

Chem handout 2015

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THE EFFECT OF ELECTRICITY ON SUBSTANCES.

TERMS IN ELECTROLYSIS.

1) Define;

(a) Electrolysis:

Electrolysis is the decomposition of a compound, in aqueous solution or molten state, by passing an electric current through.

(b) An electrolyte, and describe giving examples, the different types of electrolytes:

An electrolyte is a compound which when in aqueous solution or molten state, conducts electric current with decomposition at the electrodes as it does so.

TYPES OF ELECTROLYTES

There two types of electrolytes,

Strong electrolytes.

Weak electrolytes

(i) strong electrolytes:

Are the one which completely ionizes in aqueous solution and easily conducts electric current.

Examples of strong electrolytes:

All strong acids, strong bases and strong ionic compounds are examples of strong electrolytes,

- Dilute Sulphuric acid.
 - Dilute hydrochloric acid.
 - Dilute nitric acid solution
- } Strong acids
-
- Sodium hydroxide solution.
 - Potassium hydroxide solution
- } Strong bases.
-
- Potassium chloride.
 - Magnesium chloride solution
 - Sodium iodide solution.
 - Potassium Iodide solution.
 - Copper (II) sulphate solution
 - Copper (II) chloride.
 - Sodium chloride solution
- } Strong ionic compounds etc.

NB. All strong electrolytes completely ionize in aqueous solution as shown below by some examples.

- Dilute sulphuric acid, $\text{H}_2\text{SO}_{4(\text{aq})} \longrightarrow 2\text{H}^+_{(\text{aq})} + \text{SO}_4^{2-}_{(\text{aq})}$.
- Dilute hydrochloric acid, $\text{HCl}_{(\text{aq})} \longrightarrow \text{H}^+_{(\text{aq})} + \text{Cl}^-_{(\text{aq})}$
- Sodium hydroxide solution, $\text{NaOH}_{(\text{aq})} \longrightarrow \text{Na}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$
- Copper (II) Sulphate, solution, $\text{CuSO}_{4(\text{aq})} \longrightarrow \text{Cu}^{2+}_{(\text{aq})} + \text{SO}_4^{2-}_{(\text{aq})}$
- Potassium Iodide solution, $\text{KI}_{(\text{aq})} \longrightarrow \text{K}^+_{(\text{aq})} + \text{I}^-_{(\text{aq})}$.

(ii) Weak electrolytes; Are the one which partially ionize in aqueous solution, and do not easily conduct electricity.

All weak acids and weak bases are weak electrolytes forexample.

- Carbonic acid,
 - Phosphoric acid
 - Suphurous acid
 - Phosphorous acid
 - Ethanoic acid
 - Methanoic acid.
- } Organic acids and all other organic acids are weak Electrolytes.
- Ammonia solution.

NB, All weak electrolytes partially ionize in aqueos solution As equation shown below:

- Carbonic acid, $\text{H}_2\text{CO}_{3(\text{aq})} \rightleftharpoons 2\text{H}^+_{(\text{aq})} + \text{CO}_3^{2-}_{(\text{aq})}$
- Sulphurous acid, $\text{H}_2\text{SO}_{3(\text{aq})} \rightleftharpoons 2\text{H}^+_{(\text{aq})} + \text{SO}_3^{2-}_{(\text{aq})}$
- Ethanoic acid, $\text{CH}_3\text{COOH}_{(\text{aq})} \rightleftharpoons \text{CH}_3\text{COO}^-_{(\text{aq})} + \text{H}^+_{(\text{aq})}$
- Methanoic acid, $\text{CHOOH}_{(\text{aq})} \rightleftharpoons \text{CHOO}^-_{(\text{aq})} + \text{H}^+_{(\text{aq})}$
- Ammonia solution, $\text{NH}_4\text{OH}_{(\text{aq})} \rightleftharpoons \text{NH}_4^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$

NB, The following can be noted.

- All electrolytes are made up of ions; The positively charged ions are called cation and negatively charged ions called Anions.
- The conducting particles of current, in all electrolytes are called IONS.
- An electrolyte does not conduct electric current in its solid state .

Reason: In aqueous solution, the ions making up electrolytes are free to move (they are mobile) and so can conduct electric current.

Melting the compound to molten state breaks down the strong electrostatic forces of attraction between the ion, and so making the ions free to move to carry electric current.

(c) Non-electrolytes, and mention examples of non-electrolytes.

Non-electrolyte is a substance when in aqueous solution or molten state can does not conduct electric current, and is not decomposed by electric current.

Examples include;

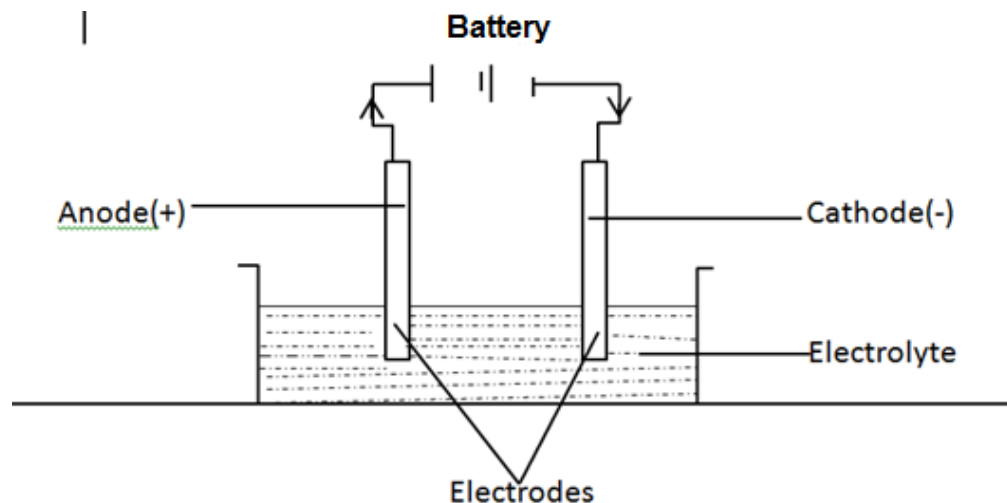
- Sulphur
- Sugar
- Ethanol
- Methylbenzene.
- Napthalene
- Urea
- Trichloromethane
- Tetrachloromethane
- Iodine
- Paraffin

NB;

Non- electrolytes do not conduct electricity, because are made up of molecules but not ions; so exist in molecular states and molecules do not conduct electricity.

(d) Electrodes; and describe the different types of electrolytes.

- Electrodes, are two poles made up of carbon or metals at which current as a flow of electrons either enter or level the electrolyte,
These are two type of electrodes, anode and cathode;
Consider the diagram for the electrolyte cell below



- (i) Anode; Is a positive electrode at which the electrons enter the external circuit or leaves the electrolyte

- (ii) Cathode; Is a negative electrode at which the electrons leave the external circuits or enters the electrolyte.

NB

- (i) Electrodes are conductor of electricity: A conductor is a solid substance which conducts electric current.
- (ii) Conductors are made up of free electrons, which are the conductors particles of current.

Examples of conductors include;

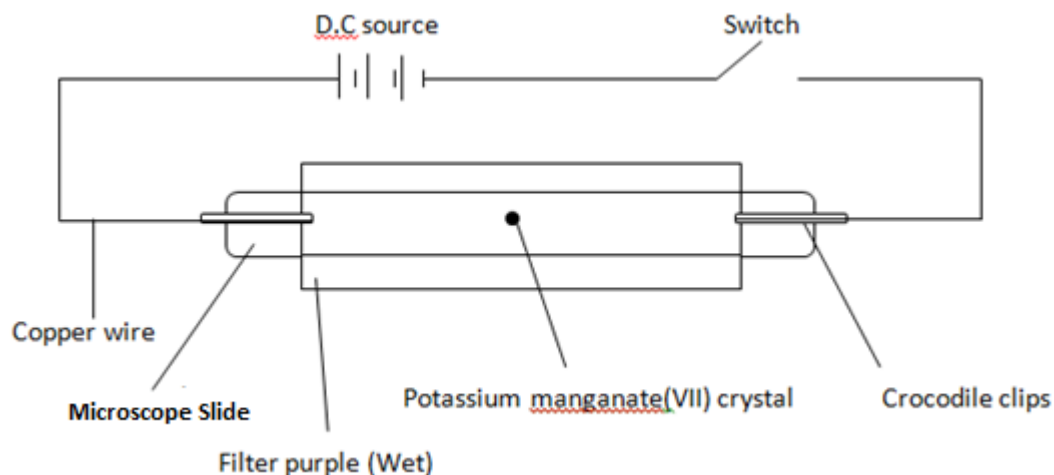
- Graphite
- Platinum
- Copper
- Zinc
- Silver
- Magnesium, and other metals

B) MOVEMENT OF IONS DURING ELECTROLYSIS.

(2) Explain the ionic theory of migration of ions to account for the phenomena of electrolysis:

- Substances called electrolytes contain electrically charged particles called ions, which are oppositely charged: The positively charged ions are called cations and negatively charged ions are called anions.
- When in aqueous solution or molten state, the ions of electrolyte are moving freely within the solution.
- When no current is passing through the electrolyte, the ions are wandering randomly within the solution or molten electrolyte.
- When electric current is applied to the electrolyte, the negatively charged ions, the anions move to the positively charged electrode called anode, where they lose electrons and become atoms, and are said to be discharged.
- The positively charged ions Called cation, move to the negatively charged electrode called cathode, where they gain electrons, and become atoms which are said to be discharged.
- Generally, anions are attracted to anode and cations are attracted to cathode.

(3) The setup of the apparatus below was used to investigate the movement of ions during electrolysis.



- (a) State what was observed
- (i) When the switch was closed:
The purple colour moves towards the anode on left hand side.
NB,
Potassium manganate (vii) crystals consists of, K^+ (Potassium ions) and MnO_4^- (manganate ions). The manganate ions are responsible for the purple colour in potassium manganate (VII) Crystal.
Since MnO_4^- are negatively charged, the purple colour of MnO_4^- ions moves towards anode, of opposite charge.
- (ii) If potassium manganate (VII) crystals are replaced with copper (II) Sulphate crystals and switch closed once again
The blue colour moves towards the cathode on right hand side.

NB:

- Copper (II) sulphate crystals, $CuSO_4$ consists of Cu^{2+} (copper (II) ions) and SO_4^{2-} (sulphate ions).
- The copper (II) ions are responsible for the blue colour in copper (II) sulphate crystals
- Since Cu^{2+} are positively charged, the blue colour of Cu^{2+} ions moves towards the cathode of opposite charge:

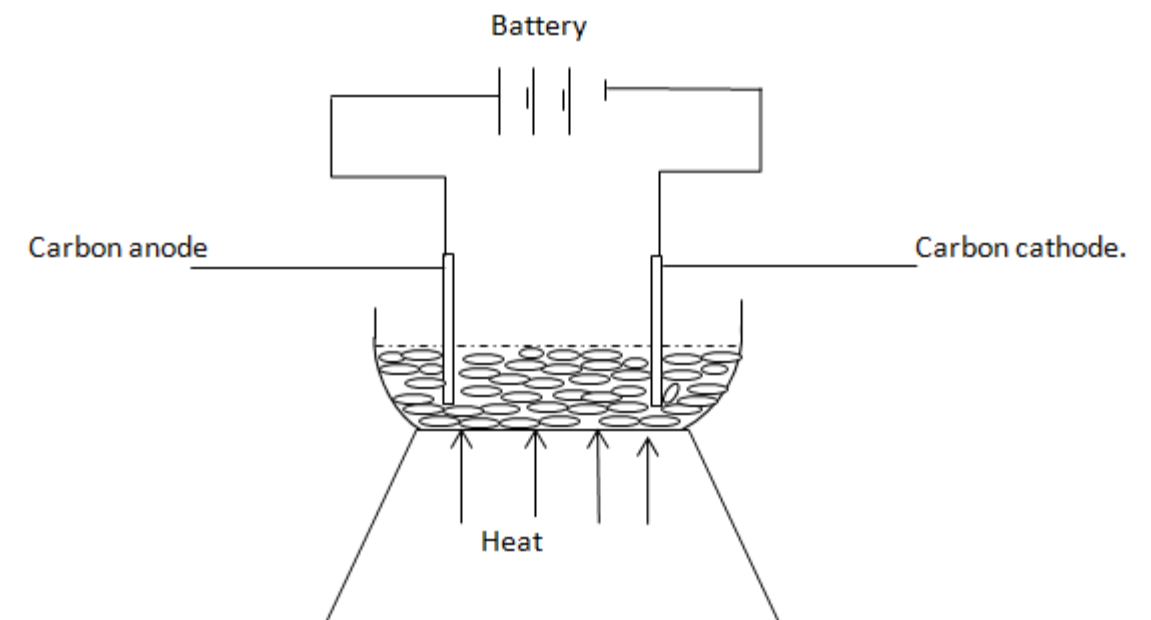
(c) State any general conclusion that can be drawn following the reason you have made in (b) above:

Ions move to the electrodes of opposite charge according to ionic theory of electrolysis, Cations move towards the cathode and anions move to anode.

