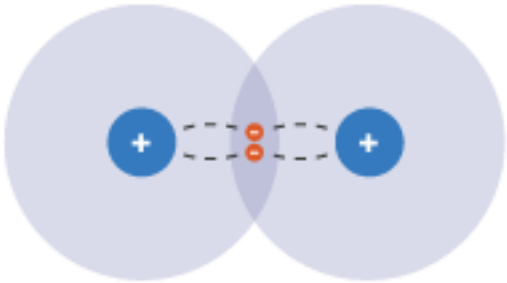
Bonding, Structure and properties

Atoms can be held together by chemical bonds. When atoms form bonds, they can achieve a stable electron arrangement (full outer electron shell). To achieve a stable electron arrangement atoms can lose, gain or share electrons. There are different types of bonds that hold atoms together.

Covalent Bonding

A covalent bond is a shared pair of electrons between atoms of two non-metal elements.



A covalent bond happens when the positive nuclei from two different atoms are held together by their common attraction for the shared pair of electrons held between them.

Covalent bonds are strong bonds.

Atoms that share pairs of electrons form molecules.

A molecule is a group of atoms held together by covalent bonds.

A diatomic molecule is a molecule containing only two atoms.

Molecular Elements

There are 7 diatomic elements (diatomic means 2 atoms in a molecule):

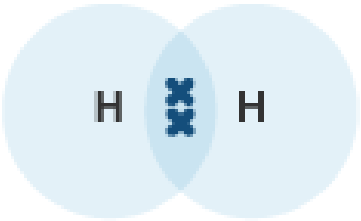
Hydrogen (H_2), Oxygen (O_2), Nitrogen (N_2), Fluorine (F_2), Chlorine (Cl_2), Bromine (Br_2), Iodine (I_2)

If you remember "**F**ancy **C**lancy **O**wes **H**im **N**othing **B**ut **I**ce" then you will have remembered that the seven diatomic elements are Fluorine, Chlorine, Oxygen, Hydrogen, Nitrogen, Bromine and Iodine.

Diagrams can be used to show how the outer electrons are shared to form the covalent bonds in a molecule, e.g. hydrogen

Hydrogen (H_2)

Both hydrogen atoms have only one electron, but by forming a single covalent bond, both can have a full outer shell. The shape of the molecule formed is called linear.

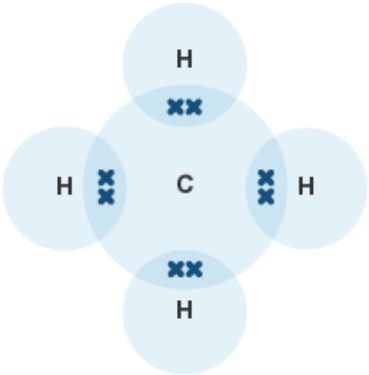


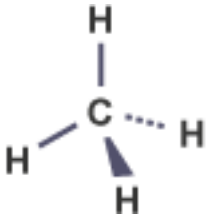
A shared pair of electrons between two hydrogen atoms

This can also be shown as H-H.

Methane (CH_4)

Carbon atoms have four outer electrons so need four more for a full outer shell. The carbon forms four single bonds to the hydrogen atoms, so all the atoms now have a full outer shell of electrons.



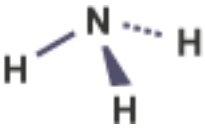


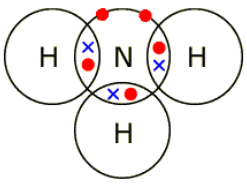
The shape formed is called tetrahedral.

A methane molecule has four shared pairs of electrons

Ammonia (NH_3)

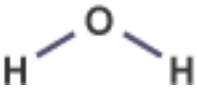
Nitrogen atoms have five outer electrons so needs three more for a full outer shell. Nitrogen forms three single covalent bonds to hydrogen atoms. The shape formed is called pyramidal.

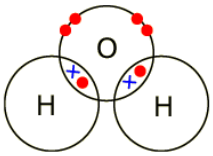




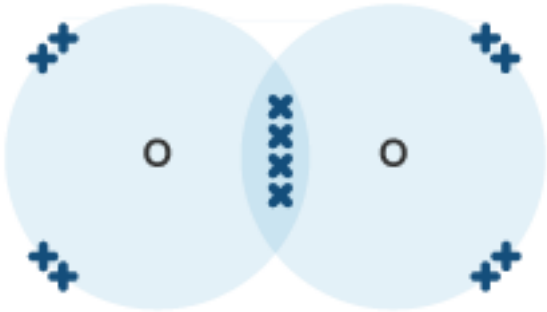
Water (H_2O)

Oxygen atoms have six outer electrons so need two more for a full outer shell. The oxygen forms two single covalent bonds with the two hydrogen atoms. The shape formed is called bent.





