Electricity and Chemistry

Electrochemistry:

It is a branch of chemistry that deals with the reactions involving the conversion of chemical energy into electrical energy and vice-versa.

Electrochemical reactions:

A chemical reaction which takes place when electricity flows through the substance.

Electrolysis:

The decomposition of an ionic compound (molten or aqueous) by electricity is called electrolysis.

The liquid that decomposes is called the *electrolyte.*

Non-electrolyte is any substance that does not conduct electricity such as distilled water.

Weak electrolyte:

A poor conductor of electricity, because it is only partially ionized. (E.g. ethanoic acid)

Strong electrolyte:

It is a good conductor of electricity because it is completely ionized.

(E.g. potassium chromate, sulphuric acid)

Conductors:

A conductor is a substance that conducts electricity but is not chemically changed in the process.

(E.g. carbon, metals and alloys)

Insulators:

Solid covalent non-metals don't conduct electricity as there are no electrons that can carry electricity as they are involved in bonding.

Some insulators include all non-metals (except silicon and such) and plastics.

Electrolysis of molten salts using inert electrodes:

The electrolysis of molten salts is comparatively easy to understand because only one of type of positive ion (cation) and negative ion (anion) is present.

Molten salts are elctroysed into their elements; a metal is produced at the cathode and a non-metal is produced at the anode.

Electrolysis of molten lead (II) bromide $PbBr_2$:

Electrolyte: Lead (II) bromide
Electrodes: Carbon (graphite) or platinum

Reactions:
- At anode (Positive electrode):

$2\ Br^- - 2e = Br_2$

- At cathode (Negative electrode):

$Pb^{2+} + 2e^- = Pb$

- Net reaction:

$PbBr_2 = Pb + Br_2$ which is molten Pb at the cathode and Bromine gas at anode.

Cations (Positive)	The ease	Anions (Negative)
K		SO_4^{2-}
Na	of discharge	NO_3^-
Ca		OH^-
Mg	***INCREASES***	CL^-
H		Br^-
Cu	downwards	I^-
Ag		

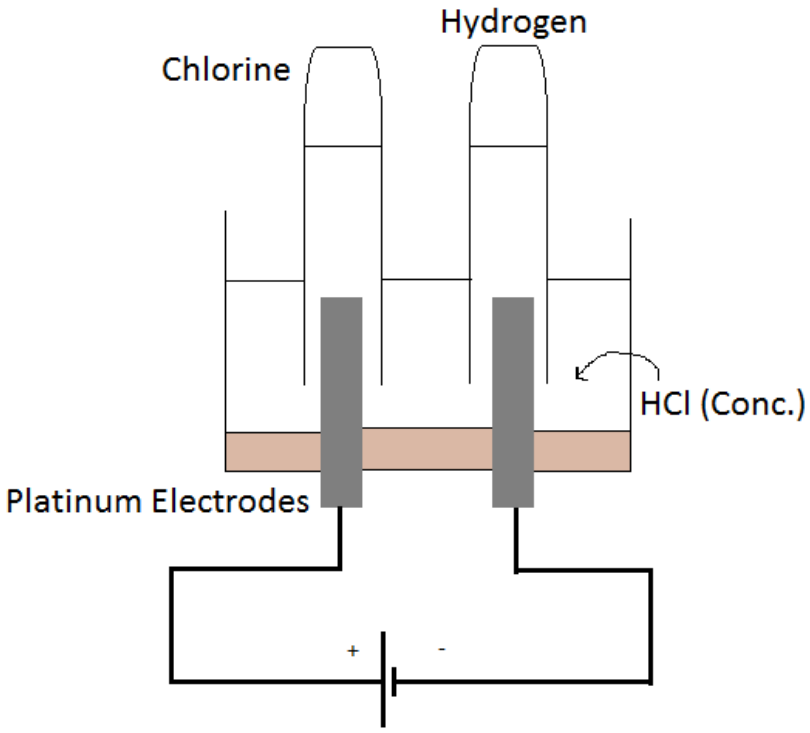
Electrolysis of aqueous electrolytes

In the electrolysis of aqueous solutions there will always be a few H^+ ions and OH^- ions from water.
These may be discharged at the electrodes instead of the ions of the electrolyte.
This table shows the ease of discharge of ions:

