Electrolysis

Conductors

Metals and graphite are the only solids which conduct electricity, but no chemical change is involved. Liquid (melted) metals also conduct, but again there is no chemical change.

Electrolytes

These are liquids which conduct electricity, and are decomposed by it. They are ionic substances which are dissolved in water or have been melted. This includes all acids and metal compounds.

Examples: Copper sulphate solution, iron chloride solution, molten sodium chloride, dilute sulphuric acid.

Non-electrolytes are covalent substances, e.g. pure water, sugar solution, alcohol, petrol.

Electrolysis

This is when an electric current passes through an electrolyte.

Electrons enter the solution through the negative electrode (cathode), cause a chemical change and leave by the positive electrode (anode).

Molten electrolytes are split into their elements by electrolysis. The metal is produced at the cathode (-), while the non-metal is produced at the anode (+)

e.g. Lead Bromide (molten) = Lead (at the cathode) + Bromine (at the anode)

$$PbBr_2 \rightarrow PB\,(l) + BR_2\,(g)$$

Electrolysis

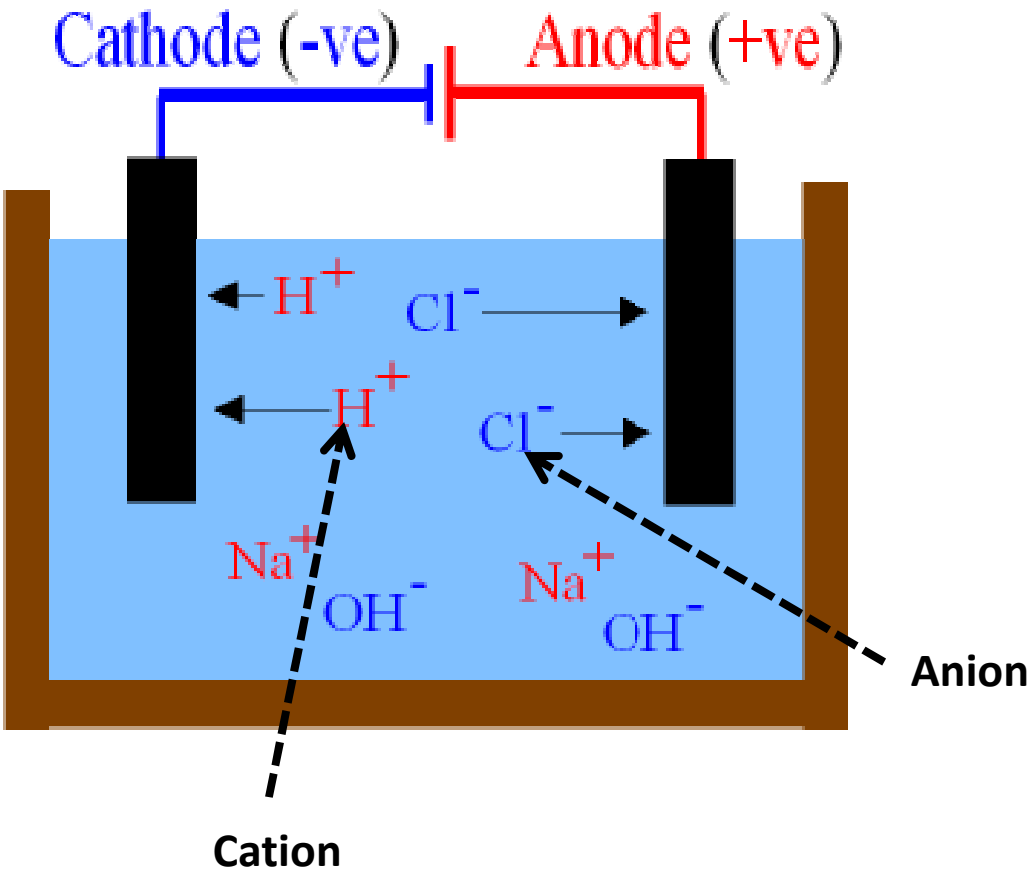
With aqueous electrolytes, the electrolyte is also split up, but if the metal is reactive, then hydrogen from the water is produced at the cathode in place of the metal.

