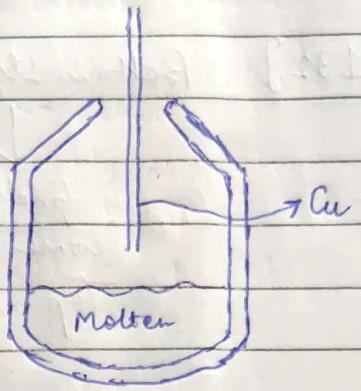


cylindrical vessel

Here, water cooled Lance  
is introduced  
from top



There is 99.5% O<sub>2</sub>

Out of total weight  
of charge

25-30% scrap can be → process  
taken care of completed  
within:



∴ 100-300 tons  
can be produced  
per hour

20-25 mins :- refine  
time

30-35 mins ← tap-tap  
time  
("tap to tap")

## POST-MINOR 2

### LECTURE 30 (28/03/2023)

#### 135] Changing pattern of steel making

1) Bessemer

2) Open Hearth → quality of products  
↓ was better

but consuming

lot of fuel & taking

↓ too much time

& too much capital  
reqd.

3) LD process (Oxygen steel  
making) → significantly  
better

but it also  
had its limitations

## Limitations of LD process

(i) Not proper mixing

(entire charge not thoroughly homogenized)

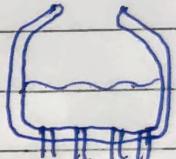


thus, composition & temp.

was not homogeneous

4.) In 1967 → Bottom Blowing

this solved the earlier limitation of improper mixing



OBM,

(Oxygen Bottom Melting)

Q-BOP

(Quiet-Basic Oxygen Process)

## Limitations of bottom blowing

(i) construction & maintenance of tuyeres

(ii) High H<sub>2</sub> content

although it acts as reducing agent

it also dissolves in steel

→ leading to

(iii) High Refractory consumption near tuyeres

## Hydrogen Cracking

5) Combined Blowing

(a) Top & bottom blowing of O<sub>2</sub> ← this was done initially

involves distributing O<sub>2</sub> from top

& only a small part

of it is blown from bottom

reducing the problems of bottom blowing

(a) Top & Bottom O<sub>2</sub> blowing ~ called Combined Blowing

(b) Top O<sub>2</sub> & Bottom Ar

(inert gas) ~ called

Hybrid Blowing  
OR

Bath Agitated Process  
OR

LBE (Lance Bubbling Equilibrium)

[136] In general we can say:

A. Oxygen Steel making

(i) LD, LD-AC

(ii) Bottom Blowing - OBM, Q-BOP

(iii) Combined Blowing

Most new  
steel plants are  
either using

OR

This is the  
most popular

Combined blowing  
Hybrid process

O<sub>2</sub> top  
& bottom

B. Electric Steel Making

- Electric Arc Furnace

[137] Changing Pattern of Steel Making

{ % Steel Produced }

Year	Bessemer	OH	BOP	Electric Steel
1950	10	80	—	10
1970	—	41	43	16
1990	—	15	57	28
2000	—	10	60	30
2010	—	< 2	66	32
	(In some places like Russia still used bcz of ease of use of melt)			
2020	—	—	60	40

{Expected in future : — — 55 45 }

→ electric will increase

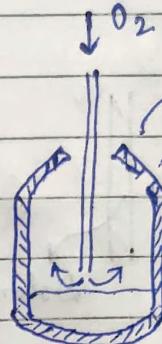
NOTE: India is largest producer of DRI in the world.

### 138] LD Steel Making (BOF)

LD: Linz-Donowitz

Basic principles of LD steel making:

cylindrical vessel



the mouth is smaller & can be eccentric or concentric

→ Tap hole

→ or BOF

\* O<sub>2</sub> is blown at supersonic speed

tip of the lance

~ 1-1.5 m height  
(it doesn't touch the molten metal)

In Bessemer: gas bubbles pass through metal

but → Here gas is blown from top

that does NOT happen here

20-25 mins : refine time  
30-35 mins : tap-tap

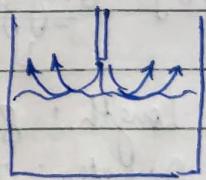
High Reaction Rate:

Reason: Lot of splashing occurs when O<sub>2</sub> hits molten metal

lot of volume of CO is produced also

due to which small droplets of Emulsion or foam (consisting of metal-slag-gas) is formed inside the converter

leading to high rxn. rate

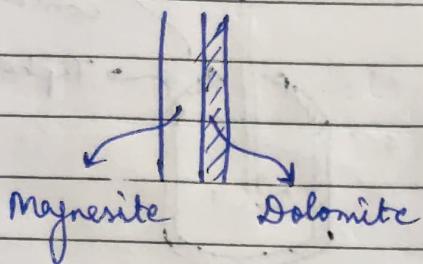


139] Steel plates present

\* & refractory lining is present →  
↓ (refractory bricks)

otherwise  
steel itself  
will melt  
due to high  
temp.

