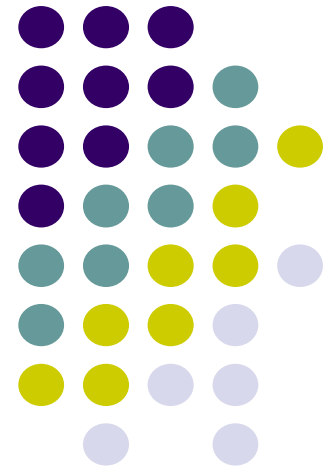


ME 216 – Engineering Materials II

Chapter 7

Production of Nonferrous Metals



Mechanical Eng. Dept.
Gaziantep University

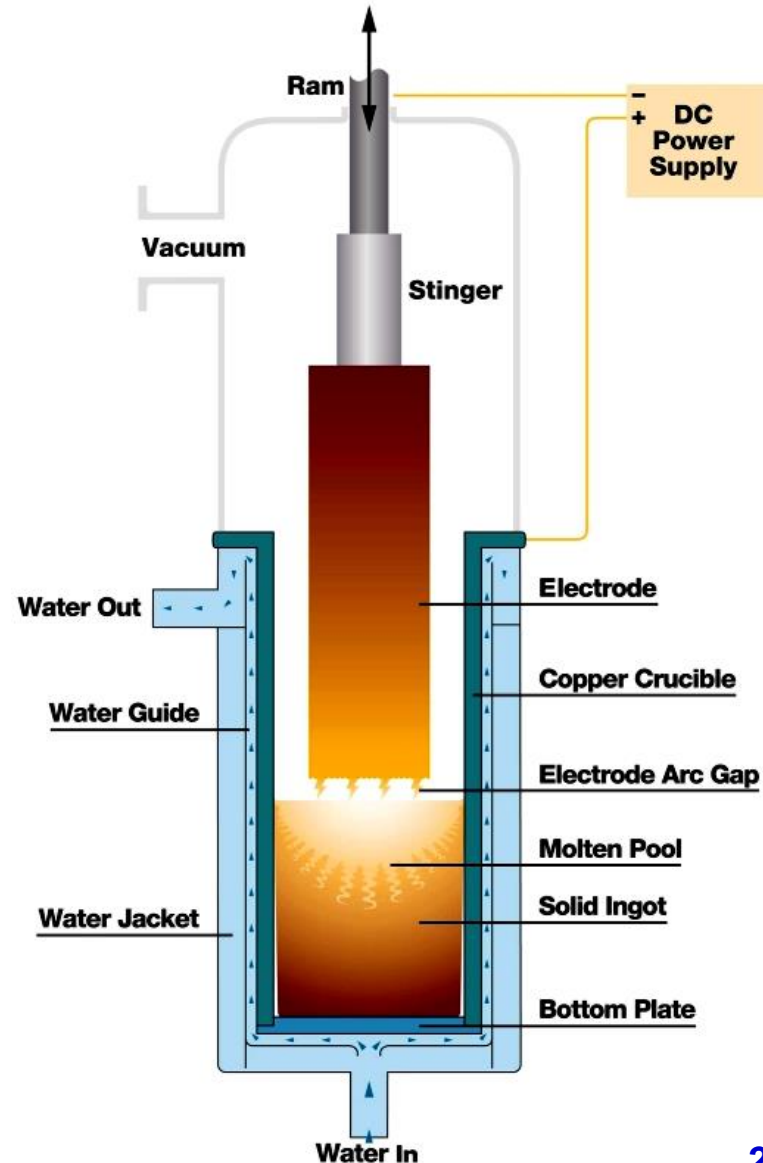
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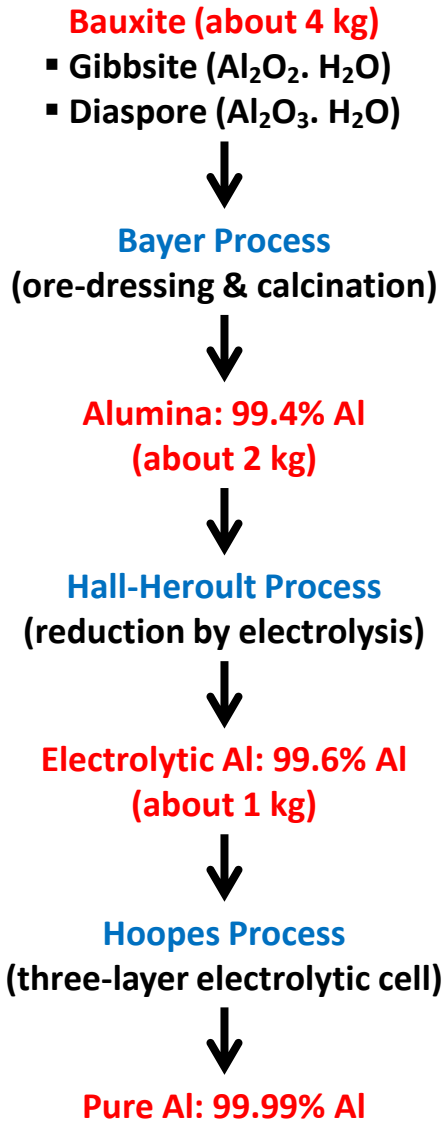
- Even though ferrous metals and alloys are the most important and widely used engineering materials, **nonferrous metals and alloys** also find significance in engineering construction.
- They have a wide range of properties and uses for which ferrous alloys are not suitable.
- **Most of the useful engineering alloys are made from two or more of the following metals**, and various types and grades of these metals are obtained from refining processes:
 - **Aluminum (Al)**
 - **Copper (Cu)**
 - **Lead (Pb)**
 - **Magnesium (Mg)**
 - **Nickel (Ni)**
 - **Tin (Sn)**
 - **Zinc (Zn)**
- In general, nonferrous metals and alloys are **more expensive** than any iron or steel, but they hold their place in industry since they **meet special requirements** (e.g. **copper** is most useful due to its electrical properties, **aluminum** and **magnesium** are very light and provide very high strength/weight ratios, **tin** and **lead** have good corrosion resistance).



