LECTURE 13
28/01/2023

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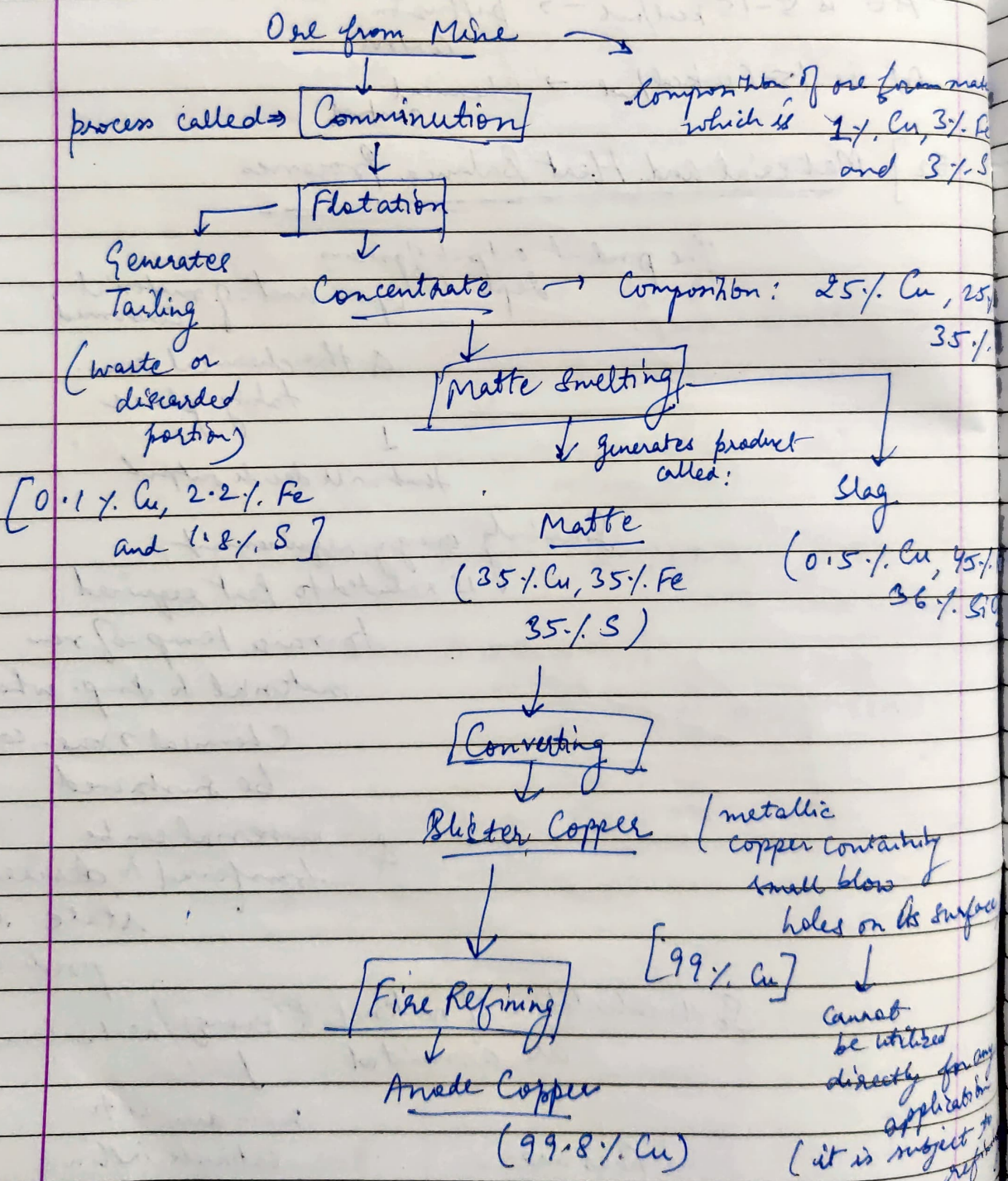
53] Flow sheet for copper products or from Copper Sulphide ore by Pyrometallurgical Process



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↓

Electrolytic Refining

↓

Casting

↓

Billets of Copper (99.99% Cu)

54] Material Balance Procedure

(i) It is essentially application of law of conservation of mass
(i.e. the mass of material should remain the same in input & output)

⇒ Mass input = Mass Output + Mass accumulation (or depletion)

⇒ Accumulation = Input − Output

Continuous process: $\frac{\text{Mass input}}{\text{Unit time}} = \frac{\text{Mass output}}{\text{Unit time}}$

(ii) Stoichiometry: Not only total mass, but also all the elements are conserved
(i.e. the same mass of elements put in, the same amount of elements come out
{although the combinations of elements may change})

55] Steps in Material Balance Calculation

(i) Write complete flow sheet of process
(in which each process as "□", shows input & output)

(ii) Gather all data (or variables) of process, equipments used, T, P, etc.

