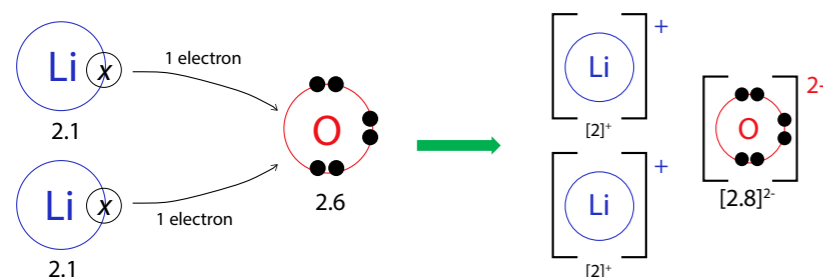


# 1.4 – Bonding

## Ionic bonding

When a metal and a non-metal react together, the metal atom loses electrons and becomes a cation (+), and the non-metal gains electrons and becomes an anion (-). There are strong electrostatic forces of attraction between these oppositely charged ions. This is called ionic bonding.

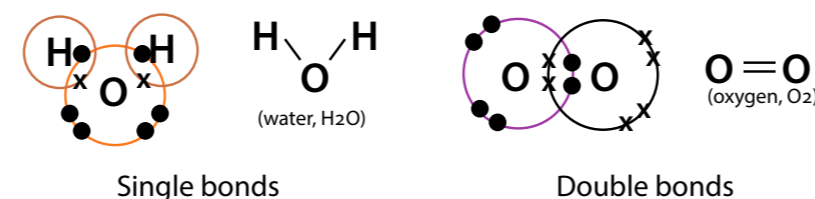
Dot and cross diagrams show how ionic bonds form.



## Covalent bonding

When non-metals bond together, each atom gives one electron to form a bond pair in which the electron spins are opposed. A covalent bond is the electrostatic attraction between the positive nuclei of the bonded atoms and the shared electrons between them. Atoms only share electrons in their outermost shells.

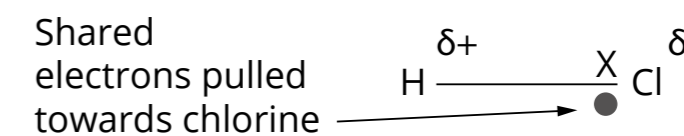
Dot and cross diagrams show how covalent bonds form.



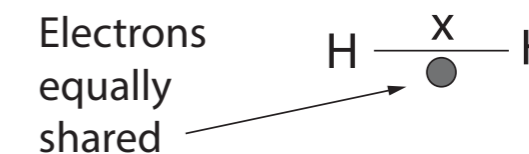
## Electronegativity and polarity

Electronegativity is a measure of how strongly atoms attract electrons in a covalent bond. The higher the electronegativity value, the better the element can attract bonding electrons.

In a covalent bond, the electron pair is not usually shared exactly evenly between the two atoms. Normally, the atoms have different electronegativities and the bonding electrons are pulled towards the more electronegative atom. This atom will take up a slightly negative charge and the other becomes slightly positive. The partial charges are written above the atoms using the symbol  $\delta$  (delta). The bond is said to be **polar**.



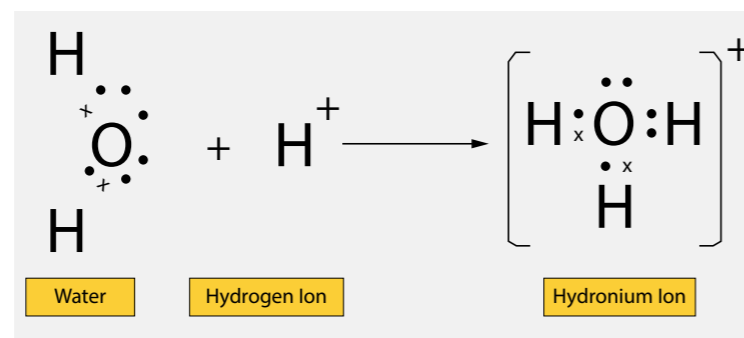
If the two atoms are the same, the atoms have equal electronegativities, so the electrons are equally shared and the bond is said to be non-polar.



In general, bonds where the electronegativity difference between the two atoms is less than about 0.4 will be non-polar covalent bonds. If the electronegativity difference is between 0.4 and about 1.9 then they will be polar covalent bonds. If the difference is about 2.0 or more, they will be ionic.

## Coordinate bonding

The same as a covalent bond but both electrons forming the bond pair come from the same atom.



