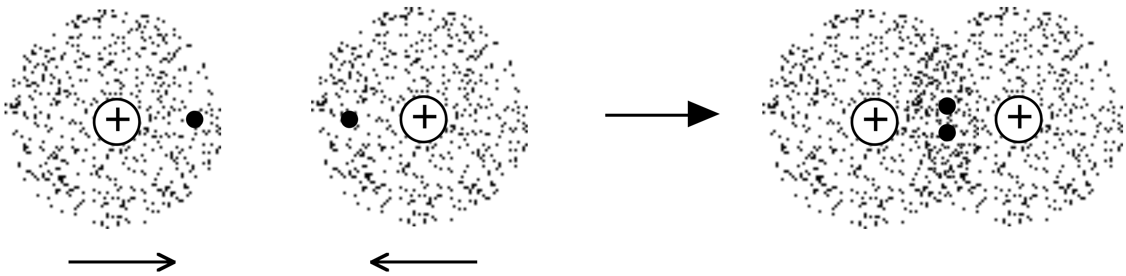
BONDING

Atoms form bonds with other atoms by pairing up their unpaired electrons. There are three ways they can do this: by covalent, electrovalent or metallic bonding.

COVALENT BONDING

Covalent bonds are formed between two non-metal atoms. An unpaired electron from one atom pairs up with an unpaired electron from the other atom:



The attraction of the negative electron pair for the two positive nuclei holds the two atoms together. Covalent bonds are very strong.

The resulting cluster of atoms in called a 'molecule'.
Molecules consisting of two atoms only are known as 'diatomic'.

e.g. H· ·H -> H:H

Hydrogen thus consists of diatomic molecules of H_2.

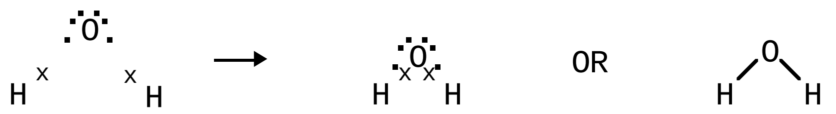
Other diatomic molecules are: Nitrogen N_2, Oxygen O_2 and Carbon monoxide CO.

The halogens are all diatomic elements:

Fluorine	F_2
Chlorine	Cl_2
Bromine	Br_2
Iodine	I_2

We can easily deduce the formulae of other simple covalent molecules

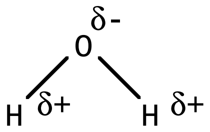
EXAMPLE 1: Water



Structural formula

The molecular formula of Water is therefore H_2O.

Oxygen has a greater attraction for the bonding pair of electrons than Hydrogen. This causes the electron pair to drift towards the O (making O slightly negative, δ-) away from the H (making H slightly positive, δ+). These bonds are described as 'polar covalent'. Water is therefore polar:

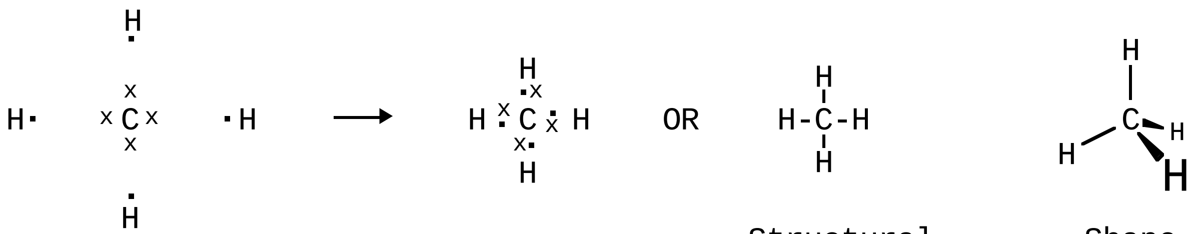


The mass of the H_2O molecule is just the sum of the relative atomic masses of its component atoms:

mass of H_2O molecule = (2 x RAM of Hydrogen) + (1 x RAM of Oxygen)
= (2 x 1) + (1 x 16)
= <u>18 amu</u>

This is known as the 'formula mass'.

