Electrolytic Process

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Electrolyte :-

→ An electrolyte is a substance that produces an electrically conducting solution when dissolved into a polar solvent like water.

→ When electric energy moves through these type of solution they produce some chemical changes and this process is called electrolytic process.

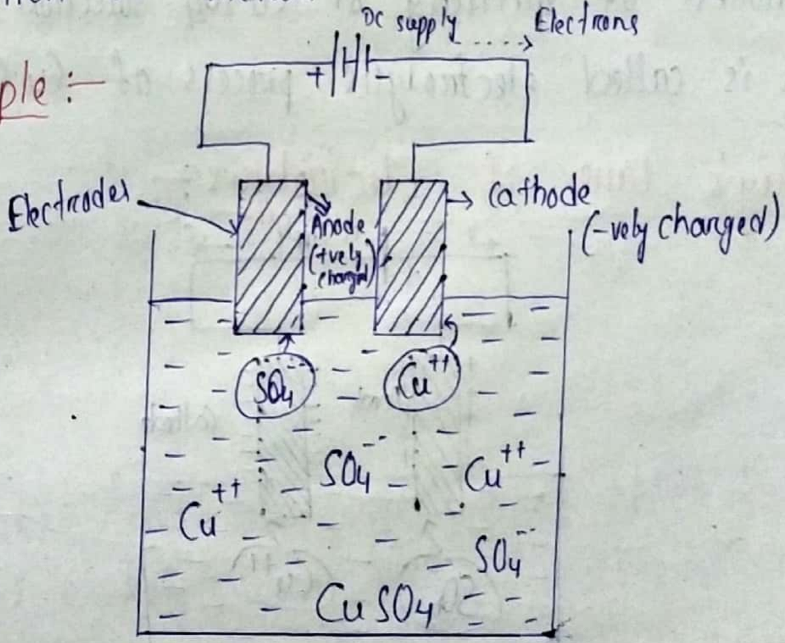
→ Some examples of electrolytic process are,

(i) Extraction of pure metals from their ores

(ii) Manufacturing of various chemicals.

(iii) Electro-deposition of metals

Basic Principle :-



→ Atoms of electrolytes are closely bound together but bond becomes weaker dissolved into a polar solvent like water.

→ The molecules of electrolytes splits up into two types of ion carrying electric charges called anions and cations.

→ These +vely and -vely charged ions are moving freely in the electrolytic solution.

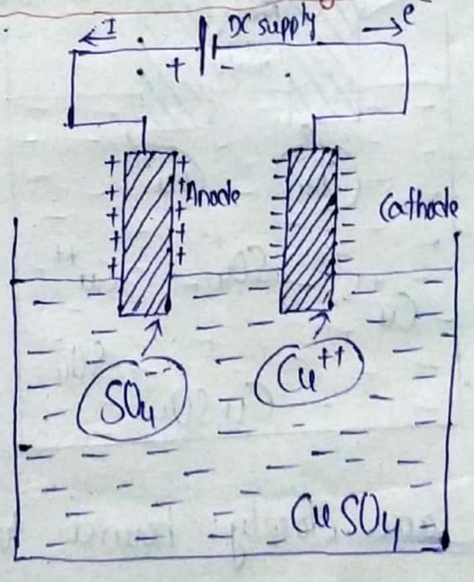
→ When two electrodes are dipped into the solution and connected with dc supply, ions associated with +ve charge are attracted by the cathode and ions associated with -ve charge are attracted by the anode. This process is called electrolytic process.

Ex:- * When $CuSO_4$ dissolved in water its splits into two ionic forms such as +vely charged copper ions (Cu^{++}) and -vely charged sulphate ions (SO_4^{--}) or sulphaion moving freely in the solution.

* When a potential difference is applied between two electrodes then +vely charged copper ions will move towards the cathode and -vely charged sulphaions will move towards the anode.

* The process of splitting of $CuSO_4$ solution into two types of charges is called electrolysis process of $CuSO_4$.

Faraday's Law of Electrolysis :-



This law governing the electrolysis process were formulated by Faraday. That's why it is called Faraday's law of electrolysis.

Faraday's 1st law :-

According to this law, chemical deposition due to flow of current through an electrolyte is directly proportional to the quantity of electricity passed through it i.e mass of chemical deposition is directly proportional to the quantity of electricity.

i.e $M \propto Q$

$\Rightarrow M \propto It \quad (\because Q = It)$

$$\Rightarrow \boxed{M = ZIt}$$

where 'I' is steady current in amperes flowing through the electrolyte in 't' seconds.