- Furnaces used for smelting nonferrous metals are **different from those for iron and steel**.
- **Blast furnace** (similar but smaller than those for iron smelting) is used for **reducing oxide ores** of nonferrous metals (e.g. **copper, tin, lead, zinc**). Some ores contain **sulphides** which are decomposed in **roasting ovens** to drive off sulphur and leave the oxide. **Reverberatory furnace** (similar to open-hearth furnace) is often used **to smelt nonferrous metals**.
- **Vacuum arc furnace** (consumable electrode unit) is a **special type of electric furnace**. It is used for melting various metals (such as **high purity steels, titanium, zirconium**). The metal used to charge the furnace is fashioned into long rods by briquetting and welding into **electrode**. **Vacuum in furnace** is constantly maintained to remove gases before being absorbed by metal. By this method of melting in **water-cooled mold** at the base of furnace, **a solid ingot** is gradually formed.



PRODUCTION OF ALUMINUM



BAYER PROCESS

1. MIXING

- Crushing & grinding **bauxite ore**.
- Mixing with **caustic soda, lime, sodium hydroxide, and hot water**.

2. DIGESTION

- Under high pressure & heat, **caustic soda** dissolves **alumina** in bauxite to form **sodium aluminate**.

3. CLARIFICATION

- **Sodium aluminate** remains liquid.
- Iron oxides and other solid impurities are pumped to disposal as **red mud**.