1) Electrolysis of Concentrated hydrochloric acid

Electrolyte: Concentrated Hydrochloric acid
Electrodes: Graphite electrodes
Ions present: H^+ and Cl^-
Cathode reaction:
$2H^+ + 2e^- = H_2$ (A colourless gas is produced at the cathode which burns with a pop)
Anode reaction:
$2Cl^- - 2e^- = Cl_2$ (A yellow gas is produced at the anode which bleaches litmus paper)

This apparatus is used:



2) Electrolysis of concentrated Sodium Chloride (Brine)

Electrolyte: Sodium Chloride (NaCl)

Electrodes: Platinum electrodes

Ions present:

Na^+	Cl^-
H^+	OH^-

Cathode reaction:

Here H^+ is more easily discharged than Na^+ so Hydrogen gas is produced.

$2H^+ + 2e^- = H_2$

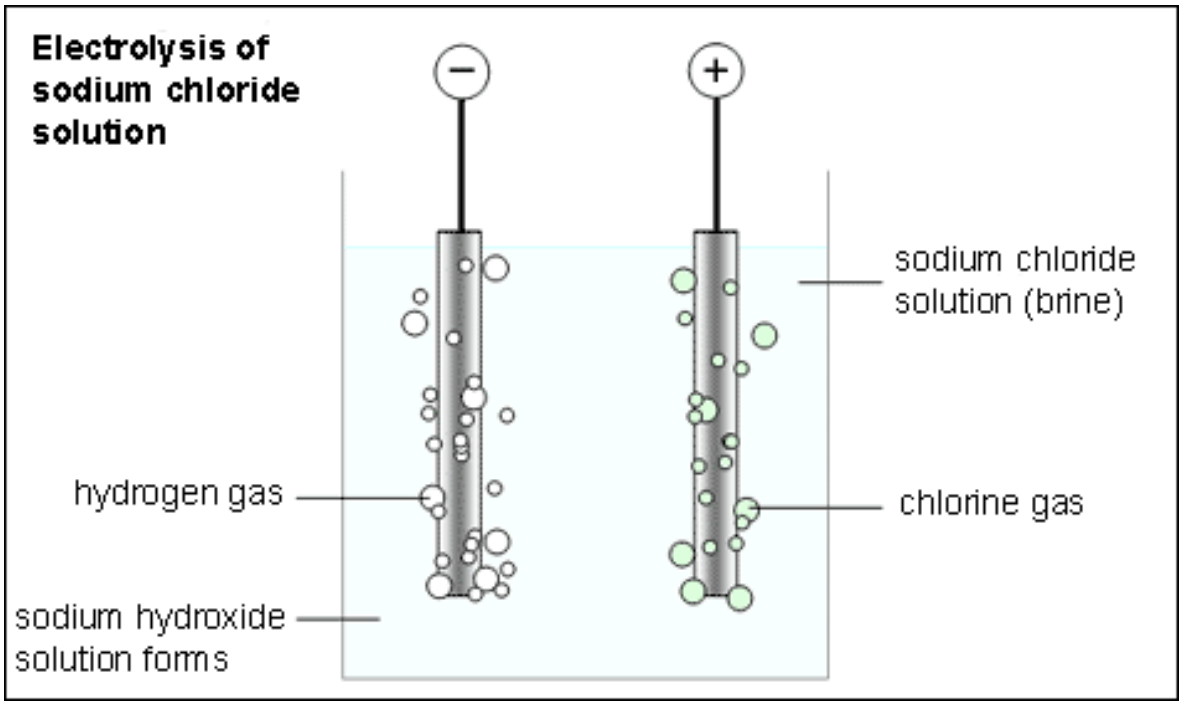
Anode reaction:

Here Cl- is more easily discharged that OH- so Chlorine gas is produced.