e.g. Copper chloride (aq) = Copper (at the cathode) + Chlorine (at the anode)

e.g. Sodium chloride (aq) = Hydrogen (at the cathode) + Chlorine (at the anode)

Because positive ions go to the cathode, they are called Cations

Because negative ions go to the anode, they are called Anions



Electrolysis

Change at the electrodes

During electrolysis ions move towards the electrodes.
When an ion reaches the electrode they either lose or gain an electron depending on their charge.

Negatively charged ions *lose* electrons to become neutral atoms
Positively charged ions form neutral atoms via *gaining* electrons.

Gaining electrons is called reduction.

Losing electrons is called oxidation.

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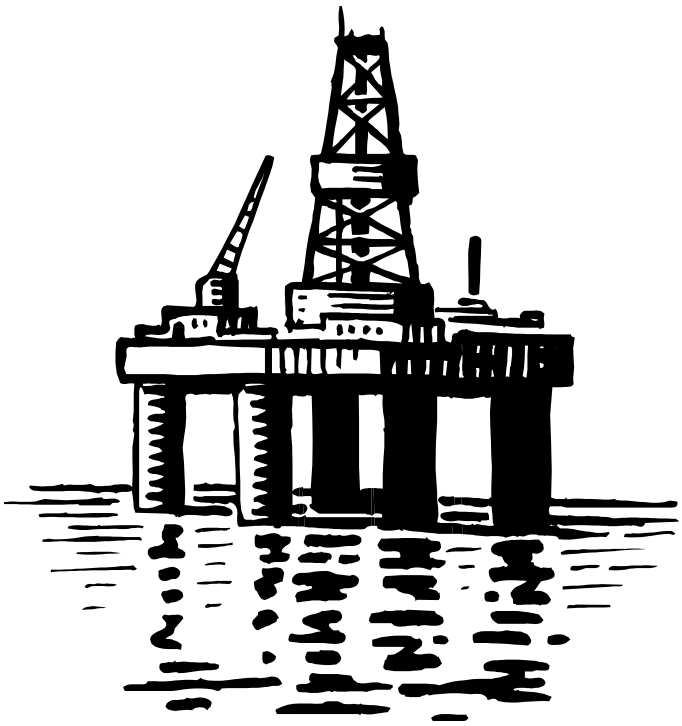


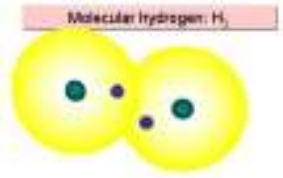
Electrolysis of NaCl (l)

Electrolysis of Sodium Chloride Solution

The main ions present in sodium chloride solution are Na^+ and Cl^-, but there are also a few H^+ and OH^- ion present because water is very slightly ionised.

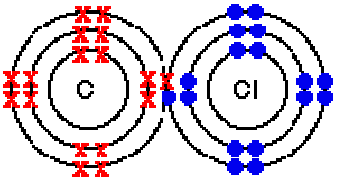
The Na^+ ions and H^+ ions are attracted to the negative cathode. Here the H^+ ions pick up electrons, since hydrogen is less reactive than sodium.
The hydrogen ions gain electrons (reduction)to form hydrogen atoms, which then pair up to form hydrogen molecules.

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



The Cl^- ions are attracted to the positive anode. Here they lose electrons (oxidisation) to form chlorine atoms. These atoms pair up to form chlorine molecules. Chlorine gas is given off at the anode.

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



The products are hydrogen and chlorine, but Na^+ and OH^- ions are left in solution to make sodium hydroxide (NaOH)

Uses of products:

Chlorine: Purifying water, making PVC plastic.
Hydrogen: Making margarine or ammonia.
Sodium Hydroxide: Making soap.