EXAMPLE 2: Methane



Structural formula

Shape

The molecular formula of Methane is therefore CH_4.

Both Carbon and Hydrogen have equal attractions for the bonding pair of electrons so there is no electron drift in the C-H bonds. These bonds are described as 'non-polar' covalent. Methane is therefore non-polar.

formula mass of H_2O = (1 x RAM of Carbon) + (4 x RAM of Hydrogen)
= (1 x 12) + (4 x 1)
= <u>16 amu</u>

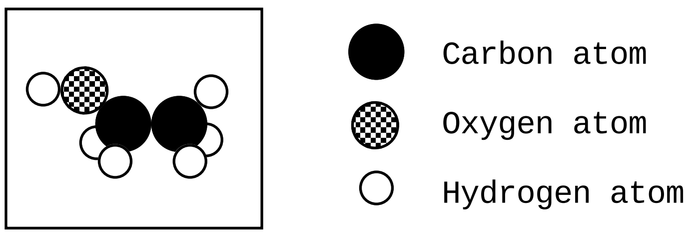
State symbols are often used after formulae to tell us whether the substance is a solid (s), liquid (l) or gas (g) e.g. $CH_4(g)$.

PROBLEM

Write the formula of this well known substance from its picture.

How well do you know this substance?

Not too well I hope!



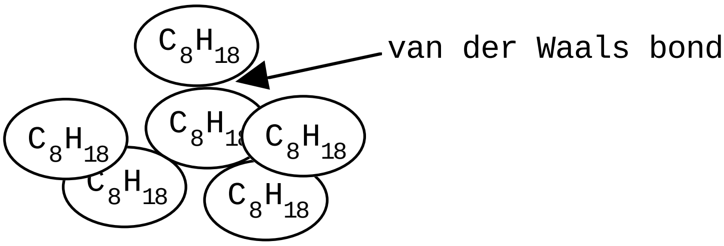
Writing some formulae is easy because the names contain prefixes which tell how many atoms are present e.g.

Nitrogen monoxide	NO
Nitrogen dioxide	NO_2
Sulphur trioxide	SO_3
Dinitrogen tetroxide	N_2O_4

BONDING BETWEEN COVALENT MOLECULES

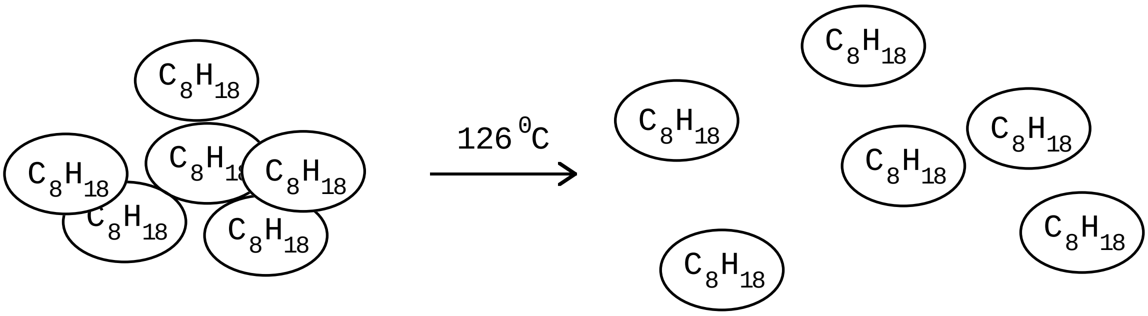
Due to the random movement of electrons over the surface of molecules negative charge builds up where the electrons *are* and positive charge where they *are not*. This allows molecules in covalent solids and liquids to stick together. The bonds formed between the molecules are called **van der Waals** bonds.

e.g. liquid Octane



We must make the distinction between the strong **covalent** C-C and C-H bonds **within** the molecule and the much weaker **van der waals** bonds **between** the molecules.

When covalent substances melt or boil it is the van der Waals bonds which break, not the covalent bonds e.g the boiling of Octane:



liquid Octane gaseous Octane

van der Waals bonds are weak so melting points and boiling points are low e.g. Octane C_8H_{18} M.P.- 57 ^{0}C ; B.P. 126 ^{0}C.