More than one bond can be formed between atoms leading to double and triple bonds. Examples of these are diatomic oxygen (double bond) or nitrogen (triple bond).



Oxygen molecules have a double bond: two shared pairs of electrons

This could also be written as:

O=O

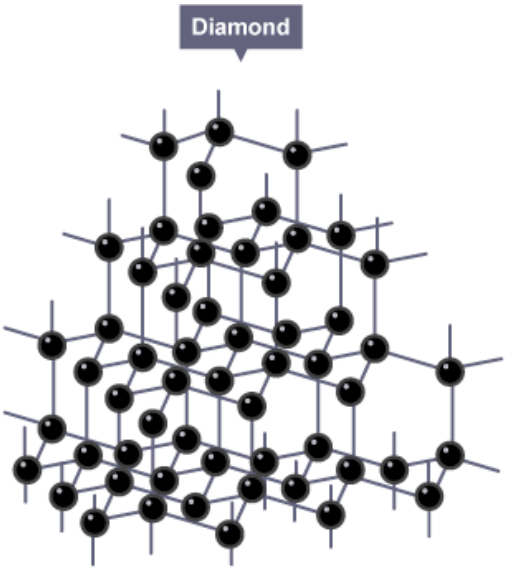
Substances that consist of covalent molecules are usually gases or liquids at room temperature.

Covalent molecular substances tend to have low melting and boiling points because they have weak forces between the molecules and these are the forces that are broken NOT the strong covalent bonds between the atoms.

Covalent molecular substances do not conduct electricity.

Covalent Networks

Boron, carbon and silicon are all examples of covalent network elements.



Covalent networks have high melting and boiling points because all the atoms are interlinked by strong covalent bonds which take a lot of energy to break.

They are all hard solids at room temperature and do not conduct electricity.

Ionic Bonding

Ionic bonds are formed between a metal and non-metal, for example sodium chloride.

The ionic bond is the electrostatic force of attraction between a positively charged metal ion and a negatively charged non-metal ion.

Metals form positive ions because they lose electrons to become stable.

Example: Magnesium (Mg) has the electron arrangement 2,8,2.

To become stable it must lose its two outer electrons to obtain a full outer energy level.

Atoms are neutral because they have equal numbers of protons and electrons however, when they lose two electrons they are no longer neutral. They change into ions with a two positive charge.

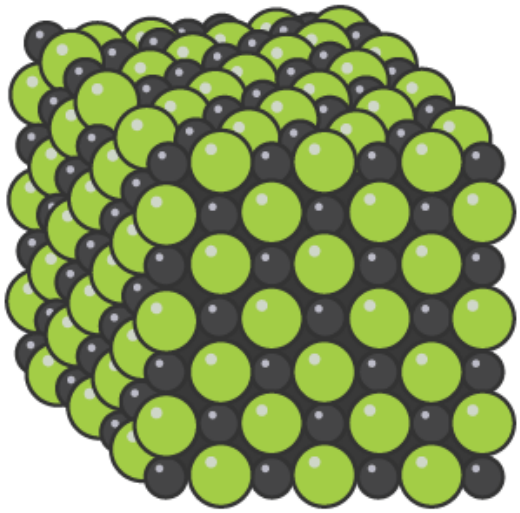
Non-metals form negative ions because they gain electrons to become stable.

Chlorine (Cl) has an electron arrangement 2,8, 7.

To become stable it must gain an electron to obtain a full outer energy level (2, 8, 8).

When these two charged particles come together they form an ionic bond because the positive magnesium ion is attracted to the negatively charged chloride ion.

Ionic compounds form what is known as a lattice structure.



This is a regular repeating arrangement of metal and non-metal ions which creates compounds with very high melting points which conduct when molten or in solution but never when solid.

Ionic compounds dissolve in water easily; when they do this their lattice breaks up completely. Therefore they can conduct as their ions are free to move.

Ionic substances do not conduct electricity when solid as the ions are not free to move around.

All ionic compounds have a high melting point and boiling point.

Ionic substances can be broken down by electrolysis.

Electrolysis

An electric current is a flow of charged particles.