'Z' is constant of proportionality or electro chemical equivalent of substance

Unit of Z = kilogram / Coulomb

$= Kg/C$

$= Kg\,C^{-1}$

Faraday's 2nd law :-

This law states that when same quantity of electricity is passed through several electrolytes, the mass of substances deposited are proportional to the respective chemical equivalents.

Application of Electrolytes :-

(a) Electrotyping & Electroplating :-

The anode is made up of the metal to be deposited, whereas the cathode is one where the metal is deposited and both the electrodes are immerged in a suitable electrolyte.

(b) Refining of Metal :-

The impure metal is placed in anode. When dc supply is applied, the pure metal deposited in cathode.

(c) Extraction of pure metals from ores :-

Here the ore is treated with strong acid or melted and dc supply is passed through this solution, the solution is splitted and pure metal is deposited in cathode.

Current Efficiency :-

→ The current efficiency is defined as the ratio of actual quantity of substance deposited to the theoritical quantity.

i.e

$$\text{Current Efficiency} = \frac{\text{Actual quantity of substance deposited/liberated}}{\text{Theoritical quantity}}$$

→ Because of impurities the quantity of substance is slightly less than the calculated value.

→ This is taken into account by a factor called current efficiency. This value always lies between 90-98 %.

Energy Efficiency :-

The ratio of theoritical energy required to the actual energy required for depositting a given quantity of metal is known as energy efficiency.

i.e.

$$\text{Energy Efficiency} = \frac{\text{Theoritical energy required}}{\text{Actual energy required}}$$

Electro-Deposition :-

→ The process of depositting a coating of one metal over another metal electrically is called electro-deposition.

→ It is used for protective, decorative and functional purposes such as electroplating, electro forming, electro facing and for repair purpose.

→ There are several factors which affect the type of electro deposition are ;

(a) Nature of Electrolyte
(b) Current density
(c) Temperature
(d) Conductivity
(e) Electrolyte concentration
(f) Throwing power
(g) Polarisation

(a) Nature of Electrolyte :-

(i) The formation of smooth deposits largely depends upon the nature of electrolyte.

(ii) The electrolyte from which complex ions can be formed provides a smooth depositer.

(b) Current Density :-

(i) Current density is also responsible for the formation of deposits.

(ii) At low current density, the nature of deposits are coarse and crystalline in nature.

(iii) At high current density, the deposit of metal will be uniform and fine-grained. So the rate of formation of smooth deposits will only happen when the current density is high.

(c) Temperature :-

A low ~~to~~ temperature of the solutions favours formation of small crystals of metal. Whereas at high temperature, large crystals are formed. So a high temperature gives rise to a increased conductivity and high current density.

(d) Conductivity :-

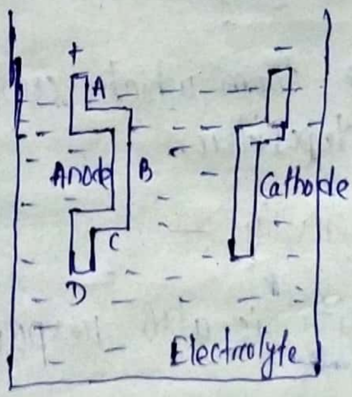
(i) The use of a solution of good conductivity is important from the view of economy and power consumption.

(ii) A electrolyte with good conductivity can give rise to a fine and smooth deposits.

(e) Electrolyte Concentration :-

A higher current density which is helpful for obtaining smooth and fine-grained deposits can be obtained by increasing the electrolyte concentration.

(f) Throwing Power :-



(i) The distance between two electrodes i.e anode and cathode is one of the important factor for electro-deposition.

(ii) The distance between various portions of two electrodes will be different due to their irregular shapes.

(iii) Due to unequal distance, the resistance of current path through the electrolytes for the various portions of cathode will be different but potential difference between anode and cathode will be same. That's why the current density will be more on the portion nearer to cathode and less on the far positions. This results an uneven deposits of metals.

Advantages of reverse current plating :-

→ Unsound and inferior metal is depleted during this period and flat level surfaces are produced.

→ Metal surface is brightened causing elemination of buffing a polishing operation.

Extraction of Metals :-

It is an electrochemical process for the production of metal with purity. There are two methods of extraction of metals.

→ Ore is treated with a strong acid to obtain a salt and solution of such a salt is electrolysed to obtain the metal.

→ Ore is available in molten state and is electrolysed in a furnace to get pure metal.

The methods used for extracting Zinc and Al.

Ore + strong acid ⟶ salt
↓
sol^n → Electrolyte

Mother state.