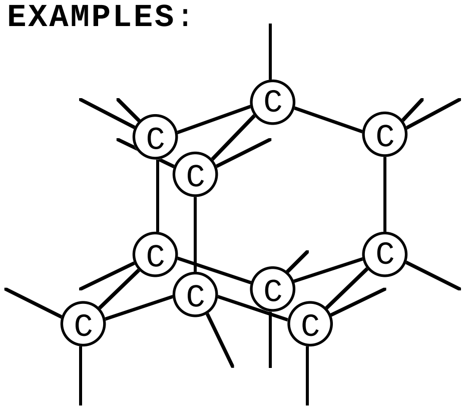
There are no bonds between the molecules in covalent gases. The molecules just move about bumping into each other occasionally.

Due to the weakness of the van der Waals bond these compounds are soluble in most solvents e.g. Octane dissolves in hydrocarbon solvents but not in water.

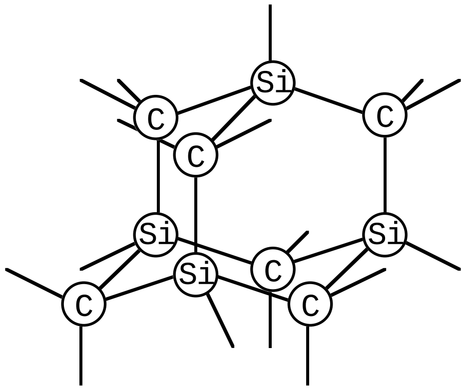
NETWORK SOLIDS

Some covalent substances form giant networks - giant molecules

EXAMPLES:



Carbon (Diamond)



Silicon carbide SiC

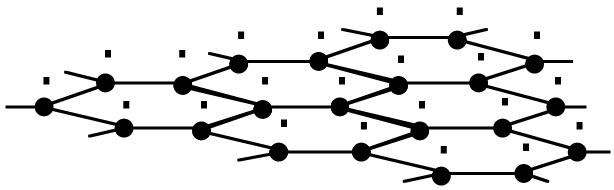
When these networks melt it is the covalent bonds which break. Covalent bonds are strong so melting points and boiling points are high e.g. Diamond M.P. 3550 ^{0}C ; B.P. 4827 ^{0}C.

Due to the strength of the covalent bonds these substances are insoluble in most solvents.

Since there may be millions of Carbon atoms in a diamond we just write 'C' for its formula.

Similarly, we cannot include every single atom in the formula of Silicon carbide. Formulae like $Si_{341487897564784768758566}C_{341487897564784768758566}$ would be extremely silly! We write formulae expressing the simplest ratio instead. The simplest ratio between the Si and C atoms in Silicon carbide is 1:1 so the formula is SiC.

Covalent substances do not conduct electricity. An electric current is a flow of charged particles. There are no charged particles able to move through covalent substances. There is one exception: Carbon (graphite).

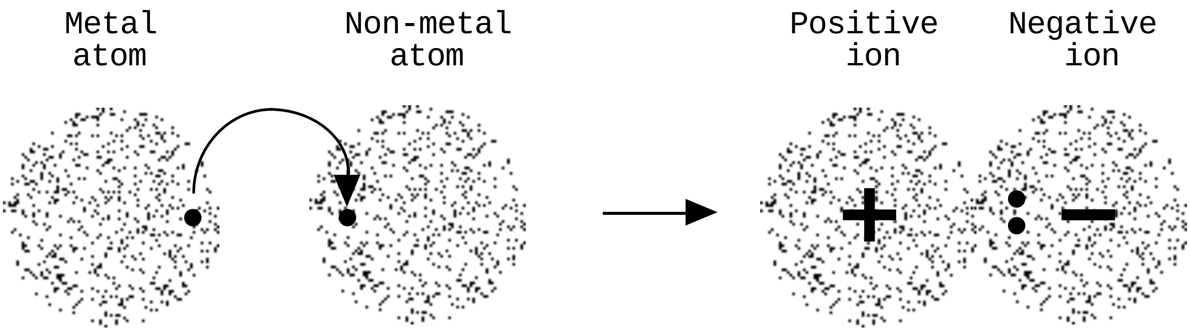


● = Carbon

Graphite consists of layers of Carbon atoms. Each Carbon atom forms only three bonds leaving one unpaired electron left over. These unpaired elctrons move across the layers and allow graphite to conduct electricity.

