Topic 7 : Properties of Substances

Revised April 1995

Most properties can be related to the type of bonding. In electrovalent substances the ions are held together by the attraction of unlike charges e.g. Sodium chloride

Na^+ Cl^- Na^+ Cl^-
Cl^- Na^+ Cl^- Na^+
Na^+ Cl^- Na^+ Cl^-
Cl^- Na^+ Cl^- Na^+

Electrovalent bonds are **VERY STRONG.** This has two major consequences :

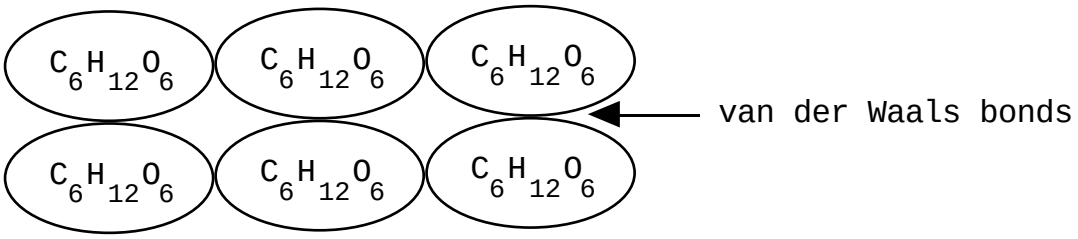
1. When a solid melts the attractive forces between its particles must be overcome to allow these particles to move. Melting points of electrovalent substances are therefore very high (Sodium chloride MP = 801 ^{0}C). The melting points of electrovalent substances are always very much higher than room temperature (20^{0}C) so electrovalent substances are **all** solids at room temperature.

2. When a substance dissolves in a solvent the particles in the substance are pulled apart by the solvent molecules. Most solvents are unable to dissolve electrovalent substances. The exception is Water which dissolves all but the most strongly bonded.

   e.g. Sodium chloride dissolves in Water :

   Na^+ Cl^- Na^+ Cl^-
   Cl^- Na^+ Cl^- Na^+

   In covalent substances the molecules are held together by very weak forces called van der Waals bonds e.g. Glucose



   The strength of van der Waals bonds depends on the surface areas in contact. In general, the bigger the molecules the stronger the attraction between them.

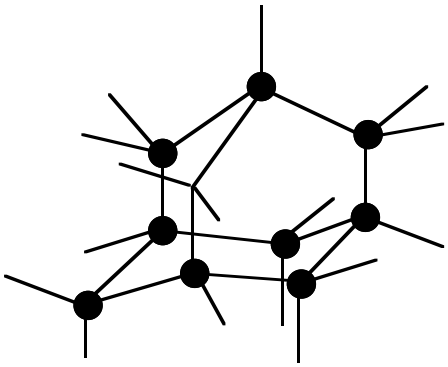
The weakness of these van der Waals bonds has two major consequences :

1. Melting points of covalent compounds are low, increasing with molecular size : small molecules tend to be gases or liquids ; larger molecules tend to be solids at room temperature. The MP of Glucose is 146 ^{0}C.

2. Most covalent substances dissolve in a wide variety of solvents including Water.
   e.g. Lubricating oil dissolves in Hexane and other hydrocarbons ; it does not dissolve in Water.

Some covalent substances are networks held together by the covalent bonds themselves.

e.g. Carbon (Diamond) :



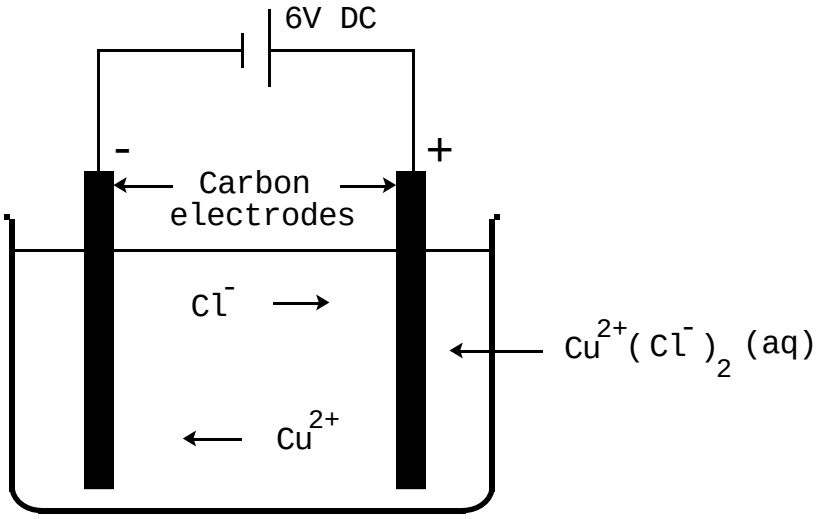
Covalent bonds are much stronger than van der Waals bonds so melting and boiling points are high. These substances are therefore solids at room temperature.