Magnesite refractory  
layer present  
initially,  
over which a layer of  
Dolomite is present



Once the refractory  
lining is melted  
it can last upto 100-300 heats

(after which when  
refinery is turned off

{ Generally there  
are always 3 vessels  
↓ at any time  
it can be changed  
(replaced) }

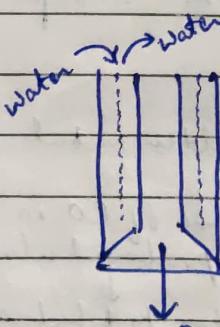
2 are in use  
& 1 is in repair }

140] Oxygen Lance

Length: 8-10 m

Diameter: 20-25 cm

The lance can  
be taken out  
very quickly if needed



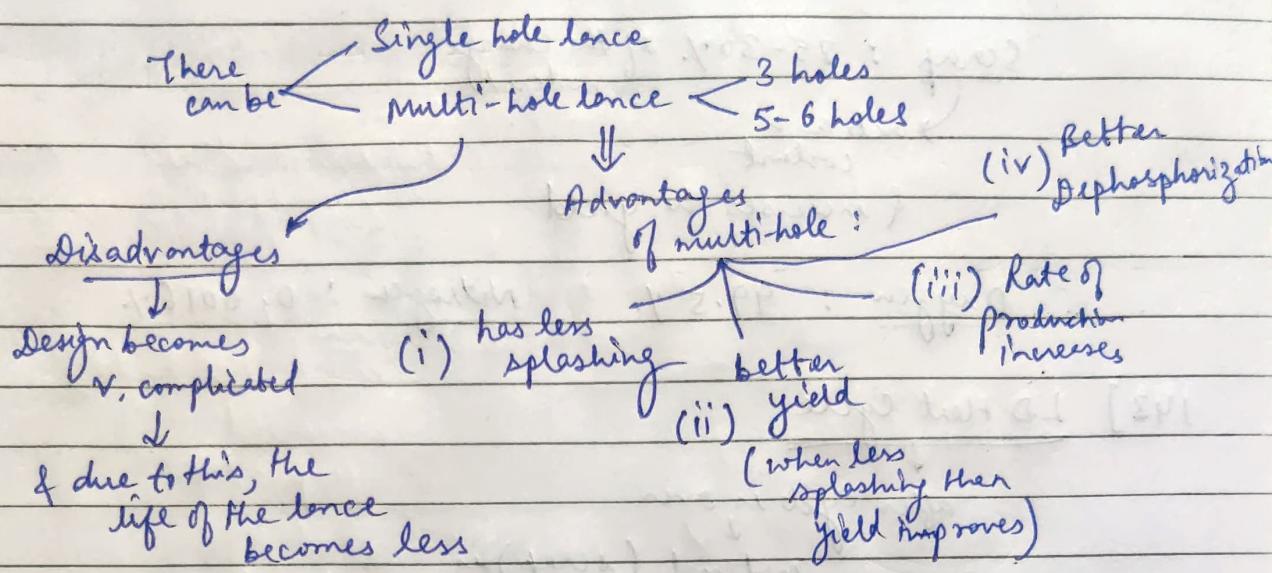
2-3 metres  
of lower end is  
made of concentric  
Copper pipes

↓  
& water  
cooled plates  
are provided

O<sub>2</sub> (comes from  
inner pipe)

(to prevent any damage  
to it, in case such a  
situation arises

or else it could even  
lead to a blast)



#### 141] Waste Gas Handling

At point where gas impinges

temp. of  $2500^{\circ}\text{C}$  to  $3000^{\circ}\text{C}$  may be produced

at point where gas impinges

$\downarrow$  1% of Iron gas blown off

NOTE: An accident happened in Rourkela Steel plant

dust from fumes settled on roof of the plant & accumulated over time

the roof collapsed one day, killing several workers

it was later realized that the extremely heavy weight of dust was responsible for the roof collapse.

this went unnoticed

LECTURE 31 (29/03/2023)

#### 142] Raw material (in LD converter)

$\text{CaCO}_3 \xrightarrow{\text{Calcined}} \text{CaO}$  is used

P should not be  $> 0.5\%$ .

Burnt Dolomite  $\rightarrow$  used as flux

Scrap : 25-30% of the charge material

acts as a coolant

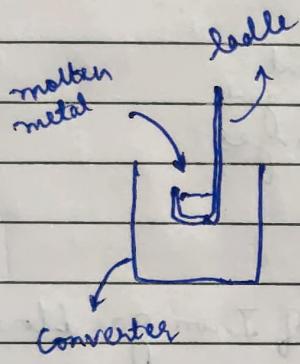
& increases the yield

Oxygen : 99.5%, Nitrogen : 0.0016%

### 143] LD Heat Cycle

after cycle is over

material (scrap) is brought to raw material section



it is shaken a little

and then the scrap is melted & the liquid metal is poured into the Converter

with the help of a ladle

The height of the oxygen lance can be varied (nowadays it is computer controlled)

(by fitting the ladle)

this process occurs for 25-30 mins

then the converter is tilted & a small sample (as a pellet) is taken out for analysis

Finally end point is reached

then converter is tilted & the slag is removed

then metal is removed from tap hole carefully

(without removing slag)

Deoxidation is performed

(using deoxidizers

such as Fe-Si, Fe-Mn, etc.