Metal to be extracted	Treatment of ore	Solution
Al	–	Fused cryolite
Copper	Roasted and treated with H_2SO_4	Copper sulphate.
Mg	–	Fused magnesium chloride or carnalite
Sodium	–	Fused sodium hydrite or sodium chloride and sodium nitrate.
Zinc	Treated with conc. H_2SO_4	Zinc chloride and Zinc sulphate.

Extraction of Zinc :-

Here aqueous solution of salt is used. The ore, Zinc oxide is treated with conc. H_2SO_4, roasted and passed through various chemical processes in order to remove impurities by precipitation. The zinc sulphate solution is then electrolysed is done in a large lead-lined wooden box having a no. of Al as cathode and lead as anode. Zinc gets deposited on the cathodes.

Current density on the cathodes = 1000 A/m^2

Voltage/cell = 3.5 V

no. of cells = 100 to 150 cells in series

Pressure = 500 V

Energy consumption = 3000 to 5000 kWh/tonne

Extraction of Aluminium :-

→ It is an example of fused electrolyte process

Aluminium is produced from bauxite containing aluminium oxide or alumina, silica (sillicon oxide) and iron oxide. The bauxite ore is first reduced to aluminium oxide by chemical treatment and then dissolved in fused cryolite. The mixture obtained is electrolysed in a large shallow rectangular steel bath lined with steel and carbon, projecting downward into the bath and the bottom of the bath forms cathode.

The liquid metal deposits at the cathode and settles at the bath bottom and is periodically siphoned out into large ladles from which it is ~~pound~~ poured into big moulds. The aluminium obtained by this process is 99.5% pure.

Energy consumption = 20 000 to 25000 units/tonne. This electrolytic process needs large amount of electric power and the process is contineous, so such plants are installed near hydroelectric power station. Temp. = 1000°C

Applications of Electrolysis :-

Electro-plating :-

It is an electrolytic process and is an art of depositing a superior or more noble metal on an inferior or a base metal by means of electrolysis of an aqueous solution of a suitable electrolyte.

eg:- Iron is a metal which can easily corroded by atmospheric air, moisture and carbon dioxide, so is coated with nickel or chromium electrolytically by electro-plating.

→ Picture frames and machinary parts are often chromium plated to protect them from corrosion.

→ To repair worn-out parts of a machinary.
→ For ornamentation and decoration purpose.

The electrolytic deposits are crystalline in nature. The crystals must be very fine in order to get firm, coherent and uniform deposits. For this purpose suitable electrolyte should be used and current density should have appropriate value. The article to be coated with the superior metal should be in as high a state of priority as possible.

Preparation for plating :-

(a) Removal of oil, grease or other organic material.
(b) Removal of rust, scale, oxides or other inorganic coating adhering to the metal.
(c) Mechanical preparation of the surface of the metal to receive the deposited metal.

Sequences :-

→ First soaps, hot alkali solutions or organic solvents such as gasoline or carbon tetrachloride are used.
→ Second various acids, alkali and salt solutions, mechanical abrasion and electrolytic cleaning.
→ Third mechanical abrasion and polishing is used.

Cleaning Methods :-

To get uniform deposits, the object to be electro-plated should be cleaned, polished and degreased. If not deposit formed may not be well adherant to the base metal and is likely to be peel off.

For smooth, bright and strong deposits, the surface upon which a layer of a noble metal is required should be thoroughly cleaned first mechanically by grinding or scratching or sand blasting and then chemically by treatment with hot alkalies (if greasy surface) or with dilute acids (if surface has oxide films) or with organic solvents.

Electrolytic Bath :-

→ For copper plating, two types of electrolytic baths are used.

(i) In acid type bath,

Solution → 150 - 200gm of $CuSO_4$ / 1000 cc + 25 - 35gm of H_2SO_4 / 1000 cc

Current density → 150 - 400 A/m^2

Temp → 25 to 50°C

Deposits → Thick and rough (Polishing required)

Anode - Copper

(ii) In cyanide bath,

Solution → 6gm of copper cyanide + 28gm of sodium cyanide + 6gm of sodium carbonate + 6 gm of sodium bisulphate

/1000 cc per each

Current density = 50 - 150 A/m^2

Temp = 25 to 40°C

Deposits = Smooth

Anode = Copper

→ For silver plating,

Solution → 24gm of Silver cyanide + 24gm of pottasium carbonate + 36gm of potassium cyanide

Current density = 50 - 150 A/m^2

Temp = 20 - 35° C.

Electric Traction

D.t - 29.01.2020

Electrical Traction:—

It means a locomotion in which the driving force obtained from electric motor.

