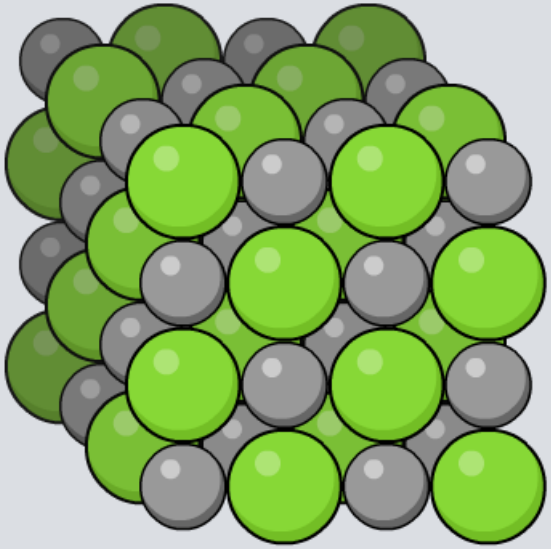
Intermolecular Forces



Types of intermolecular force

The molecules in simple covalent substances are not entirely isolated from one another. There are forces of attraction between them. These are called **intermolecular forces**.

There are three main types of intermolecular force:

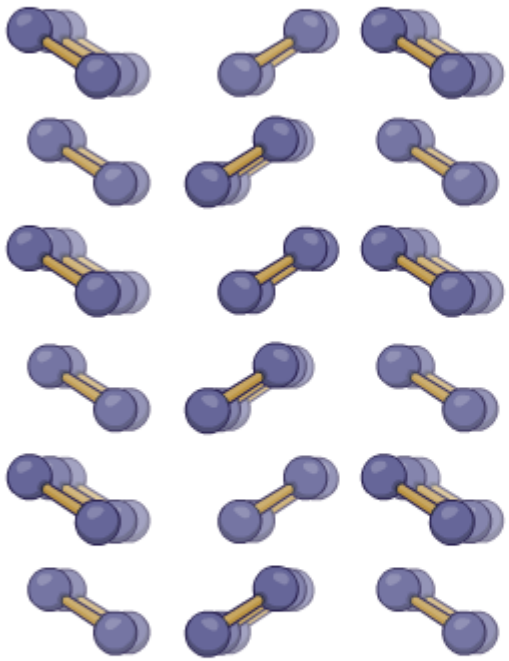
- **van der Waals forces** – for example, found between I_2 molecules in iodine crystals.
- **permanent dipole–dipole forces** – for example, found between HCl molecules in hydrogen chloride.
- **hydrogen bonds** – for example, found between H_2O molecules in water.

Van der Waals forces

How do van der Waals forces hold molecules together?

In a crystal of iodine the molecules of iodine (I_2) are held together by **van der Waals** forces.

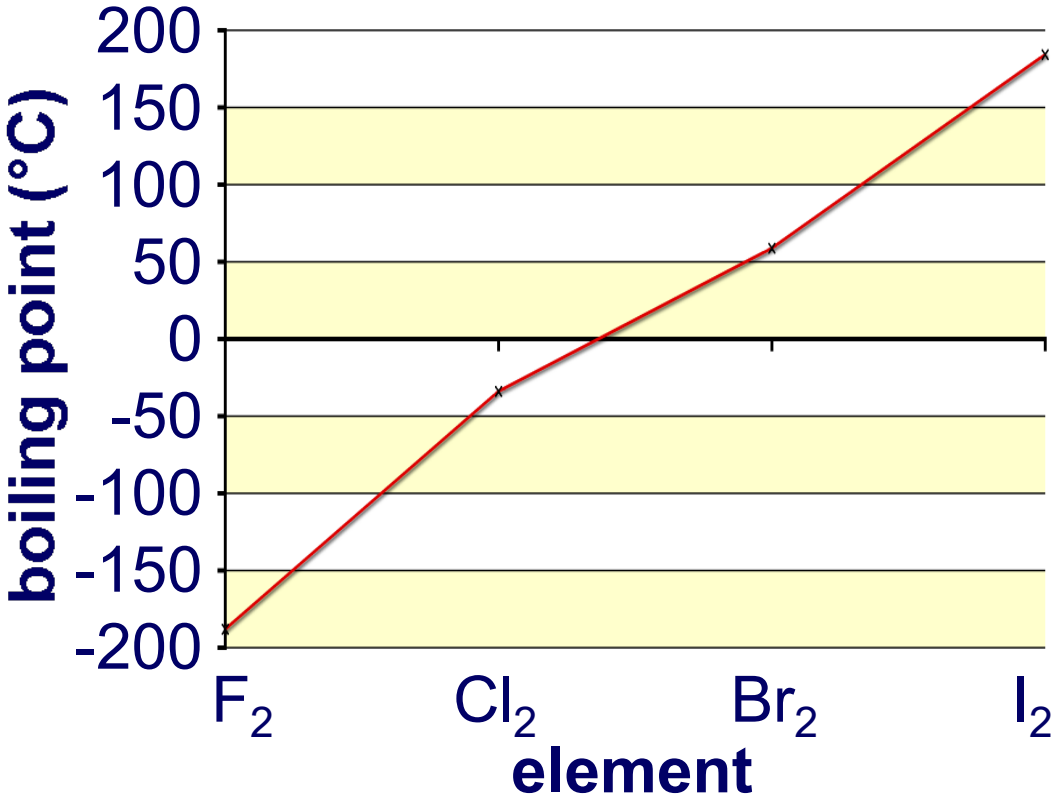
Click "**play**" or the iodine molecules to find out more about these forces.



