

3. Vedanta Aluminium Company	6. Madras Aluminium Company (Malco), Mettur, Salem Dist., T.N.	1965	40,000
	7. Bharat Aluminium Company (Balco), [Taken over by Vedanta in 1981]	1975	6,00,000
	Korba, Chhattisgarh		
8. Jharsuguda, Sambalpur, Odisha		2007	18,00,000

{ One of the world's largest Al-plants (except for China) }

## 226] EXTRACTION OF COPPER

↓  
Copper is the oldest metal produced by mankind (since about 10,000 years)

- Properties:
- 1) High electrical & thermal conductivity  
(~50% is used to make electrical conductors)
  - 2) It has good formability / workability / plasticity & Good alloying capability
  - 3) Has good corrosion resistance (due to ability to form alloys)
    - Cu-Zn
    - Cu-Sn
    - Cu-Ni

## 227] Ores of Copper

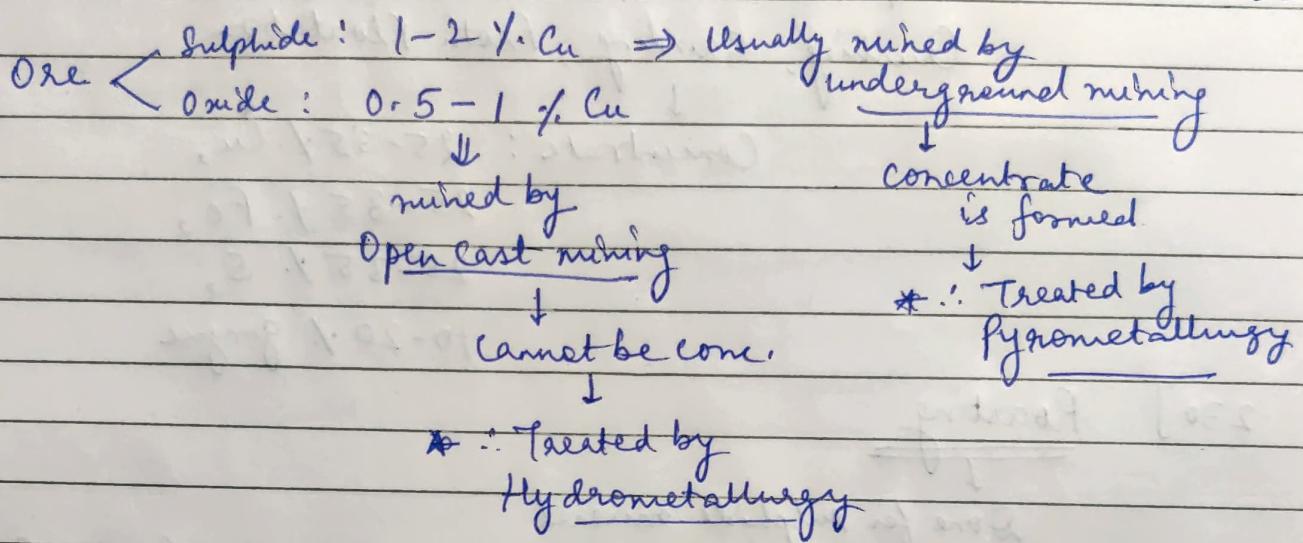
Earth's crust — 0.01% Cu only

> 90% is in the form of Sulphides

sulphide

Most important copper mineral — Chalcopyrite —  $\text{CuFeS}_2$   
 Chalcocite —  $\text{Cu}_2\text{S}$

Most imp. oxide copper mineral — Azurite —  $2\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$   
 Malachite —  $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$



{ NOTE: Pyrometallurgy will always be preferred whenever it is possible ]

### 228] Steps in Extraction of Copper (for sulphide ore, Pyromet.)

1. Concentrate of the ore
2. Roasting (may or may not be done) → used to be done earlier
3. Matte Smelting  
+  
Reverberatory Furnace or Flash Furnace ↑ nowadays it is optional
4. Converting (to convert matte to blister copper)
5. Refining (fire refining, electrorefining)

