



eduresource.com

Electricity and Chemistry

Electrolysis

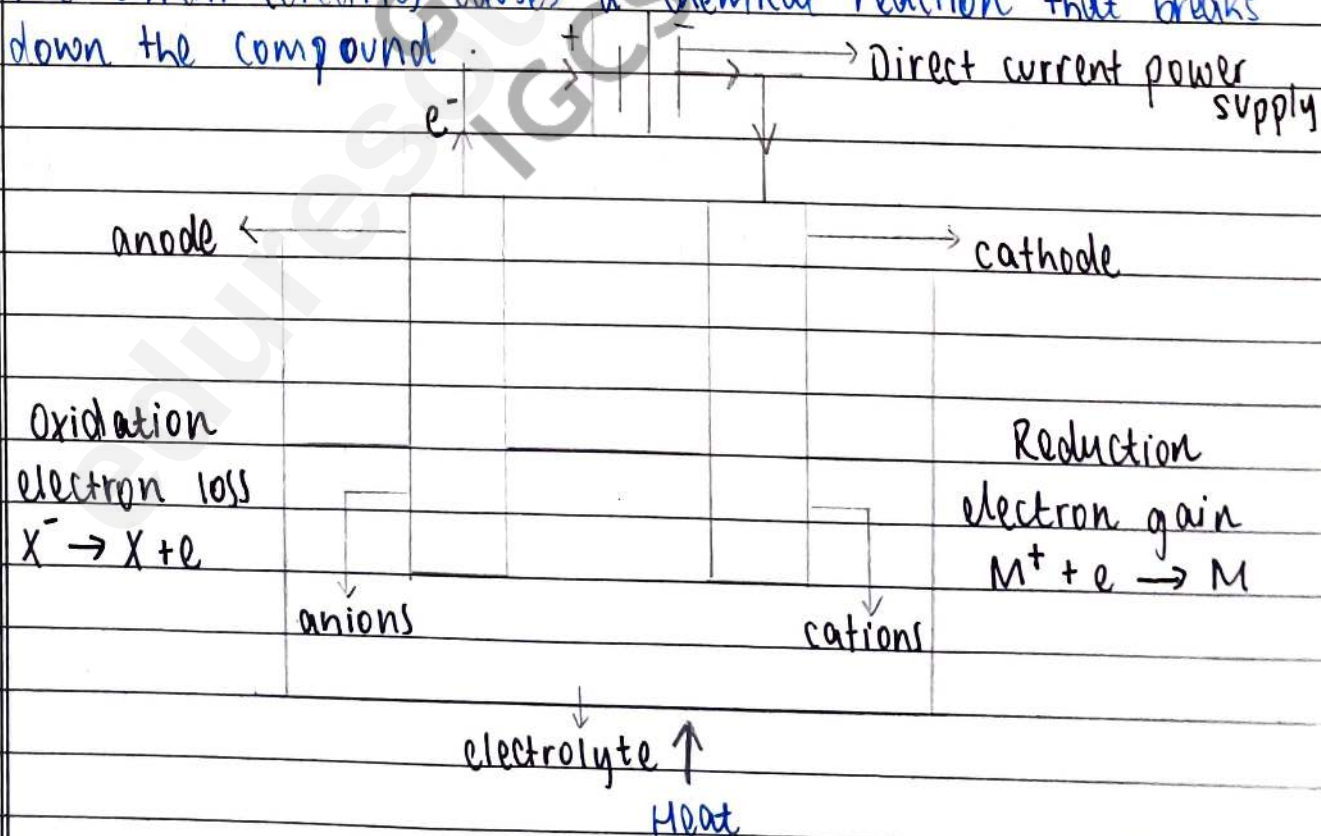
- passing an electric current through ionic substances that are molten or in aqueous solution, breaks them down into elements.
- happens only with ionic substances.
- does not happen with covalent compounds as they do not have ions.
- the substance broken down is called an electrolyte.

