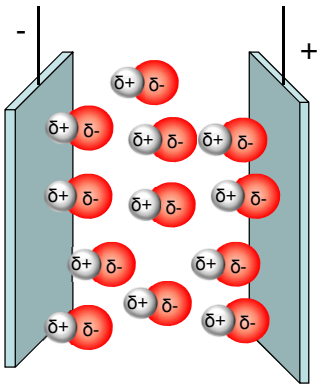




A jet of a polar Compound issued from a burette will be attracted towards a charged rod.

The stronger the dipole the bigger the deflection

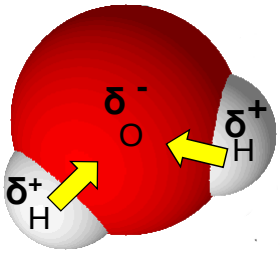
EXTRA

Hydrogen bonding

It occurs in compounds that have a highly polarised hydrogen atom attached to one of the three most electronegative atoms of nitrogen, oxygen and fluorine, which must have an available lone pair of electrons.

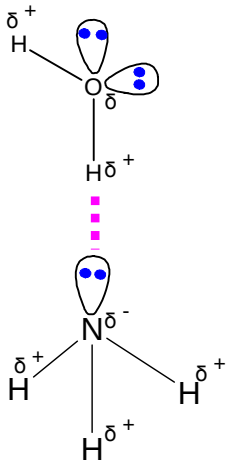
eg compounds with these bonds –O-H -N-H F-H

Examples of compounds that hydrogen bond: water, alcohols, carboxylic acids, ammonia, amines, amide
hydrogen fluoride.



KEY

The small size of the hydrogen atom and the oxygen, nitrogen, fluorine atoms allow the atoms to approach each other closely, which makes the force of attraction strong. The force of attraction is also made strong because the difference in electronegativity is significant.



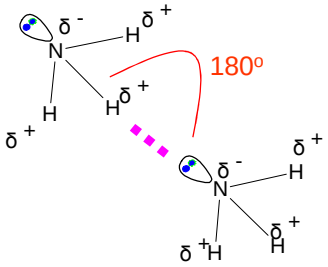
•Hydrogen bonds are significantly stronger than van der waals and permanent dipole bonding.
• All compounds that hydrogen bond between molecules will have van der waals attraction in addition.

KEY

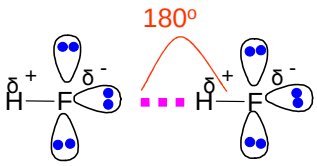
Drawing Hydrogen Bonds

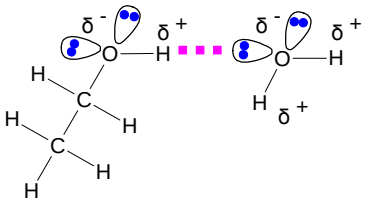
The hydrogen bond is normally represented as three dots

The hydrogen bond should have an bond angle of 180º with one of the bonds in one of the molecules



Always show the lone pair of electrons on the O,F,N





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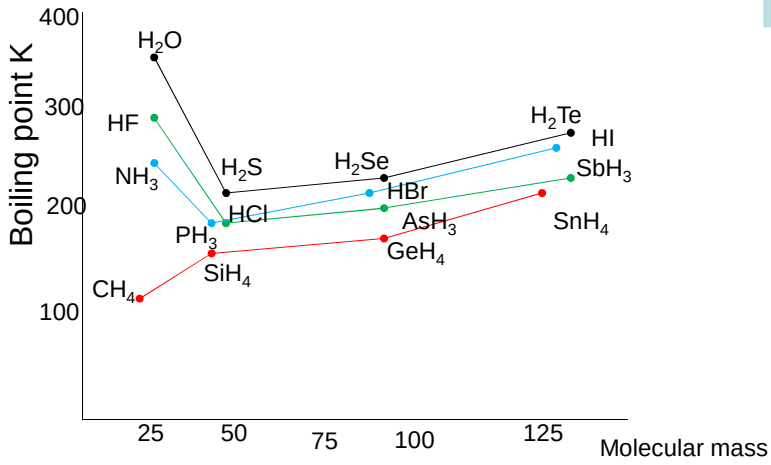


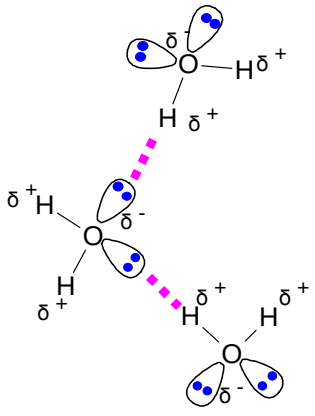
The anomalously high boiling points of H_2O, NH_3 and HF are caused by the hydrogen bonding.

The general increase in boiling point from H_2S to H_2Te is caused by increasing van der waals due to an increasing number of electrons.

KEY

Hydrogen Bonding in Water

Water can form two hydrogen bonds per molecule, because oxygen is very electronegative, and it has two lone pairs of electrons in water.