## 229] Concentration of Ore

Ore - 1-2% Cu

↓  
(conc. is reqd., otherwise  
slag will be so large that  
we can't extract metal)

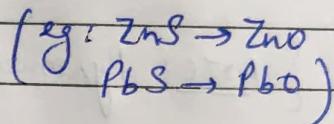
Crushing, Grinding, Froth Flotation

↓  
Concentrate : 25-35% Cu,  
25-35% Fe,  
25-35% S,  
10-20% gangue

## 230] Roasting

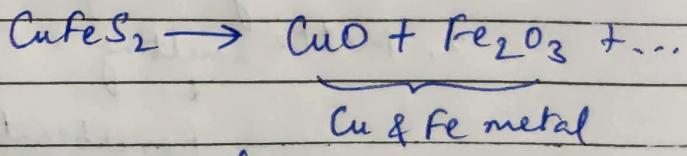
Done for sulphide mineral

Dead roasting → involves complete  
conversion of sulphide  
to oxide



but for Cu sulphides  
dead roasting is NOT done \*

↓  
∴ Dead roasting will give  
two oxides:

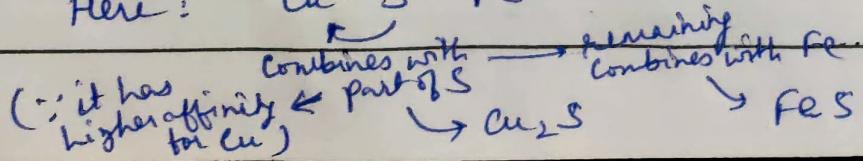


(these cannot be  
practically separated)

Whereas in matte  
smelting

↓  
500-700°C } partial roasting done

Here :  $Cu - S - Fe$



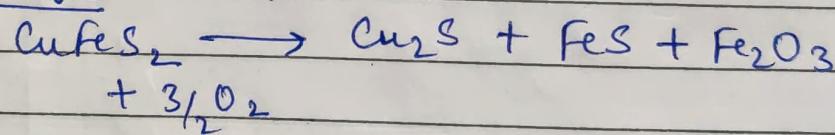
$\text{Cu}_2\text{S} - \text{FeS}$  & remaining Fe stays in the  
Matte form of oxide

Multiple Hearth Roaster  $\leftarrow$  (outdated now)  
Fluidized Bed Roaster

If smelting is done in  
Reverberatory furnace  
then Roasting is done  
but if  
Furnace  
Reason not done  
(since roasting &  
smelting are carried out  
in a single furnace)

{ Thus nowadays  
roasting is not done much }

### 231] Roasting



### 232] Matte Smelting

Objective: (i) liquid sulphide matte - Cu, S, Fe  
(ii) Liquid slag , free form copper

Matte : Solution of Cu & Fe

$\downarrow$   
after separation from  
smelting furnace it is  
subjected to converting

Slag forms an immisible layer

+  
& due to difference in density, slag floats  
& is removed

Reverberatory Furnace

↓  
was main furnace used earlier (for hundreds of years)

After this, Electric furnace → but nowadays even this is not used

↓  
& Nowadays Flash Furnace  
is used (since 1965)

