# INORGANIC CHEMISTRY

## PAPER-V


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# CHAPTER-1 : ELECTROPLATING

**Electroplating:**

- **Theory**
- **Purpose Of Electroplating**
- **Nature Of Good Deposit**
- **Factors Influencing Electroplating**
- **Electroplating Of Chromium and**
- **Electroplating Of Gold.**

# ELECTROPLATING

**Electroplating is defined as-“ the process of deposition of coating metal on the base metal by passing a direct current through an electrolytic solution containing the soluble salt of the coating metal”.**

## Introduction:

- **Electroplating is an important technique widely used in industries for producing metallic coatings. The common coating metals used are Zn,Cu,Ni,Cr,Ag,Pt etc..**

- **Electroplating was first discovered by Luigi Brugnatelli in 1805, through using the electrodeposition process for the electroplating of Gold.**

## Examples:

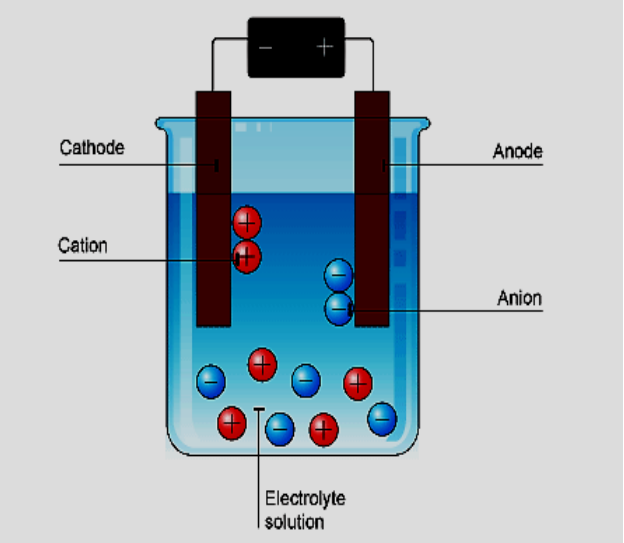
**Nickel plating, Gold plating, Chromium plating etc.,**

# ELECTROPLATING ..

**Electroplating is one specific type of electrolysis.**

- **Electrolysis is the process in which a direct electric current is passed through an electrolytic cell , chemical reaction takes place at the contacts between the circuit and the solution**

- **An electrolytic cell has three component parts:**
  - **Electrolyte: Cell filled with a suitable salt solution of the metal being deposited**
  - **Anode: A pure metal rod or plate.**
  - **Cathode: It is the object being plated.**

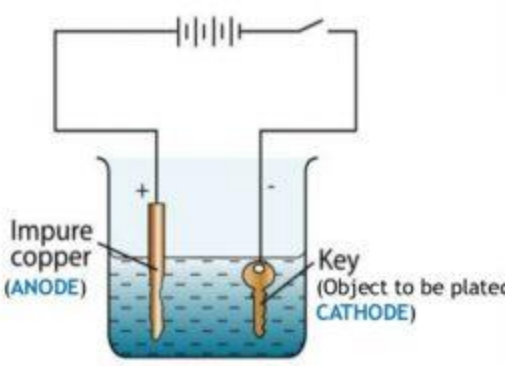


# ELECTROPLATING ..

- A solution of the desired metal which is to be coated (electrolyte) is taken in the beaker. Two electrodes connecting with the battery are immersed in it.

- One electrode is the article to be coated which is connected to negative terminal of battery (cathode)

- The other electrode is the (anode) pure metal whose coating is to be applied, which is connected to positive terminal of battery. The whole set up is known as electrolysis.