Positively charged ions (cations) $\rightarrow$ negative electrode (cathode)
Negatively charged ions (anions) $\rightarrow$ positive electrode (anode)
 $\rightarrow$ (moves to)

Cathode + ive ions gains electrons

Anode - ive ions loses electrons

- the current (electric) causes a chemical reaction that breaks down the compound.



The electrolyte of aqueous solution

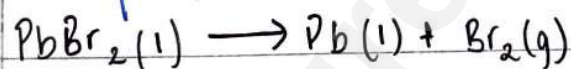
- Electrolysis can be carried out on solutions of ionic compounds in water so that the ions in the solution are free to move.

Example: electrolysis of molten lead bromide.

- The electrodes used are graphite rods.
- The electrode attached to the positive terminal is the anode.
- The electrode attached to the negative terminal is the cathode.
- Molten lead bromide contains lead ions and bromide ions.

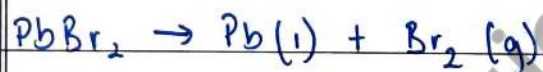
Pb^{2+} ions Br^{-} ions.

- Electrons flow from the battery to the cathode.
- In the liquid, the ions move to the electrode of opposite charge.
- At the cathode, Pb^{2+} ions accept the electrons and lead is deposited at cathode.
- At anode, Br^{-} ions give up electrons and reddish brown vapours of bromine gas bubbles off.
- Electrons flow from the anode to the positive terminal of the battery.
- The process results in ^{decomposition} ~~decomposition~~ of lead bromide.



1. Electrons flow from the negative terminal of the battery to the cathode.
2. In the liquid, the ions move to the electrode of opposite charge.
3. At the cathode (-), the Pb^{2+} ions accept electrons. Lead begins to appear below the cathode.
4. At the anode (+), the Br^{-} ions give up electrons. Red-brown bromine vapours appear and bubble off.
5. Electrons flow from the anode to the positive terminal of the battery.

Result is : Lead Bromide has decomposed :



Note :

- Electrons carry current through wires and electrodes.
- Ions carry current through liquid.
- Graphite electrodes are inert. They carry current into liquid, but remain unchanged. (Electrodes made of platinum are also inert).

Electrolysis breaks the molten ionic compound down to its elements, giving the metal at the cathode, and the non-metal at the anode.

Electrolysis of aqueous solutions

molten NaCl

sodium (cathode)

chlorine (anode)

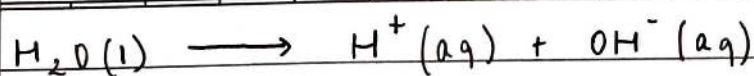
concentrated NaCl

hydrogen (cathode)

chlorine (anode)

Downloaded from eduresource.com

Water, although being molecular, produces ions.



Rules for electrolysis of a solution

At the cathode (-), either a metal or hydrogen forms.

- The more reactive an element, the more it 'likes' to exist as ions.
- If the metal is more reactive than hydrogen, hydrogen bubbles off.
- If the metal is less reactive than hydrogen, the metal forms.

At the anode (+), a non-metal other than hydrogen forms.

- If it is concentrated solution of a halide, then the halide will form.
- If the halide solution is dilute, or there is no halide, then oxygen will form.

Discharge / Order of Reactivity Series

potassium

sodium

calcium

magnesium

aluminium

zinc

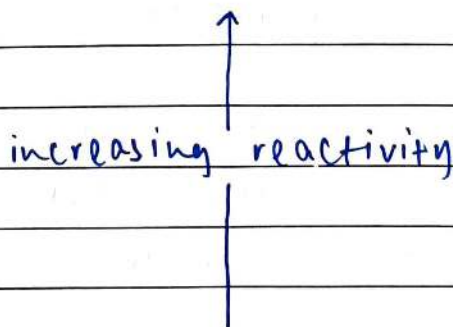
iron

lead

hydrogen

copper

silver



REACTIONS AT THE ELECTRODES

This is what happens to molten lead bromide when the switch is closed:

- First, ions move.