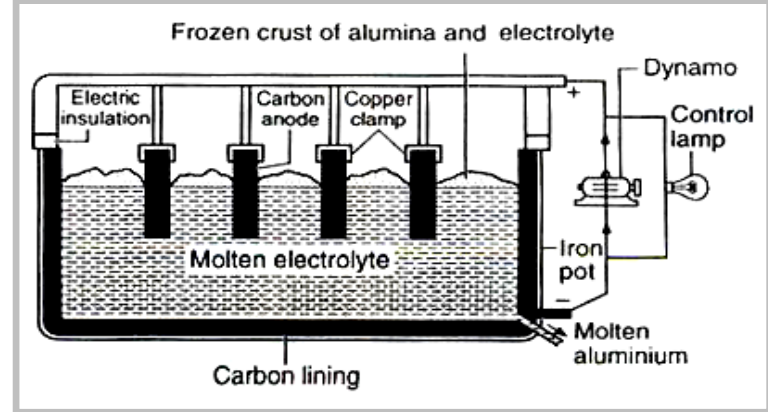
4. PRECIPITATION

- **Sodium aluminate** is seeded with **aluminum hydroxide**, and converted to **aluminum hydrate**.
- As cooling continues, **aluminum hydrate** settles to bottom while **sodium hydroxide** rises to top.

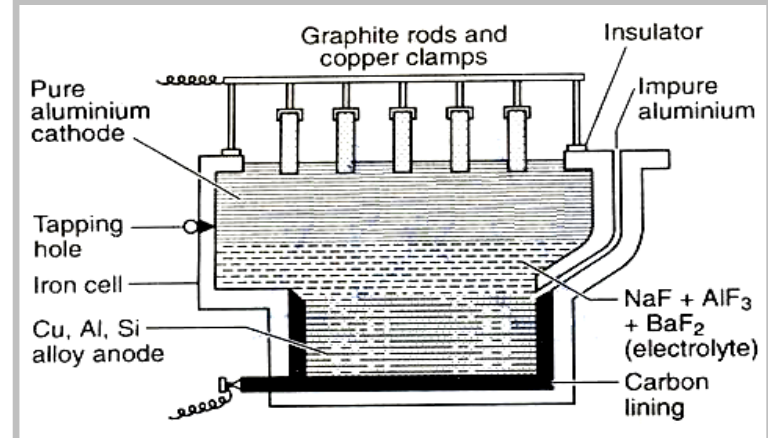
5. CALCINATION

- **Aluminum hydrate** is calcinated (roasted) at $1100\text{ }^\circ\text{C}$ to remove water, and **pure alumina (99.4%)** is obtained.

HALL-HEROULT PROCESS



HOOPES PROCESS



Facts and Properties:

- ★ White or grey-white metal
- ★ Melting point of $660\text{ }^\circ\text{C}$

- ★ Very ductile & malleable
- ★ Better strength-to-weight ratio than steel
- ★ Good thermal & electrical conductivity

PRODUCTION OF COPPER

Sulphide Ores

- Chalcocite (Cu_2S): 79.8% Cu
- Chalcopyrite (CuFeS_2): 34.5% Cu

Ore-Dressing

- **Crushing** in jaw crushers
- **Grinding** in ball mills
- **Concentrating** by froth floatation