\* { Lecture 42 is given in Manish Verma's Notes }

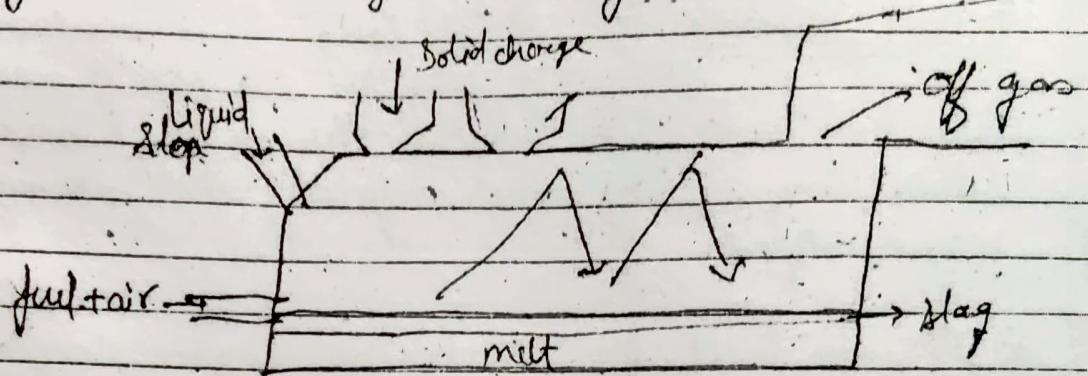
{ attached alongside this page }

## LECTURE 42 (28/04/2023)

Date \_\_\_\_\_  
Page No. \_\_\_\_\_

Lecture-Semifinal Matti Smelting

Reverberatory furnace (Used for over 100 years until 1965) →



This furnace is called reverberatory because of the reverboration of the heat. ~~the heat going~~

The height of furnace is low so after burning of fuel the heat reflects back to the charge.

\* Reason for becoming obsolete → (by blast furnace).

1) High fuel consumption.

2) Low concentration of  $\text{SO}_2$  in the off gas ( $2-3\% \text{ SO}_2$ ) with it not possible to recover  $\text{SO}_2$  and due to this it was let off in the atmosphere and produce pollution. (Economical)

\* Despite it, it is very versatile (any type of charge can be added (lumpy fine mix), or ore could feed (can be fed, even the liquid slag coming out can be recycled)).

\* Any type of charge can be given

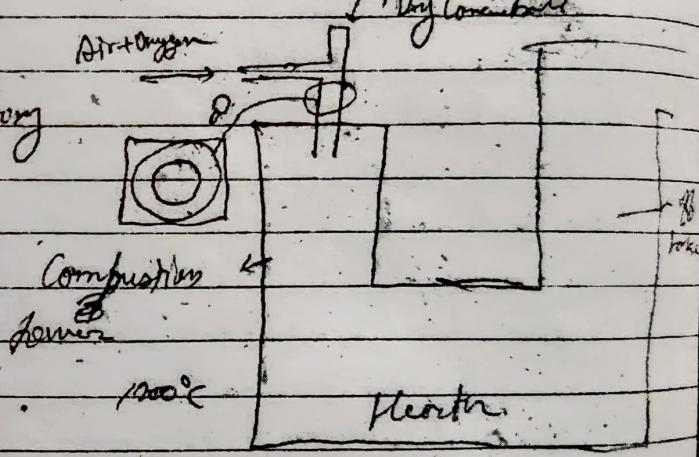
\* Even the slag in liquid slag can be fed.

Use of pre heated charge, enriched oxygen, better SO<sub>2</sub> recovery and <sup>heat</sup> to sulfide for a longer time.

Flash Furnace → It has long been realized that instead of going in two steps of roasting and smelting, roasting heat gets wasted thus a single step method is a better way. By combining it, the ~~present~~ flash furnace was developed.

It was built by Outokumpu copper company in 1950 in Finland.

After 1965, no new reverberatory furnace was built only flash were built.



As soon as it comes inside the combustion zone, it burns in a flash, but the particles take time to hit the surface and by the time they fall there is enough heat to melt them.

Here the charge must be dry and sized particles otherwise it will stick in the pipe.

Advantages →

Energy cost (fuel) is very much reduced because the heat of oxidation of sulphides taking place in combustion furnace is enough for smelting. (Even if it is not)

(burners are provided).

2) Rich  $\text{SO}_2$  is produced (10-15%) and thus the recovery becomes easy.

### Limitations →

1) It is not versatile like a reverberatory furnace.

2) Copper losses in the slags are high (slag contains 0.7% I<sub>2</sub>) rather than reverberatory (0.3-0.5%). It is due to low settling time (in reverberatory, there is a long time to settle down of metal).

3) Low settling flame.

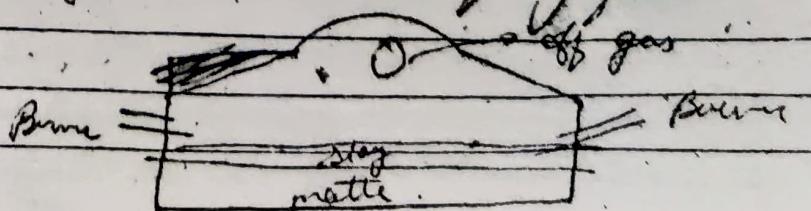
4) High magnetite concentration.