$2Cl^- - 2e^- = Cl_2$

Net reaction:

$NaCl_{(aq)} = NaOH + H_2 + Cl_2$



3) Electrolysis of copper(II) sulphate with:

a) Graphite electrodes:

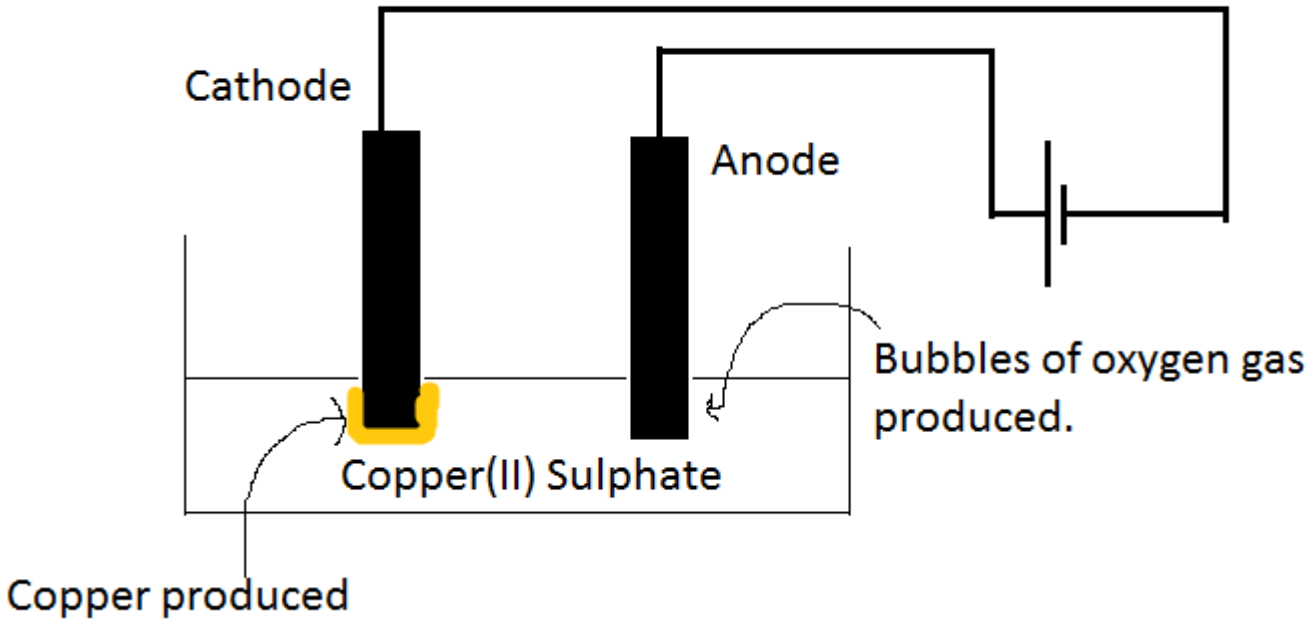
Cathode:

$Cu^{2+} + 2e^{-} = Cu$

Anode:

$4OH^{-} = 2H_20 + O_2 + 4e^{-}$

This electrolysis produces Copper at the cathode and oxygen at the anode.



b) Copper electrodes (Purifying impure copper)

Metals can be refined or purified by electrolysis. The impure metal forms the anode and the pure metal forms the cathode. The electrolyte is an aqueous metal salt.

In the purification of copper, impure copper is used as the anode and a thin sheet of pure copper is used as the cathode.

The following reaction occurs:

At anode, the copper is ionized (becomes an ion):

$Cu - 2e^- = Cu^{2+}$

At the cathode, the copper ion is unionized, which produces solid copper on the cathode:

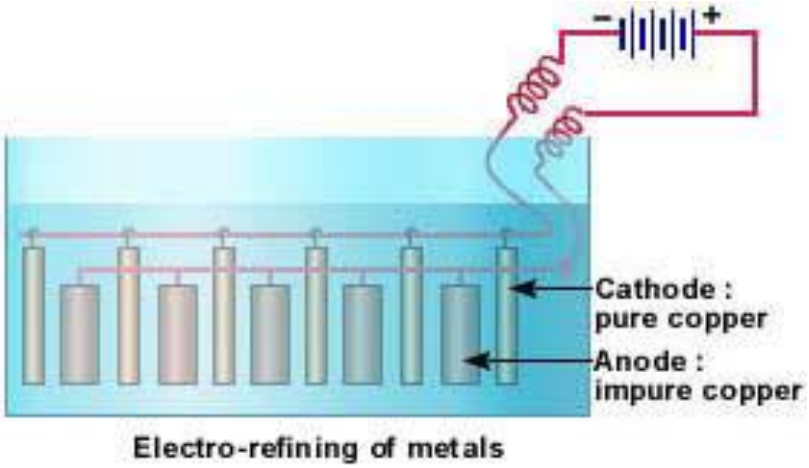
$Cu^{2+} + 2e^- = Cu$

As electrolysis takes place the pure copper sheet gains mass and the anode (impure copper) loses mass and the impurities are deposited under the anode in the container.

This means that the copper ions had left the impure copper side and joined the pure copper side.

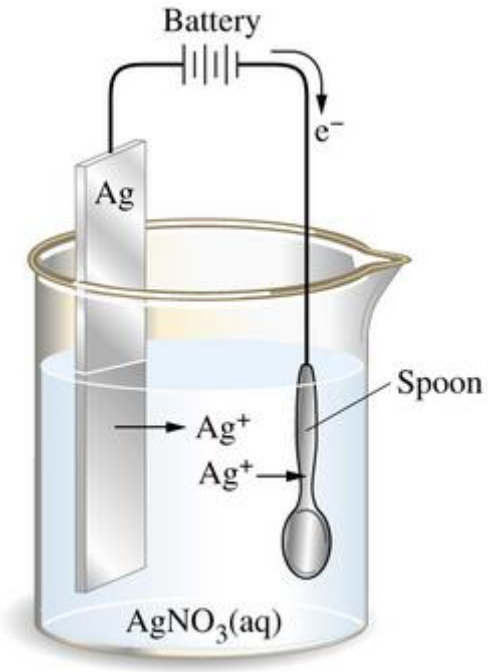
The colour of the copper (II) sulphate solution does not change as the concentration of copper ions in the solution does not change.

This is done on large scale and is the way how impure copper is purified.



Electro-refining of metals

Electroplating of metals:



Electrolysis can be used to form a very thin coating of a metal on the surface of another metal object. This can be used for decorative purposes or for protection against corrosion.

If for example an object made of copper is to be silver plated, the object is made to be the cathode, a piece of silver is the anode and silver (II) sulphate solution is the electrolyte.

Anode reaction:

$Ag - e^- = Ag^+_{(aq)}$

Cathode reaction:

$Ag^+ + e^- = Ag$

Uses of electroplating:

- To give a protective layer of the metal on the object. This also happens when galvanizing with zinc.
- To give an attractive layer, e.g. electroplating steel with chromium gives it a shiny appearance and a protective anti-scratch layer. The steel also has to be electroplated with layers of copper and nickel before it is electroplated with chromium.

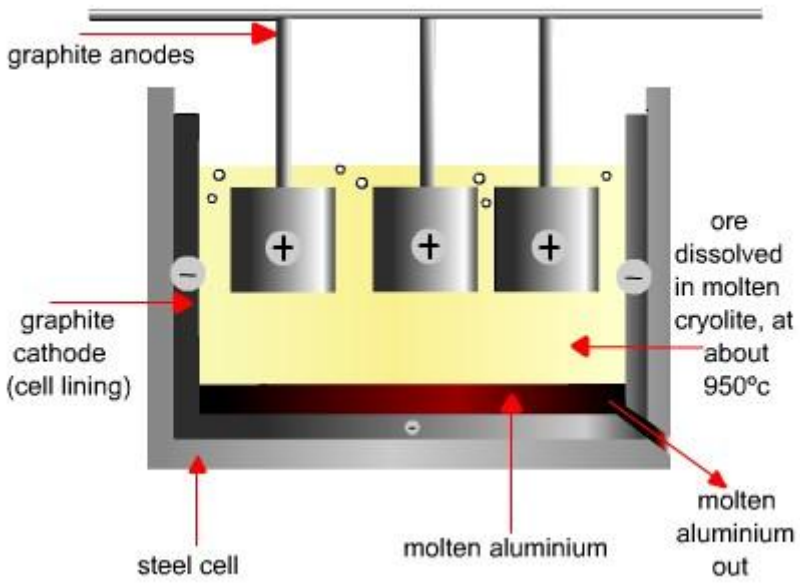
Conditions for electroplating an object with a metal M:

- The object must be made the CATHODE
- The electrolyte must be a solution of salt of metal M (commonly a nitrate)
- The anode is a strip of metal M
- The object to be plated has to be very clean with no grease or smudges on it
- The object has to be rotated in the electrolyte so an even layer of the metal M can be plated over it.

<u>The manufacture of aluminium:</u>

The method used to extract the metal form its ore depends on the position of the metal in the reactivity series. If the metal is high up in the series, its ores are stable and can be only be obtained by electrolysis.

Aluminium is extracted from bauxite (Al_2O_3) by electrolysis. However, bauxite has a very high melting point but can be dissolved in molten cryolite at 900 degrees Celsius. In other words, the cryolite is used to lower the melting point of bauxite.



Cathode reaction:

$4\ Al^{3+} + 12\ e^- = 4\ Al$

Anode reaction:

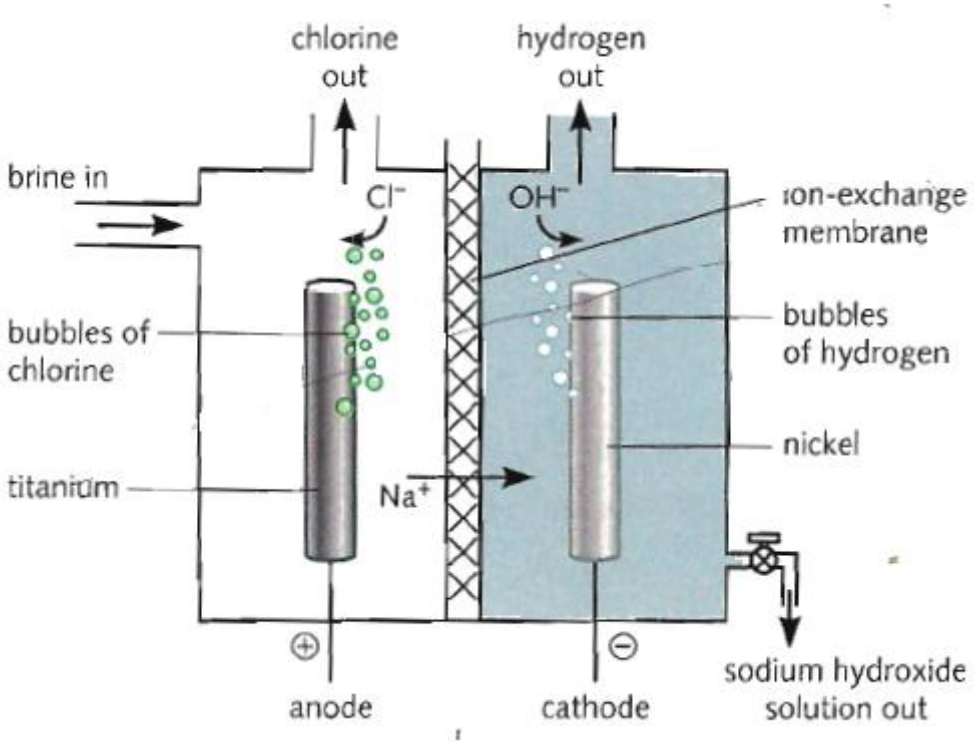
$6\ O_2^- = 3O_2 + 12\ e^-$

Carbon dioxide is also produced from this reaction. It is produced from the carbon electrodes burning in the heat and oxygen produced.