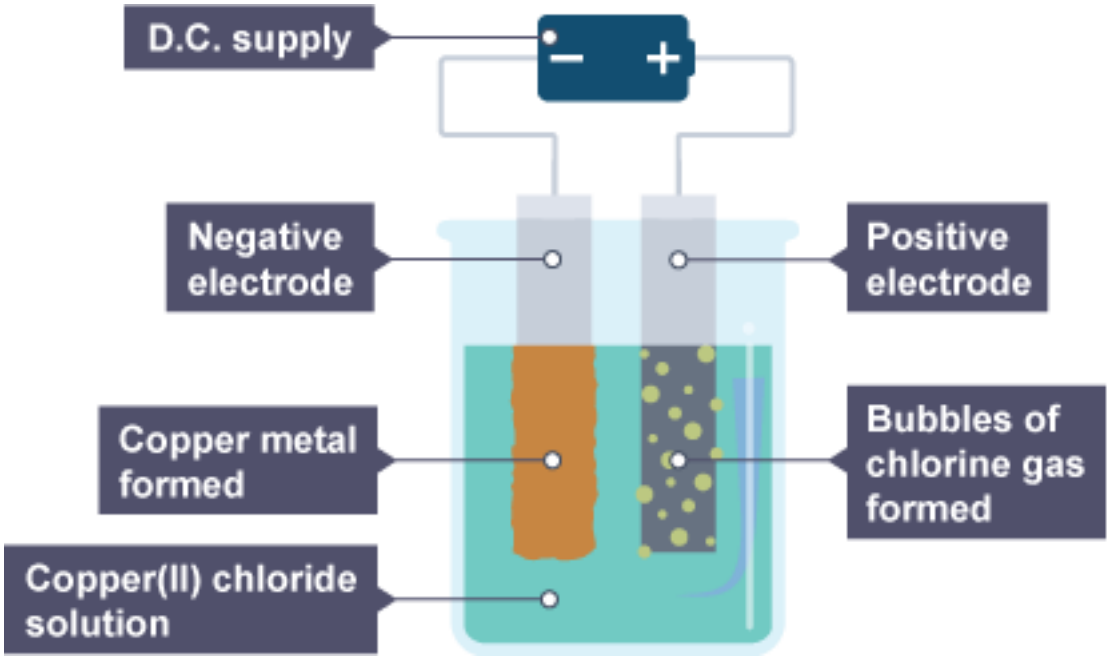
Electrons flow through metals and wires and ions flow through solutions.

Electrolysis is the breaking up of an ionic solution using electricity.

An electrolyte is a substance used to complete the circuit. An ionic solution or paste is usually used.

A direct current (DC) power supply must be used if the products of electrolysis are to be identified as you need a positive and a negative electrode.

Apparatus used for electrolysis in the lab:



The copper chloride solution is broken up because electricity is passed through the solution.

The positive copper ions are attracted to the negative electrode. When the copper ions get to the electrode they pick up two electrons to form copper metal (reduced).

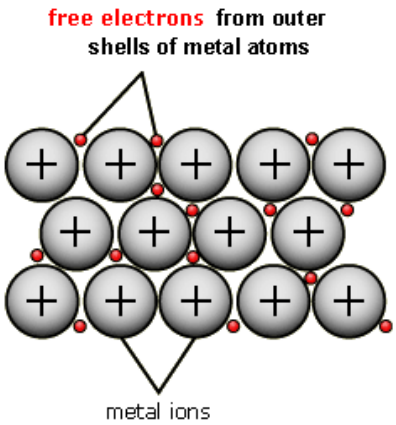
$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

The negatively charged chloride ions are attracted to the positive electrode. When the chloride ions get to the electrode they lose their extra electrons to become chlorine gas (oxidized)

$$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$$

Metallic Bonding

The bonding found in metal elements. The metal atoms lose their outer electrons which are then free to move from one metal ion to the next. The electrons are said to be "delocalised". This free movement of electrons is why metals conduct electricity.



Solubility summary – "like dissolves like"

Ionic compounds dissolve in solvents like water or ethanol.

Covalent compounds (like candle wax) dissolve in covalent solvents (like hexane).

Electrical Conductivity summary

Metals elements conduct when solid or liquid.

Non-metal elements never conduct apart from carbon in the form of graphite.

Covalent compounds never conduct.

Ionic compounds do not conduct when solid as the ions are not free to move, however ionic substances conduct when molten (liquid) or in solution because the ions are now free to move.

Type of bonding	**Electrical conductivity**			**Melting / boiling points**
	Solid	**Liquid**	**aqueous**	
Metallic	Yes	Yes	(Insoluble)	High
Ionic	No	Yes	Yes	high
Covalent molecular	No	No	No	low
Covalent network	No	No	No	high