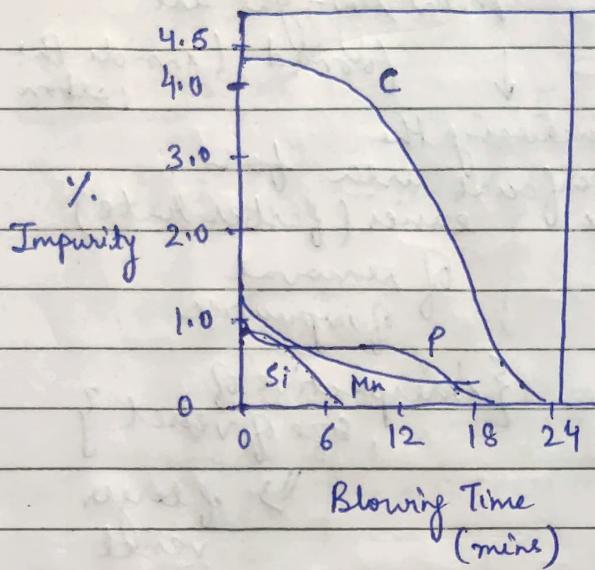
which are added in calculated quantities

Alloying

(Alloy addition)

may be done, in case high alloy steel needed

144] Refining during LD Process



Silicon  $\rightarrow$  removed  
at v. fast rate (within 6 min)  
after getting oxidized

Mn  $\rightarrow$  initially rate is high  
but gradually the rate slows down

slows down later due to increase in temp. & due to increase in basicity } In acid bath removal is good } But in basic it is slow }

C & P  $\rightarrow$  removal is simultaneous in oxygen converter  
 $\downarrow$   
at lower temp. the rxn. does not occur

P removal initially is slow but gradually increases (after 5-8 min) due to formation of basic slag

Rate of oxidation of impurities is v. high in oxygen converter (without any bubbling formation) due to the oxygen jets which impinge on molten metal

Due to these jets  
↓  
Foam / Emulsion of  
metal-slag-gas are  
↓ formed (inside the carbon)  
thus increasing the  
interfacial area for  
easier (faster rate)  
of removal  
of impurities.  
{ irrespective of  
size of vessel }  
→ if larger  
vessel  
↓  
we will simply  
use larger quantity  
of oxygen

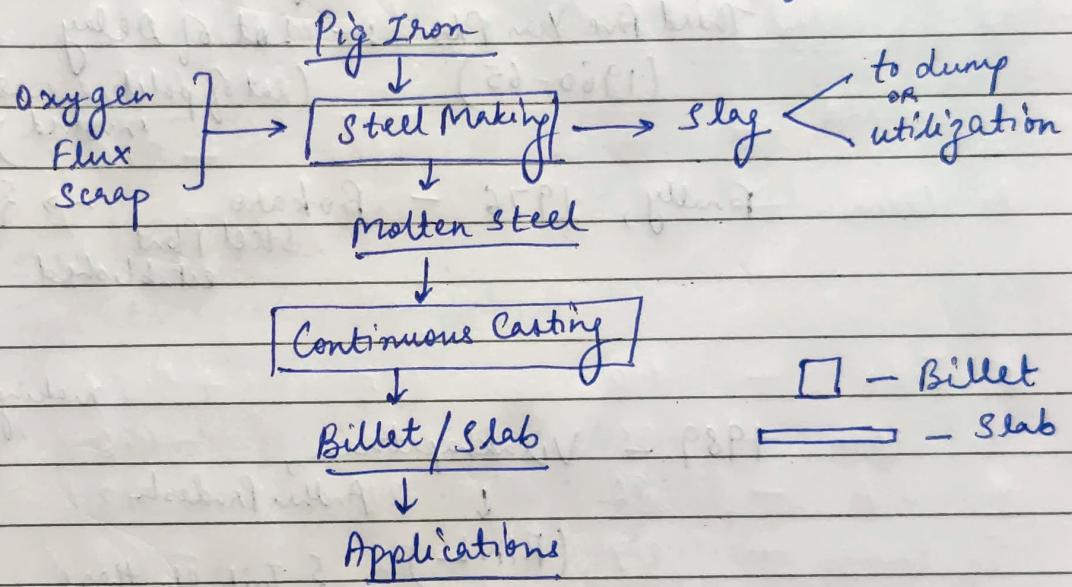
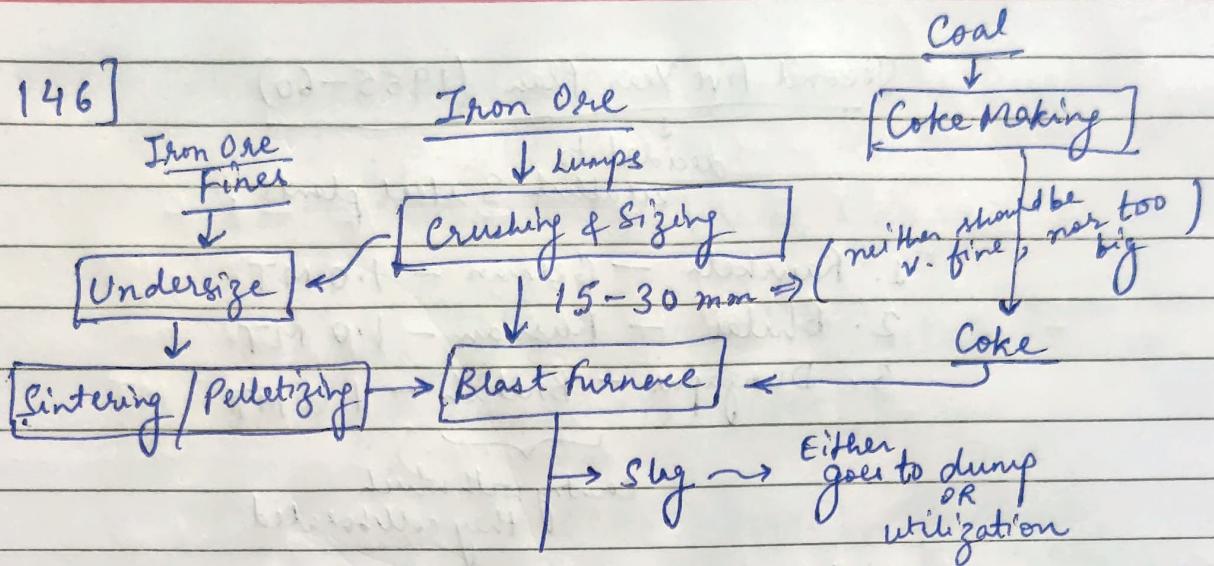
145] Along with C removal  
dephosphorization  
also takes place