Strength of van der Waals forces

The strength of van der Waals forces increases as molecular size increases.

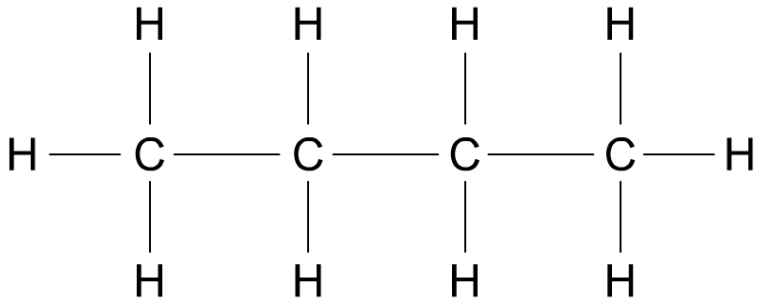
This is illustrated by the boiling points of group 7 elements.



Atomic radius increases down the group, so the outer electrons become further from the nucleus. They are attracted less strongly by the nucleus and so temporary dipoles are easier to induce.

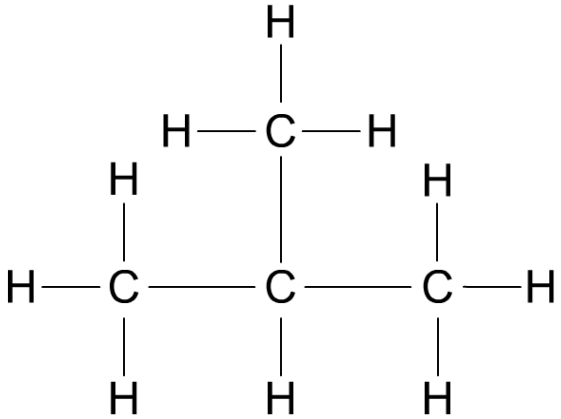
Strength of van der Waals forces

The points of contact between molecules also affect the strength of van der Waals forces.



butane (C_4H_{10})