NOTE:

The mnemonic for ionic migration is CAT at CAT and An at An meaning cations go cathode and anions go at anode.

(4) Below is a diagram showing the electrolysis of molten lead (II) bromide.



(a) State what was observed at both anode and cathode before melting lead (II) bromide

(i) Anode: No observable change.

(ii) Cathode: No observable change:

(b) Explain your observation in (a) above.

Before melting, lead (II) bromide is in solid state, and its ions (Pb^{2+} and Br^-) are held together in one position by strong electrostatic forces of attraction, so the ions are not free to move hence no conduction of electricity:

(c) State what was observed at both anode and cathode after melting lead (II) bromide to molten state:

(i) Anode: Reddish-brown vapour evolved.

(ii) Cathode: A grey solid deposited at cathode.

(d) Write down the equation for the reaction that took place at:

(i) Anode: $2\text{Br}^-_{(\text{L})} \longrightarrow \text{Br}_{2(\text{g})} + 2\text{e}^-$

(ii) Cathode: $\text{Pb}^{2+}_{(\text{L})} + 2\text{e}^- \longrightarrow \text{Pb}_{(\text{s})}$

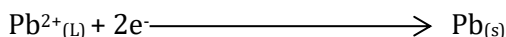
(e) Name the substance formed at;

(i) Anode: Bromine gas

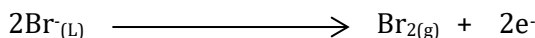
(ii) Cathode: Lead solid.

(f) Explain your observations in (c) above;

- (i) Cathode: The lead(II) ions, Pb^{2+} from molten lead (II)bromide are attracted to the cathode, where they are discharged by gaining of two electrons to form lead atom.



- (ii) Anode: The bromide ions, Br^{-} from molten lead (II) bromide are attracted to anode, and discharge by loss of electrons to form bromide molecules.



NOTE

- (i) At the cathode, electrons are gained
(ii) At the anode, electrons are lost.

C) THE SELECTIVE DISCHARGE OF IONS

(5) (a) State the three factors that affect the selective (preferential) discharge of ions at respective electrodes:

- (i) The position of the metal or group in the electrochemical series.
- (ii) Concentration of the ions.
- (iii) The nature of electrodes used.

(b) Explain the above factors that affect the selective discharge of ions at the respective electrodes:

- (i) The position of the metal or group in the electrochemical series.

Considering the arrangement of anions and cations, as given below; if other factors (factor 2 and 3) are maintained constant.

Cations

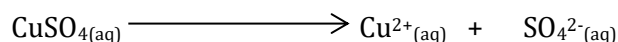
- (i) Potassium ion – K^{+}
- (ii) Sodium ion- Na^{+}
- (iii) Calcium ion- Ca^{2+}
- (iv) Magnesium ion- Mg^{2+}
- (v) Aluminium ion- Al^{3+}
- (vi) Zinc ion- Zn^{2+}
- (vii) Iron (II) ion- Fe^{2+}
- (viii) Lead (II) ion,- Pb^{2+}
- (ix) Hydrogen ion- H^{+}
- (x) Copper (II) ion- Cu^{2+}

(xi) Silver ion- Ag^{+}

Anions:

- (i) Sulphate ion,- SO_4^{2-}
- (ii) Nitrate ion,- NO_3^{-}
- (iii) Chloride ion,- Cl^{-}
- (iv) Bromide ion,- Br^{-}
- (v) Iodide ion,- I^{-}
- (vi) Hydroxide ion,- OH^{-}

If there are two ions of the same charge in the solution, the least reactive ion (less reactive) is discharged in preference of the one higher in the series; for example during electrolysis of copper cathode and potassium anode:



NOTE, In all electrolysis of aqueous solutions, water molecules take part in ionization:

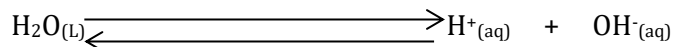
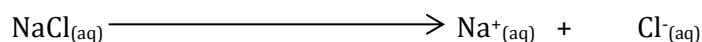
At the anode, both sulphate ions and hydroxide ion migrate at anode, but hydroxide ions, $\text{OH}^{-}_{(aq)}$ being lower than (less reactive than) sulphate ions, $\text{SO}_{4}^{2-}_{(aq)}$, The hydroxide ions are selected out and discharged at the anode.

At cathode, Copper (II) ions, Cu^{2+} are selected out and discharged at cathode in preference of hydrogen ions, $\text{H}^{+}_{(aq)}$ since it is lower than (less reactive than) hydrogen ions.

(ii) The concentration of the ions.

If two or more ions of similar charge are present in solution, the one which is more concentrated is discharged in preference of the one which is less concentrated:

For example in electrolysis of concentrated sodium chloride solution,



At cathode, Chloride ions, $\text{Cl}^{-}_{(aq)}$ are selected out and discharged at anode in preference of hydroxide ions because of the high concentration of chloride ions.

(iii) The nature of electrodes used:

This factor can influence the choice of the particular ion for discharge.

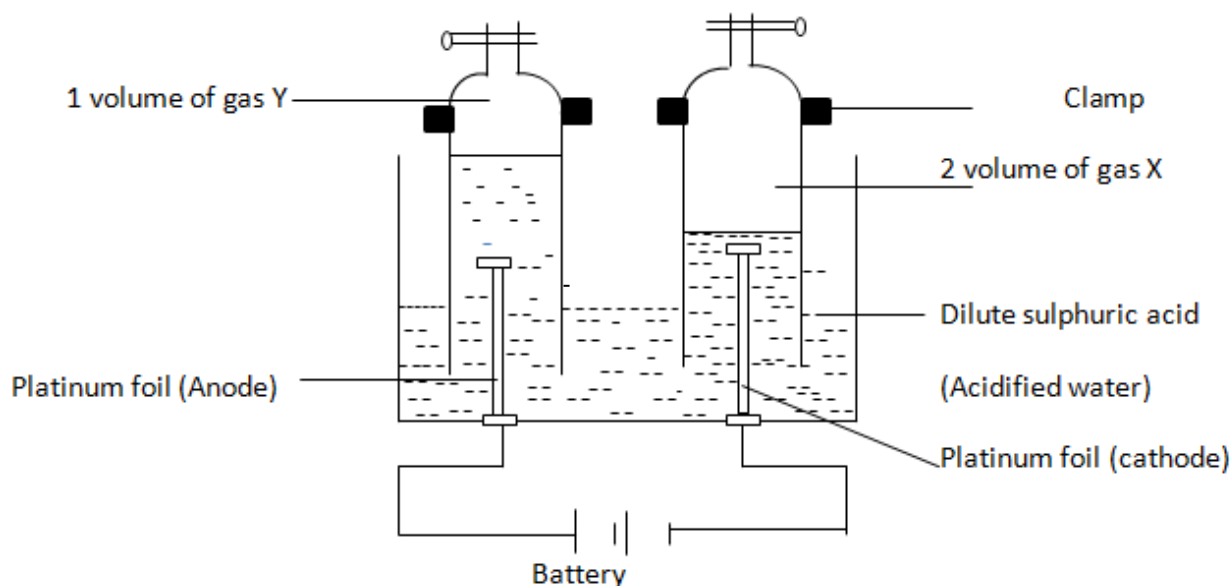
The most important contrast is electrolysis of a solution of sodium chloride with mercury cathode and with platinum cathode:

- The cathode product is hydrogen gas with platinum cathode where hydrogen ions, (H^{+}) is discharged in accordance with the order of the electrochemical series, Sodium ion (Na^{+}) Being higher in the series.
- If a mercury cathode is used, Sodium ion (Na^{+}) is discharged to form sodium amalgam with mercury. This requires less energy than the discharge of hydrogen ions, (H^{+}) forming hydrogen gas. Sodium amalgam is the product at cathode:

D) **EXAMPLES OF ELECTROLYSIS OF SOME ELECTROLYTES.**

ELECTROLYSIS OF ACIDIFIED WATER:

(1) Below is a diagram for the electrolysis of dilute sulphuric acid.(acidified water).



- (a) State what was observed at the;
 - (i) Anode: bubbles of a colourless gas evolved.
 - (ii) Cathode: bubbles of a colourless gas evolved.
- (b) Name the gaseous product;
 - (i) Y, Oxygen
 - (ii) X, Hydrogen gas.
- (c) Write equation of the reaction at the;
 - (i) Anode: $4\text{OH}^-_{(\text{aq})} \longrightarrow 2\text{H}_2\text{O}_{(\text{l})} + \text{O}_{2(\text{g})} + 4\text{e}^-$
 - (ii) Cathode: $2\text{H}^+_{(\text{aq})} + 2\text{e}^- \longrightarrow \text{H}_{2(\text{g})}$
- (d) Describe how the gaseous product at both anode and cathode can be identified:
 - (i) Gas Y: By inserting a glowing splint in a glass tube containing oxygen gas, the gas (oxygen gas) relights a glowing splint.
 - (ii) Gas X, By applying a flame to a test tube, containing a mixture of air and hydrogen gas (gas X) A pop sound is made.

NOTE: (Explanation of product formed at anode and cathode).

Ionisation equation.

- (i) Sulphuric acid. $\text{H}_2\text{SO}_{4(\text{aq})} \longrightarrow 2\text{H}^+_{(\text{aq})} + \text{SO}_4^{2-}_{(\text{aq})}$
- (ii) Water $\text{H}_2\text{O}_{(\text{l})} \longrightarrow \text{H}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$

At cathode, the hydrogen ions migrate to the cathode gain electrons and become hydrogen gas.

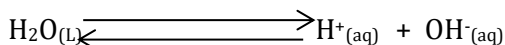
At anode, the hydroxide ions and sulphate ions migrate to the anode, the hydroxide ions being less reactive (lower than)sulphate ions, are discharged and oxygen gas is liberated at anode.

(e) Explain what happened to the concentration (overall acidity) of the electrolyte during electrolysis.

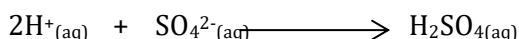
The concentration (_{total} acidity) of electrolyte remained constant.

Reason;

The discharge of hydroxide ions at anode disturbs the ionic equilibrium of water, so more water ionizes to restore it .



The excess hydrogen ions H^+ produced, with incoming Sulphate ions, SO_4^{2-} forms sulphuric acid and its concentration remains the same.



NB₁: The electrolysis of dilute sulphuric acid is called “electrolysis of acidified water” because its water molecules decomposing to form hydrogen and oxygen.

NB₂: The ratio of volume of gases produced during electrolysis of acidified water (dilute sulphuric acid) at cathode and anode is 2:1 (2 volumes of H_2 : 1volume of O_2)

Since it's the same quantity of electricity passing through the all, so we multiply the equation at cathode by 2 so as to balance the electrons with those of equation at anode.

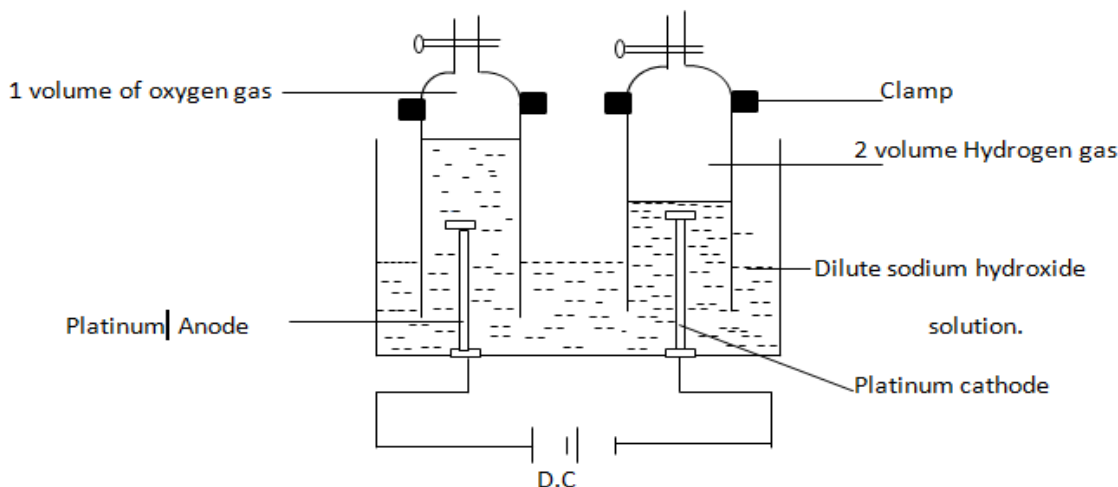
Initial cathode equation ($2\text{H}^+_{(\text{aq})} + 2\text{e}^- \longrightarrow \text{H}_{2(\text{g})}$)X2

At cathode: $4\text{H}^+_{(\text{aq})} + 4\text{e}^- \longrightarrow 2\text{H}_{2(\text{g})}$

At anode: $4\text{OH}^-_{(\text{aq})} \longrightarrow 2\text{H}_2\text{O}_{(\text{L})} + \text{O}_{2(\text{g})} + 4\text{e}^-$

ELECTROLYSIS OF SODIUM HYDROXIDE SOLUTION.