↓  
but this only occurs till  
the emulsion is present

But after carbon has been removed  
the emulsion is no longer present  
↓  
& thus dephosphorization stops

{ Thus we need to ensure  
that dephosphorization  
gets completed  
before complete C  
removal }

146]



147]

### Iron and Steel Industry in India

Historical { Wootz steel  
Delhi's Iron Pillar

Modern Steel

1908 - Jamshedji Tata : TISCO

1912 - Production started

1912 - Bhadravati, Karnataka,  
Vizvavaya I & S Ltd. (VISL)

1936 - Indian Iron & Steel Co.

(IISCO),

1955 - TISCO, IISCO  
& VISL

Burnpur (Asansol),  
West Bengal

## Second Five Year Plan (1955-60)

decided to establish 3 steel plants:

1. Rourkela - German - 1.0 MT
2. Bhilai - Russian - 1.0 MT
3. Durgapur - British - 1.0 MT

country with which they collaborated

## Third Five Year Plan :- Lot of Delay

(1960-65) (lot of politics was involved)

Finally, 1976 - Bokaro Steel Plant established → { huge amount of politics was involved before its establishment }

1989 - Visakhapatnam, Andhra Pradesh  
(RINL)

{ Initially these were under a company named HSL (Hindustan Steel Ltd.) }

Later renamed to SAIL

{ Steel Authority of India Ltd. }

LECTURE 32 (31/03/2023)

## 148] Major Steel Plants in India

### A. Public Sector

(a) Steel Authority of India Ltd. (SAIL)

Present capacity (mT)

1. Bhilai Steel Plant, Bhilai, Chhattisgarh - 7.5
2. Durgapur Steel Plant, Durgapur, W.B. - 2.2
3. Rourkela Steel Plant, Rourkela, Orissa - 4.2  
→ (L.D. process was used here)
4. Bokaro Steel Plant, Bokaro, Jharkhand - 5.8
5. Indian Iron & Steel Co. (IISCO), Burnpur, W.B. - 2.5
6. Visvesvaraya Iron & Steel Co (VISL), Bhadravati, Karnataka - 0.2  
→ (charcoal B/F was used here earlier)
7. (b) Rashtriya Ispat Nigam Ltd., Visakhapatnam, A.P. - 7.3

### B. (c) Private Sector

8. Tata Steel, Jamshedpur - 10.0  
(earlier called TISCO)
9. Tata Steel, Kalingnagar, Orissa - 3.0
10. Tata Steel BSL (Bluson Steel Ltd.), Angul, Orissa - 5.6
11. JSW Steel, Haripet, Bellary, Karnataka - 12.0  
(earlier stood for: Jindal Steel Works)  
but now called: Jindal South West  
→ \* (largest steel plant uses Corex process)
12. JSW Ispat Steel, Dolvi, Maharashtra - 3.0
13. JSW Bluson Steel, Samalpur, Orissa - 2.5
14. Jindal Steel & Power Ltd. (JSPL),  
Jharsuguda, Orissa - 3.6  
Raigarh, Chhattisgarh }  
} (largest coal based sponge plant)
15. JSPL, Angul, Orissa - 6.0
16. Essar Steel Ltd., Hazira, Suret, Gujarat - 10.0

### 149] All Steel Plants

Two categories

1. Integrated Steel Plant → B/F - BOF  
→ 2 MT
2. Mini Steel Plants, DRI - EAF / Induction F/c  
(i.e. Direct reducible iron) → 0.5 - 2 MT

### 150] World Steel Production (in mT)

	2021	2022	% change
World	1952	1880	-3.6%
1. China	1032	1010	-2.1% (China for the first time has had a 'minus' sign here)
2. India	118	125	+5.9%
3. Japan	96	90	-6.6%
4. USA	86	81	-5.8%
5. Russia	77	72	-6.5%

### 151] Hydrometallurgy

It is the production of metal from an ore/concentrate

\* This process of selective dissolution is called Leaching → by its selective dissolution in a solvent (generally or mostly an aqueous sol.)  
and then, recovery of metal/compound from the purified solution. (in 99% cases)

Hydrometallurgy also involves  
↓  
recovery of metal from  
scrap or metallurgical waste.

& also recovery  
of precious metals (like Gold, Silver, etc.)  
from Electronic waste

### 152] Major steps in Hydrometallurgy

1. Preparation of ore/concentrate  
for leaching
2. After preparation — leaching of the ore/concentrate
3. Separation of the leach liquor from  
the residue
4. Purification of the leach liquor
5. Recovery of the metallic value from the  
leach liquor.