Concentrated Cu

Smelting in Reverberatory Furnace

Matte Cu: 40-45% Cu

Converting in Bessemer Converter

Blister Cu: 98% Cu

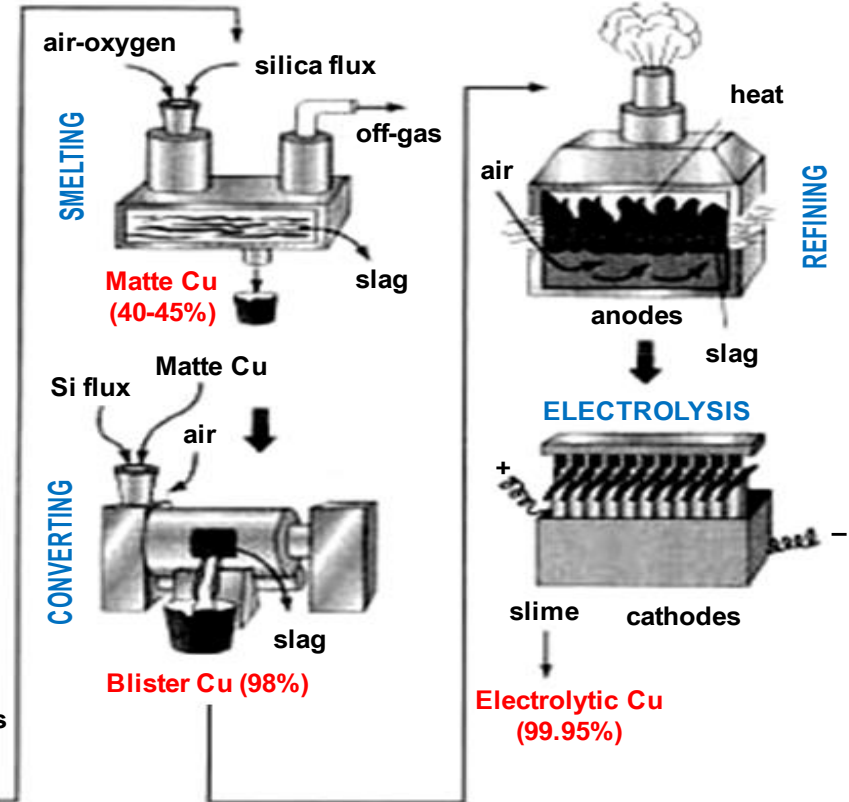
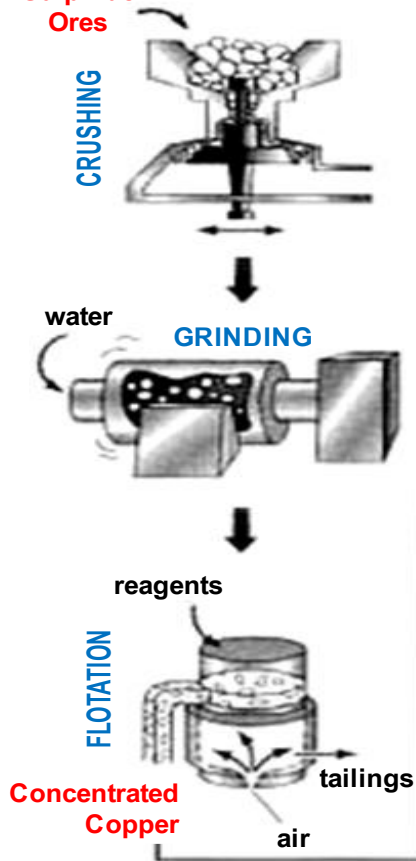
Refining (Poling) in Reverberatory Furnace

Tough-pitch Cu: 99% Cu

Electrolysis to deposit Cu on cathodes

Electrolytic Cu: 99.95% Cu

Sulphide Ores



Further refining by melting under protective atmosphere to remove residual oxygen (0.03-0.06%)

Oxygen-Free High-Conductivity (OFHC) Copper

Facts and Properties:

- ★ Soft, heavy, reddish metal
- ★ Melting point of 1083 °C
- ★ High ductility
- ★ Excellent thermal & electrical conductivity

PRODUCTION OF LEAD

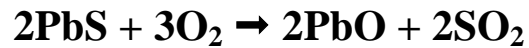
Galena (PbS): 1-10% Pb



Concentrating by floatation



Roasting with O₂ (at 600-700 °C)



Smelting with coke (in blast furnace at 900 °C)



Crude Pb: 60-80% Pb



Refining by heating (in air at 400 °C)