5) High grade of the matte is maintained (60%) (even little loss will be high % copper loss).

Due to this, slag is treated separately.

\* INCO Furnace → (International Nickel Company of Canada)

Commercial oxygen (95% to 98%) is used for burning the concentrate.



because of it. Advantages are →

4) The off-gases contains very high  $\text{SO}_2$  (% 80-88%)

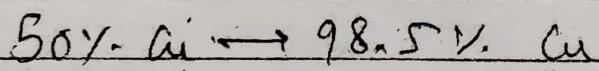
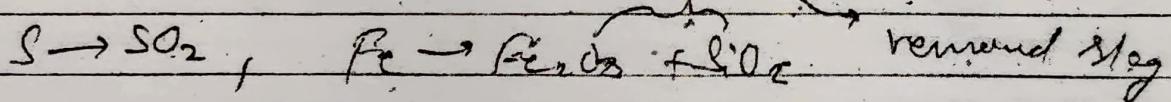
Drawbacks →

1) The temperature near the burner is very high and due to it the refractory is required.

\* After the matte is produced, the next step is converting.

(Converting (Copper matte to Copper metal)) →

$\text{Cu}-\text{Fe}-\text{S}$  both iron & sulphur gets oxidised to remove



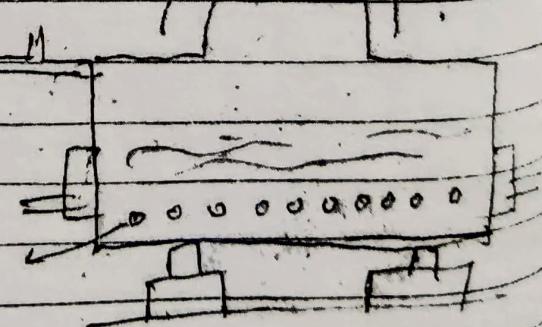
off-gases

It is done by blowing air

The molten matte is charged in the barrel shaped converter.

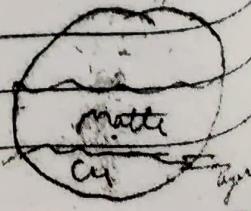
Converser. It is provided in a saddle and air is provided through the tuyers.

Tuyers



Tuyers are provided in the slightly slanted fashion rather than at the bottom like Bessemer converter.

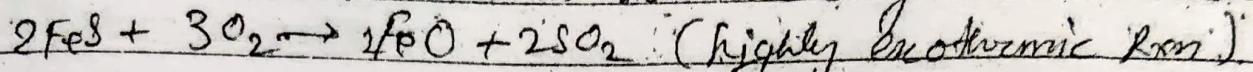
Br



The converter is known as Pierce Smith Converter.

The oxidation of the matte ~~is~~ takes place in two steps

(i) Slag forming stage.  $\rightarrow$  Initially the matte consists of  $\text{MnS}$  &  $\text{FeS}$ ; when oxidation is done  $\text{FeS}$  first oxidises

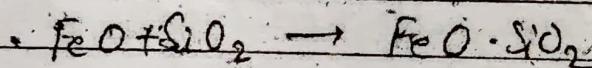


$$\Delta H_c = -256 \text{ kCal}$$

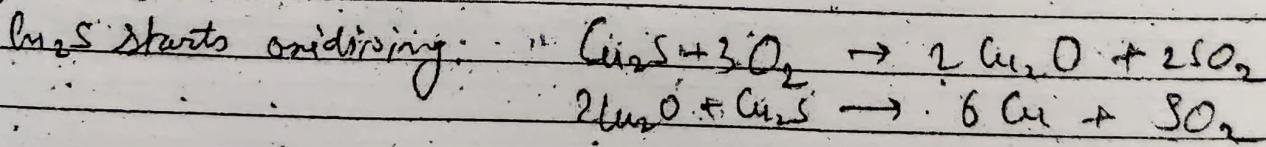
It is also an autogenous reaction.