Very few compounds are purely ionic or purely covalent. Many substances contain bonds that are intermediate in character between pure covalent and pure ionic bonds. These are called polar bonds. The degree of ionic or covalent character depends on the difference in electronegativity between the bonded atoms. The greater the difference in electronegativity, the greater the ionic character.

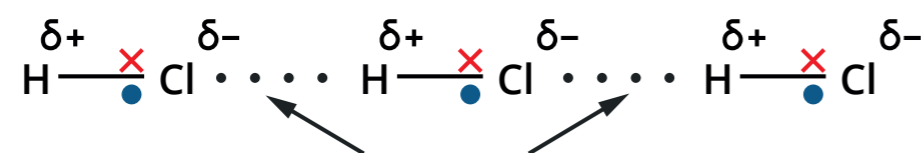
## 1.4 – Bonding

### Forces between molecules

You need to know about three types: dipole-dipole forces, induced dipole-induced dipole forces and hydrogen bonds.

#### Dipole-dipole forces

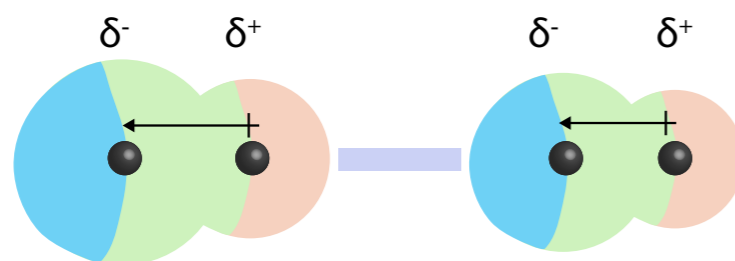
Polar molecules have dipoles, one end has a slightly positive charge, the other a slightly negative charge due to a difference in electronegativities between the atoms in the molecule. If these dipoles arrange themselves so that the negative region of one molecule is close to the positive region of another molecule, there will be an attraction between them.



Permanent dipole-dipole interactions between HCl molecules

#### Induced dipole-induced dipole forces

Even molecules with no dipoles show intermolecular bonding. Electrons are in constant motion around the nuclei; therefore at any particular moment the distribution of the electron cloud around the nuclei will not be symmetrical. At this moment, the molecule would have a temporary dipole.



The  $\delta^+$  end of the molecule can pull the electron cloud of a neighbouring molecule towards it, giving the left side of that molecule a  $\delta^-$  charge, i.e. it induces a temporary dipole in the neighbouring molecule. The two dipoles are attracted to each other.

The second dipole induces a dipole in a third molecule, etc. The dipoles will always be aligned correctly to produce an attraction between the molecules.

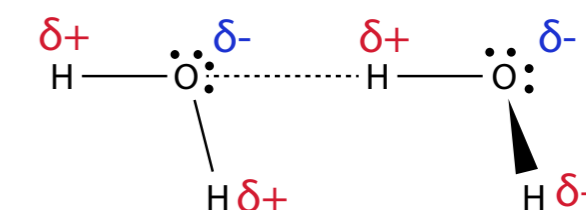
The strength of induced dipole-induced dipole forces increases with increasing numbers of electrons in the molecule. The more electrons in a molecule, the greater the fluctuation in the electron cloud around the nuclei and the larger the temporary and induced dipoles created. This means stronger forces between the molecules.

These two types of intermolecular forces together are called **van der Waals forces**.

#### Hydrogen bonds

These are special intermolecular forces that occur between molecules containing hydrogen atoms bonded to small very electronegative elements which have lone pairs – fluorine, oxygen or nitrogen.

Because fluorine, oxygen and nitrogen are highly electronegative and the hydrogen atom is so small, the  $\delta^+$  charge in the bonded hydrogen atom is spread over a small volume and so it has a high charge density. The highly polarising  $\delta^+$  hydrogen atom then attracts a lone pair of electrons from a small highly electronegative atom in another molecule. The  $\delta^+$  hydrogen atom is sandwiched between two electronegative atoms. It is covalently bonded to one and hydrogen-bonded to the other.



#### Effects of hydrogen bonding

**Increases boiling points** – When a liquid boils, energy is needed to overcome all the forces of attraction between the molecules of the liquid. Since hydrogen bonds are stronger than van der Waals forces, molecules that form hydrogen bonds have a higher boiling temperature than molecules of a similar size that cannot hydrogen bond.

**Increases solubility** – The most significant intermolecular forces between water molecules are hydrogen bonds. Covalent compounds that can replace these bonds by forming new hydrogen bonds with water will dissolve.