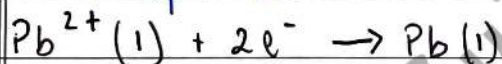
Opposite charges attract.

- Positive lead ions move to the cathode.
- Negative bromide ions move to the anode.

Moving ions carry current.

- At the cathode, the lead ions each receive two electrons and become lead atoms.

Half equation:



Lead collects on electrode and eventually drops off it.

- At the anode, the bromide ions each give up an electron, and become atoms. These then pair up to form molecules.

Half equation:



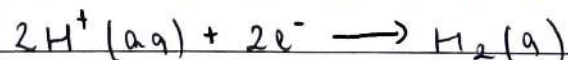
Electrolysis: a redox reaction.

Reduction $\rightarrow$ Gain of electrons. $\rightarrow$ Takes place at cathode.

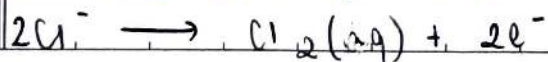
Oxidation $\rightarrow$ Loss of electrons $\rightarrow$ Takes place at anode.

For a concentrated solution of NaCl.

- At the cathode, the H^{+} accept electrons. (reduction).



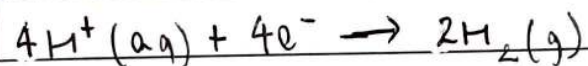
- At the anode, the Cl^{-} give up electrons. (oxidation).



Na^+ and OH^- is left. A solution of NaOH is formed.

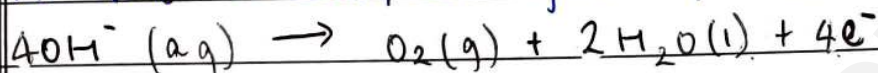
For a dilute solution of NaCl .

- At the cathode, H^+ accept electrons. (reduction).



(4 electrons shown)

- At the anode, OH^- give up electrons. (oxidation).



While hydrogen and oxygen bubbles off, Na^+ and Cl^- are left, forming NaCl .

Water has been decomposed.

CONDUCTORS AND INSULATORS

Only solids that conduct electricity are metals and graphite.

- They conduct because of their free electrons.
- Electrons get pumped out of one end of the solid by the battery, while more electrons flow in the other end.
- For the same reason, molten metals conduct.

(It is hard to test molten graphite as at room pressure, graphite goes from solid to gas (sublimation)).

Molecular substances are non-conductors / insulators.

- They contain no free electrons, or other charged particles, that can flow through them.
- Ethanol does not conduct.

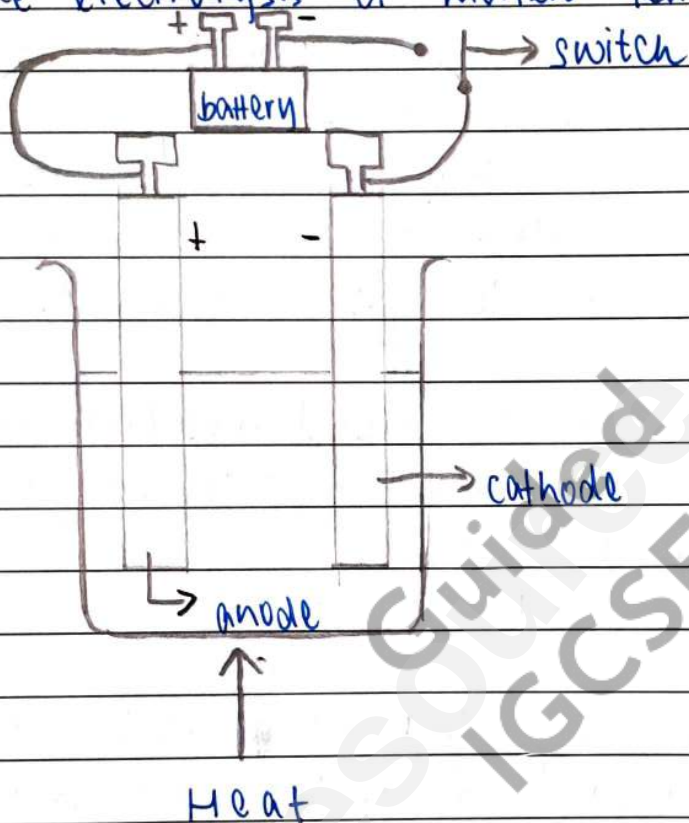
Ionic substances do not conduct when solid. But do conduct when melted or dissolved in water - and they decompose at the same time.