(2) (a) Draw well labeled diagram for electrolysis o dilute sodium hydroxide solution.



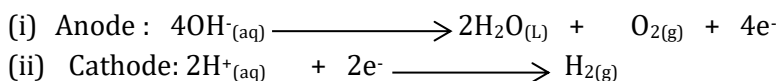
(b) State what was observed at the;

- (i) Anode: bubbles of a colourless gas evolved.
- (ii) Cathode: bubbles of a colourless gas evolved

(c) State the product formed at the;

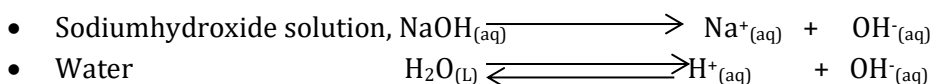
- (i) Anode: Oxygen gas.
- (ii) Cathode: Hydrogen gas.

(d) Write equation for the reaction at,



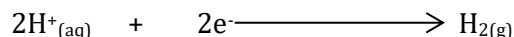
NB: Explain of products at anode and cathode:

Ionizations equation:

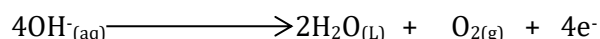


At cathode: Both sodium ions (Na^+) and hydrogen ions (H^+) migrate to the cathode, but its only hydrogen ions selected out and discharged at cathode, since hydrogen ions are less reactive (lower than) sodium ions in the reactive series.

The hydrogen ions, gain electrons and become hydrogen gas.



At anode: The hydroxide ions migrate to anode, they lose off excess electrons, and get discharged at anode forming oxygen gas.

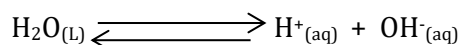


(e) Explain what happened to the concentration of the electrolyte during electrolysis:

The concentration of the electrolyte(alkalinity) remains constant.

Reason (Explanation)

The discharge of hydrogen ions, $\text{H}^+_{(\text{aq})}$ at cathode disturbs the ionic equilibrium of water, so more water ionizes to restore it,



The excess hydroxide ions, $\text{OH}^-_{(\text{aq})}$ produced, with incoming sodium ions, Na^+ ions forms sodium hydroxide solution hence maintaining the concentration of the alkali.

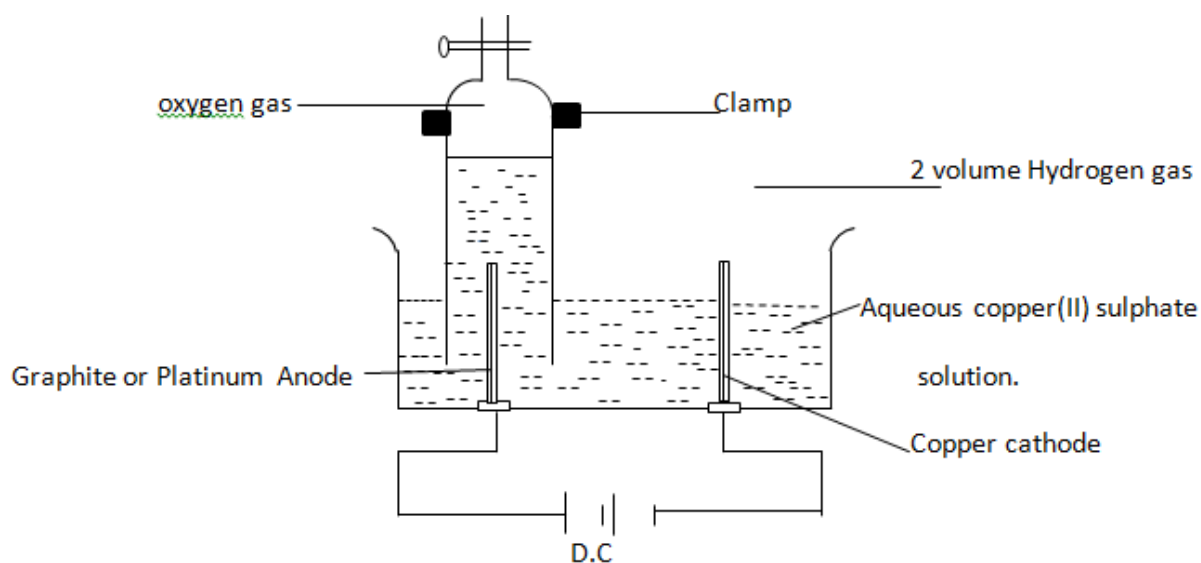
(f) Litmus solution was added to the solution around the cathode.

- (i) State what was observed
The colourless solution around the cathode turned blue.
- (ii) Give a reason for your answer in (f) (i) above.
This is because the resultant solution around cathode is alkaline due to formation of sodium hydroxide solution.

ELECTROLYSIS OF COPPER (II) SULPHATE SOLUTION USING COPPER CATHODE AND PLATINUM OR GRAPHITE ANODE.

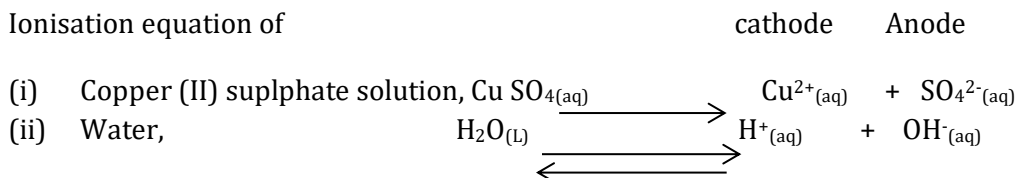
- (3) (a) Draw a labeled diagram for the electrolysis of aqueous copper (II) sulphate solution using copper cathode and graphite or platinum anode.

(1) diagram for electrolysis o dilute sodium hydroxide solution.



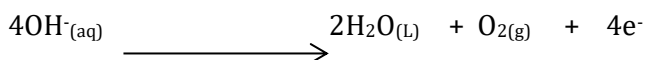
- (b) State what was observed at the;
- Anode: Bubbles of a colourless gas evolved.
 - Cathode: size of cathode increased
- (c) Name the product formed at;
- Anode: Oxygen gas.
 - Cathode: Copper solid.
- (d) Write down the equation of the reaction that took place at;
- Anode: $4\text{OH}^-_{(\text{aq})} \longrightarrow 2\text{H}_2\text{O}_{(\text{L})} + \text{O}_{2(\text{g})} + 4\text{e}^-$
 - Cathode: $\text{Cu}^{2+}_{(\text{aq})} + 2\text{e}^- \longrightarrow \text{Cu}_{(\text{s})}$

Explanation of products formed cathode and anode;

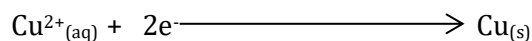


At the anode,

Both sulphate ions, $\text{SO}_{4}^{2-}_{(\text{aq})}$ and hydroxide ions, $\text{OH}^{-}_{(\text{aq})}$ migrate to the anode but only hydroxide ions are discharged at the anode being less reactive (lower than) the sulphate ions in the electrochemical series. The hydroxide ion loses excess electrons and then forms oxygen gas.



At the cathode, Both copper (II) ions, Cu^{2+} and hydrogen ions, H^{+} migrate to cathode but only copper (II) ions are discharged at the cathode being less reactive than hydrogen ions and so gain electrons forming copper solid.



(e) Explain what happened to the concentration of the electrolyte (dilute copper (II) solution decreases as the solution decreases and the blue colour of solution fades as copper is deposited because copper(II) IONS are removed from the solution. The pH of the resultant solution is acidic.

(f) Litmus paper was dropped into the solution around the anode; at the end of electrolysis experiment.

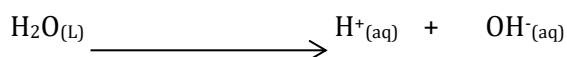
(i) State what was observed:

The blue litmus paper turns red.

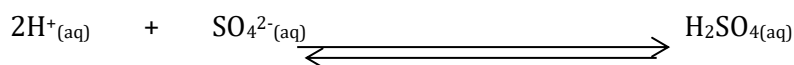
(ii) Explain your observation above.

The solution around the anode is acidic, due to the formation of sulphuric acid.

The discharge of hydroxide ions at the anode, disturbs the ionic equilibrium of water, so more water ionizes to restore it.



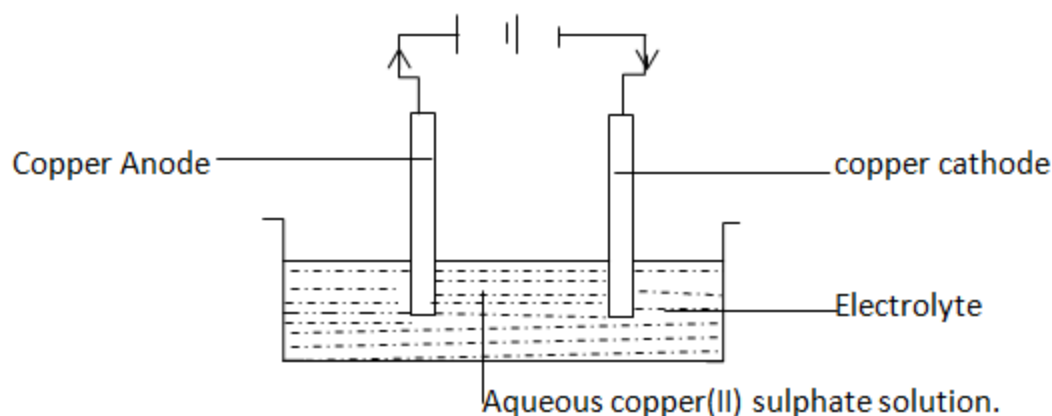
The excess hydrogen ions produced, with incoming Sulphate ions, SO_{4}^{2-} forming sulphuric acid



NOTE: When aqueous dilute copper (II) Sulphate solution is electrolyzed using graphite or platinum anode and copper cathode, Oxygen is formed at anode and copper is formed at cathode.

ELECTROLYSIS OF DILUTE COPPER (II) SULPHATE SOLUTION USING COPPER ELECTRODES

(2) Below is a diagram for the cell used for the electrolysis of dilute (aqueous copper (II) sulphate solution.



(3) State what was observed at the;

- (i) Anode: The size of anode decreased
- (ii) Cathode: The size of cathode increased

(4) Write down the equation of above reaction at the;

- (i) Anode: $\text{Cu}_{(s)} \longrightarrow \text{Cu}^{2+}_{(aq)} + 2e^{-}$
- (ii) Cathode: $\text{Cu}^{2+}_{(aq)} + 2e^{-} \longrightarrow \text{Cu}_{(s)}$

Explanation of the product formed at both cathode and anode.

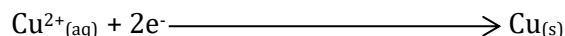
Ionisation Equations;

- (i) Dilute copper (II) Sulphate solution, $\text{CuSO}_{4(aq)} \longrightarrow \text{Cu}^{2+}_{(aq)} + \text{SO}_4^{2-}_{(aq)}$
- (ii) Water, $\text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}^{+}_{(aq)} + \text{OH}^{-}_{(aq)}$

At the anode, Both sulphate ions SO_4^{2-} and hydroxide ions, OH^{-} migrate to the anode, but none is discharged, instead copper anode dissolves in solution forming copper (II) ions, and size decreases.



At the cathode, both copper (II) ions, Cu^{2+} and hydrogen ions H^{+} migrate to the cathode, but copper (II) ions are selected out and discharged at the cathode because copper ions are less reactive (lower reactivity) than hydrogen ions, so copper (II) ions gain electrons from anode forming copper deposit on cathode. So its size increased.



(c) Explain what happened to the concentration of copper (II) sulphate solution at end of electrolysis experiment.

The concentration of copper (II) sulphate does not change and blue colour of solution does not fade (remains blue). This because when copper anode dissolves in solution as ions produce electrons which are gained by copper (II) ions at cathode forming copper solid hence concentration is constant.

(d) State the industrial application of above electrolysis(Electrolysis of dilute copper (II) sulphate using copper electrodes).

In the purification of copper,

(e) Explain briefly how the industrial application stated in (d) is carried out.

- During the electrolysis process, the impure copper (Blister copper) is made the anode and the cathode is a sheet of pure copper.
- The impure copper dissolves in solution and is transferred to the cathode where it is deposited and the impurities remain at the anode electrode.