<u>The Electrical Conductivity of Substances</u>

An electric current is a flow of charged particles. It can be either a flow of electrons or a flow of ions.

1. <u>Electrovalent Substances</u> (e.g. Na^+Cl^-)
   These conduct when dissolved in Water or when molten. The current is due to a movement of ions between the two electrodes. In the solid state the ions cannot move and so the solid does not conduct.
   Conductivity is a useful way of showing that a solution contains ions.
   Positive ions move towards the negative electrode ; negative ions move towards the positive electrode. What happens to the ions when they reach the electrodes ?

Example 1 : Copper(II) chloride dissolved in Water.



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

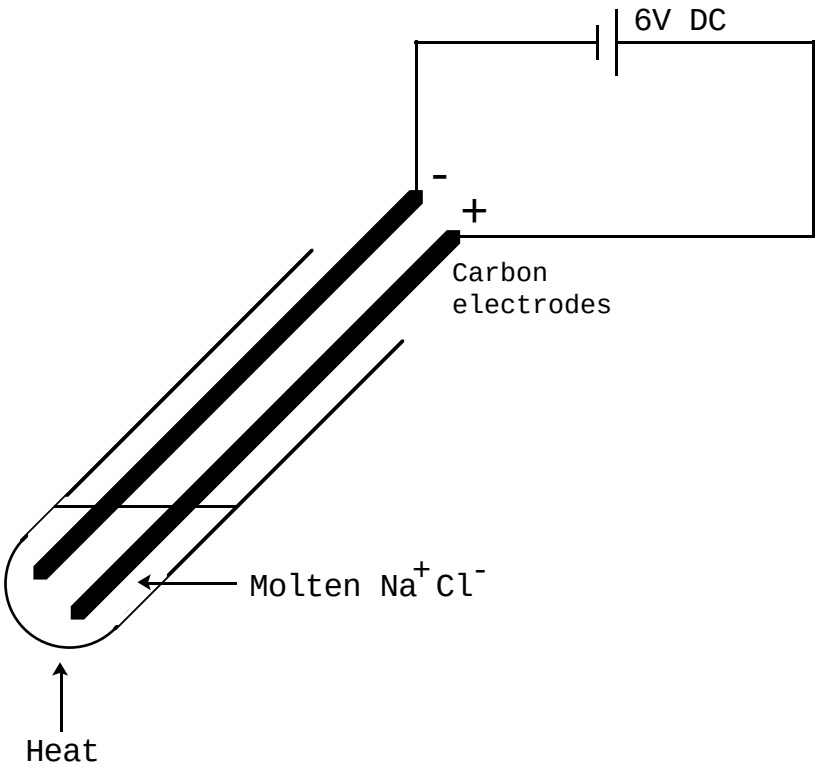
$$Cu^{2+} + 2e \rightarrow Cu$$

Gain of electrons is called REDUCTION (**R**eduction **I**s **G**ain : **RIG**). The Copper ion is reduced.
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 :

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

Loss of electrons is called OXIDATION (**O**xidation **I**s **L**oss : **OIL**). The Chloride ion is oxidised.
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 ELECTROLYSIS and leads to chemical change. The solution containing ions is called the **electrolyte**. The process is only applicable to electrovalent compounds ; other compounds do not contain ions.
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 !

Example 2 : Electrolysis of molten Sodium chloride



At the negative electrode Sodium ions gain electrons (Reduction) becoming Sodium metal :

$$Na^+ + e \rightarrow Na$$

Flashes of yellow light are seen as the Sodium catches fire in the air.
At the positive electrode, Chloride ions lose electrons (Oxidation) becoming Chlorine gas :