- Ionic substances contain no free electrons.
- They contain ions, which have a charge.
- The ions are free to move when the substance is molten or dissolved, conducting.

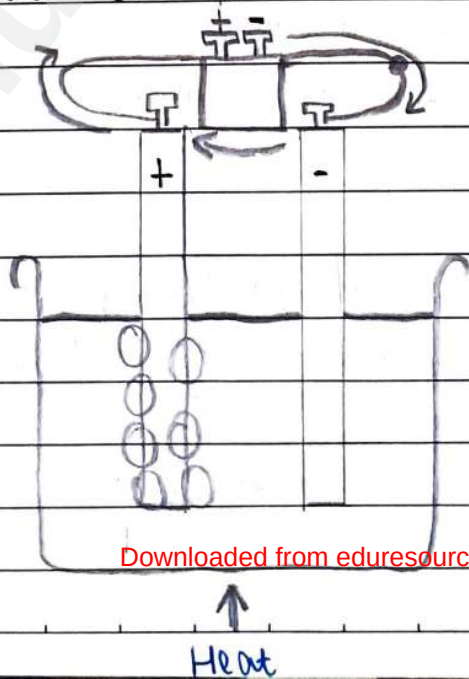
- Decomposition brought by electricity is electrolysis.
- A liquid that contains ions, conducting electricity, is called an electrolyte.
- Everything above carbon is extracted using electrolysis.

PRINCIPLES OF ELECTROLYSIS

Electrolysis: breaking down by electricity
The electrolysis of molten lead bromide.



- The graphite rods are the electrodes (anode and cathode.)
- Molten lead bromide:



USES OF ELECTROLYSIS

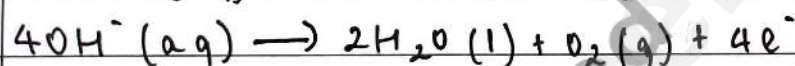
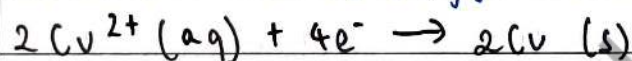
When electrodes are not inert

Electrolysis of $\text{Cu}^{2+} \text{SO}_4^{2-}$ solution (includes H^+ ions and OH^- ions).

- When using inert electrodes

• At the cathode, copper ions are discharged

• At the anode, oxygen bubbles off.



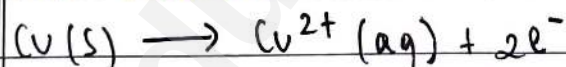
The blue colour of the solution fades as the copper ions are discharged.

- When using copper electrodes

• At the cathode, copper is formed and coats the electrode



• At the anode, the anode dissolves, giving copper ions in the solution.



The anode dissolves, giving copper ions, which then move to the cathode to form copper. The cathode grows larger, and the blue colour does not fade.

When not using inert electrodes, it leads to two uses of electrolysis:

- purifying (refining)

- electroplating

Purifying copper

- Anode is made of impure copper
- Cathode is pure copper.
- Electrolyte is dilute copper (II) sulfate solution.
- Copper in anode dissolves.
- Impurities do not dissolve, but just drop to the bottom as a sludge.
- A layer of pure copper builds up on the cathode. When the anode is almost gone, the electrodes are replaced.
- Copper deposited on cathode is 99.9% pure.
- Sludge may contain valuable metals, which can be recovered and sold.