Ex — Electric train, Trolly bus, Tram cars and diesel electric and gas turbine vehicles.

Ideal Traction System:—

(i) The maximum tractive effort should be exerted at the time of starting in order that a rapid acceleration may be attempt.

(ii) The equipments should be capable of overload for short period.

(iii) The wear cause on the track should be minimum.

(iv) The locomotive should able to run in any root.

(v) Breaking should be possible without excessive wear on the track shoe and possible of regenerative breaking.

Advantages of Electrical Traction:—

(i) It is the cheapest method from all other method of traction.

(ii) These are smooth acceleration and breaking.

(iii) It is free from smoke and flue gases.

(iv) Low maintenance cost.

(v) It can be started without any loss of time.

(vi) High starting torque.

(vii) Regenerative breaking is used which feed back 40% of energy.

(viii) Saving in high grade coal.

(ix) More passenger carry capacity at high speed.

(x) Less wear and tear of the track.

(xi) No need for providing extra generator and battery for fan and lights in the train.

(xii) Centre of gravity is lower.

Disadvantages :-

(i) High initial expenditure.

(ii) Failure of supply is a problem to face in electrical traction.

(iii) Electrically operated vehicle have to move only on electrified track.

(iv) Additional equipment is required for breaking.

(v) Protection are to be taken to prevents the disturbances to the near by telephone lines.

System of track electrification :-

(1) DC System

(2) AC System → 3-ϕ AC System
→ 1-ϕ AC system → At standard frequency (50 Hz)
→ At low frequency (16.666 Hz)
→ Kundu system (1ϕ to 3ϕ)

DC System :-

→ DC traction in India only present in some part of Mumbai and some part of Chennai.

→ Here operating voltage is 600 V dc for sub-urban railways and 1500 - 3000 V dc for main lines.

→ The motor receives power from own overhead lines with help of a pantograph and railway steel track is return conductor.

→ The substations are receive power from 3-ϕ, 66 kV / 33 kV / 11 kV and distance between the substation is 3 to 5 km for suburban areas and 40 to 50 km for main lines.

AC System :-

(a) 3-ϕ AC System -

→ This system employes 3-ϕ slip ring induction motor and speed control is being obtained by combination of pole changing and rotor resistance method.

→ Regenerative breaking is obtained immediately as speed exceeds the synchronous speed.

→ Here operating voltage is 3600 V and frequency is 16.666 c/s

→ The major disadvantage is use of two conductors and third being the railway track itself

1-ϕ Standard Frequency System :-

→ This system is also known as composite system of traction.

→ It is employed in India on South-North and East-south railway.

→ The system has a 1-ϕ overhead wire supplies 25 kV and 50 c/s.

→ The substations are supplied at high voltage upto 132 kV which is step down to 25 kV by transformer.

→ Driving force is obtained from dc series motor.

1-ϕ Low Frequency System :-

→ Here operating voltage is 1-ϕ, 15 kV and 16.66 c/s.

→ It is used in Germany, Sweden, Australia.

→ In some urban part of USA, the operating voltage is 11 kV and 25 c/s.

1-ϕ to 3-ϕ System :-

→ Here 1-ϕ high voltage AC system is employed for distribution network.

→ The locomotive convert 1-ϕ AC to 3-ϕ AC and 3-ϕ AC supplied to 3-ϕ induction motor.

→ Here operating voltage is 16 kV and 50 c/s.

→ It is used in Hungary.

Method of supply power to Railway station :-

(a) Overhead system

(b) Conductor - rail system.

Advantage of 25 kV AC for Railway Traction :-

(i) Due to high voltage less cross-sectional area of wire is required and shape of the transmission line is less catenary.

(ii) Distance between two substation is increased.

(iii) Switching and protection system is better as compare to dc.

Disadvantage :-

(i) It is not electrically stable.

(ii) It affects the near by communication lines.