Enough heat is produced to continuously keep the molten matte condition.

At the same time, flux is added ( $\text{SiO}_2$ ) which reacts with  $\text{FeO}$  to form the slag. The slag is then removed (done 4-5 times).



(ii) Copper Blowing Stage  $\rightarrow$  The left  $\text{Cu}_2\text{S}$  is known as whitomel. Because it appears as a white metal in molten state.



\* Reason that the blowing is done not from bottom & from sides  $\rightarrow$

As the air is blown, heat is produced only if it passes through matte & if it is produced through metal, it will cool it down & ~~lose~~ heat without.

This copper is known as blister copper.

After it 0.1% S & 0.5% O is still present in there with some other impurities.

When it solidifies, S & O combine to form SO<sub>2</sub> and they do not get enough time to escape and forms blow holes & blisters on the surface. It also makes copper very weak & uneven.

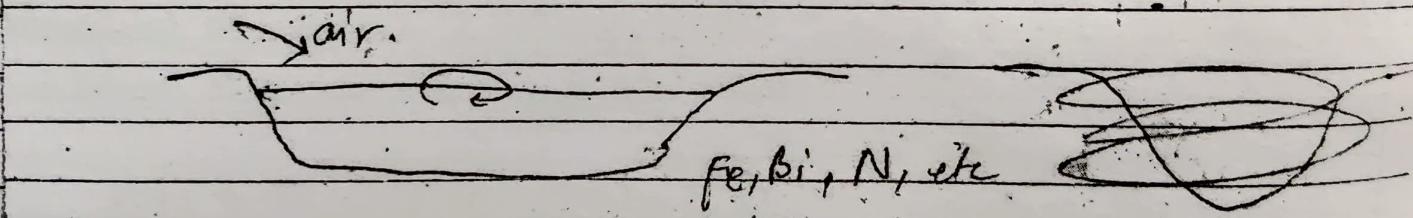
#### 4. Refining of Blistered Copper 98.5% → 99.99%

Refining is done in two stages →

(i) [Fire refining] followed by (ii) [Electrorefining]

(D) It is done by the preferential oxidation of the impurities like S, As, Fe and removing them.

It is done by either putting in heart furnace & allowing it to contact with air & stirred



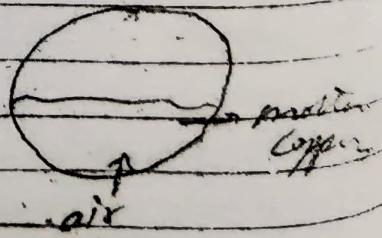
More recently the process is done by blowing air

The oxygen content of metal increases as the air is blown.

It is done in two steps.

(1) Oxidation of impurities (Open Heart)

(2) Deoxidation of bath (done by putting green loggers)



### Decarburization

Wooden logs produce CO<sub>2</sub>, etc and sulphur etc are removed. It is known as Piling.  
The logs are known as Poles.

Nowadays it is done by passing methane ~~after~~ or natural gas.

After fire refining. 98.5% → 99.5%

↓  
Electro refining.

## Lecture 43 (29/04/2023)

233] Blister copper : 98.5% Cu

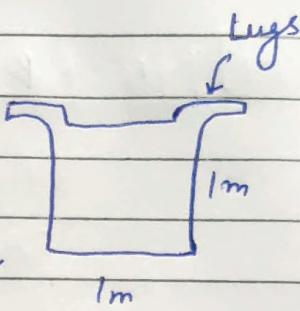
we need 99.99%.

fire refining  $\rightarrow$  99.5%

Electrorefining  $\rightarrow$  99.99%.