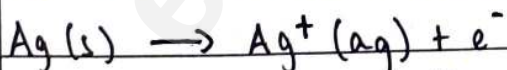
Electroplating

- Using electricity to coat one metal with another, to make it look better or to prevent corrosion.

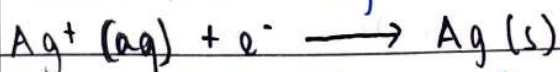
Electroplating a steel jug.

- Jug is used as a cathode.
- Anode is silver.
- Electrolyte is a solution of soluble silver compound, silver nitrate.

- At the anode, silver dissolves, forming silver ions.



- At the cathode, silver ions are attracted. They receive electrons, forming a coat of silver on the jug.



- When the layer of silver is thick enough, the jug is removed.

To electroplate, cathode - object to be electroplated, anode - metal X, electrolyte - solution of soluble compound of X.

EXTRACTING ALUMINIUM

Aluminium oxide from aluminium ore

- Aluminium is the most abundant metal in Earth's crust.
- It is found in bauxite, a mineral ore, which contains 50-65% aluminium oxide, Al_2O_3 . Aluminium oxide is also called alumina.
- There are impurities in bauxite - iron, silicon and titanium.

Steps

- Purify the ore. The ore is crushed, and then mixed with sodium hydroxide. Aluminium oxide reacts with sodium hydroxide and dissolves.