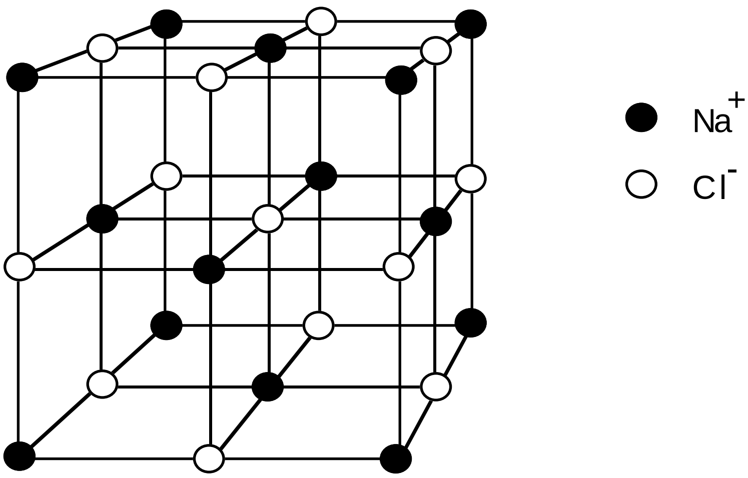
ELECTROVALENT BONDING

Electrovalent (ionic) bonds are formed between a metal and a non-metal atom. An unpaired electron from the metal jumps in beside the unpaired electron on the non-metal. The non-metal atom becomes negatively charged because it has gained an electron; The metal atom becomes positively charged because it has lost an electron. Charged particles, called **<u>ions</u>**, are formed:



The unlike charges on the ions hold them together. This is an electrovalent bond.

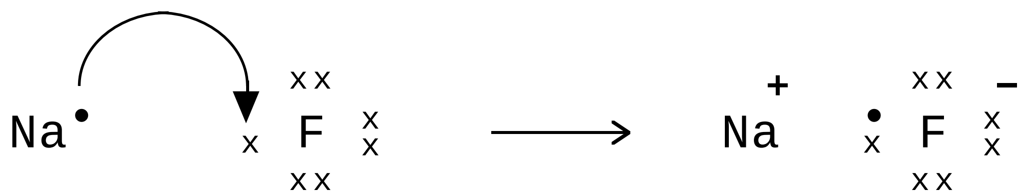
Electrovalent compounds form giant lattices e.g. Sodium chloride



Formulae of electrovalent substances give the ratio of positive to negative ions e.g. Na^+Cl^-.

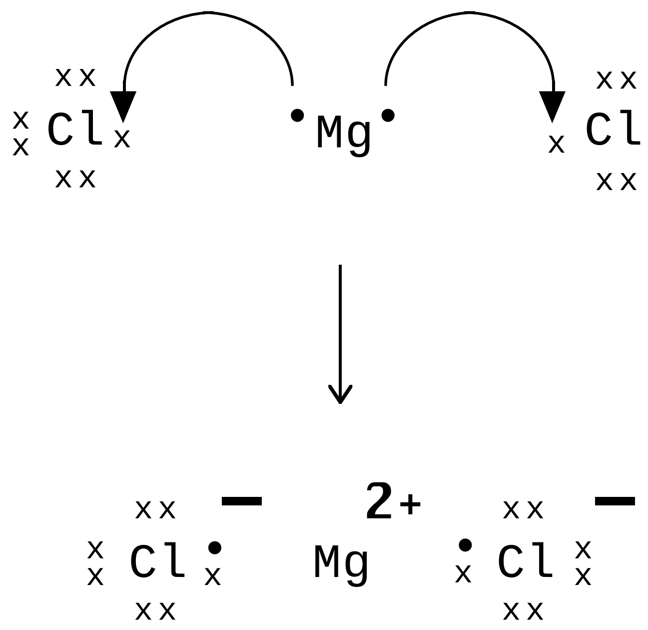
We can deduce these formulae from the periodic table.