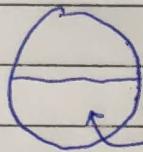
Done in  
two steps

Oxidation      Deoxidation of Cu



S  $\rightarrow$  0.05-0.01%  
O  $\rightarrow$  0.6%

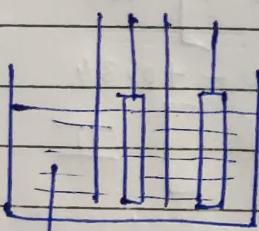
Weight of these  
anodes  
is  $\sim 350$  kg



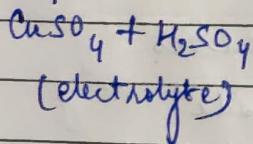
→ rotary furnace

Natural Gas,  
Methane ( $\text{CH}_4$ )

Molding wheel  $\Rightarrow$



(Previous  
metals like  
Ag, Au, etc.  
remain in Anode)



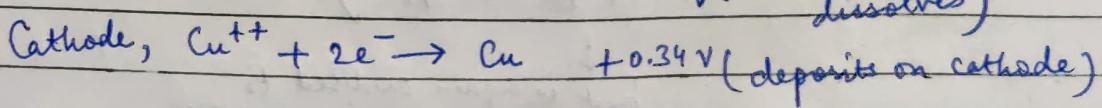
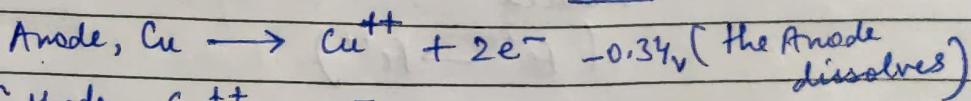
remain in Anode

called

"Anode Sludge")

234] Electrorefining of Copper

$E^\circ$



$$\therefore \text{Theoretical voltage} = 0V \Rightarrow \boxed{E^\circ_{\text{cell}} = 0V}$$

But due to other factors, such  
as resistance of bath, anode & cathode,  
bus bars & electrolyte



$$\text{Actual voltage reqd.} = \underline{0.2 - 0.25 V}$$

### 235] Impurities in Anode

(after ~99.5%  
what are the remaining 0.5%?)

These are in  
3 groups!

Group I: Fe, Ni, Co, ...

due to higher  
values

they remain in  
inside electrolytic  
cell

& their conc. keeps  
increasing

Emf series

Fe ] I  
Ni  
Pb

H - O ] III  
Sb  
As

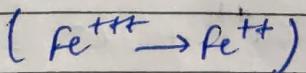
Bi  
Cu - +0.34  
Ag ] II  
Au

Due to this: (i) Resistance of electrolyte increases

(ii) They contaminate the cathode

(due to physical occlusion)

(iii)  $\text{Fe}^{+++}$  gets preferentially reduced i.e. getting "stuck"



but is again oxidised to  
Ferrie iron

leading to decrease in current efficiency

Group II : Precious metals like Ag, Au, Pt, etc.

↓  
They do not dissolve from Anode  
(i.e. they remain there)

They get collected { as "Anode Sludge"  
at the bottom of electrolytic cell  
\* OR "Anode Mud")  
↓  
& is later removed while cleaning the cell.

Group III : Sb, As, Bi

They dissolve along with Cu

↓  
& also have a tendency to deposit on Cathode along with Cu

236] Electrolyte

40-50 g/L Cu —  $CuSO_4$

175-225 g/L  $H_2SO_4$

+ Impurities, Temp — 60-65 °C

Current Density (C.D.) — 1.7-2.4 asd

Each Anode : 350 kg

In 25-30 days → Anode gets completely dissolved

Within this same amount of time, 2 cathodes are produced : Cathode - 100-150 kg

237] Extraction of Copper from Oxide Ores  
by Hydrometallurgy

> 20% Cu is extracted  
by Hydrometallurgy



A great boost  
to hydrometallurgy  
has come from  
development of Solvent Extraction

1-5 kg Cu / cubicm — Earlier  
done through  
Cementation

Electrowinning (E.W.) but this Cu was  
↓ very impure and needed

40-50 kg Cu / cubicm. ↓ to be  
pure < 90% refined by Pyrometallurgy)

238] Hydrometallurgy of Copper

Steps: 1) Preparation of Ore — Commination  
( sulphide ore → dead roasting ) Crushing  
Grinding