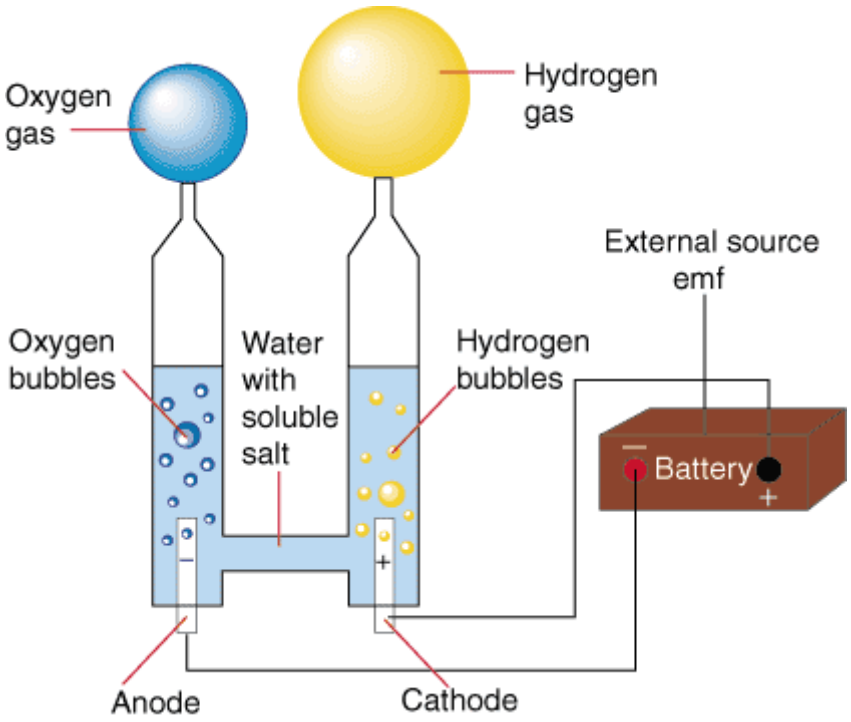
<u>Manufacture of sodium hydroxide from brine (Conc. NaCl):</u>

Several different types of electrolytic cell have been used for the electrolysis of brine. The modern membrane cell is the safest for the environment and uses the least electricity. Other types of cell use either a flowing mercury cathode, or a diaphragm (partition) made from asbestos.

The membrane cell has a titanium anode and a nickel cathode. Titanium is chosen for the anode as it is not attacked by chlorine. The anode and cathode compartments are separated by an ion exchange membrane. This membrane is selective; it allows Na+ ions and water to flow through, but no other ions. This means that, while Na+ ions can move freely to the cathode, the products are kept separate and cannot react with each other. The Na+ and OH- ions collect in the cathode compartment.



<u>The electrolysis of water:</u>



Pure water is a very poor conductor of electricity. However it can be made to decompose if some dilute sulphuric acid is added.

A Hoffmann voltameter can be used to keep the gases produced separate.

After some time the volume of the gas in each arm can be measured and tested. The gas collected in the anode is oxygen gas, while the one collected at the cathode is hydrogen.

The ratio of the volumes is 1:2

This experiment is effectively the electrolysis of water:

- At the anode:

  Hydroxide ions from the water are attracted and become oxygen gas:

  $4OH^-_{(aq)} = O_{2\,(g)} + 2H_2O\,(l) + 4e^-$

- At the cathode:

  Four hydrogen ions pick up these 4 electrons to form TWO molecules of hydrogen gas

  $2H^+_{(aq)} + 2e^- = H_{2(g)}$

This apparatus can also be used in the electrolysis of concentrated hydrochloric acid, where the products are hydrogen at the cathode and chlorine at the anode.

Why are copper and other metals used as wires?

Copper and other metals have free electrons in their lattices that can carry the electrical charge from one end of the metal to the other.

Aluminium steel-cored wires are used to transmit very high voltages of electricity on pylons from power stations to industries, factories, homes and offices, because aluminium is a very good conductor of electricity.

The wires are steel-cored to make them stronger.