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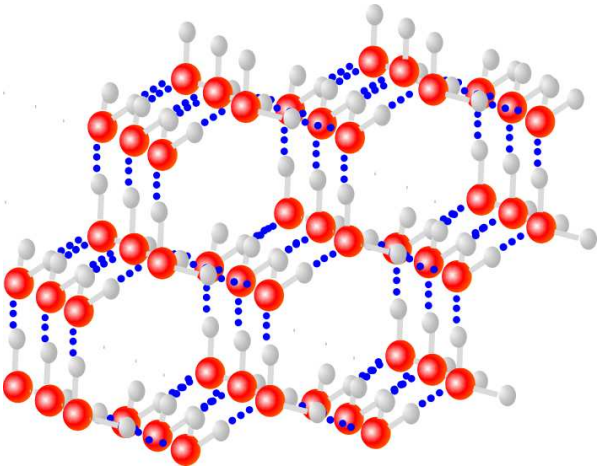


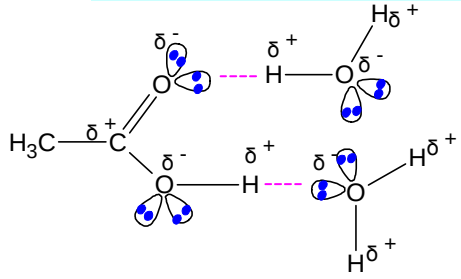
In ice the hydrogen bonds hold the water molecules together in a regular structure

Ice is less dense than water because the water molecules are held slightly further apart in the ice structure than they are in liquid water.

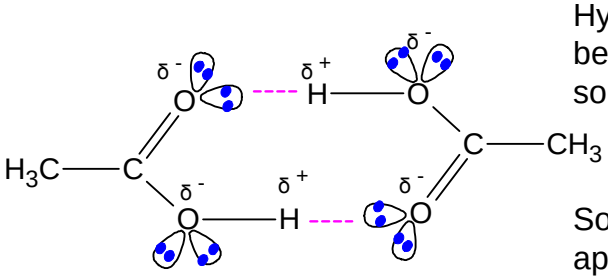
Bond strengths

Covalent bonds are	hundreds of	kJ/mol
Hydrogen bonds	tens	kJ/mol
van der Waals forces	units	kJ/mol

Hydrogen bonding in carboxylic acids



Hydrogen bonding between ethanoic acid and water

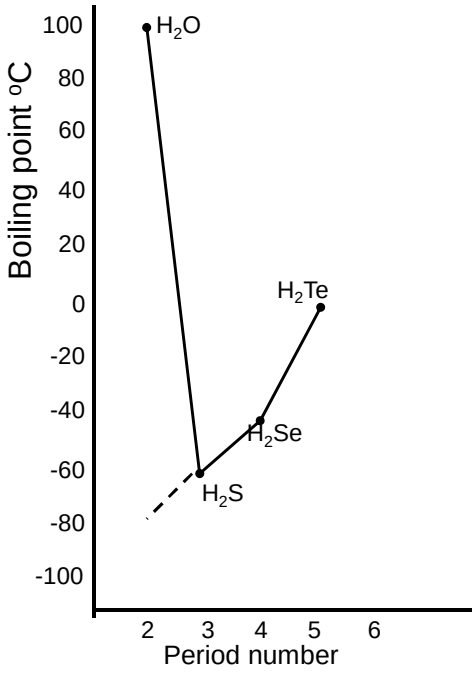


Hydrogen bonding between dimer in solid ethanoic acid

Solid Ethanoic appears to have Mr of 120

To work out what the boiling point of water without hydrogen bonding would be, extrapolate the line from H_2S to H_2Te down to water.

It gives a value of about -80°C



Properties of compounds with hydrogen bonding

- higher boiling points
- tend to be soluble in other compounds with hydrogen bonds (water, ethanol) eg ammonia, HF, carboxylic acids will dissolve in water and ethanol.
- Higher viscosity: the stronger the bonding the more viscous the liquid.
- Higher surface tension

Dissolving

Compounds that do not hydrogen bond have difficulty in dissolving in compounds with hydrogen bonding eg hexane does not dissolve in water.

If the solute cannot form strong enough bonds with the water to compensate for the energy needed to break the hydrogen bonds in water, it will not dissolve.

Generally 'like dissolves in like'.

Bonding in solute	Bonding in Solvent	Solution forms
Van der Waals	Van der Waals	yes
Van der Waals	Hydrogen bonding	no
Hydrogen bonding	Van der Waals	no
Hydrogen bonding	Hydrogen bonding	yes

EXTRA

Do all alcohols dissolve in water?

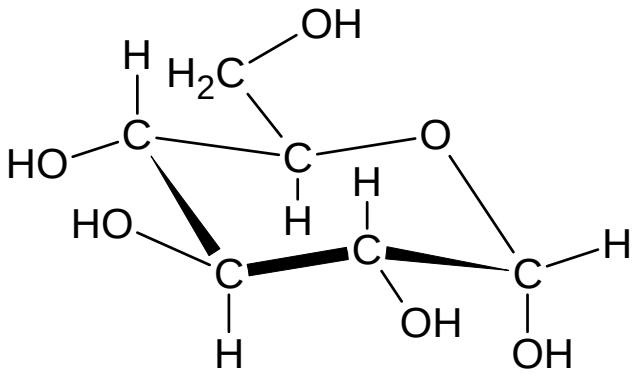
- Methanol to butan-1-ol dissolve in water
- Alcohols larger than pentan-1-ol only partially dissolve in water.
- Alcohols larger than octan-1-ol do not dissolve in water at all.

If a compound has a significantly large hydrocarbon chain (that is non-polar), eg octanol, it will prevent to some extent hydrogen bonding occurring between the –O-H bonds in the alcohol and those on water.

The hydrocarbon chain gets in the way of the hydrogen bonds.

EXTRA

Would this substance dissolve in water ?



Yes: It is glucose

EXTRA