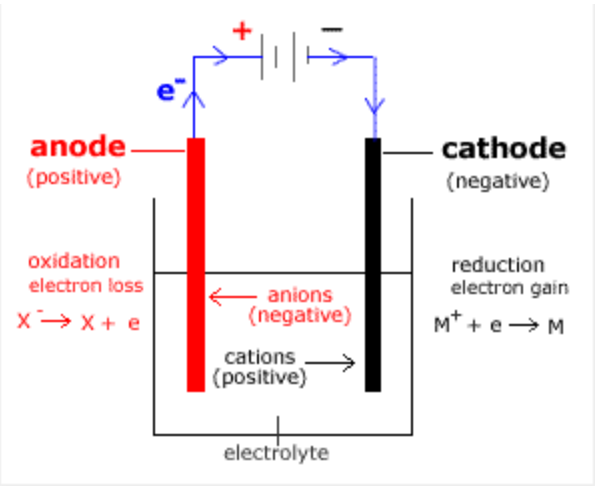


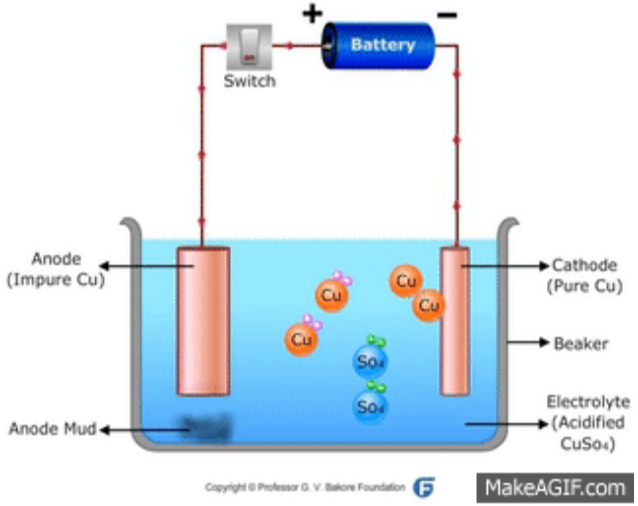
# ELECTROPLATING ..

**Upon electrolysis the anode metal dissolves as $Mn^+$ & the metal ions migrate to the cathode and get deposited there. Thus a thin coating of metal is produced on the article made as cathode.**

**Anode:** $M \xrightarrow[\text{(oxidation)}]{} Mn^+ + ne^-$ **(anodic dissolution of metal)**

**Cathode:** $Mn^+ + ne^- \xrightarrow[\text{(reduction)}]{} M$ **(cathodic reduction of metal)**



# ELECTROPLATING ..

**In ideal situation ,both the process takes place at the same rate and the concentration of $Mn^{+}$ ion in the solution remains a constant.**

**i.e., the rate at which the anode is dissolved is equal to the rate at which the cathode is plated.**

**The process of electroplating is continuous which provide uniform and smooth coatings.**

**Example:**

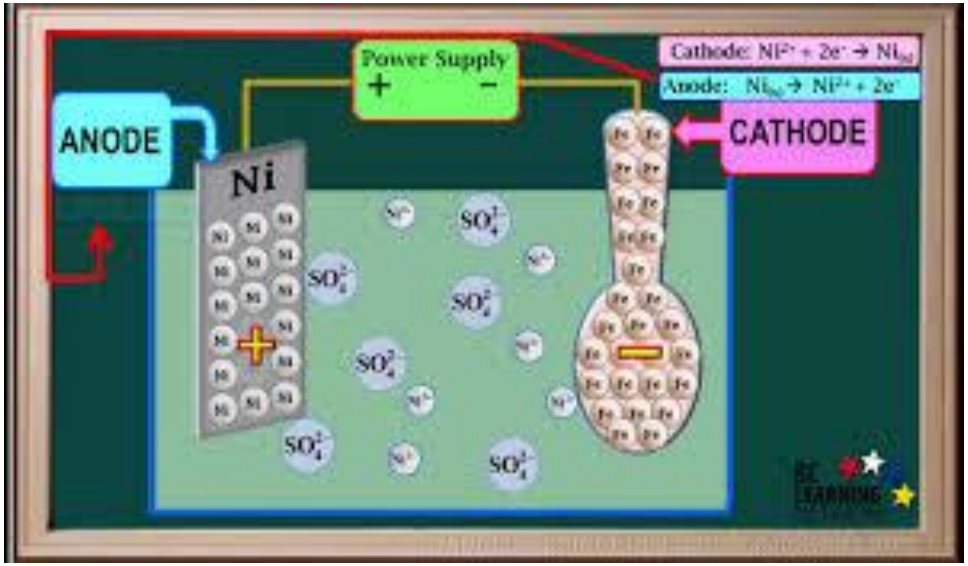
**Electroplating of Iron spoon with Nickel.**