### 153] Hydrometallurgical treatment

↓  
mainly carried  
out for low grade ores

→ i.e. ores that  
can't be treated  
\* by Pyrometallurgy

(otherwise the first  
choice is always  
Pyromet.)

e.g.: Copper ore

Sulphide - 1% Cu — Concentrate: 30% Cu — Pyromet.  
Oxide - 1% Cu — cannot be  
\* concentrated

∴ We need  
Hydromet.

## 154] Advantages and Limitations

### Advantages of Hydrometallurgy

- 1) They are ideally suited for i.e. hydromet. methods Lean & Complex ore
- 2) There is greater control over each & every step (unlike pyromet) while, hydromet. is a slow process
- 3) Recovery of valuable metals as by-products
- 4) Handling of ores is easier
- 5) Environmentally better
  - for sulphide ores
  - In pyro In Pyro In Hydro
  - ↓ ↓ ↓
  - $\text{SO}_2$   $\text{CO}_2$  produced produced
  - Also transport of  $\text{H}_2\text{SO}_4$  is very cumbersome
  - elemental sulphur is produced
- 6) In pyromet. Hot coke is required
- 7) In Pyro high capital investment, large scale products
- 8) Hydromet. carried out at Room temp.
- 9) Pyromet. cannot be used for Reactive and Refractory metals (e.g.: Al) (e.g.: W, Ti, Mo, etc.) i.e. high melting pt. Thus, there is lesser corrosion
- 10) Last step of Hydromet. is Electrowinning which produces V. high purification (& refining further is not required, unlike pyromet.)

## LECTURE 33 (01/04/2023)

### 155] Limitations of Hydrometallurgy

1) Requires v. large volume of relatively dilute solution

(∴ Here output is v. small per unit vol.  
∴ It is v. large)

2) Many chemicals used in hydromet. are expensive & must be regenerated

& they are also used in large quantity  
thus if they can't be regenerated then the economics may not work out

3) The chemicals are v. corrosive & poisonous

(e.g.: In Gold leaching NaCN & KCN (are used)  
highly poisonous)

5) Electricity is used at the end

extremely high consumption of energy

(It is the most energy consuming step)

thus energy consumption overall is high despite the process being at room temp.

\* NOTE! Despite these limitations

the advantages outweigh the disadvantages

thus, use of hydromet. is increasing.

## 156] Steps in Hydrometallurgy

### 1. Preparation of Ore

it is not directly treated by solvent after mining

(i) Size reduction : Smaller the size of particles

Crushing, grinding

If ore is porous

not much crushing/grinding is reqd.

larger the surface area

(or interfacial area)

& thus greater rate of rxn.

\* should not get too fine

as it will make particles that won't settle down easily

& also higher energy will be reqd. in crushing so much

### (ii) Conversion to Soluble form

e.g.: Sulphides  $\rightarrow$  not directly soluble

$\therefore$  They are converted to soluble form

by Roasting  $\rightarrow$  oxide form is easily soluble

e.g.:  $CuS \xrightarrow{\text{converted}} CuO$

e.g.:  $Zn, Mo, Co, etc. \rightarrow$  (which is easily soluble)

### (iii) Concentration

The volume and weight decreases  $\rightarrow$  thus leaching becomes easier

(as requirement of solvent decreases)

Many times while  
doing concentration  
↓  
gangue minerals  
also get removed

e.g.: Gold ore  
subjected to  
concentration → to make  
leaching easy  
(since they are in v. small  
quantity : 2-3 g / ton of ore)

### 157] Steps in Hydromet.

2. Leaching → "Selective dissolution"

↓  
to relatively  
dissolve the reqd. ore  
minerals &  
leave gangue minerals  
as residue

### 158] Factors affecting choice of solvent

1. Chemical character of material & gangue

2. Cost of reagent (or solvent)

↓ should be inexpensive { since it is  
used in large quantity  
& it is also wasted }

3. Selective leaching

↓  
should only dissolve ore  
minerals

& NOT the gangue minerals

4. Ability to regenerate

↓  
e.g.:  $H_2SO_4$  is regenerated  
during the electrolytic (EW)  
process

e.g.:  $NaOH$  is regenerated  
during bauxite leaching

5. Corrosive nature of solvent  
↓  
should not be highly  
corrosive  
( bcz if it is too corrosive  
then we should choose  
↓ vessel that is appropriate  
eg: Aqua-Regia will dissolve  
everything including  
the vessel  
itself )

### 159] Different Solvents

1. Water : Used for water soluble  
↓ minerals

eg:  $\text{CuSO}_4$ ,  $\text{ZnSO}_4$ , chlorides, borates,  
etc.