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

Coloured Ions

Fact : Potassium sulphate $(K^+)_2SO_4^{2-}$ is colourless

Conclusion : both K^+ and SO_4^{2-} must be colourless

Fact : Copper(II) sulphate $Cu^{2+}SO_4^{2-}$ is **blue**

Conclusion : since SO_4^{2-} is colourless, **Cu^{2+} must be blue**

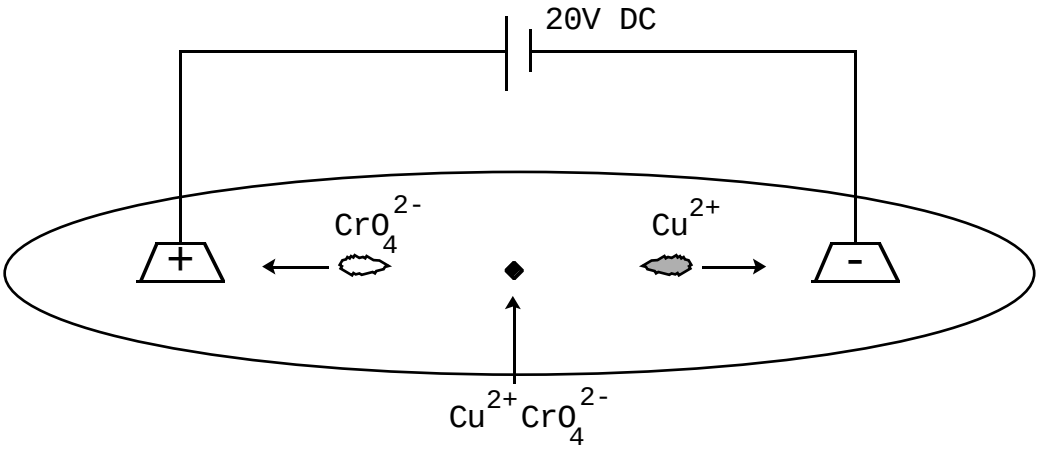
Fact : Potassium chromate $(K^+)_2CrO_4^{2-}$ is **yellow**

Conclusion : since K^+ is colourless, **CrO_4^{2-} must be yellow**

Movement of Coloured Ions Towards Charged Electrodes

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

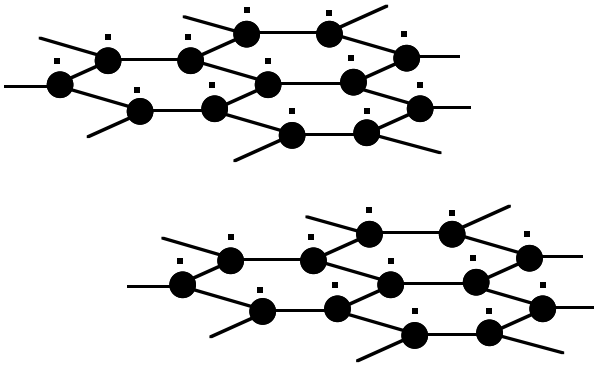
When the current is passed, a blue colour (due to the Copper ion) is seen moving towards the negative electrode and a yellow colour (due to the chromate ion) is seen moving towards the positive electrode.



2. Covalent Substances (e.g. C_6H_{14})

They do not contain ions and so **do not conduct** in any state. There are exceptions :

Carbon (Graphite)



Graphite conducts (remember Carbon electrodes!) because each Carbon atom has one unpaired electron not used in bonding. These unpaired electrons 'swarm' across the layers and are responsible for the current.

Water

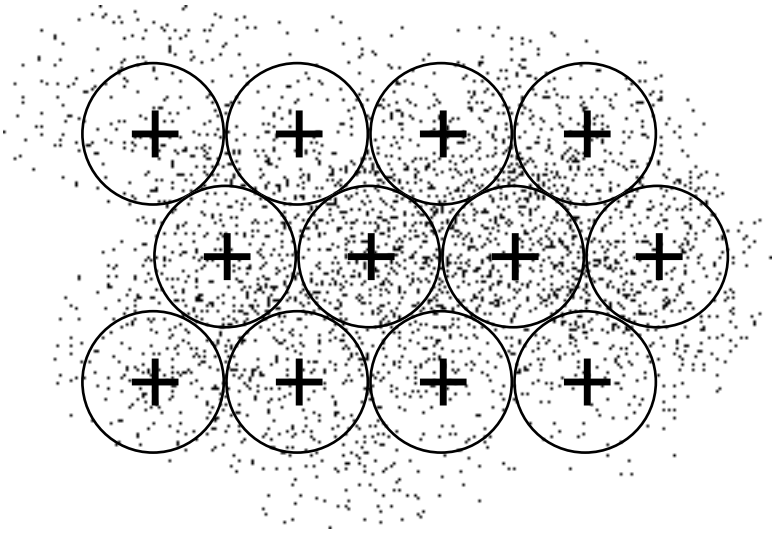
Water is a very poor conductor. This is because it is slightly ionised :

$$H_2O \rightleftharpoons H^+ + OH^-$$

3. Metals (e.g. Silver)

All metals conduct electricity in the solid or liquid states. Metals have a low EAP. Electrons are therefore easily detached from the atoms and 'swarm' through the structure. The current is due to this movement of electrons.

Bonding is due to the attraction of the negative electrons for the positive metal ions left behind:



(Non-metals are non-conductors mainly because of their high EAP.)