EXAMPLE 1 Sodium fluoride



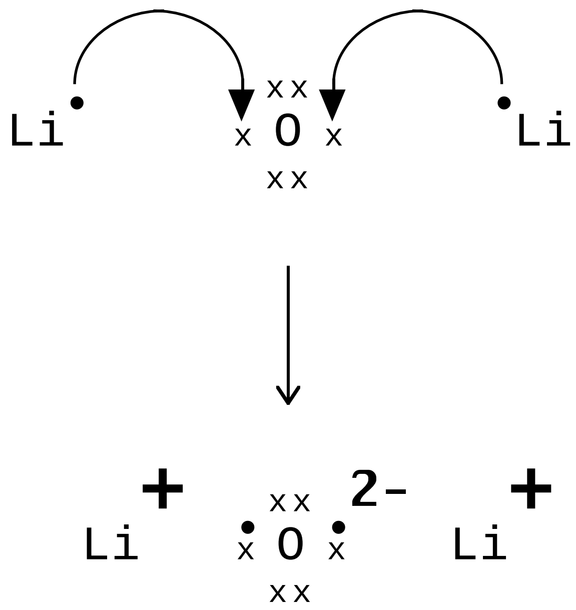
Na^+F^-

EXAMPLE 2 Magnesium chloride



$Mg^{2+}(Cl^{-})_2$

EXAMPLE 3 Lithium oxide



$(Li^{+})_2O^{2-}$

EXAMPLE 4 Copper(II) oxide

It is difficult to predict valencies of transition metals like Copper so the valency is usually stated by including the Roman numeral in the name - TWO in this case.

The formula of Copper(II) oxide is therefore $Cu^{2+}O^{2-}$.

EXAMPLE 5 Magnesium sulphate

Some ions consist of more than one atom. The sulphate ion consists of one Sulphur atom bonded to 4 Oxygen atoms. It has a 2- charge. Its formula is SO_4^{2-}.

The formula of Magnesium sulphate is therefore $Mg^{2+}SO_4^{2-}$.

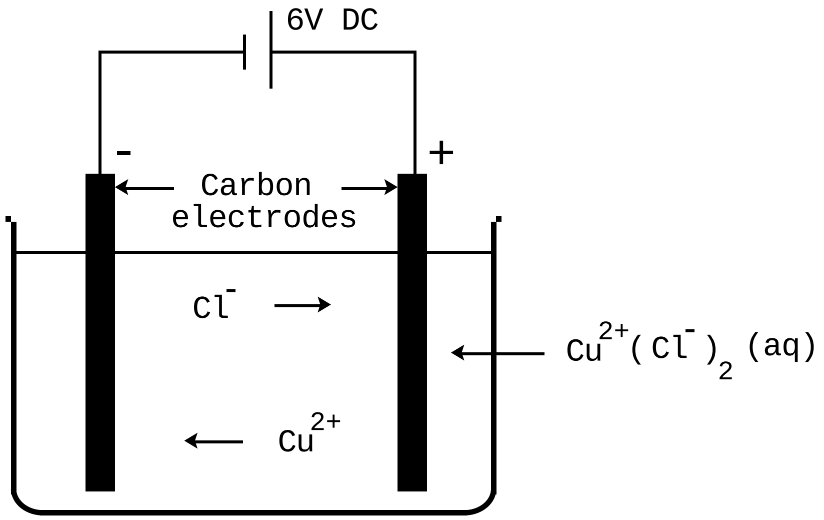
Electrovalent bonds are very strong and are broken only at high temperatures. Melting points and boiling points are therefore high e.g. Na^+Cl^- M.P. 801 ^{0}C ; B.P. 1439 ^{0}C. All electrovalent substances are solids at room temperature.

Due to the strength of the electrovalent bond these compounds are insoluble in most solvents. Water **<u>CAN</u>** dissolve a few.

Though electrovalent substances contain charged particles they do not conduct when solid. This is because the ions cannot move. They **<u>DO</u>** conduct in solution or when molten: the moving ions carry the current.