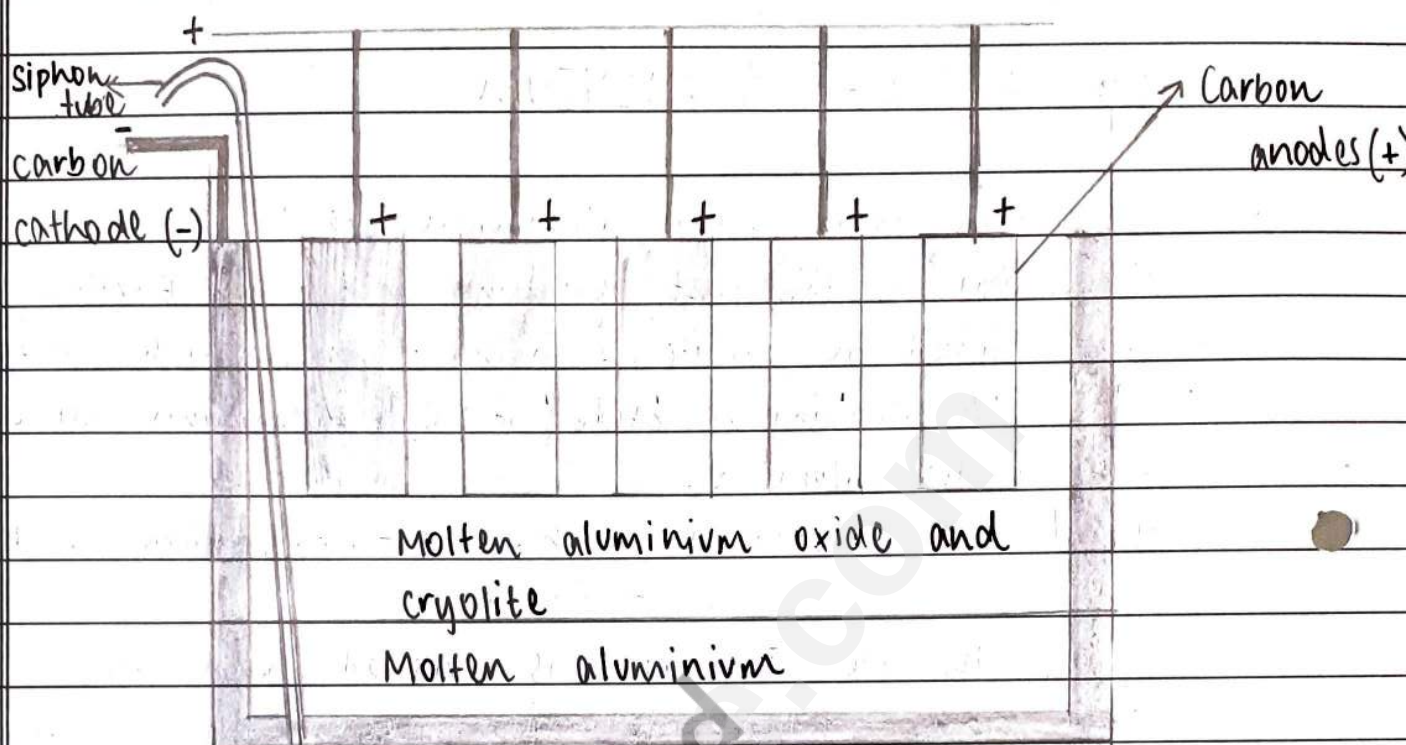
Sodium aluminate

- Impurities are insoluble in sodium hydroxide, and hence, are filtered off.
- Sodium aluminate undergoes further treatment and is heated to make pure aluminium oxide.

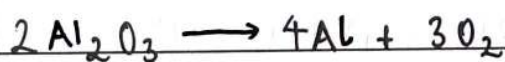
Extracting aluminium from aluminium oxide

- Aluminium oxide is required to be molten; however, has a melting point of 2040°C . It requires a lot of energy to keep the aluminium oxide at 2040°C .
- This is solved by dissolving it in large amounts of molten cryolite (Na_3AlF_6)
- Cryolite melts at about 1000°C , lowering the melting point of the electrolyte.
- Sometimes, CaF_2 is added to lower the melting point.
- Not only is the melting point decreased, but the electrical conductivity of the electrolyte is improved.

carbon is less reactive than aluminium.
↳ cannot extract Al.



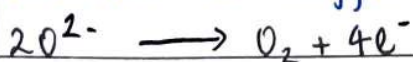
Aluminium is used in aircraft bodies and satellites.



- The high electric current keeps the electrolyte molten.
- At the cathode, aluminium ions gain electrons and are reduced to aluminium. The liquid aluminium falls to the bottom of the cell and is removed using a siphon tube.



- At the anode, the oxide ions lose electrons and are oxidised to oxygen.



- The oxygen reacts with the hot carbon anodes to form carbon dioxide gas. As the carbon anodes 'burn away', they are replaced.