↓  
(water) it is also used when  
v. large quantity  
dissolution is taking place  
( & large quantity of  
solvent is reqd.)

eg: In-situ condition, } → f it  
Dump condition, etc. } can be  
left for  
along time  
to dissolve  
them

\* { In Commercial  
situations : Water is almost  
never used  
↓  
bcz it has v. low  
dissolving power }

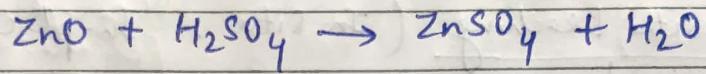
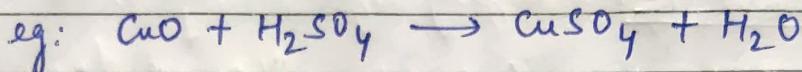
2. Acids → Most common  
solvents

These are  
Among them also :  $\text{H}_2\text{SO}_4$  (Sulphuric acid)  
is most commonly used

(we generally use dilute  $\text{H}_2\text{SO}_4$ )

The advantage  
of  $H_2SO_4$  is

↓  
we don't require fine grinding / crushing  
(as it can easily dissolve them even if not fine)



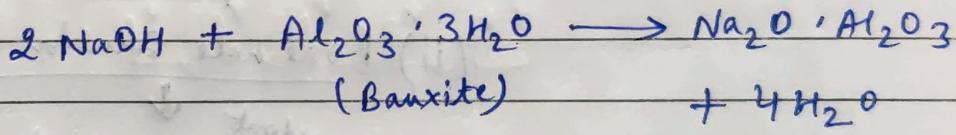
It is also regenerated during electrolysm :  $CuSO_4 + H_2O \rightleftharpoons Cu + \frac{1}{2}O_2 + H_2SO_4$

3. Bases : eg:  $NaOH$ ,  $Na_2CO_3$ ,  $NH_4OH$

↓  
 $NaOH$  is the most commonly used

(eg: In Bayer Process )

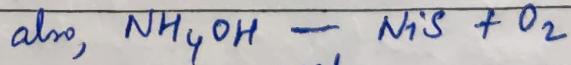
Sodium Aluminate



{ Takes place at high Temp.,  
High Pressure in Autoclave }

Also used for

Carbonaceous minerals :  $NH_4OH + O_2$ ,  $Na_2CO_3$  — Cu-oxides, carbonates

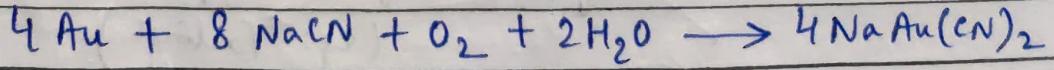


used for

(since Au doesn't dissolve in others early)

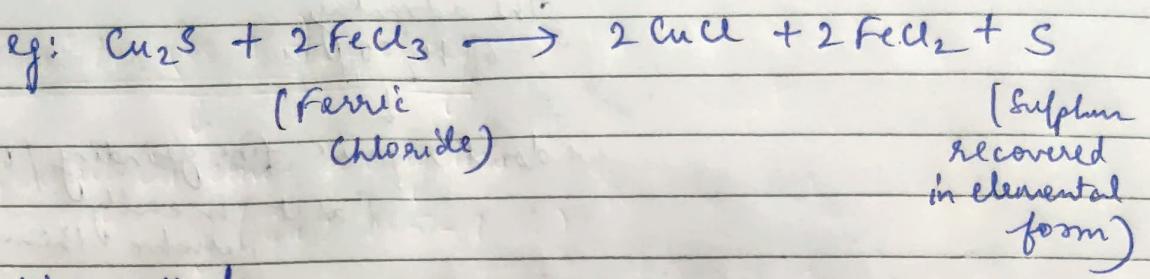
4. Aqueous Salt Solution :

eg:  $NaCN$ ,  $KCN$  → used for Gold leaching



\* But since  $NaCN$  &  $KCN$  are poisonous nowadays they are being replaced by  $Sd. Thiosulfate$ , etc.)

+  $4 NaOH$



## [160] Leaching Methods

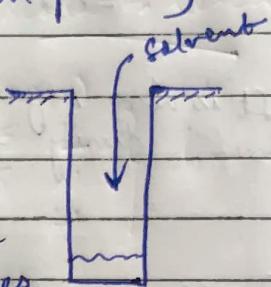
### 1. In-situ Leaching (In-situ : "In-place")

↓  
also called

"Solution Mining"

often done  
in Old Mines

(i) (i.e. abandoned  
mines)



~~(in open-cast mines)~~ OR

(ii) Boore hole Solution mines

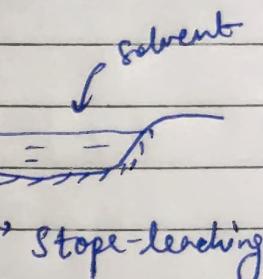
pump down  
↓  
solvent

(i.e. making  
a hole & pump out  
instead of  
digging)



fracture  
(due to explosives  
that blasted the  
rock)

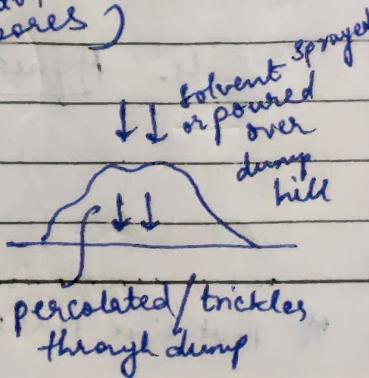
so that solution  
can go into the  
pores