NB: (I) ELECTROLYSIS OF AQUEOUS COPPER (II) SOLUTION IS SUMMARIZED BELOW

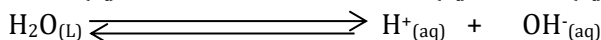
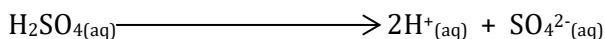
Using platinum anode or graphite anode and copper electrode.	Using copper anode and copper cathode.
(i) Oxygen gas is evolved at anode	Copper anode dissolves in solution and mass of anode decreases.
(ii) Copper is deposited at cathode, so its size and mass of cathode increases.	Brown copper solid is deposited at cathode, so its size and mass of cathode increases.
(iii) The concentration of copper (II) sulphate solution decreases as the blue colour fades away. PH changes.	The concentration of copper (II) sulphate solution remains the same (blue colour remains blue and PH remains unchanged)

REVISION

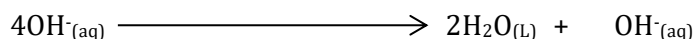
Explain the following observations during electrolysis.

(a) During electrolysis of dilute sulphuric acid, the solution at the anode becomes more acidic, while that at the cathode becomes less acidic using platinum electrode.

In electrolysis of dilute sulphuric acid, sulphuric acid and water ionizes



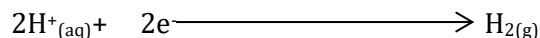
Equation at the anode.



Hydroxide ions are discharged at anode, since they are less reactive than sulphate ions in the electrochemical series the discharge of hydroxide ions at anode disturbs the ionic equilibrium of

water, so more water ionizes to restore it, hence producing an excess of hydrogen ions making the solution around the anode more acidic.

Equation at cathode:

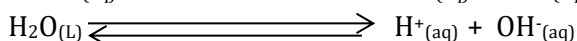
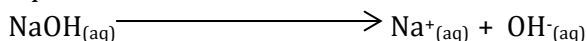


Hydrogen ions are discharged at cathode, and as more water ionizes. The low concentration of hydrogen ions makes the solution less acidic, since they are removed from the solution.

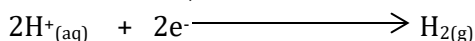
- (b) During the electrolysis of dilute sodium hydroxide solution, Using platinum electrodes, the solution at the cathode becomes more alkaline.

Solution:

In electrolysis of dilute sodium hydroxide solution, sodium hydroxide and water ionizes as equations below.



At the cathode,



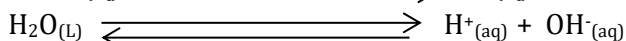
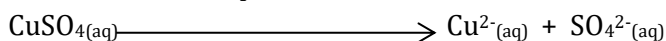
Hydrogen ions are discharged at the cathode, being less reactive than sodium ions in the electrochemical series.

The discharge of hydrogen ions at cathode disturbs the ionic equilibrium of water, and so more water ionizes to restore it which produces excess hydroxide ions. The low concentration of hydrogen ions at cathode makes the solution less acidic.

- (c) During electrolysis of dilute copper (II) sulphate solution using graphite electrodes, the blue solution becomes colourless.

Solution:

During electrolysis of dilute copper (II) sulphate solution, copper (II) sulphate solution and water ionizes as equation below.



Equation at a cathode;



At the cathode, copper (II) ions are discharged which are then removed from solution. The removal of copper (II) from solution decreases the concentration of copper (II) ions and thus solution eventually turns from blue to colourless.

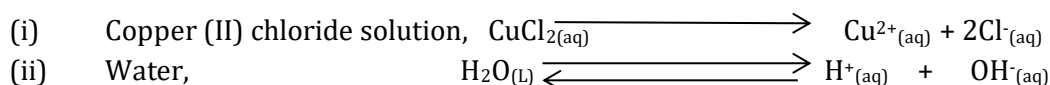
ELECTROLYSIS OF AQUEOUS SOLUTION COPPER (II) CHLORIDE USING GRAPHITE ELECTRODE.

(5) A dilute solution of copper (II) chloride solution was electrolyzed using graphite as electrodes.

- (a) State what was observed.
- (i) Cathode: a brown solid layer deposited at the cathode.
 - (ii) Anode; bubbles of the colourless gas evolved.
- (b) Name the substance produced at;
- (i) Cathode; Copper solid.
 - (ii) Anode; Oxygen gas.
- (c) Write down the equation of the reaction which took place at,
- (i) Cathode: $\text{Cu}^{2+}_{(\text{aq})} + 2\text{e}^{-} \longrightarrow \text{Cu}_{(\text{s})}$
 - (ii) Anode: $4\text{OH}^{-}_{(\text{aq})} \longrightarrow \text{O}_{2(\text{g})} + \text{H}_2\text{O}_{(\text{L})} + 4\text{e}^{-}$

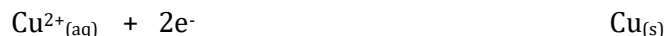
Explanation of products formed at cathode and anode.

Ionisation equations:



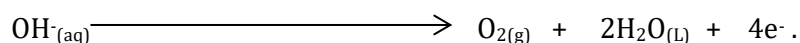
At cathode; both copper (II) Ions, Cu^{2+} and hydrogen ions, H^{+} migrate to the cathode:

Copper (II) ions being lower than (less than) hydrogen ions are selected out and discharged at the cathode instead of hydrogen ions, so the copper (II) ions gain electrons to form copper solid;



At anode, Both chloride ions, $\text{Cl}^{-}_{(\text{aq})}$ and hydroxide ions (OH^{-}) migrate to the anode.

Hydroxide ions are discharged at the anode, being lower than chloride ions, So the hydroxide ions lose electrons to form oxygen gas.



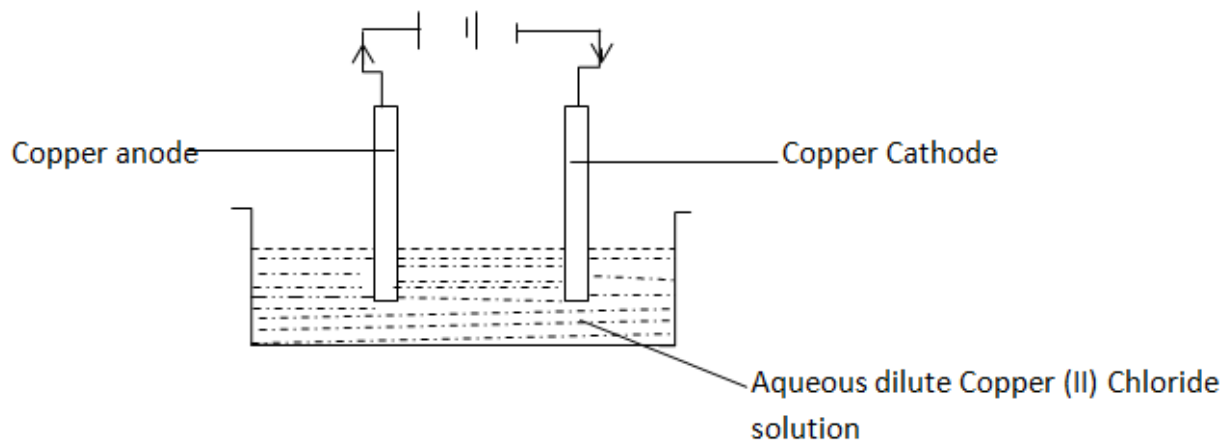
NOTE

The electrolysis of aqueous dilute copper (II) sulphate solution using platinum or graphite anode and copper cathode(or cathode can as well be graphite).

GIVE THE SAME PRODUCTS, as the electrolysis of aqueous dilute copper (II)Chloride solution using graphite anode and graphite cathode; The equation and observation are also the same.

ELECTROLYSIS OF AQUEOUS COPPER (II) CHLORIDE SOLUTION USING COPPER ELECTRODES.

(6) Below is a diagram showing the electrolysis of aqueous dilute copper(II) chloride solution.



(a) State what was observed at the;

- (i) Anode: size of copper decreases.
- (ii) Cathode: A brown solid layer deposited on cathode and its mass increases.

(b) Write down the equation of reaction which took place at;

- (i) Anode: $\text{Cu}_{(s)} \longrightarrow \text{Cu}^{2+}_{(aq)} + 2e^{-}$
- (ii) Cathode: $\text{Cu}^{2+}_{(aq)} + 2e^{-} \longrightarrow \text{Cu}_{(s)}$

Explanation of products at both anode and cathode:

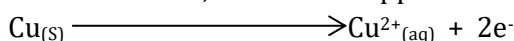
Ionisation equations;

- (i) Copper (II) chloride solution: $\text{CuCl}_{2(aq)} \longrightarrow \text{Cu}^{2+}_{(aq)} + 2\text{Cl}^{-}_{(aq)}$
- (ii) Water; $\text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}^{+}_{(aq)} + \text{OH}^{-}_{(aq)}$

At anode;

Both chloride ions, Cl^{-} and hydroxide ions, OH^{-}

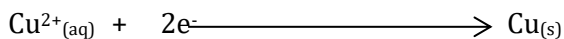
Migrate to the anode; BUT NONE IS DISCHARGED, instead copper anode dissolves away in solution as ions, so mass of copper anode decreases.



At cathode;

Both copper (II) ions, Cu^{2+} and hydrogen ions, H^{+} migrate to the cathode but only copper (II) ions are discharged because copper (II) ions are less reactive (lower than) hydrogen ions in the electrochemical series.

So copper (II) ions gain electrons (from anode) forming copper solid.



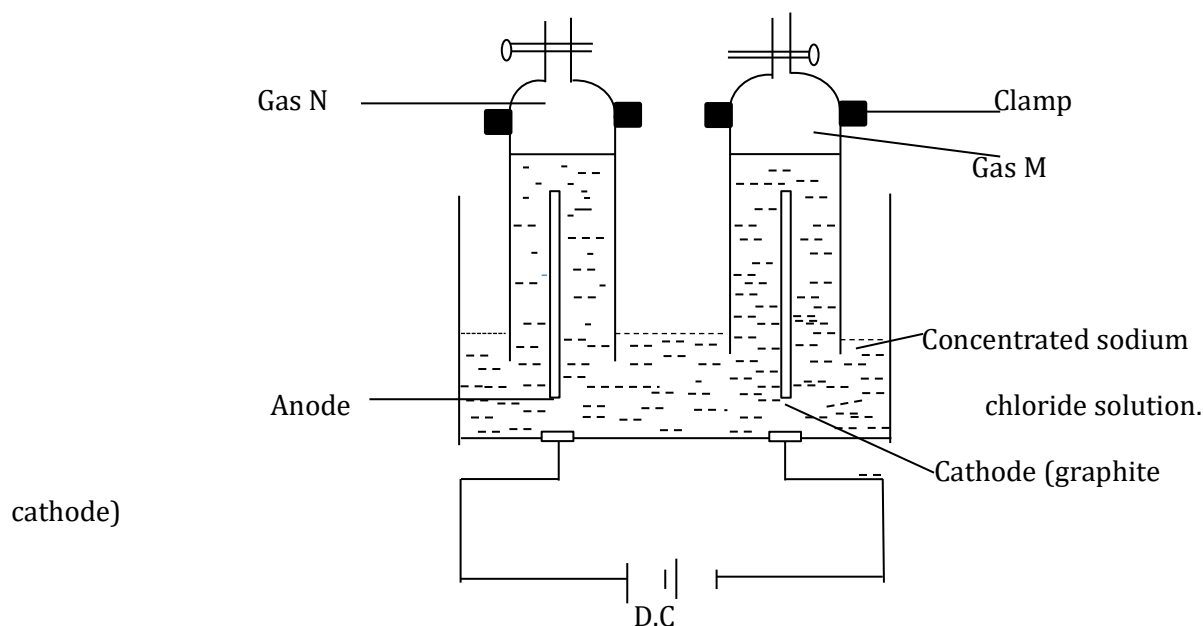
NOTE;



The electrolysis of aqueous copper (II) sulphate using COPPER ELECTRODES (both anode and cathode), THE SAME OBSERVATION AND THE SAME EQUATIONS, as the electrolysis of aqueous dilute copper (II) chloride solution using copper electrodes;
In both cases, the concentration of electrolyte remains the same.

ELECTROLYSIS OF CONCENTRATED SODIUM CHLORIDE SOLUTION (BRINE)

(7) Below is a diagram for electrolysis of concentrated sodium chloride solution:



(a) Identify gas;

- (i) N Chlorine gas.
- (ii) M Hydrogen gas.

(b) (i) State any one other substance which can be used as cothode apart from graphite carbon.
Platinum.

(ii) Name the substance that can be used to as the anode
Graphite carbon.

(iii) Give a basic reason to why the substance named in (ii) above is suitable to be used as anode.

Graphite carbon is used as anode because it is not attacked by chloride gas.

NB: Platinum is not used, at anode because platinum is attacked by chlorine gas.