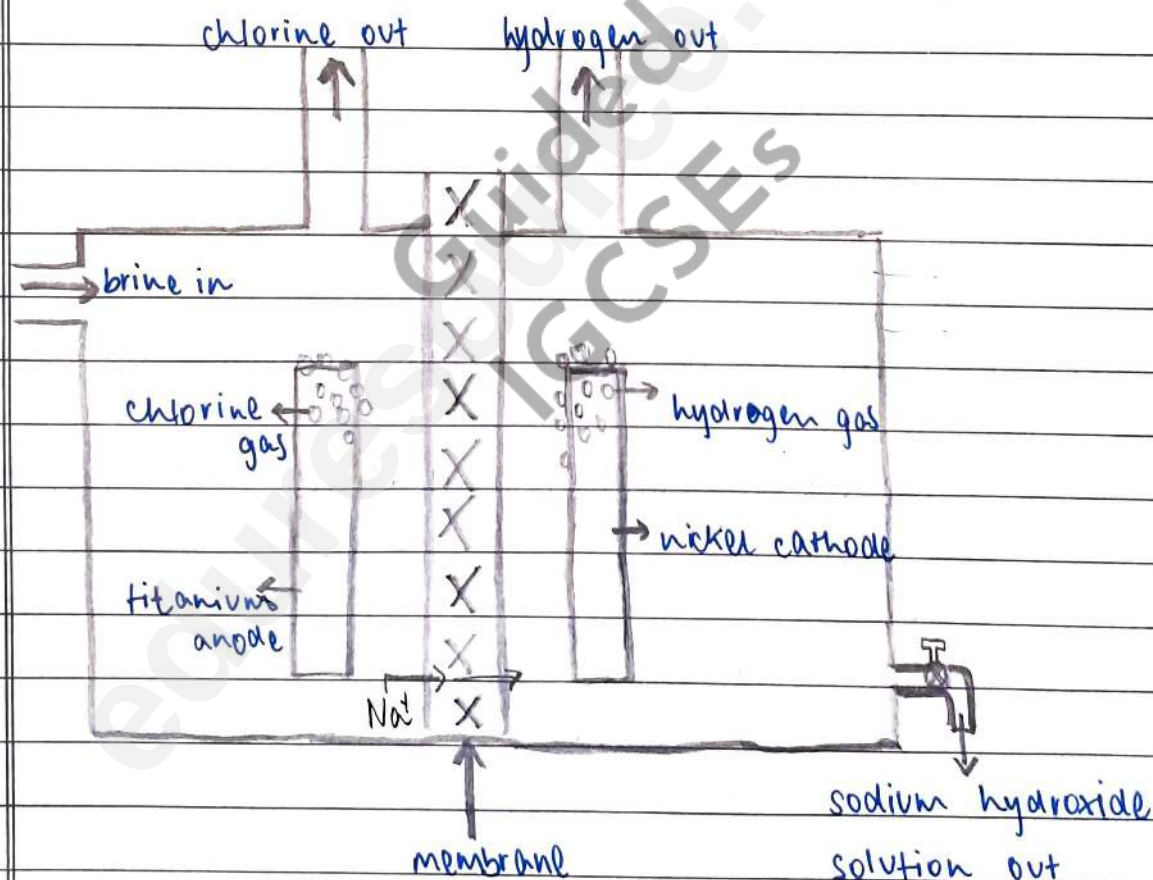
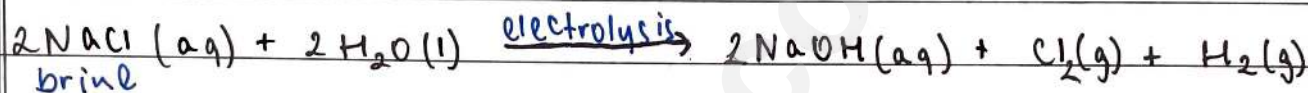
Aluminium has a thin layer of oxide, and thus, it does not react.

ELECTROLYSIS OF BRINE

What is brine?

Brine is a concentrated solution of sodium chloride.

- It can be obtained by:
 - pumping water into salt mines, to dissolve salt.
 - evaporating seawater.



Taksh Shrivastava

Reduction: At the cathode, hydrogen is discharged in preference to sodium. $2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$

Oxidation: At the anode, chlorine is discharged in preference to oxygen. $2\text{Cl}^-(\text{aq}) \longrightarrow \text{Cl}_2 + 2\text{e}^-$

- Na^+ and OH^- ions are left behind, giving a solution of sodium hydroxide.
- Some of the solution is evaporated to give a more concentrated solution.
- Some is evaporated to dryness, giving solid sodium hydroxide.

What are the products of brine used for?

Chlorine, a poisonous yellow-green gas

- plastic PVC ($\frac{1}{3}$ used)
- solvents for degreasing and drycleaning.
- medical drugs
- weedkillers and pesticides
- paints and dyestuffs
- bleaches
- HCl and hydrogen chloride.
- sterilising agent to kill bacteria in water supplies and swimming pools.

Sodium hydroxide solution, alkaline and corrosive

- soaps
- detergents
- viscose (rayon) and other textiles
- paper
- ceramics
- dyes
- medical drugs

Hydrogen, colourless flammable gas

- nylon and hydrogen peroxide.
- harden vegetable oils to make margarine.
- fuel in hydrogen fuel cells.