boiling point = 272 K



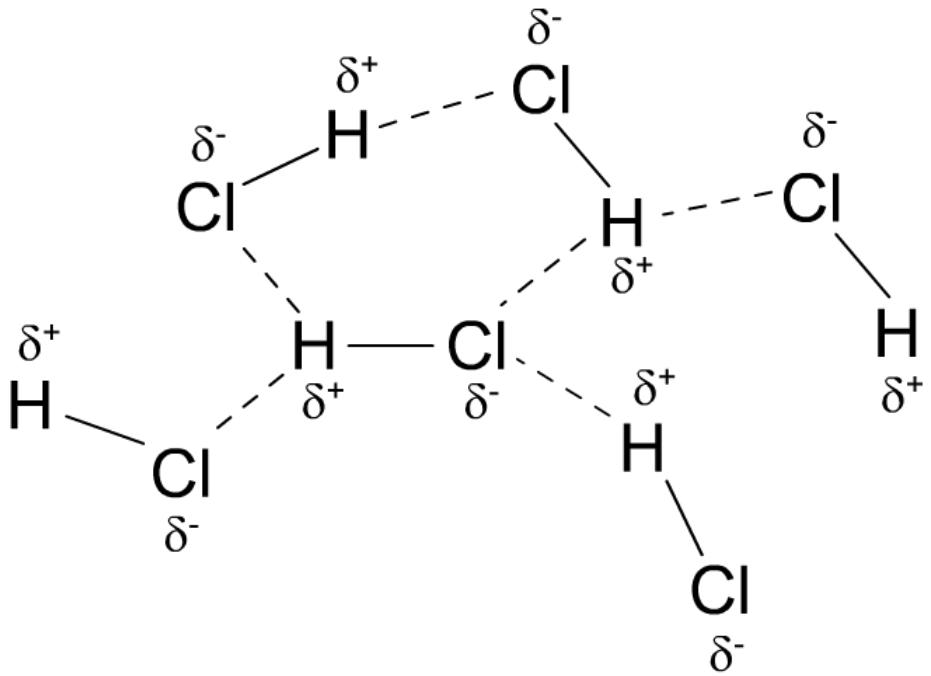
2-methylpropane (C_4H_{10})

boiling point = 261 K

Straight chain alkanes can pack closer together than branched alkanes, creating more points of contact between molecules. This results in stronger van der Waals forces.

Permanent dipole–dipole forces

If molecules contain bonds with a permanent dipole, the molecules may align so there is **electrostatic attraction** between the opposite charges on neighboring molecules.



Permanent dipole–dipole forces (dotted lines) occur in hydrogen chloride (HCl) gas.

The permanent dipole–dipole forces are approximately one hundredth the strength of a covalent bond.

Permanent dipole–dipole or not?

Do these molecules exhibit permanent dipole–dipole forces?

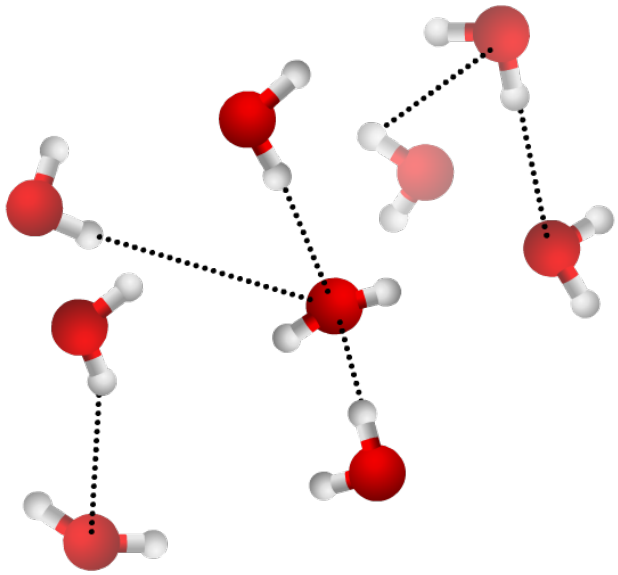
yes	no

methane (CH_4)

What is hydrogen bonding?

When hydrogen bonds to nitrogen, oxygen or fluorine, a larger dipole occurs than in other polar bonds.

This is because these atoms are **highly electronegative** due to their high nuclear charge and small size. When these atoms bond to hydrogen, electrons are withdrawn from the H atom, making it slightly positive.