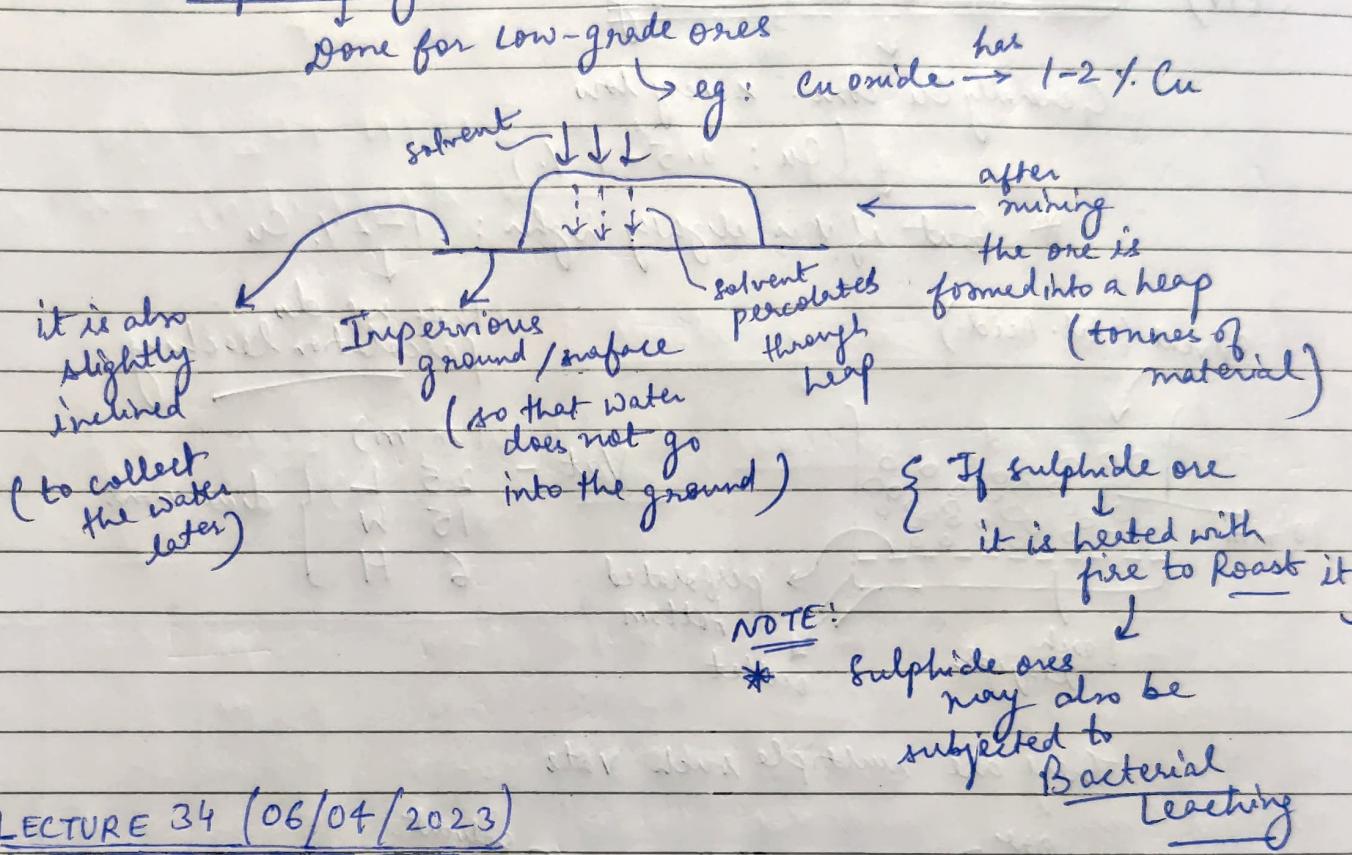
### 2. Dump Leaching

done for recovery  
of minerals from "dumps"

(e.g. Tailings)



### 3. Heap Leaching



LECTURE 34 (06/04/2023)

## 161] Leaching Methods

- (i) In-situ leaching
- (ii) Dump leaching
- (iii) Heap leaching

we have discussed all these

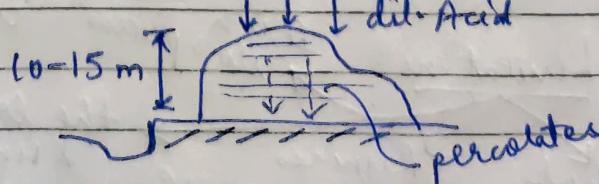
old mines

slope leaching

Aphalt Plastic Sheet

Mine waste  
concentrated waste (Tailings)

Bore-hole solution leaching



162]

(iv) Percalation (or Vat) Leaching

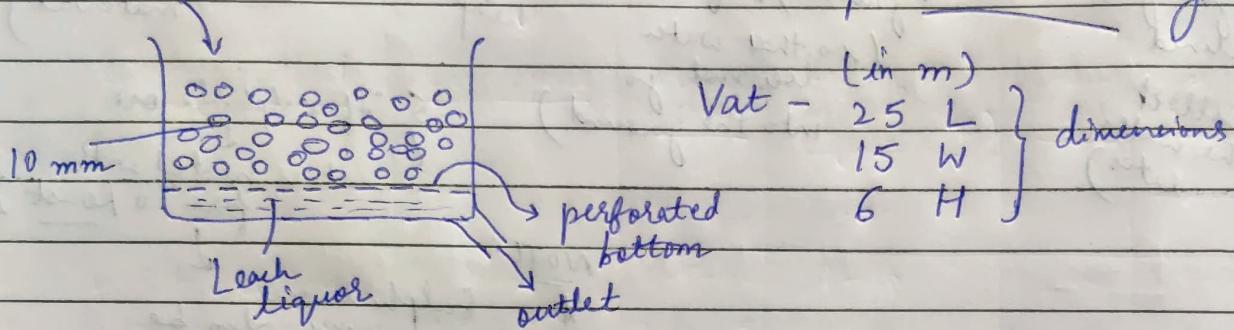
Generally Cu conc. is very low

(Cu: 0.5-1 %)