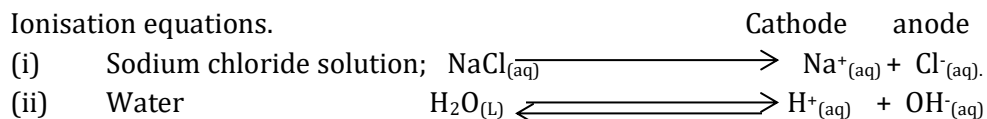
(c) Write down the equation that took place at the;

- (i) Anode: $2\text{Cl}^-_{(\text{aq})} \longrightarrow \text{Cl}_{2(\text{g})} + 2\text{e}^-$
- (ii) Cathode: $2\text{H}^+_{(\text{aq})} + 2\text{e}^- \longrightarrow \text{H}_{2(\text{g})}$

- (d) State what was observed at the;
- Anode: A greenish-yellow gas
 - Cathode: Bubbles of a colourless gas evolved.
- (e) State the volume ratio of the hydrogen gases.
1: 1 ratio of chlorine and hydrogen gases.

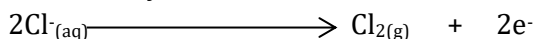
NB, Explanation of the products at both anode and cathode:

Ionisation equations.



At anode;

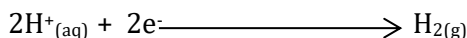
Both chloride ions, Cl^- and hydroxide ions, OH^- migrate to anode, but ONLY Chloride ions are selected out and are discharged at anode because of the higher concentration of chloride ions than hydroxide ions, So chloride ions lose excess electrons forming Chlorine gas.



At cathode;

Both Sodium ion, Na^+ and hydrogen ions, H^+ migrate to cathode but only hydrogen ions are selected out and are discharged at cathode because hydrogen ions are less reactive (lower) than the sodium ions in the reactivity series.

So hydrogen ions gain electrons to form hydrogen gas.

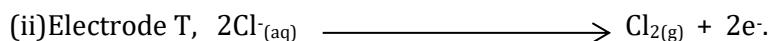
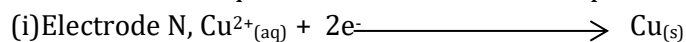


- (f) At the end of electrolysis, experiment; 10cm^3 of the solution around the cathode was obtained in the test tube; then divided into two equal portions in the test tubes, labeled 1 and 2.
- Litmus paper was dropped in the first portion in test tube 1 state what was observed.
The red litmus paper turned blue:
 - Litmus solution was added into the second portion in the test tube 2 state what was observed.
The colourless solution in test tube turned blue:
- (g) Explain your observation(s) in f(i) and f(ii) above:
The solution obtained around the cathode is alkaline due to the formation of sodium hydroxide solution.
The discharge of hydrogen ions at cathode disturbs the ionic equilibrium of water, so more water ionizes to restore it, $\text{H}_2\text{O}_{(\text{L})} \longrightarrow \text{H}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$.
The excess hydroxide ions produced above, with the incoming Sodium hydroxide solution Which is alkaline.
 $\text{Na}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})} \longrightarrow \text{NaOH}_{(\text{aq})}$.

During the electrolysis of concentrated sodium Chloride solution, using graphite anode and Mercury cathode, leads to the discharge of sodium at the cathode, which dissolves in flowing

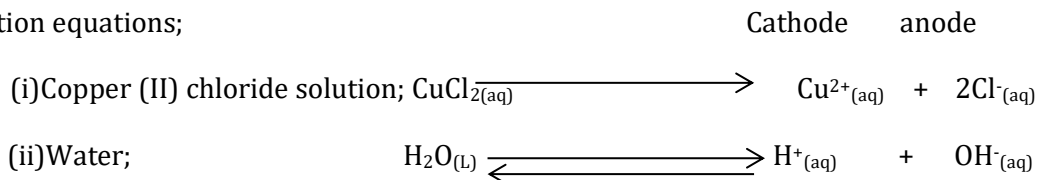
mercury as cathode forming sodium amalgam, The electrolysis of this kind is applied in the industrial manufacture of chlorine and sodium hydroxide.

(h) Write down the equation of reaction that took place at;



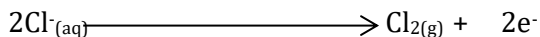
NB, Explanation of above equation and observation at both Anode and Cathode.

Ionisation equations;



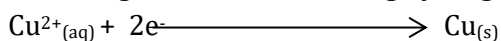
At cathode;

Both Chloride ions, Cl^{-} and hydroxide ions, OH^{-} , migrate to anode but ONLY, chloride ions are selected out and discharged at anode because of a higher concentration of Chloride ions than hydroxide ions, so forming chlorine gas.



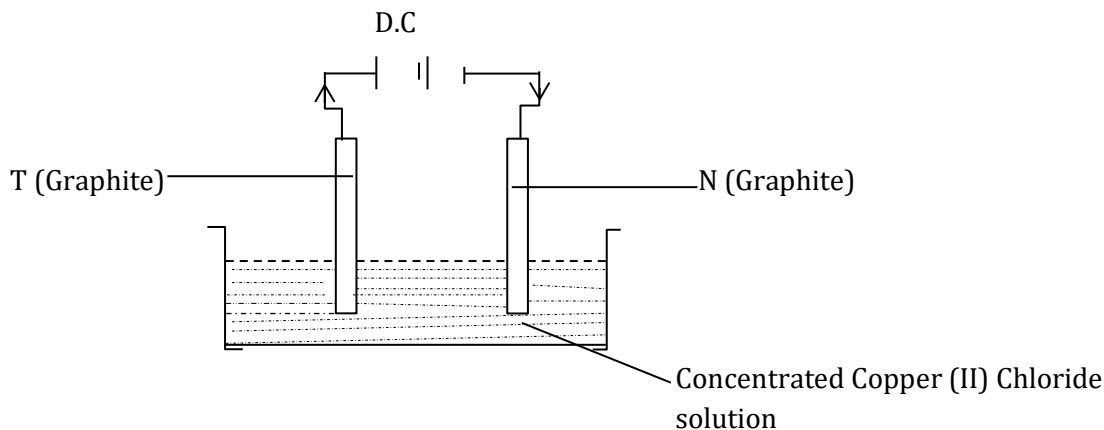
At cathode,

Both copper (II) ions, Cu^{2+} and hydrogen ions are selected out and discharged at anode because copper (II) ions are less reactive (lower) than hydrogen in the electrochemical series, so gain electrons forming hydrogen gas.



ELECTROLYSIS OF CONCENTRATED SOLUTION OF COPPER (II) CHLORIDE USING GRAPHITE ELECTRODES

(8) Below is a diagram for the electrolysis of concentrated copper (II) solution.

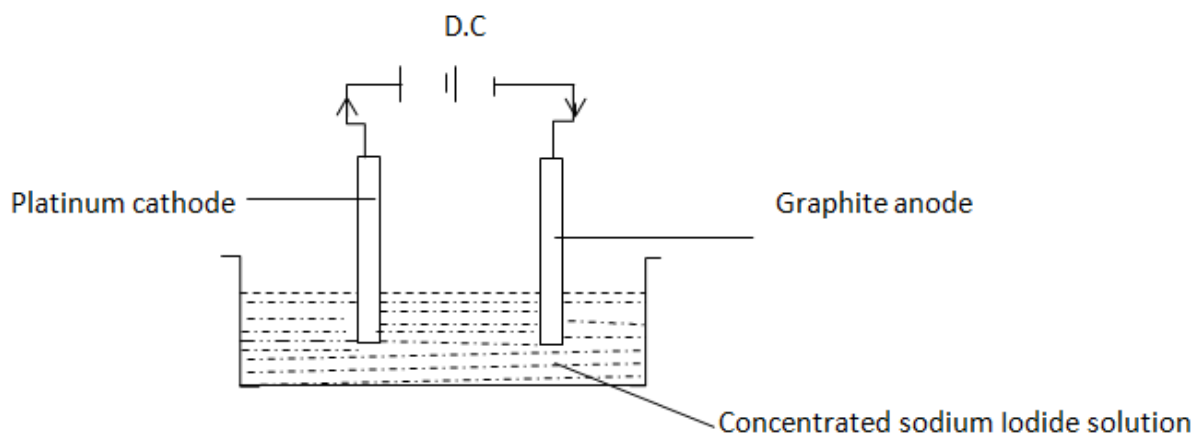


(a) Name the electrode;

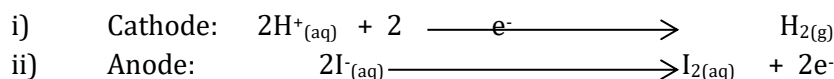
- (i) N Cathode.
- (ii) T Anode.
- (b) State what was observed at the electrode;
 - (i)N A brown copper solid deposited at cathode.
 - (ii)T Bubbles of a greenish-yellow gas evolved.
- (c) Name the substance formed at electrode;
 - (i)N Copper solid.
 - (ii)T Chlorine gas.
- (d) Explain what happened to the concentration of the electrolyte, at the end of electrolysis experiment.
 The concentration the electrolyte decreases, because Copper (II) ions are removed from solution and transferred to the cathode, which made the blue colour of electrolyte tp fade away.

ELECTROLYSIS OF CONCENTRATED SOLUTION OF SODIUM IODIDE SOLUTION USING PLATINUM CATHODE AND GRAPHITE ANODE.

(9) Below is the diagram for the electrolysis of concentrated sodium Iodide solution.

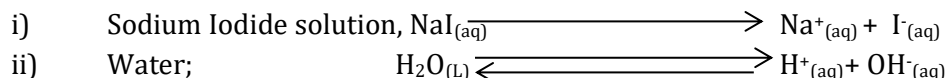


- State what was observed at the;
- i) Cathode: bubbles of a colourless gas evolved.
 - ii) Anode: A brown solution formed.
- (a) Name the substance formed at the;
- i) Cathode: Hydrogen gas
 - ii) Anode: Iodine solution.
- (b) Write the equation of reaction that took place at;



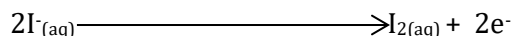
Explanation of product formed at cathode and anode.

Ionisation equation;



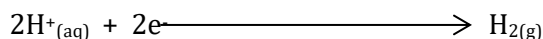
At anode;

Both Iodide ions, I^- and hydroxide ions, OH^- migrate towards the anode, but only, Iodide ions, are selected out and discharged at anode because they are higher concentration (higher) than the electrons forming Iodide solution.



At cathode;

Both sodium ions, Na^+ and hydrogen ions, H^+ migrate towards cathode but ONLY hydrogen ions are selected out and discharged at cathode because they are less reactive than sodium ions, so gain electrons to form hydrogen gas.



(c) Litmus paper was dropped into the solution around the Cathode at the end of electrolysis experiment.

i) State what was observed:

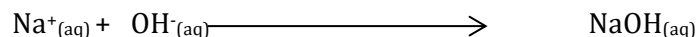
The red litmus paper turned blue.

ii) Explain your observation above.

This is because the solution around the cathode is alkaline due to the formation of sodium hydroxide solution as explained below.

The discharge of hydrogen ions at the cathode disturbs the ionic equilibrium of water, ionize to restore it, $\text{H}_2\text{O}_{(\text{L})} \xrightarrow{\text{ }} \text{H}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$

The excess hydroxide ions formed above, with incoming Sodium ions, together result in the formation of Sodium hydroxide solution which is alkaline.

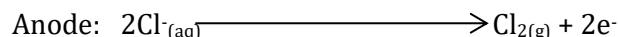


(d) If the above experiment was repeated with concentrated Sodium Chloride solution instead of sodium Iodide solution.

i) State what would be observed at the anode;

Bubbles of a greenish-yellow gas.

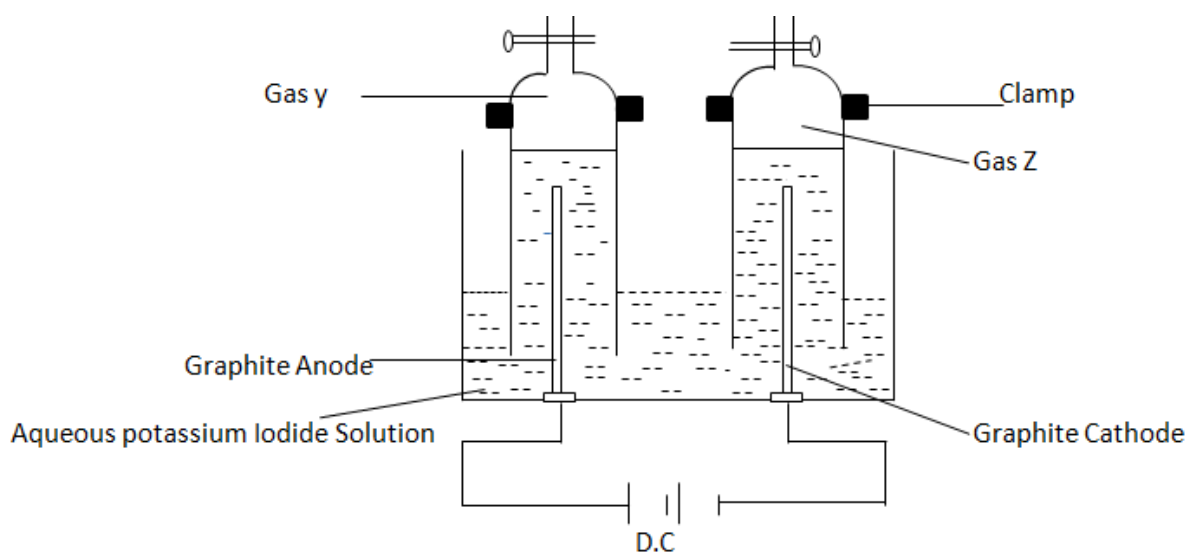
ii) Write down the equation of reaction that would take place at .