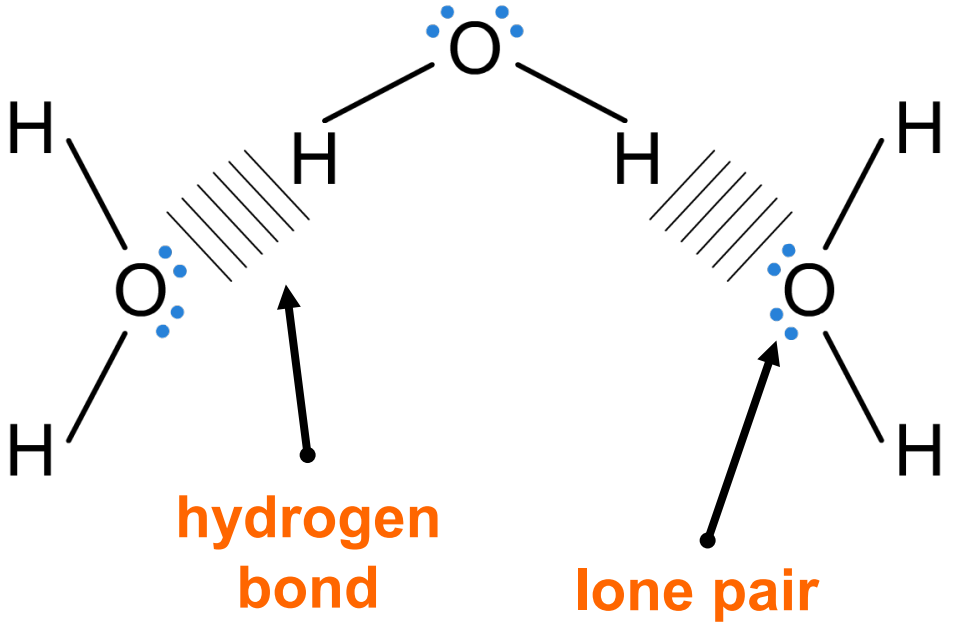


The H atom is very small so the positive charge is more concentrated, making it easier to link with other molecules.

Hydrogen bonds are therefore particularly strong examples of permanent dipole–dipole forces.