\* But if it is slightly higher: 1-2% Cu

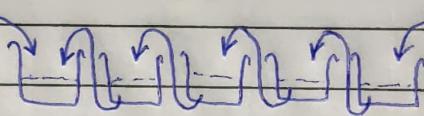
then we do  
percolation leaching

Solvent (dil. Acid)



There are multiple such vats

one



solvent

(in one go  
it may not  
be enriched)

New solid — Last Tank

but after passing  
through multiple  
vats it gets  
purified)

Fresh soln. — First Tank

Advantage → This method  
is useful for  
leaching of large

quantities of ore  
needs less (min.)  
quantity of  
solvent

\* NOTE:

It works  
mainly just  
for porous  
ores

eliminates  
filtering process

(It is a batch  
process,  
not a continuous  
process)

Limitations

It is a  
slow process

the loading  
& unloading of ore  
is difficult &  
expensive

has high  
capital cost

Requires  
huge storage  
of ore to  
treat

## (v) Agitation Leaching

Fine grinding of ore  
is done, & it is kept along with  
solvent

↓  
Pulp is formed

Advantage : Rate of leaching is fast

(∴ ore is ground, thus surface area is large)

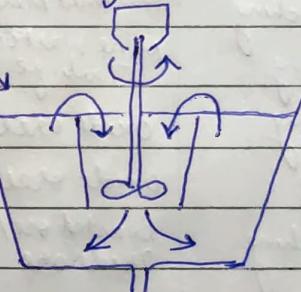
Agitation can be done  
in two ways

(a) Mechanically

(b) Air Agitation

Mechanical Agitation :

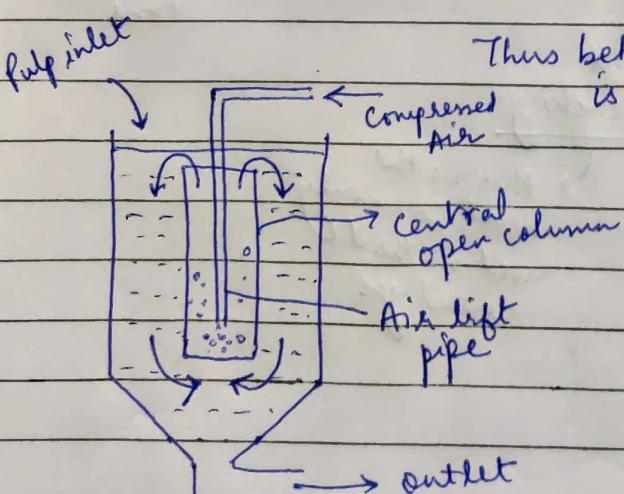
Inlet  
Acid sol.  
+ ore



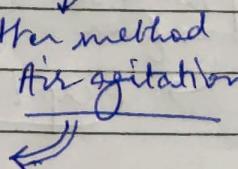
(rotation causes  
entire sol.  
to be  
stirred)

However due to  
large size of tanks

there can be  
mechanical problems



Thus better method  
is Air agitation



- Advantages
- (i) Much simpler in design
- (ii) Also supplies air inside (helpful for oxid.)

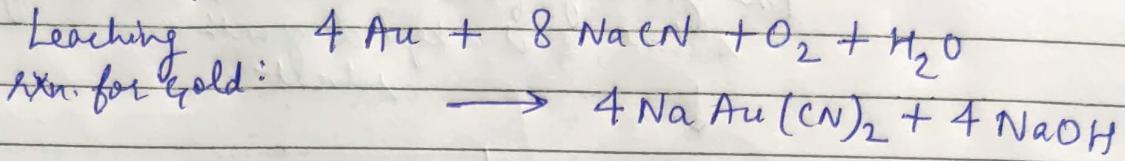
(no movement  
of large  
mechanical  
parts)

This kind of  
vat is also called  
\* Pachuka Vat

(named after a  
place called  
Pachuka in  
Mexico)

Advantage (ii) [continued] :

e.g.: In some cases  $O_2$  is must :



### 164] Comparison of Leaching Methods {With reference to Cu}

<u>Leaching Method</u>	<u>Cu Source</u>	<u>%Cu in ore</u>	<u><math>H_2SO_4</math> (kg/cubic m)</u>	<u>Leaching Time</u>	<u>Cu in leach liquor (kg/cu.m)</u>	<u>Estimated World Production (million tons/yr)</u>
1. In-situ leaching	Abandoned Mines	0.5-1.0	1-10	1-2 yrs	0.5-1.0	0.25
2. Dump Leaching	Mine Wastes Tailings	0.2-0.5	1-10	1-2 yrs	0.5-1.0	0.25
3. Heap Leaching	Oxide ore	6.0-9.0	2-10	4-6 months	2-5	2.0
4. Vat Leaching	Oxide ore	1.0-2.0	30-50	5-6 days	20-40	0.25
5. Agitation Leaching	Floated ore / Oxide ore	20-40	50-100	3-5 hrs	30-50	1.0

Total World Cu Production  $\Rightarrow$  3.75 million tons/yr  
(Primary)

From this we observe that the greatest production comes from \*

Heap Leaching

→ this is the most commonly used method nowadays

17-18 million tons