(iii) Make suitable assumptions, if necessary.
(iv) Write down overall chemical rxn. in each case
(v) Write elemental balanced equation
(vi) Choose a convenient basis of calculation, & find out the mass.

56] Heat Balance : Considerable quantity of heat is necessary to carry out pyrometallurgical processes

Cost of energy is v. high
↓
leading to high cost of material produced

(eg: In Al, 30% cost is of energy (and in general, ~30%)

Thus, to produce metal at lower cost, heat requirement needs to be minimised

In heat balance also we need to account for amt. of energy input & how much output.

Many processes have been drastically changed in last 20-30 years to reduce cost due to heat.

⇒ { Continuous Smelting of Copper }
(general discussion
↓
nothing written)

The heat balance has to be performed by taking stock of all materials put in the form of energy

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A] Heat Input

1. The sensible heat of reactant (i.e. room temp. heat). As a standard procedure, a reference temp. of 298 K (or 25°C) is taken as standard.
{ universally accepted & doesn't need to be measured }

2. Have to estimate heat content/heat changes due to chemical rxns. in the system (eg: Exothermic, Endothermic)
↓
Done using heat of formation of all compounds. (ΔH_f°)

3. ~~Heat changes (eg: Latent heat) of transformations.~~
eg: If material melted, heat change occurs due to melting

4. Change in heat content due to mixing or dilution
(these values are not v. high
↓
so appropriate assumptions are made to obtain these) approximately

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31/01/2023

57] Heat Balance (continued)

A] Heat Input

1. Sensible heat, reference temp. 25°C (298 K)
2. Change in heat content – chemical reaction – exothermic, endo. ΔH_f°
3. Changes due to change in state of substance, (allotropic transformations (latent heat of transformation)
4. Mixing & dilution in solution
5. Combustion of fuel
   – electricity

B] Heat Output

1. Solid products – Temperature & Cp value of the compounds
2. Liquid products – Temperature
3. Gaseous products – Temp., Cp
4. Heat Loss

Heat Balance Performance

1. Work out material balance
2. Select material ref. temp.
3. Chemical eqn.
4. Calculate heat input & output
5. Perform all additions & subtractions required, & calculate heat value

58] Mineral Beneficiation

Also called: Ore dressing
Mineral Processing
Milling

Reference Book:
— B. A. Wills, Mineral Processing Technology

Mining of Ores

lumps of ore called — as-mined or run-of-mine } contain: Valuable mineral + Waste (gangue) minerals

59] Mineral Beneficiation

↓

It is a process of physical or mechanical separation of ore minerals from gangue minerals

↓

to produce a concentrate containing most of the ore minerals

and a discard OR Tailing

containing bulk of the gangue minerals

Advantages: 1] It reduces cost of transportation (since waste has already been discarded)

2] It reduces the smelting cost due to decrease in size of reactor

3] ↓ cost of reagent

4] ↓ cost of energy

Useful — if it can be economically exploited

Ore minerals are → finely disseminated and intimately associated with the gangue minerals

60] Steps to separate ore from gangue:
- Liberation
- Separation

(i) Liberation → It is achieved by crushing & grinding (called Comminution) {Size reduction}
(These are V. high energy consuming steps, & thus are done in optimum way)

(ii) Concentration → it is achieved by utilizing some specific difference in properties between ore and gangue minerals.

eg: 1) Specific gravity
↓
generally measured through Hydraulic current

2) Surface properties
↓
diff. of surf. prop.s realized using Froth flotation
(air bubbles created
↓
those particles which attach, float to the top)
↓
the wettability can be controlled also, using chemicals

3) Magnetic properties
eg: Fe_3O_4 (magnetite) → this is magnetic
↓
can be separated by magnetic separation
(eg: In ZnS ore, FeS_2 is present
Fe_3O_4 ← roasted
↳ separated by magnetic separation)