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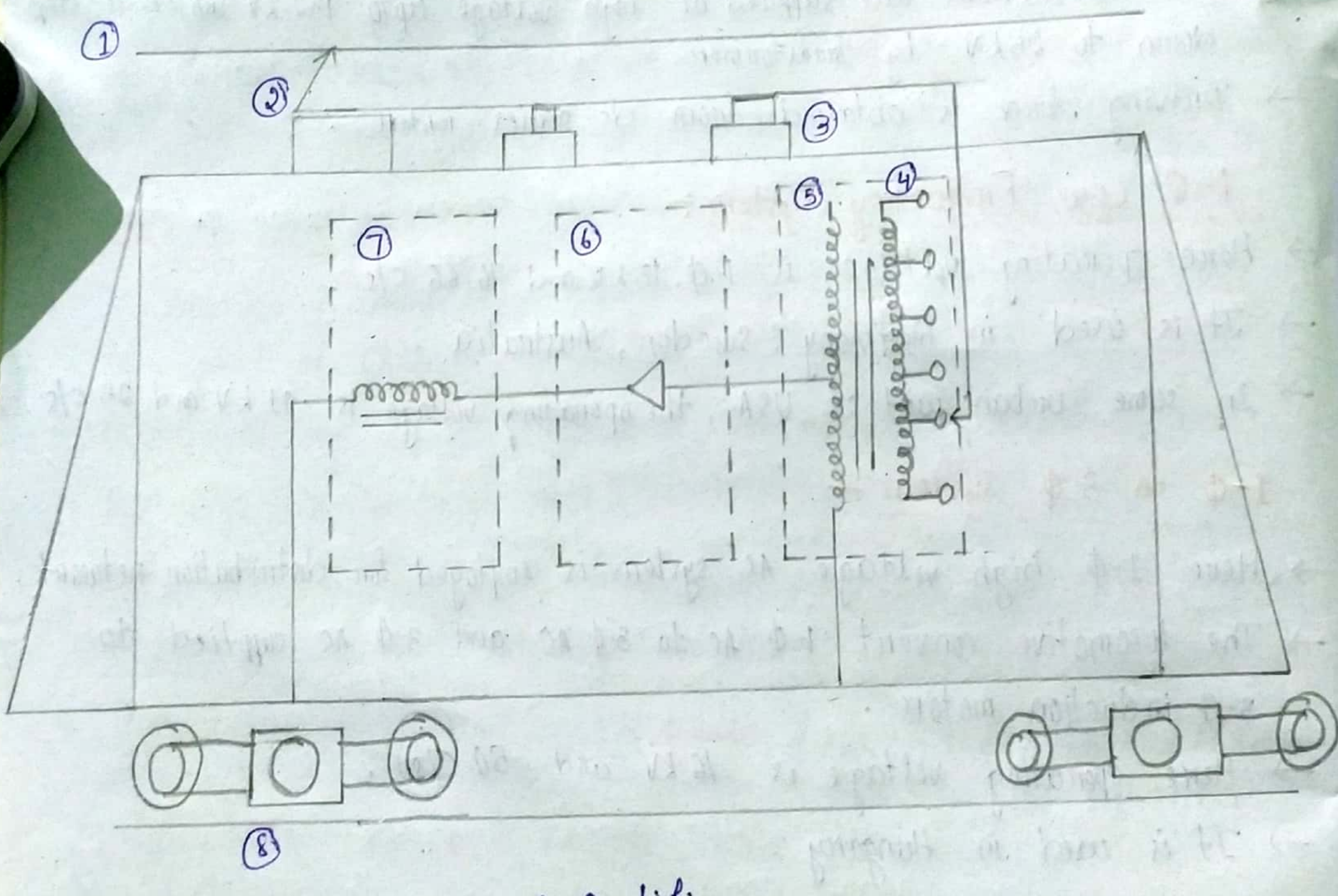
Block diagram of AC locomotive :-



1. Catenary
2. Pantograph
3. Circuit Breaker
4. OLTC
5. Transformer
6. Rectifier
7. Smoothing reactor
8. D.C motor

OLTC - On-load tap changer.

1. Catenary :-

(i) This is an overhead wire of special cross section.
(ii) The catenary is supplied at 25 kV, 50 c/s.

2. Pantograph :-

(i) This is a device used for collecting current from the catenary.
(ii) Pantograph is mounted on top of roof of a vehicle and carry a sliding shoe for contact with overhead catenary.
(iii) The pantograph is rised or lower when it required. It is controlled from the driver cabin by air pressure.

3. Circuit Breaker :-

The function of circuit breaker is to disconnect the engine from the line in case of some fault occur in electrical equipment of engine.

4. On-load Tap Changer (OLTC) :-

OLTC is used for varrying output voltage for controlling the speed of the motor.

5. Transformer :-

A tap changer transformer is installed in Locomotive for stepping down the voltage according to the requirement of traction motor.

6. Rectifier :-

Semiconductor rectifier is used for conversion of ac power to dc power.

7. Smoothing Reactor :-

(i) Smoothing reactor is used for removing ripple content on the output side of rectifier.
(ii) Dc voltage free from ripple is fed to the dc motor.

8. DC motor :-

Here dc series motor is used for driving the wheel of the locomotive.