**Here $Ni^{+}$ ions are being drawn to the surface of Iron spoon and is eventually become plate**

# ELECTROPLATING ..

**Anode:** $Ni \xrightarrow[\text{(oxidation)}]{} Ni^{2+} + 2e^-$ **(anodic dissolution of metal)**

**Cathode:** $Ni^{2+} + 2e^- \xrightarrow[\text{(reduction)}]{} Ni$ **(cathodic reduction of metal)**



# PURPOSE OF ELECTROPLATING

**There are so many fields in which the process of electroplating is used:**

- **Appearance:**

  **One the important purpose of electroplating is that, it enhances appearance of the objects i.e., to increase the commercial and decorative value of base metals . Electroplating gives smooth and attractive finish to the crude metal objects.**


- **Decorative purposes:**

  **Glass, cloth, porcelain leather wood, dried leaves etc.. are plated for decoration.**

# PURPOSE OF ELECTROPLATING ..

**Protection:**

**Protect the metal from environmental and atmospheric conditions such as corrosion.**

**Example:**

**Iron is likely to get eroded easily, in order to protect it from rusting, coatings of metal such as magnesium, zinc and aluminum are applied.**

# PURPOSE OF ELECTROPLATING ..

## Special surface properties:

- In incorporating some special surface properties. In providing mechanical properties to the metal requiring corrosion resistance under working conditions.

## Example:

- Internal combustion engines used in Aeroplanes.
- Chromium and Nickel plating is used when hardness is required.
- The machinery parts requiring corrosion resistance under working conditions are plated to avoid wear and also to improve engine performance.
- It also serves in providing many mechanical properties to the metals which it lacks such as magnetic properties, resistance, light absorption etc

# NATURE of GOOD DEPOSIT

**The following are the characteristics of a good deposit:**

1. **The deposit should have good adhesion and should be uniform.**
2. **The deposit should be hard and ductile.**
3. **It should have a fine-grained nature.**
4. **It should be bright and lustrous.**
5. **It should be continuous and non-porous.**

# FACTORS INFLUENCING

1. Metal-ion concentration
2. $P^H$ of the bath.
3. Temperature
4. Current Density

# FACTORS INFLUENCING..

## METAL-ION CONCENTRATION:

- Metal ion concentration plays an important role in the plating performance.
- In normal plating conditions, the increase of bath concentration will increase the concentration of metal ions in solution. Therefore, it will increase the deposition rate of the plating process.
- High metal ion concentration results in a coarse deposit.
- Fine adherent coating films can be obtained by a decrease in metal ion concentration.
- The low metal ion concentration in a strong solution of metal compounds can be achieved either by the addition of a compound with a Common ion or by using Complex compounds or ions as an electrolyte

# FACTORS INFLUENCING..

**Example:**

- **In Copper plating, a very low concentration of Copper ions in the electrolytic bath is obtained by using a solution of Sodium cuprocyanide, obtained by dissolving Cuprous cyanide in NaCN.**

$$NaCN + CuCN \rightleftharpoons Na[Cu(CN)_2]$$

$$Na[Cu(CN)_2] \rightleftharpoons Na^+ + [Cu(CN)_2]^- \rightleftharpoons Cu^+ + 2CN^-$$

- **Low concentration of Cuprous ions are formed through the formation of $[Cu(CN)_2]^-$**

- **This serves as a reserve of Cuprous ions and release Cuprous ions continuously for the deposition of Copper.**

# FACTORS INFLUENCING..

## $P^H$ OF THE BATH:

- The nature and appearance of the deposit depends on the $P^H$ of the plating bath. For a good electro deposit, the $P^H$ of the bath must be properly maintained.
- At higher $P^H$, precipitation of hydroxides of the metal takes place.
- At lower $P^H$, more hydrogen evolution takes place on the cathode, affecting the nature of the deposit i.e., resulting in burnt deposit.
- So optimum $P^H$ is maintained by using suitable buffers to get a good deposit.