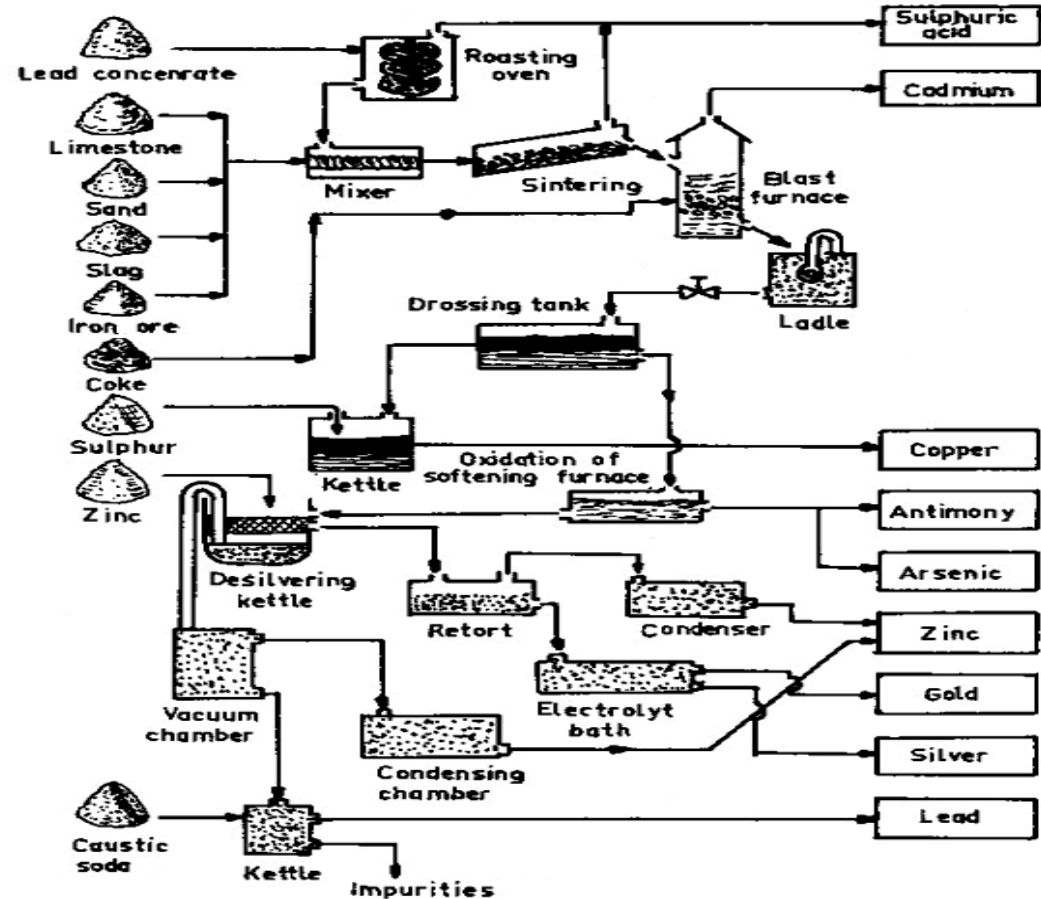


Removing impurities

- Cu (by adding sulphur)
- Sb & As (by selective oxidation)
- Zn (by distillation)
- Ag (by electrolysis)



Pure Pb: 99.9% Pb



Facts and Properties:

- ★ Heavy, greyish metal
- ★ Melting point of 327 °C
- ★ High malleability, low strength
- ★ Good corrosion resistance

PRODUCTION OF MAGNESIUM

Seawater: 1300 ppm Mg



Mixing with milk of lime



Magnesium Hydrate



Adding hydrogen chloride (HCl)