NB: The electrolysis of concentrated sodium chloride solution (paste above) is explained in number.

ELECTROLYSIS OF AQUEOUS SOLUTION OF POTASSIUM IODIDE SOLUTION:

(10) Below is a diagram for the electrolysis of aqueous solution Iodide solution using graphite electrodes.



(a) Name gas (i) Y Iodine solution

(ii) Z Hydrogen gas.

(b) State what was observed at;

i) Cathode: Bubbles of a colourless gas.

ii) Anode: brown solution

(c) Write down the equation of reaction that took place at;

i) Cathode: $2\text{H}^+_{(\text{aq})} + 2\text{e}^- \rightarrow \text{H}_{2(\text{g})}$

ii) Anode: $2\text{I}^-_{(\text{aq})} \rightarrow \text{I}_{2(\text{aq})} + 2\text{e}^-$

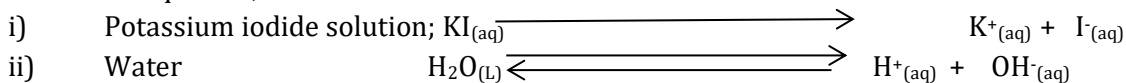
(d) Describe how the product formed at cathode can be tested or identified.

By applying a flame into a test tube containing a mixture of hydrogen gas and air, it explodes with a pop sound.

NB:

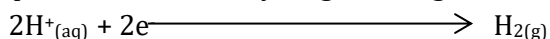
Explanation of products formed at both cathode and anode.

Ionisation equation;



At cathode;

Both potassium ions, K^+ and hydrogen ions, H^+ migrate to the cathode, but ONLY hydrogen ions are selected out and discharged, because hydrogen ions are less reactive (lower) than potassium ions. So hydrogen ions gain electrons forming hydrogen gas.



At anode: Iodide ions are of higher concentration than hydroxide ions because of being very close to hydroxide ions, so colour of iodine (brown) affects discharge of hydroxide ions.

(e) Litmus paper was dropped into the solution around the cathode at the end of experiment.

- i) State what was observed
- ii) Give a reason for your answer in (e)(i) above.

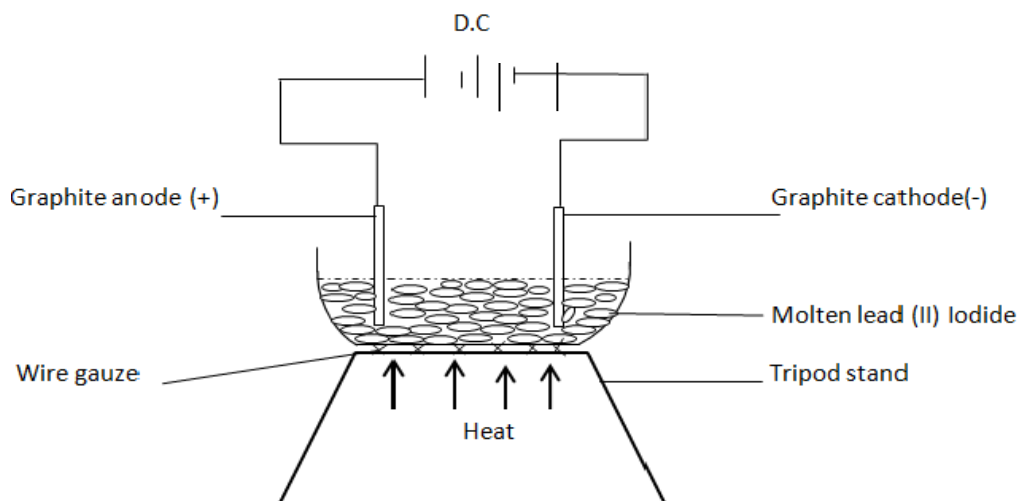
ELECTROLYSIS OF MOLTEN LEAD (II) IODIDE USING GRAPHITE ELECTRODES.

(11)(a) Explain why solid lead(II) Iodide does not conduct electricity whereas molten lead(II) Iodide conducts current.

In solid state, the ions in lead(II) Iodide (Pb^{2+} and I^-) are held by strong electrostatic forces of attraction rigidly in one position and hence current does not flow. In one position and hence current does not flow.

On melting the solid to molten state, the forces holding the ions are broken and the ions are set free and thus the free mobile ions conduct electricity:

(b) Draw a well labeled diagram that can be used to show electrolyse lead(II) Iodide.



(c) State what was observed at the ;

- i) Cathode: A grey solid deposited
- ii) Anode: A brown liquid formed.

(d) Write down the equation of the reaction that took place at;

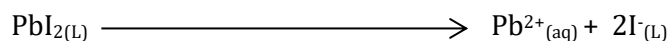
- i) Cathode: $\text{Pb}^{2+}_{(\text{L})} + 2\text{e}^- \longrightarrow \text{Pb}_{(\text{s})}$
- ii) Anode: $2\text{I}^{-}_{(\text{L})} \longrightarrow \text{I}_{2(\text{L})} + 2\text{e}^-$

(e) Name the product formed at;

- i) Cathode: Solid lead.
- ii) Anode: Iodine liquid.

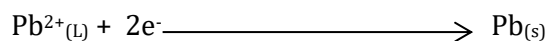
NB: Explanation of product formed at both electrodes (Anode and cathode).

When in molten state, lead(II) Iodide ionizes as equation below,



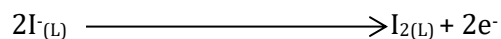
At cathode:

Lead(II) ions migrate towards cathode and gain electrons forming Solid lead.



At cathode;

Iodine migrates towards the cathode and then lose excess of electrons forming liquid.



NB

In electrolysis of all molten substances, water molecules do not take part in ionization since the electrolyte is not in solution but in only MOLTEN STATE.

E

THE INDUSTRIAL APPLICATION OF ELECTROLYSIS

(1) (a) One of the application of electrolysis is "Extraction of reactive metal elements".

List the metals extracted from their ores by electrolysis method.

- Potassium
- Sodium.
- Calcium.
- Magnesium.
- Aluminium

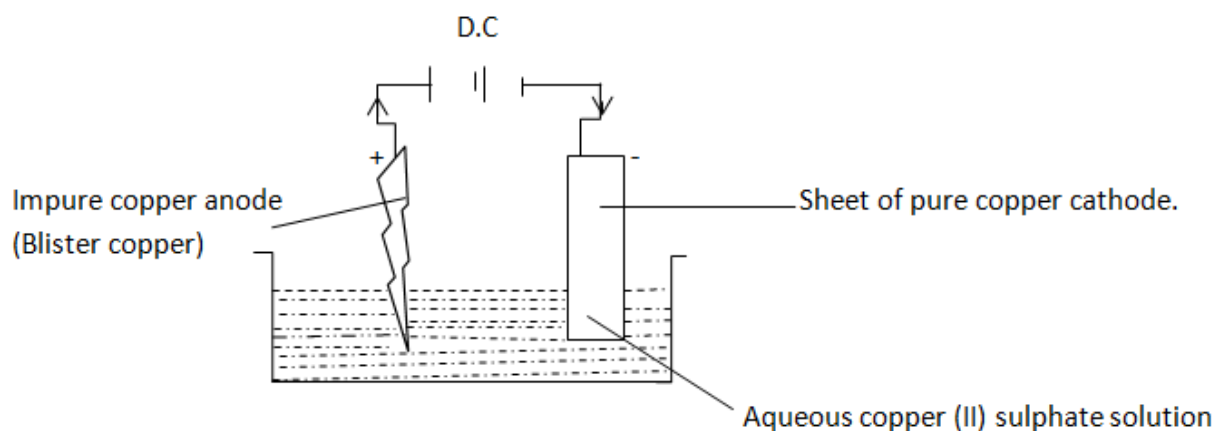
NOTE;

The extraction of reactive metals elements by electrolysis is further discussed ahead in the topic of Metal extraction on page especially the extraction of sodium, where graphite carbon is used as anode and cathode made of ions.

(b) State any other industrial applications of electrolysis.

- In electroplating forexample copper plating, silver plating, tin plating.
- In the purification of metals such as copper, zinc.
- In the manufacture of chlorine gas and sodium hydroxide.

(2) (a) Using a labeled diagram, describe the process involved in copper purification.



In the purification of copper, the impure copper is purified by electrolysis using aqueous copper(II) sulphate solution as electrolyte, and the electrolytic cell consists of a sheet of pure copper as the cathode and impure copper as the anode.

During electrolysis, the impure copper anode dissolves in solution and in the process, pure copper is transferred from the anode to the cathode, leaving impurities at the anode as anode sludge.

The pure copper transferred to the cathode can be removed by stripping

- Reaction at anode: $\text{Cu}_{(s)} \longrightarrow \text{Cu}^{2+}_{(aq)} + 2e^-$
- Reaction at cathode: $\text{Cu}^{2+}_{(aq)} + 2e^- \longrightarrow \text{Cu}_{(s)}$

NB, During the process of purification of copper;

- The size (mass) of copper anode decreases.
- The size (mass) of copper cathode increases.
- The concentration of copper(II) Sulphate solution (electrolyte) remains unchanged. (The solution remains blue in colour and pH does not change).

(b) State two industrial applications (uses) of copper.

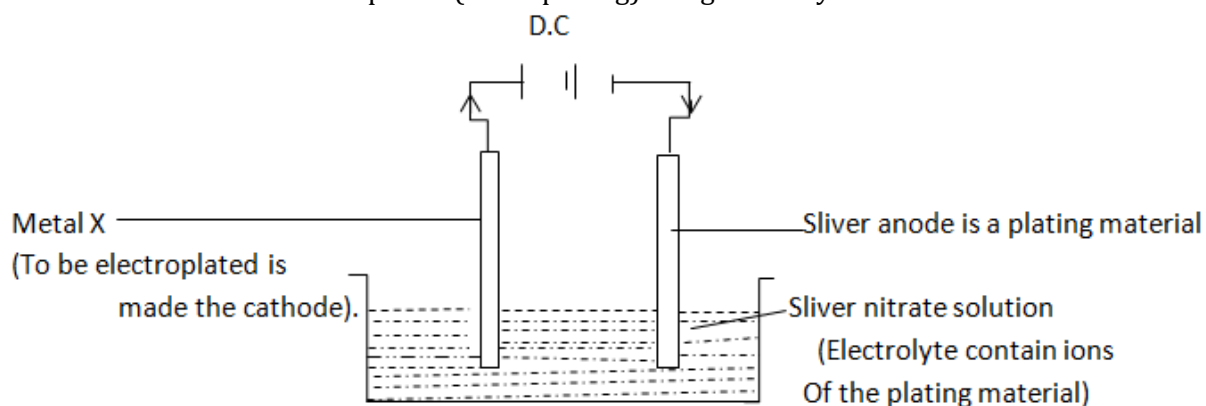
- As a conductor of electric current, in wire and cables.
- In making alloys such as brass and bronze.

NB, Brass is an alloy of copper and zinc, and bronze is an alloy of copper and tin.

(3)(a) What is meant by the term electroplating.

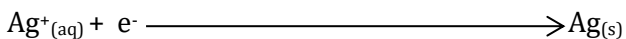
Electroplating is the process of coating a metal or other substance with another desired metal using electrolysis.

(b) A metal substance X is to be coated or plated with silver. With the aid of a labeled electrolytic cell, explain how metal X can be silver plated (silver plating) using electrolysis.



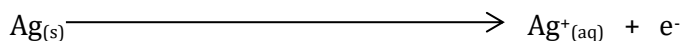
- During silver plating, the metal X to be plated with silver is made the cathode, and the plating material of pure silver is made the anode, all put in a plating bath, of a suitable electrolyte of silver nitrate solution containing ions of plating metal (silver ions).
- Silver nitrate solution contains positively charged silver ions which are attracted to the cathode (metal to be plated), and gain electrons forming silver solid which coats on the metal X.

Equation at cathode;



- Anode made of pure silver loses its electrons and forms silver ions which dissolve in solution to replace the ones moving to the cathode.

Equation at anode.



- The process continues until an adequate layer of silver has deposited to the cathode.