## Example:

In Nickel plating, borate buffer is used to maintain the $P^H$ between 4.0-4.5

# FACTORS INFLUENCING..

## TEMPERATURE:

- Conductivity of electrolyte and rate of reaction at the anode increases with temperature, which are the favorable factors for electroplating.
- At a high temperature ,a coarse deposit is obtained.
- Usually a bright ,fine & granular deposit is formed at low temperature, but the rate of deposition becomes slow.
- Thus, an optimum temperature is maintained for a particular electrolyte to get a good deposit.

## Examples:

1. Electroplating of Copper – 20-40$^0$C
2. Electroplating of Nickel- 40-70$^0$C
3. Electroplating of Chromium - 45-60$^0$C

# FACTORS INFLUENCING..

## CURRENT DENSITY:

- Thickness of metal deposited by electroplating depends upon the current density, time and density of deposited metal.
- It is desirable to use a high current density in order to increase the rate of electrodeposition.
- Within certain limits, an increase in current density decreases the crystal size and the deposit produced in that range will be fine-grained and uniform but, when the current density exceeds the limiting value then there is a tendency to produce a rough, loose and brittle deposits.
- If the current density is low then the rate of electrodeposition will be low.
- Therefore , an optimum current density should be applied to have a better deposit.

- Example: Electroplating of Chromium – 10-20 ampere/$cm^3$

# ELECTROPLATING …

## Electroplating of Chromium.

## Electroplating of Gold.

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# ELECTROPLATING OF CHROMIUM ..

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# ELECTROPLATING OF CHROMIUM

**It is a technique of deposition of thin layer of Chromium onto a metal object.**

**Chromium is a widely plated metal.**

**Chrome plating is of two types they are:**

- **Decorative Chromium**
- **Hard Chromium**

**Prior to Chrome plating, it is essential to clean the surface of base metal**

**The following methods are employed to clean the metal surface.**

**1.Solvent Cleaning: Cleaning the metal surface by using organic solvents like $CCl_4$, Toluene, Xylene, Trichloroethylene.**

**2. Alkali cleaning: For removal of organic impurities.**

**3. Mechanical cleaning: For removal of oxide layer or rust & other inorganic deposits on the metal surface.**

**4. Pickling: Used for the removal of oxides by continued acid treatment**

# ELECTROPLATING OF CHROMIUM..

**Following cell is used for Chromium plating:**

**Anode** : **Lead-Tin alloy or Lead-Antimony alloy**

**Cathode** : **Article.**

**Electrolyte** : **Chromic acid ($CrO_3$) + $H_2SO_4$ (100:1 proportion)**

**Plating bath contains a solution of chromic acid and $H_2SO_4$. $CrO_4^{2-}$ ions present in the bath are in hexavalent state Cr(VI) and are reduced to $Cr^{3+}$ ions, which are coated as Cr on the cathode.**

**Temperature of the bath is maintained at 40-45˚C.**

**Current-density is maintained at $2.5 \times 10^{-2}$ amperes/$cm^2$.**

**Chromium plating produces a hard, corrosion resistant film with an attractive and bright deposit.**

# ELECTROPLATING OF CHROMIUM..

## 1. Hexavalent coating:

Plating bath contains a solution of chromic acid and $H_2SO_4$. $CrO_4^{2-}$ ions present in the bath are in hexavalent state Cr(VI) and are reduced to $Cr^{3+}$ ions, which are coated as Cr on the cathode.

**Reaction:**

$$4H_2CrO_{4\,(aq)} + 6\,NaHSO_{3\,(aq)} + 3H_2SO_4 \longrightarrow 2Cr_2(SO_4)_{3(aq)} + 3\,Na_2SO_{4(aq)} + 10H_2O$$

$$Cr_2(SO_4)_{3\,(aq)} + H_2O \longrightarrow Cr_{\,(s)} + O_2 + H_2SO_4$$

## 2.. Trivalent coating:

$$Cr_2(SO_4)_{3\,(aq)} \longrightarrow Cr^{3+} + SO_4^{2-}$$

$$2\,H_2O_{(aq)} \longrightarrow 4OH^- + 4H^+$$

Anode: $4OH^- \longrightarrow 2\,H_2O_{(aq)} + O_2 + 4e^-$

Cathode: $Cr^{3+} + 3e^- \longrightarrow Cr_{\,(s)}$

# ELECTROPLATING OF CHROMIUM..

**NOTE:**

1. **In Chromium plating the article is first electroplated with Copper and nickel and then with Chromium.**