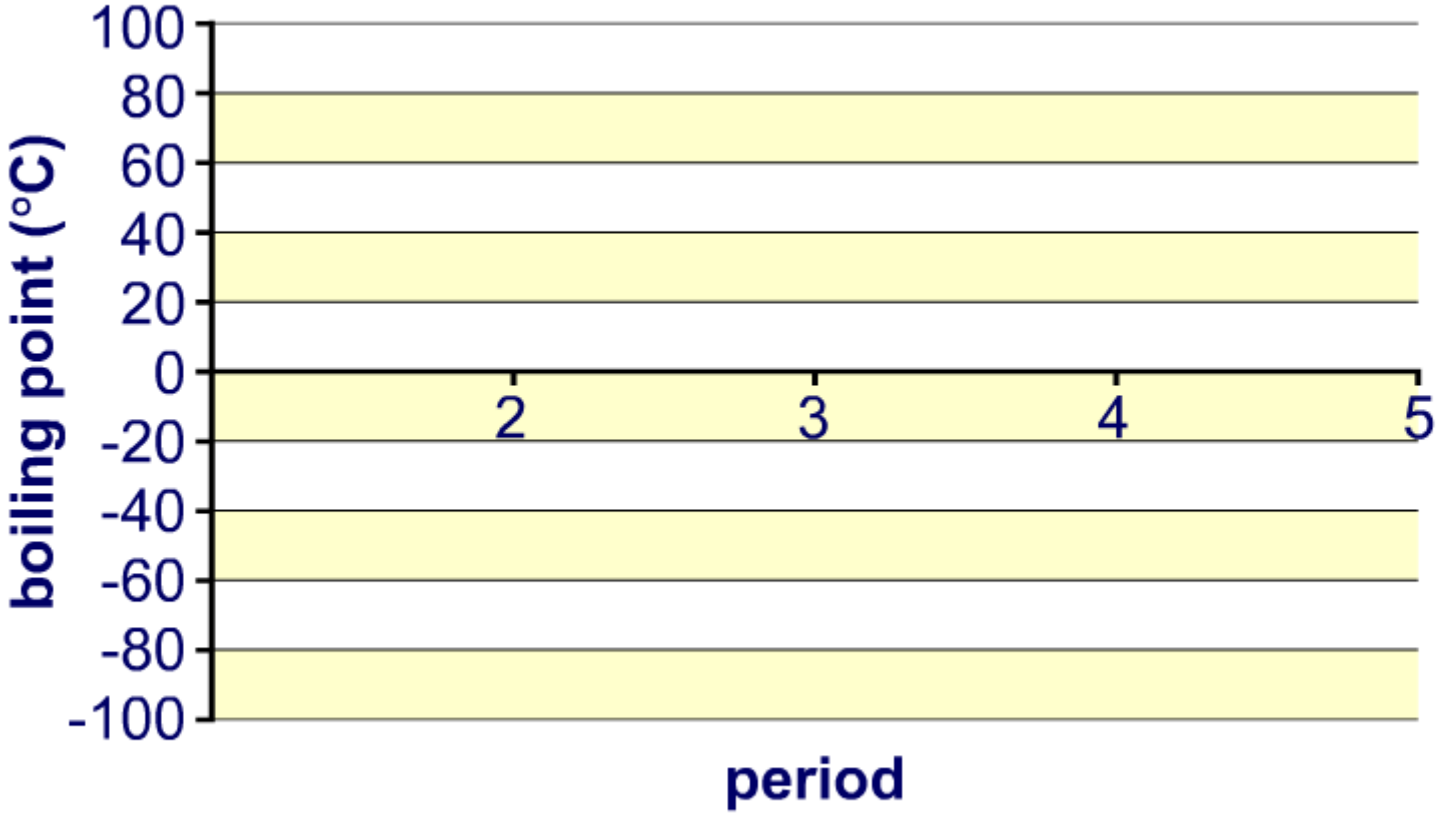
Hydrogen bonding

In molecules with OH or NH groups, a lone pair of electrons on nitrogen or oxygen is attracted to the slight positive charge on the hydrogen on a neighboring molecule.



Hydrogen bonding makes the melting and boiling points of water higher than might be expected. It also means that alcohols have much higher boiling points than alkanes of a similar size.

Hydrogen bonding and boiling points



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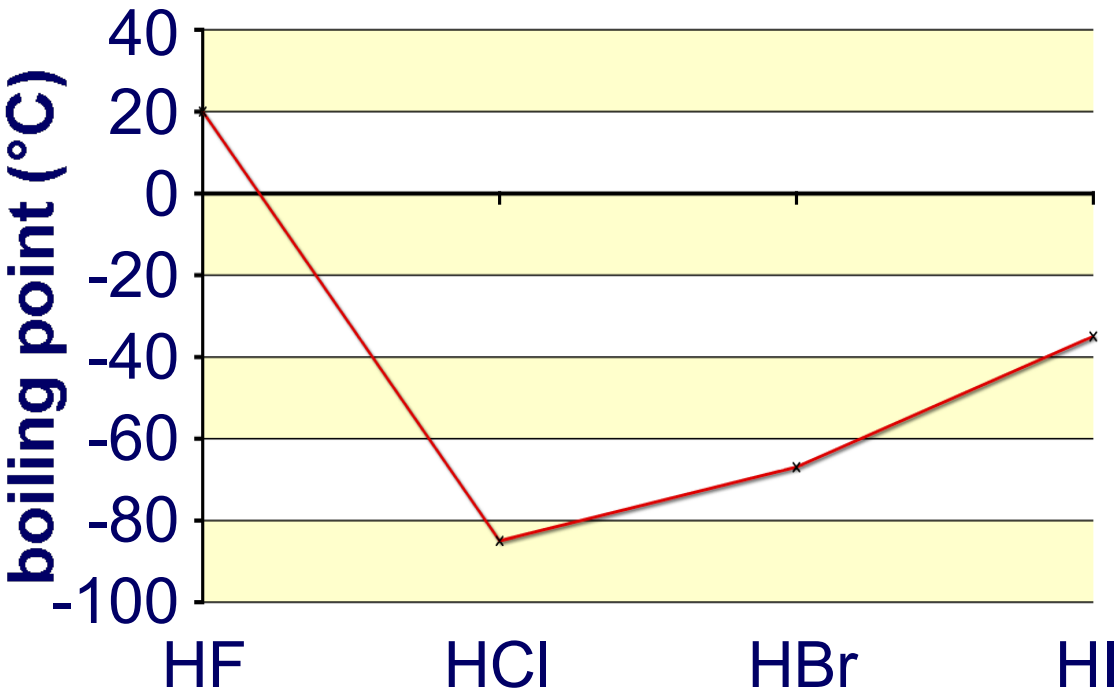
Boiling points of the hydrogen halides

The boiling point of hydrogen fluoride is much higher than that of other hydrogen halides, due to fluorine's high electronegativity.



This means that hydrogen bonding between molecules of hydrogen fluoride is much stronger than the permanent dipole–dipole forces between molecules of other hydrogen halides. More energy is therefore required to separate the molecules of hydrogen fluoride.

Permanent dipole–dipole forces

What type of forces do these molecules exhibit?

hydrogen bonding	permanent dipole–dipole forces

bromoethane
(C_2H_5Br)