Tungsten
eg: Tungsten ores
↓
Wolframite $[(Fe,Mn)WO_4]$, Fe_3O_4

eg: Beach sand

4) Electrical Conductivity
(also used for separating ore & gangue)

LECTURE 15
(02/02/2023)

6] Unit Operations of mineral Beneficiation

Process	Description	Properties of mineral Ore
COMMINUTION		
Crushing, Grinding	Breaking of mineral lumps into smaller sizes	Brittleness
SIZING		
Screening	— Separation acc. to size	— Size diff. of particles
Hydraulic classification	— Settling in liquid	— Relative diff. in size and density of particle
CONCENTRATION		
Gravity conc.		
— Jigging	— Settling in liquid	— do —
— Tabling	— Frictional movement along wet vibrating solid surface	— Density, shape, size, coeff. of friction
Magnetic separation	— separation due to magnetic field	— Magnetic properties of particles
Electrostatic separation	— Charging & charge loss of particles & deflection in electrostatic field	— Conducting and charge retention
Flotation	— Attachment of gas bubbles to minerals in aqueous solution containing suitable chemicals	— Surface properties ↓ affinity for specific active reagents

DEWATERING

Sedimentation Thickening — Settling of particles in water
Filtration — Solid-liquid separation
Drying — Removal of moisture from moist solid
} Non specific properties

62] COMMINUTION (Size Reduction)

(i) Detach dissimilar particles — ore, gangue particles
i.e. Liberation

(ii) Small sized particles (a) Blast Furnace (particles are 2-3" in size)
(b) Concentration
Hydrometallurgy

{ NOTE: Before breaking ⇒ we say grains of ore & grains of gangue
After breaking ⇒ we say particles
Also, if before breaking ⇒ bond b/w ore & gangue is weak
↓
then we can fully separate them
↓
But if strong bond
↓
then they are not fully separated
(need further processing) }

Crushing and Grinding
Jaw Crusher, Gyratory Crusher
(NOTE: Sometimes Rollers are also used)

* { Crushing ⇒ reduces size to 6mm
Grinding ⇒ reduces to < 6mm }

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03/02/2023

63] Crushing and Grinding

Crushing : Jaw crushers
Gyratory Crushers
Roll Crushers

Grinding : Closed chambers

Steel balls
pebbles
Steel rods
tubes

{ abrasion, wear, impact
↓
helps convert larger particles to smaller size }

Industrial Sizing

64] (i) Screening → always done in dry condition

Screens ⇒ ↓ ore
undersize ↓ → oversize

(ii) Hydraulic classification
→ based on size & specific gravity
→ used for particles of size < 250 μm (which screening cannot separate)
→ always in wet condition

Screens can be:
→ Stationary
→ Moving
→ Vibrating (these are considered better as they help particles pass through more easily)

Hydraulic
→ Settling Rate → depends on size, density

Thus, classification here depends on these

Terminal velocity
↓
it is that when eq^m is reached for falling particle b/w gravity & resistance force

65] Free settling → Here, main resistance to particles settling is viscosity of fluid

↓ particles are allowed to undergo free settling

↓ when vol.^{m} of particle < vol.^{m} of fluid

↓ & density of particles is small (generally < 15 wt.%)

Hindered Settling → this is more due to turbulent resistance (bez of particles in fluid)

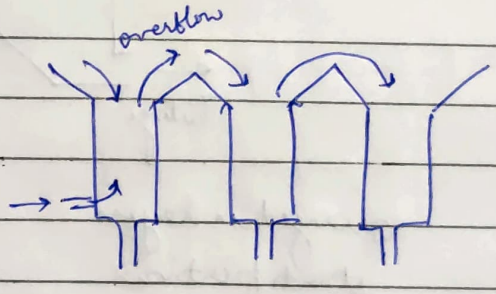
↓ When % solid is more

↓ particles get obstructed (i.e. particle crowding)

↓ Thus, settling gets hindered

Types of classifier

Hydraulic Vertical classifier



66] Concentration

↓

Gravity conc.

↓ simpler, cost effective & environmentally more preferable

↓ Two main methods:

Jigging, Heavy Media Separation

↓ for Concentrate having 3-10 mm size (most effective for this range)

{it may also be used for density 2.7 - 3.2}