NB, During electroplating process by electrolysis;

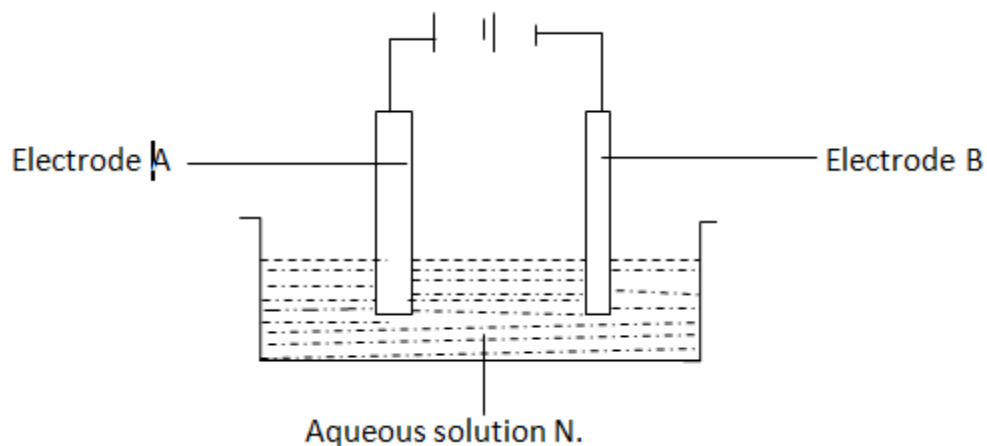
- (i) The object to be electroplated is made the cathode.
- (ii) The plating material is made the anode.
- (iii) A suitable electrolyte is used containing ions of the plating material.
- (iv) The mass (size) of the plating material decreases.

(c) State two reasons for electroplating (why metals are plated).

(i) To protect metals from corrosion.

(ii) To improve the strength, durability and appearance of metals.

(4) The diagram below shows a suitable electrolytic cell used during copper plating of Metal X.



(a) Which of the electrode A and B is ;

- i) Metal X to be plated, B
- ii) Copper electrode, A

(b) Name the suitable electrolyte N.

Copper(II) sulphate solution or copper (II) nitrate solution , Copper(II) chloride solution.

(c) Write down the equation for the reaction at electrode.

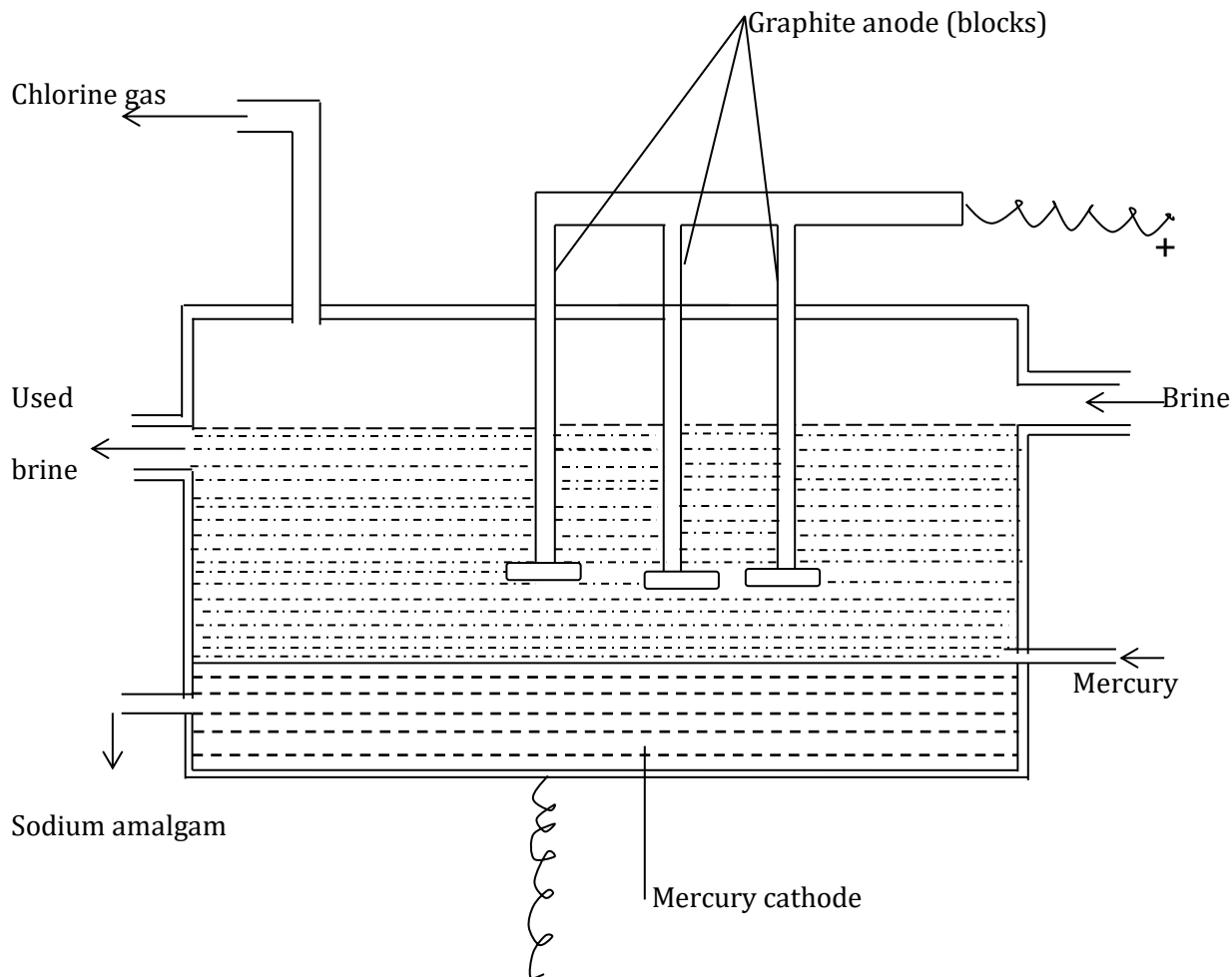
- i) A $\text{Cu}_{(s)} \longrightarrow \text{Cu}^{2+}_{(aq)} + 2\text{e}^{-}$
- ii) B, $\text{Cu}^{2+}_{(aq)} + 2\text{e}^{-} \longrightarrow \text{Cu}_{(s)}$

NOTE, Object to be plated is made the cathode, and the plating object made the anode. The plating anode dissolves in solution forming ions.

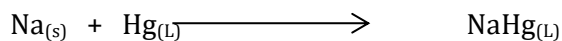
(d) Apart of copper plating, State three other applications of electroplating

- In chromium plating.
- In gold plating.
- In silver plating.

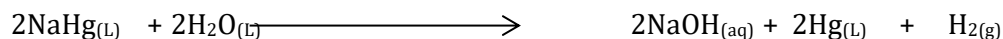
- (5) (a) Describe with the aid of a well labeled diagram the manufacture of sodium hydroxide on a large scale(include the equation(s) of reaction(s) where necessary.)



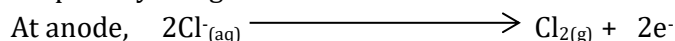
- Sodium hydroxide is manufactured by electrolysis of concentrated sodium chloride solution (brine) in a castner kellner cell.
- Purified saturated brine (concentrated sodium chloride) is electrolyzed using graphite(carbon) blocks as anode, and a stream of flowing mercury ac cathode.
- Equation, $\text{NaCl}_{(\text{aq})} \longrightarrow \text{Na}^+_{(\text{aq})} + \text{Cl}^-_{(\text{aq})}$
 $\text{H}_2\text{O}_{(\text{L})} \rightleftharpoons \text{H}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$
- The mercury cathode enables sodium ions to discharged in preference of hydrogen ions, so sodium is deposited at cathode. This discharge of sodium ions requires less energy than the discharge of hydrogen ions.
 At cathode, $\text{Na}^+_{(\text{s})} + \text{e}^- \longrightarrow \text{Na}_{(\text{s})}$
- The sodium deposited at cathode dissolves in mercury cathode forming Sodium amalgam.



- The sodium amalgam is then removed from the cell, and reacted with a stream of water forming sodium hydroxide solution, hydrogen gas and mercury.



- Mercury is then recycled by use of a pump, hydrogen gas is collected as a bi-product.
- Sodium hydroxide solution is then evaporated to dryness and solid sodium hydroxide can be obtained.
- At the anode, chloride ions, Cl^- , are discharged because of their higher concentration than hydroxide ions, so forms chlorine gas, which is collected off separately and stored in specially designed tanks.



NB,

- The anode is made of graphite carbon, because graphite carbon is an inert electrode and so cannot be attacked by chlorine gas.
- Mercury is used as the cathode because cathode enables the discharge of sodium ions with less energy in preference of hydrogen ions;
- The above electrolytic cell (Cassell cell) is the one which is used to manufacture chlorine gas on a large scale.

(b) State one industrial application (use) of sodium hydroxide.

In the manufacture of soap

Other- In the manufacture of detergents.

F

ELECTROCHEMICAL CELLS.

(1) "A Daniel cell" is one of the simplest electrochemical cell, which generates electricity by redox reaction, which involves reduction and oxidation process.

(a) Define;

(i) An electrochemical cell.

An electrochemical cell is the one in which chemical energy is transformed (converted) to electrical energy.

(ii) Redox reaction:

Redox reaction is the one in which reduction and oxidation processes are taking place at the same time.

(iii) Reduction:

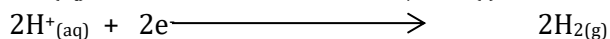
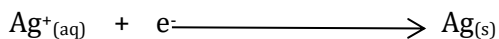
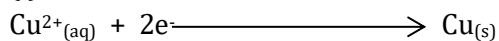
Reduction is the gaining of electrons by a substance or is the addition of electrons to a substance.

(iv) Oxidation:

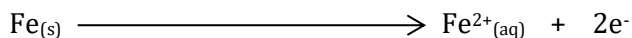
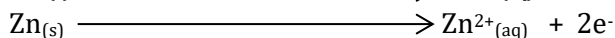
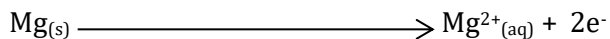
Oxidation is the loss of electrons by a substance or, is the removal of electrons from a substance.

(b) Write any three equations which show;

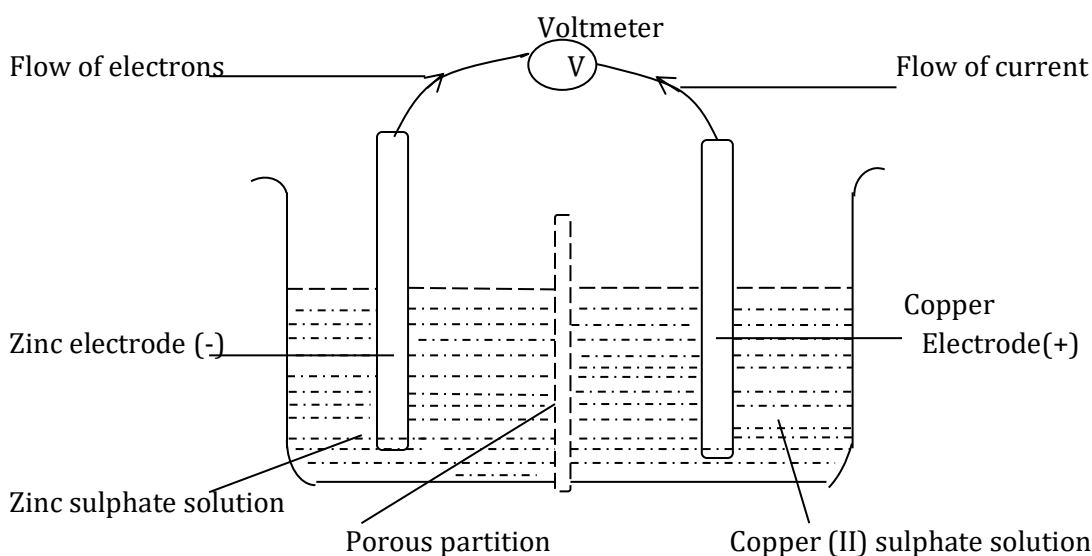
(i) Reduction:



(ii) Oxidation



(c) (i) Draw a well labeled diagram of a daniel cell.

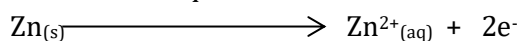


(ii) Using the diagram drawn in (i) above, briefly describe the model composition of a Daniel cell.

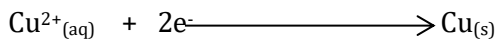
- The Daniel cell consists of a zinc rod dipped in a solution of zinc sulphate and copper rod dipping in solution of copper (II) sulphate separated by porous partition, which prevents the mixing of ions, thus completing the circuit.
- The two rods are connected by a wire across a voltmeter which measures the e.m.f produced in the cell.
- The two metal rods of zinc and copper form electrodes of the cell.

(d) Explain the reaction occurring in the Daniel cell and equation of reaction of reactions where necessary which leads to generation of electric current.

- At the zinc terminal, zinc being more electropositive than copper dissolves in solution and ionizes to form zinc ions, so zinc is oxidized to zinc ions by oxidation as equation below.