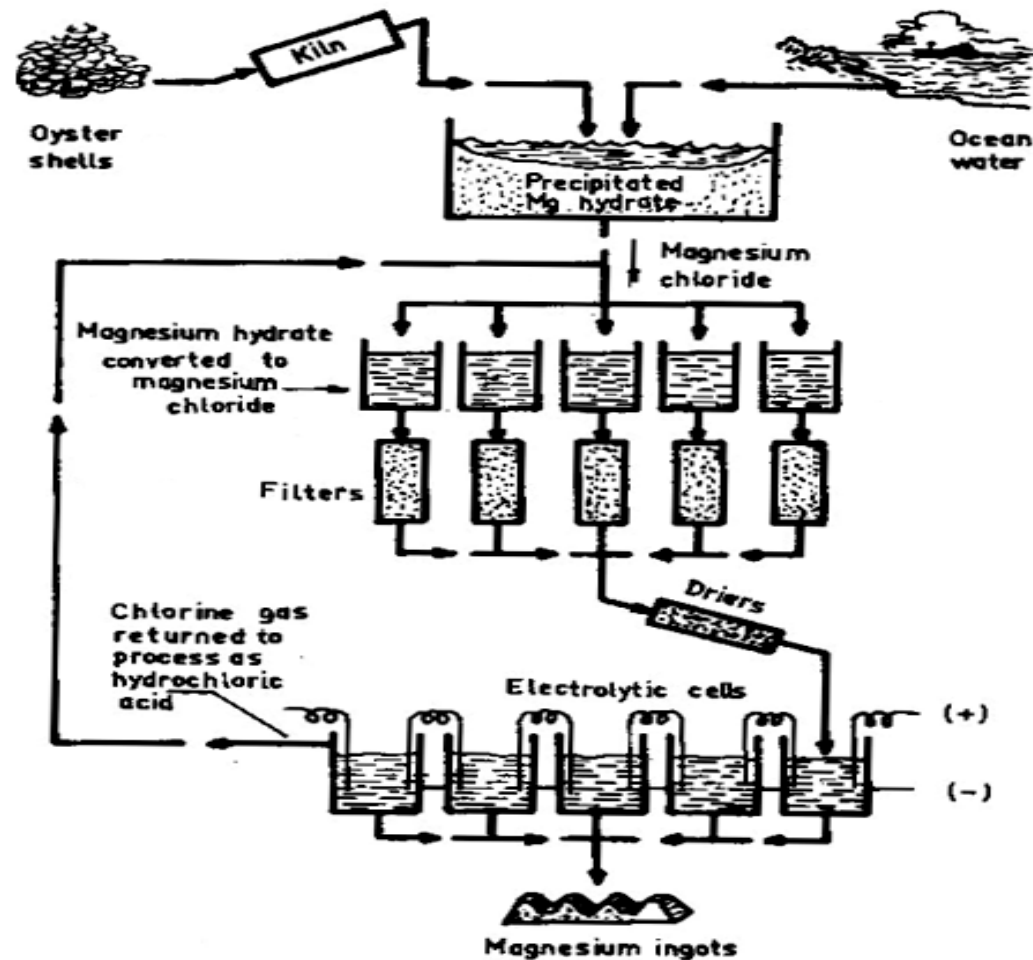
Magnesium Chloride (MgCl)



Electrolysis with carbon anodes & steel cathodes using 60,000 A in an electrolyte (Ca + NaCl)



Pure Mg (deposited on cathodes)



Facts and Properties:

- ★ Light, soft, silver-white metal
- ★ Melting point of 650 °C
- ★ Chemically active metal

PRODUCTION OF NICKEL

Pentlandite [NiS.(FeS)₂]



Concentrating by floatation



Smelting in furnace



Matte Ni
(having Cu & iron sulphides)



Refining by Mond Process:

- Crushed & heated to drive off sulphur
- Converted to NiO
- Treated with sulphuric acid to remove Cu
- Reduced with water gas (H + CO) at 300 °C



Pure Ni: 99.8% Ni

Facts and Properties:

- ★ Whitish metal
- ★ Melting point of 1452 °C
- ★ Low strength
- ★ Resistance to corrosion & oxidation

PRODUCTION OF TIN

Cassiterite (SnO₂): tin stone (1-5% Sn)



Washing to remove impurities



Heavy tin oxide



Smelting in reverberatory furnace
(with powdered coal & lime at 1200 °C)



Matte Sn



Refining in two stages:

- **Liquation** (at low temp.) to remove Cu, Fe, As
- **Oxidation** in open crucible (kettle) to remove Zn



Pure Sn: 99% Sn



Further refining by electrolysis



Pure Sn: 99.9% Sn

Facts and Properties:

- ★ White coloured metal
- ★ High malleability, low strength
- ★ Melting point of 232 °C
- ★ Good corrosion resistance

PRODUCTION OF ZINC

Sphalerite (ZnS): zinblendende, ruby jack



Floatation to remove Pb, Cu, iron sulphides



Concentrated Zinc



Roasting with O_2



Zinc Oxide



Purifying in two ways

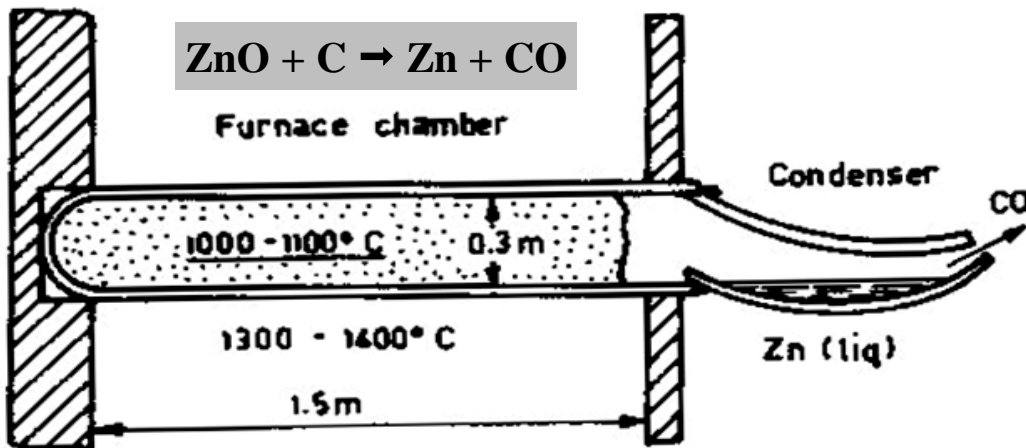


Distillation in Zinc Retort:

- **Zinc oxide** (with coke) is pressed into walls of briquettes, and retorts are placed in furnace at 1200-1400 °C.
- Due to the reaction occurring in furnace at atmospheric pressure, **Pure Zn** is produced in vapour form and then condensed at 500 °C.

Roasting & Electrolysis

- **Zinc concentrate** is **roasted & leached** (i.e. soluble particles are removed) with a weak solution of **sulphuric acid**.
- Other metals are filtered out and **the solution (zinc sulphate)** is pumped into **electrolytic tanks**.
- **Cathodes (pure Al)** and **anodes (Pb-Ag alloy)** are lowered into tanks, electric current is passed through solution, and **Pure Zn** is deposited.



Facts and Properties:

- ★ Bluish-white metal
- ★ Melting point of 419 °C
- ★ Low strength, low ductility
- ★ Easily formable & machinable
- ★ Readily attacked by alkalis and acids



- Conventional crucible (melting) methods are **not possible at high temperatures** needed to produce these metals as liquids. Thereby, they are **reduced directly to powder form**. Later, metallic powder is **consolidated by sintering** in solid state.
- Melting points of refractory metals and their processing are given below:
 - **Tungsten (W, 3410 °C)** and **Molybdenum (Mo, 2610 °C)** are reduced from their oxides of **scheelite (CaWO₂)** and **molybdenite (MoS₂)**, respectively. In both cases, first stage is to **prepare pure oxide powder** by chemical treatments. Then, it is **reduced to metal by heating** in a stream of **hydrogen gas**, which is an effective reducing agent for these metals. Such treatment gives **a clean metal**, and there is **no problem of carbide formation**.
 - **Niobium (Nb, 2470 °C)** and **Tantalum (Ta, 2980 °C)** are more reactive metals, and hence **their fluorides** are usually reduced with **sodium**.
 - **Rhenium (Re, 3170 °C)** is obtained as **by-product of** extraction and refinement of **Mo & Cu**.
 - **Osmium (Os, 3000 °C)**, being **the heaviest known metal**, is found as **a trace element** in alloys (**mostly in platinum ores**).