2) Leaching — Vat In-situ  
— Agitation Heap Leaching

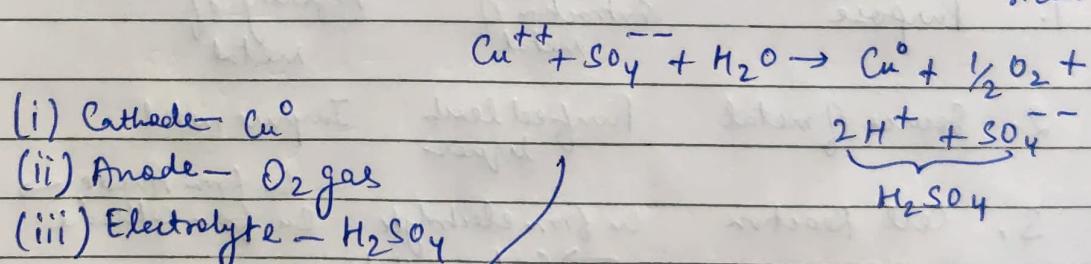
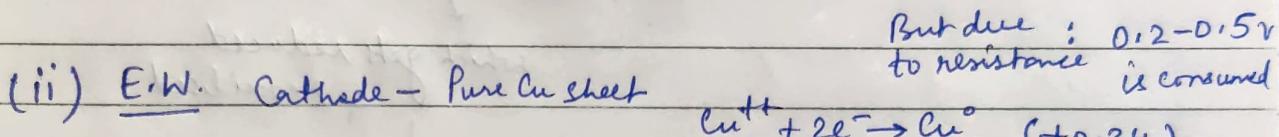
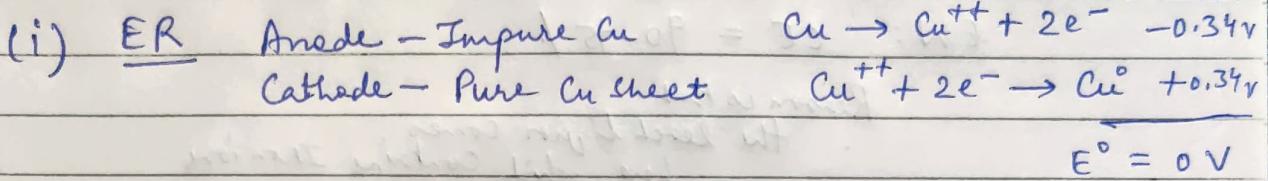
3) Purification and Concentration

1-5 Cu → 40-50 kg cu / cubicm

4) Recovery of metal from Solution  
( Leach liquor ) ← Cementation,  
E.W.

## 239] Electro-winning of Copper

{ Electrowinning - E.W.  
Electrorefining - E.R. }



\* Here Sulphuric acid is generated, which is taken out of the electrolytic cell

Here, the actual measured voltage reqd. is

2-2.5V → which is around 10 times greater than in case of ER

## 240] In presence of Fe ions in electrolyte

ER: C.E.  $> 95\%$ ,  
 (current efficiency)

EW: CE = 90-95%

Reason is that

the leach liquor comes here, which contains Iron ions

which gets reduced & reoxidised

this continuous process consumes current

Thus, C.E. is decreased.

## 241] Comparison of EW and ER of copper

<u>Item</u>	<u>EW</u>	<u>ER</u>
1. Purpose	Extraction of metal	Refining of metal
2. Source of metal	Purified leach liquor	Impure metal
3. Cell Reaction	Cu from electrolyte → Cu from cathode	Cu from Anode → Cu from cathode
4. Cell Voltage	$E_{\text{cathode}}^{\circ} - E_{\text{Anode}}^{\circ}$ ~ higher	$E^{\circ} = 0$
5. Power Consumption	Higher (8-10 times)	Lower
6. Electrode (Anode)	Insoluble	Soluble
7. Electrolyte	Higher metal ion conc.	Low metal ion conc.
8. Purification of electrolyte	Before E.W. (needs to be purified only once)	Needs to be purified during ER
9. Anode residue	NIL	Anode Sludge/mud
10. Application	Hydromet. Production	Pyromet.