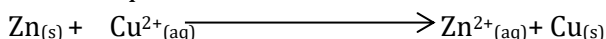


- The reaction above leaves electrons which build up on Zinc metal making it negatively charged, and so it is the cathode (negative electrode).
- The electrons from zinc terminal then moves to the copper rod, through the external circuit(wire).
- At the copper terminal, copper ions in the solution accept the electrons from cathode forming copper solid by reduction.



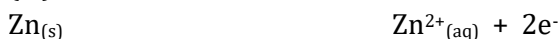
- The copper rod gains a net positive charge thus it is anode.
- As electrons flow from zinc rod to the cathode rod, current conventionally flow in the opposite direction.

Overall equation of the cell.



NB, The following can be noted;

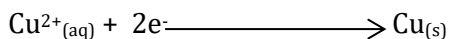
- (i) The more electropositive metal forms the cathode; and oxidation takes place at cathode.
- (ii) The less electropositive metal forms the anode, and reduction takes place at anode.
- (ii) So in the Daniel's cell, zinc is the cathode and copper is the anode.
- (iv) A zinc half cell notation, can be written from equation taking place at Zinc cathode.



The half cell notation is, $\text{Zn}_{(\text{s})}/\text{Zn}^{2+}$

The single line in the half cell notation represents a phase boundary(the boundary between the zinc metal rod and its aqueous solution).

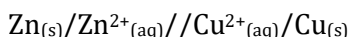
- (v) A copper half cell notation can be written from equation taking place at copper anode.



The half cell notation is, $\text{Cu}^{2+}_{(\text{aq})}/\text{Cu}_{(\text{s})}$.

The single line in the half cell notation represents a phase boundary(the boundary between the copper metal rod its aqueous solution).

- (vi) A cell convention for complete cell is written as below.



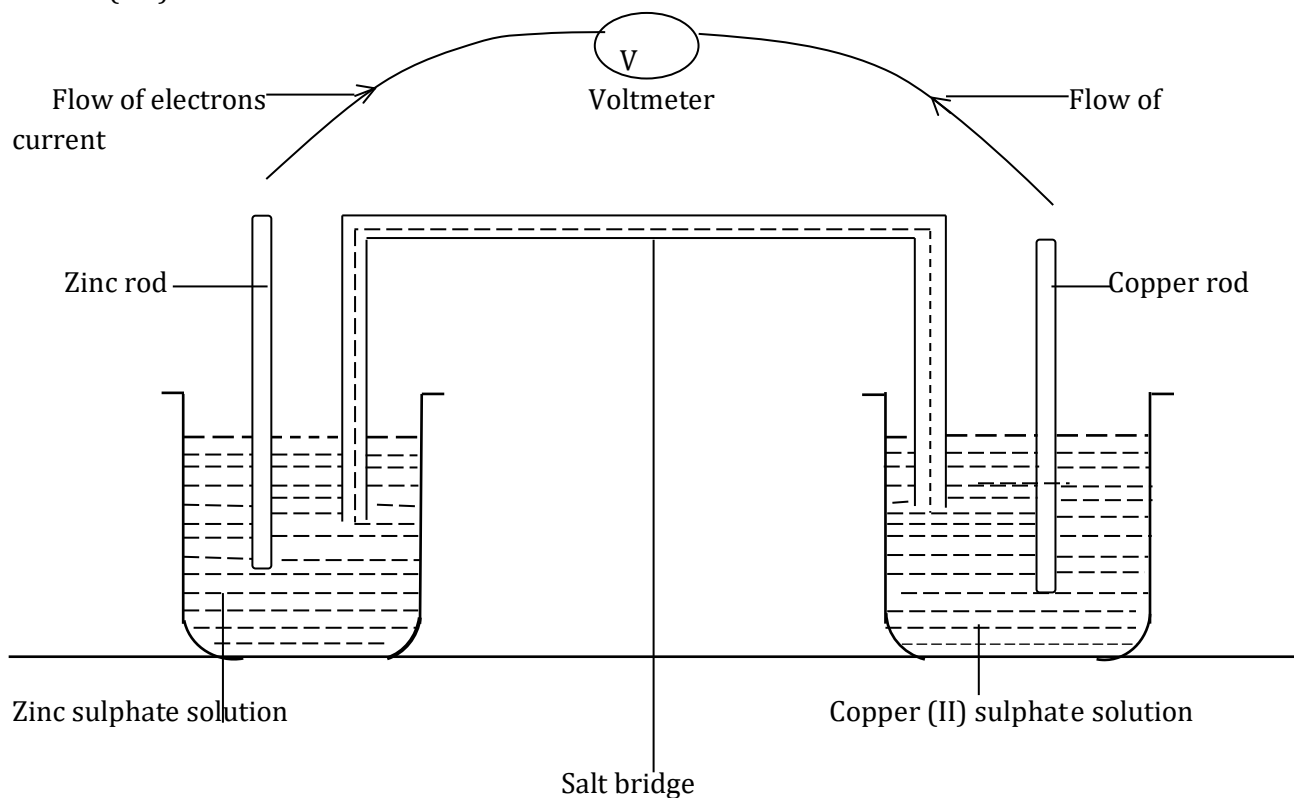
- It is written in a such a way that the negative electrode half cell is at the left hand side and the positive half cell is at the right hand side.
- The double lines in the complete cell convention represents the boundary between the two half cells.
- (vii) Each metal rod used in the electrochemical cell must be dipping in aqueous solution containing its respective metal ion; and salt forming a solution MUST BE SOLUBLE.

Forexample;

-	Zinc rod in	Zinc sulphate solution , or Zinc nitrate solution or zinc chloride solution.
-	Copper rod in	Copper(II) sulphate solution, or Copper (II) nitrate solution Or copper (II) chloride.

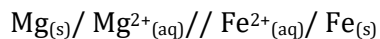
- Silver rod in Silver nitrate solution.
- Magnesium rod In Magnesium sulphate solution, or in magnesium nitrate solution, or Magnesium chloride solution.

- (viii) The Daniel's cell can be also drawn as below.



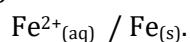
- The two compartments in figure above, are connected by the salt bridge which contains an electrolyte such as potassium chloride, which conducts electricity but does not allow mixing the two solutions.
- (ix) Note that electrons flow from the more electropositive metal rod which is the cathode, to the less electropositive metal rod which is the anode, and current flows in the opposite direction.
- (x) An electrochemical cell is also called a Voltaic cell or galvanic cell.

(2) The cell convention of an electrochemical cell is shown below.

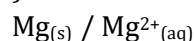


(a) Write the;

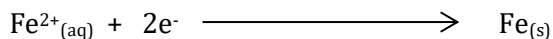
(i) Anode half cell notation:



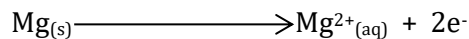
(ii) Cathode half cell notation:



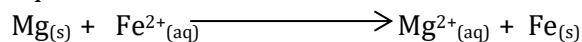
(iii) Anode half cell equation:



(iv) Cathode half-cell equation:



(v) Equation for the overall reaction:



NB,

The cell convention is written in such a way that cathode cell is on left hand side and anode cell on the right hand side.

(b) Name the substance which could be used as an electrolyte at the;

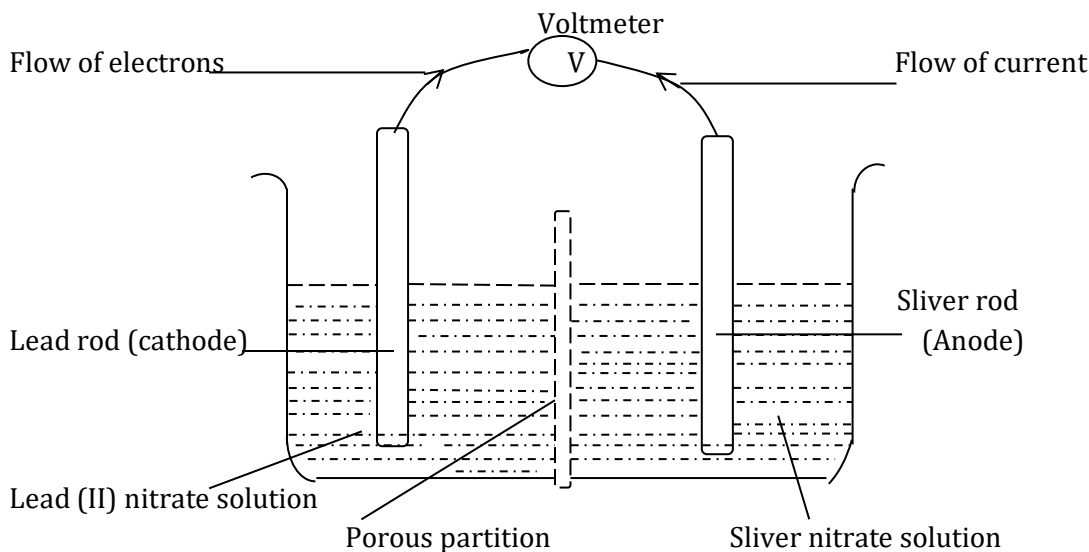
i) Cathode, Magnesium Sulphate solution.

ii) Anode, Iron (II) sulphate solution.

(3) The cell convention of an electrochemical cell is shown below.



(a) Draw the well labeled electrochemical cell for above cell convention:



(b) Write;

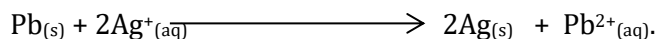
i) Half cell equation at anode.



ii) Half cell equation at cathode:



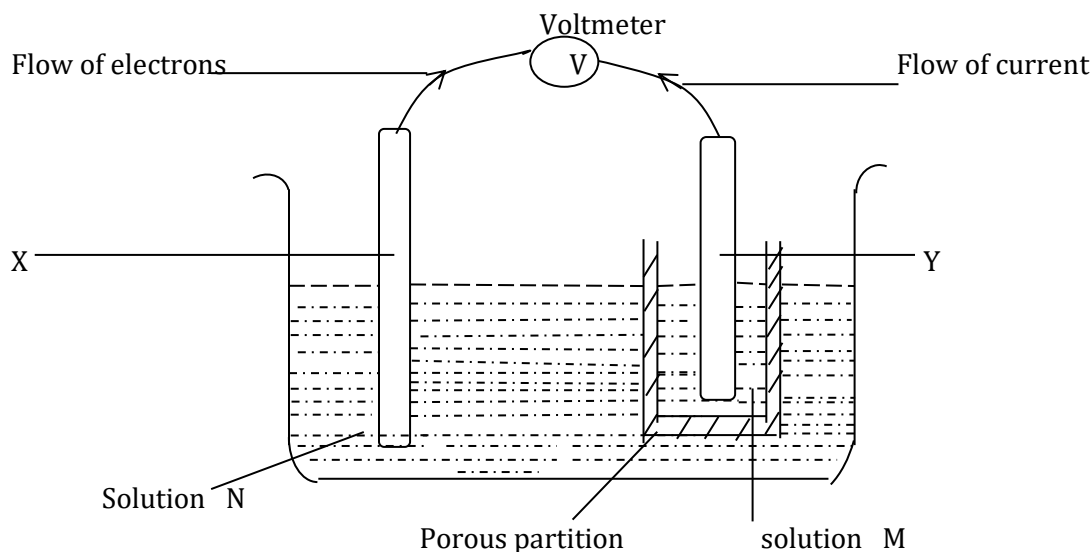
iii) The equation for overall reaction:



(c) State any two applications of electrochemical cells.

- In car batteries.
- In dry cell batteries.

(4) Given the cell diagram below consisting Zinc and Copper rod



(a) Which of rods X and Y is;

- i) Cathode: Y.
- ii) Anode: X.

NB, electrons flow from more electropositive metal (Cathode) to less electropositive metal (Anode) and Current flows in the opposite direction:

(b) Name;

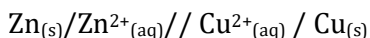
- i) N Zinc sulphate solution:
- ii) M Copper (II) sulphate solution:

(c) Write down;

- i) Half cell equation at X, $\text{Zn}_{(s)} \longrightarrow \text{Zn}^{2+}_{(aq)} + 2e^{-}$
- ii) Half cell equation at Y, $\text{Cu}^{2+}_{(aq)} + 2e^{-} \longrightarrow \text{Cu}_{(s)}$
- iii) The equation for complete cell.

$$\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \longrightarrow \text{Zn}^{2+}_{(aq)} + \text{Cu}_{(s)}$$

(d) Write the cell convention for complete cell.



(e) The above cell convention forms a Daniel's cell

Define a Daniel cell.

A Daniel cell is an electrochemical cell that consists of a zinc rod dipped in zinc sulphate solution and second half cell consisting of copper rod dipped in copper (II) sulphate solution and two solutions being of same molar concentration and connected by a salt bridge or porous portion.

FACT FILE;

The Daniel cell was invented by a British
Chemist John Frederic Daniel in 1836.

By , Mr. Ssemogerere hasems – chemistry dept 2015

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