EXPERIMENT

Pass an electric current through a solution of Copper(II) chloride in water:



N.B. (aq) 'means dissolved in water'

At the negative electrode (Cathode) Copper ions **GAIN** electrons (2 to cancel the charge) becoming Copper metal :

$$Cu^{2+} + 2e \rightarrow Cu$$

We see a brown deposit of Copper at the cathode.

At the positive electrode (Anode) Chloride ions **LOSE** electrons (1 to cancel the charge) becoming Chlorine atoms. They do so in pairs so that they can form the diatomic Chlorine molecule :

$$2Cl^- \rightarrow Cl_2 + 2e$$

We can see (and smell !) the Chlorine, a greenish yellow gas, bubbling off at the anode.

Passing an electric current through a solution or a melt containing ions is called **<u>ELECTROLYSIS</u>** and leads to chemical change.

A DC current is always used in electrolysis. The battery pumps electrons on to one electrode making it negative and away from the other making it positive. This is called a **Direct Current** (DC) : it always flows in the same direction.

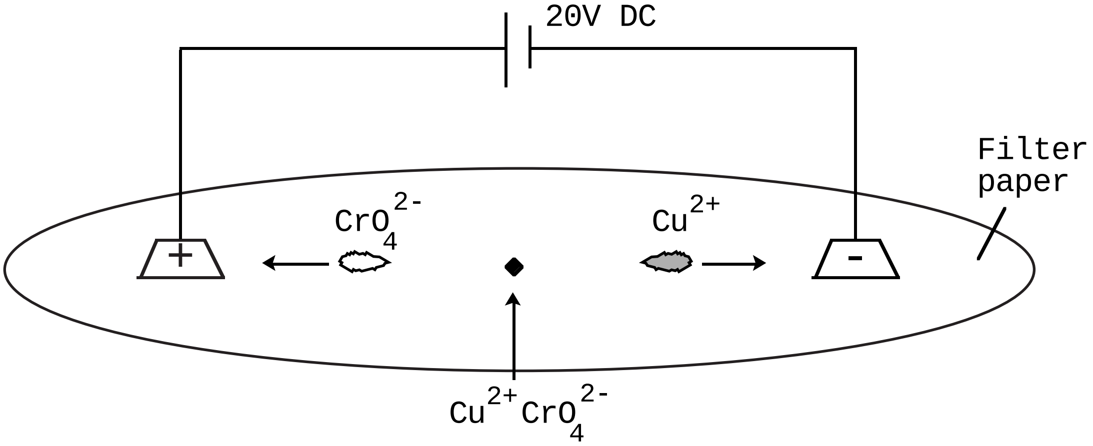
In an **Alternating Current** (AC) the electron flow changes direction 50 times a second. The electrodes would change their charge 50 times a second ! Ion discharge would be impossible !

EXPERIMENT

Electrolyse Copper(II) chromate solution on filter paper.

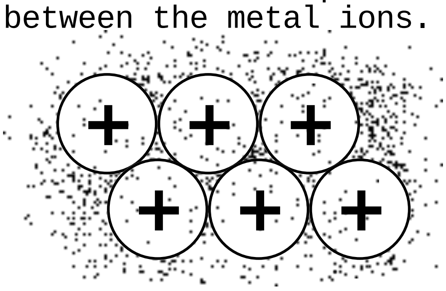
Copper(II) chromate is **green** being composed of the **blue** Cu^{2+} ion and the yellow CrO_4^{2-} ion.

When the current is passed, a blue colour (due to the Copper ion) is seen moving towards the negative electrode and a yellow colour (due to the chromate ion) is seen moving towards the positive electrode.



METALLIC BONDING

This is the bonding between the millions of metal atoms inside a piece of metal. Each metal atom loses its outer unpaired electrons and so becomes a positive ion. The unpaired electrons swirl about in between the metal ions.



The moving electrons allow metals to conduct electricity.

The attraction between these negative electrons and the positive ions holds the metal together. This is metallic bonding.

Metallic bonds are strong so melting points and boiling points are high e.g. Titanium M.P. 1660 ^{0}C ; B.P. 3287 ^{0}C