Purifying Copper

The following ions are present in copper sulphate solution: Cu^{2+}, SO_4^{2-} (from $CuSO_4$) H^+, OH^- (from water).

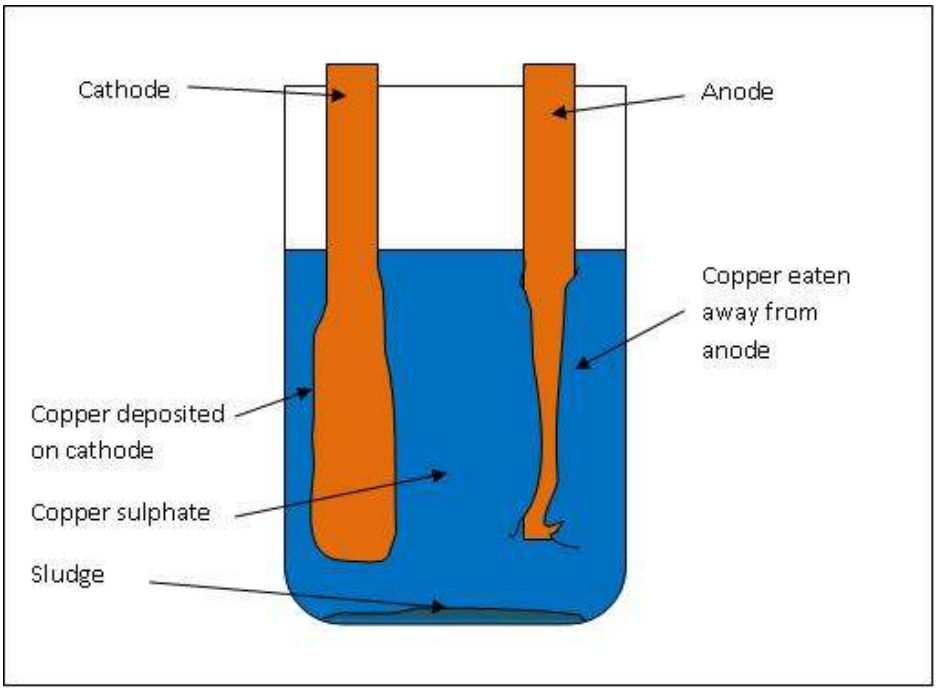
The H^+ ions and Cu^{2+} are attracted to the cathode but Cu gains electrons (reduction) more easily so that copper is deposited

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

At the anode, rather than the sulphate or hydroxide ions releasing their electrons, the atoms in the copper anode release their electrons (oxidisation) and form ions that then enter solution

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

Therefore, at the cathode, copper ions from solution are being deposited, and the cathode increases in mass. At the anode the copper atoms from the anode are going into solution as copper ions. The concentration of copper ions in solution remains unchanged.



Other Uses of Electrolysis

Reactive Metal Extraction

Many of the more reactive metals (e.g. sodium, magnesium, calcium) can only be extracted from their ores by electrolysis.

Electroplating

Electroplating allows a thin layer of one metal to be deposited on another.
e.g. Iron can be protected from rust by coating with chromium or nickel, or a cheap metal can be coated with silver or gold to make it look expensive.

The object to be plated is placed as the cathode, while the metal to coat it is placed as the anode. The coating metal is also present in the solution.

e.g. to nickel plate a piece of iron, the iron would be the cathode, the nickel would be the anode and the solution would be nickel sulphate.

Electrolysis would cause Ni^{2+} ions in solution to be deposited on the iron cathode.

$$Ni^{2+} + 2e^- \rightarrow Ni$$

These ions would then be replaced by Nickel metal slowly dissolving from the anode.

$$Ni \rightarrow Ni^{2+} + 2e^-$$

Extraction of Aluminium

Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite.

Cryolite is used to lower the melting point of aluminium oxide

Graphite electrodes are used

Aluminium forms at the negative electrode and oxygen at the positive electrode.

The positive electrode is made of carbon, which reacts with the oxygen to produce carbon dioxide.