2. **Insoluble anodes are used to maintain the Cr(III) concentration, as they oxidize Cr(III) to Cr(VI).**

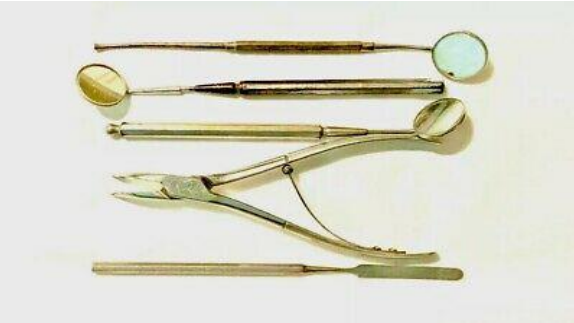
3. **In chrome plating,Sulphate ion provided by $H_2SO_4$ is believed to act as a catalyst.**

# APPLICATIONS

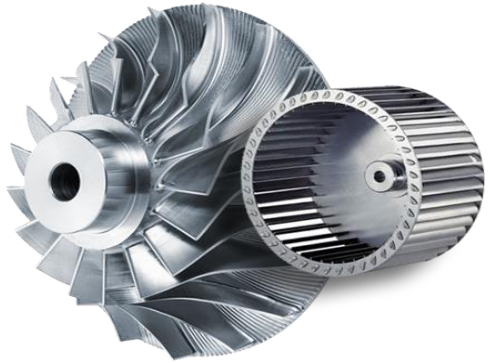
**It is extensively used in automobile industry, dental tools , in surgical instruments and in sanitary fittings.**

**It is used in parts of aircraft, textile & paper industry.**

**In engineering industry- in rods & pipes of hydraulic cylinders, railway wheel bearings , holders etc..**



**Dental tools**



**Aircraft part**

**Hydraulics**

# ELECTROPLATING OF GOLD ..

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# ELECTROPLATING OF GOLD

**It is a method of depositing a thin-layer of gold onto the surface of another metal most often Copper or Silver.**

**Gold plating is an easy technique, but before beginning the process the surface of the metal to be plated must be very clean.**

**Surface preparation includes the use of solvents, abrasive materials, alkaline cleaners, acid etching or combination can be used.**

## This is necessary for two reasons:

- **To improve adherence (dust and dirt)**
- **To keep the plating tank free of contaminants.**

# ELECTROPLATING OF GOLD ..

**Following cell is used for Gold plating:**

| | |
|---|---|
| **Anode** | **: Gold –also carbon, stainless steel and nichrome** |
| **Cathode** | **: Article.** |
| **Electrolyte** | **: $K[Au(CN)_2]$ + $Na_3PO_4$ (buffer)** |
| **Current-density** | **: 1-5x $10^{-2}$ amperes/$cm^2$.** |
| **Temperature** | **: 60-80˚C** |

**Gold is a stable metal and it takes harsh chemicals to dissociate and form ions. So gold is usually complexed with cyanide called Cyano aurate.**

**In order to get uniform, coherent deposit, low concentration of gold ions is required, which is done by using a complex cyanide bath for coating.**

# ELECTROPLATING OF GOLD ..

The direct reduction from the complex is generally considered as the most likely mechanism for the deposition from cyanide complexes.

i.e., $K[Au(CN)_2] \longrightarrow K^+ + [Au(CN)_2]^-$

$[Au(CN)_2]^- + e^- \longrightarrow Au + 2CN^-$


In the presence of various addition agents and by using a suitable current-density and temperature the colour and shade of deposit can be altered.

**NOTE:**

While plating the article, they are first electroplated with copper and then with gold.

# ELECTROPLATING OF GOLD ..

## Applications:

**Used for decorative purpose as in jewellary, watch-cases, pen-points etc..**