Welcome to

Aakash + BYJU'S LIVE

General Principles and Processes of Isolation of Elements

Introduction

Elements in earth crust occurs in **free** as well as in **combined state**.

Pure state

Examples: **C, S, Au, noble gases,** etc.

As **oxides, halides, sulphides,** etc.

Examples: **Fe, Cu**, etc.

The metals in the combined state involve various **processes** for their **extraction** and **isolation**.

Minerals and Ores

Minerals	Ores
The compounds of **metal** which are **naturally available** in earth's crust and can be obtained by **mining**	The **minerals** from which a metal can be **extracted economically** and **conveniently**
Example: FeS_2 (**Iron pyrite**)	Example: Galena (PbS), fluorspar (CaF_2), dolomite ($CaCO_3.MgCO_3$), anglesite ($PbSO_4$), bauxite ore ($Al_2O_3.2H_2O$), hematite (Fe_2O_3)

All ores are **minerals,** but **all minerals** are **not ores**.

FeS_2

Mineral

Abundantly present
in earth's crust

But **cannot** be used
as an **ore**

Comparison

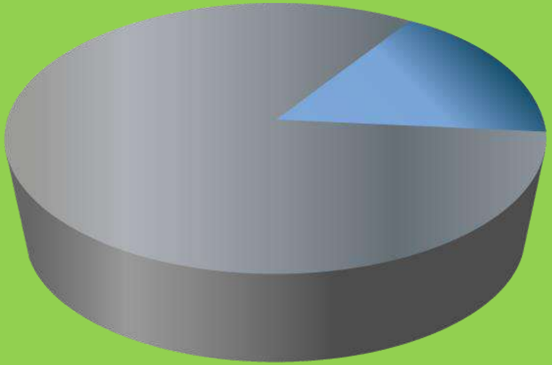
Ore rarely contains only a **desired substance**

They are usually contaminated with an **earthly** and **undesired substance** known as **gangue.**

Example: SiO_2 (**Silica**)

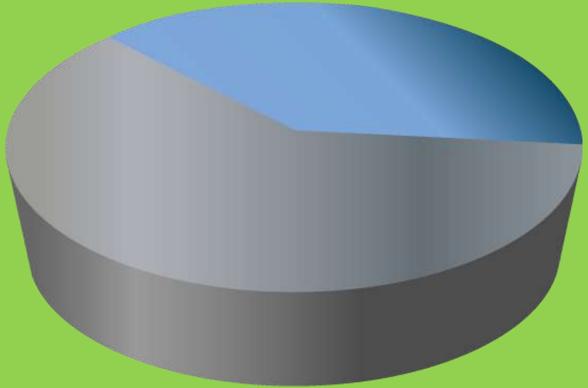
Metal

Impurity



Ores

Minerals



Occurrence of Metals

Among metals, **aluminium (Al)** is the most abundant followed by **iron (Fe)** and third most abundant metal is **Calcium(Ca)** in earth's crust.

Occurrence of Aluminium

Third most abundant element in earth's crust

Among all the metals, **aluminium** is the **most abundant.**

Major component of igneous minerals including **mica** and **clays**

Many **gemstones** are **impure** forms of Al_2O_3.

The impurity ranges from **Cr** (in **ruby**) to **Co** (in **sapphire**).

Occurrence of Iron

Iron forms a **variety** of compounds.

Iron is also essential in **biological systems.**

Haemoglobin

Occurrence of Calcium

Calcium is vital for **teeth** and **bones.**

It is an **essential** component for **cement** and **glass industry.**

Principal Ores of Some Metals

Metal	Ore	Composition
Aluminium	Bauxite	$AlO_x(OH)_{3-2x}$ [Where o< x <1]
	Kaolinite (a form of clay)	$[Al_2(OH)_4Si_2O_5]$
Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
	Siderite	$FeCO_3$
	Iron pyrites	FeS_2

Principal Ores of Some Metals

Metal	Ore	Composition
Copper	Copper pyrites	$CuFeS_2$
	Malachite	$CuCO_3, Cu(OH)_2$
	Cuprite	Cu_2O
	Copper glance	Cu_2S
Zinc	Zinc blende or sphalerite	ZnS
	Calamine	$ZnCO_3$
	Zincite	ZnO

Principal Ores of Some Metals

Metal	Ore	Composition
Silver	Silver glance or Argen	Ag_2S
	Ruby silver	$3Ag_2S.Sb_2S_3$
Magnesium	Kieserite	$MgSO_4.H_2O$
	Magnesite	$MgCO_3$

Metallurgy

Metallurgy is the subject that deals with the science and technology for the **extraction** of **metals economically**.

Types of metallurgy

- Pyrometallurgy
- Hydrometallurgy
- Electrometallurgy

Pyrometallurgy

Type of **metallurgy** which involves extraction and purification of metals by **processes** involving the **application** of **heat.**

Ores of **less reactive** elements like **iron**, **zinc,** and more

Hydrometallurgy

Extraction of any metal from its ore by preparing an **aqueous solution** of a salt of the metal and **recovering** the **metal** from the solution.

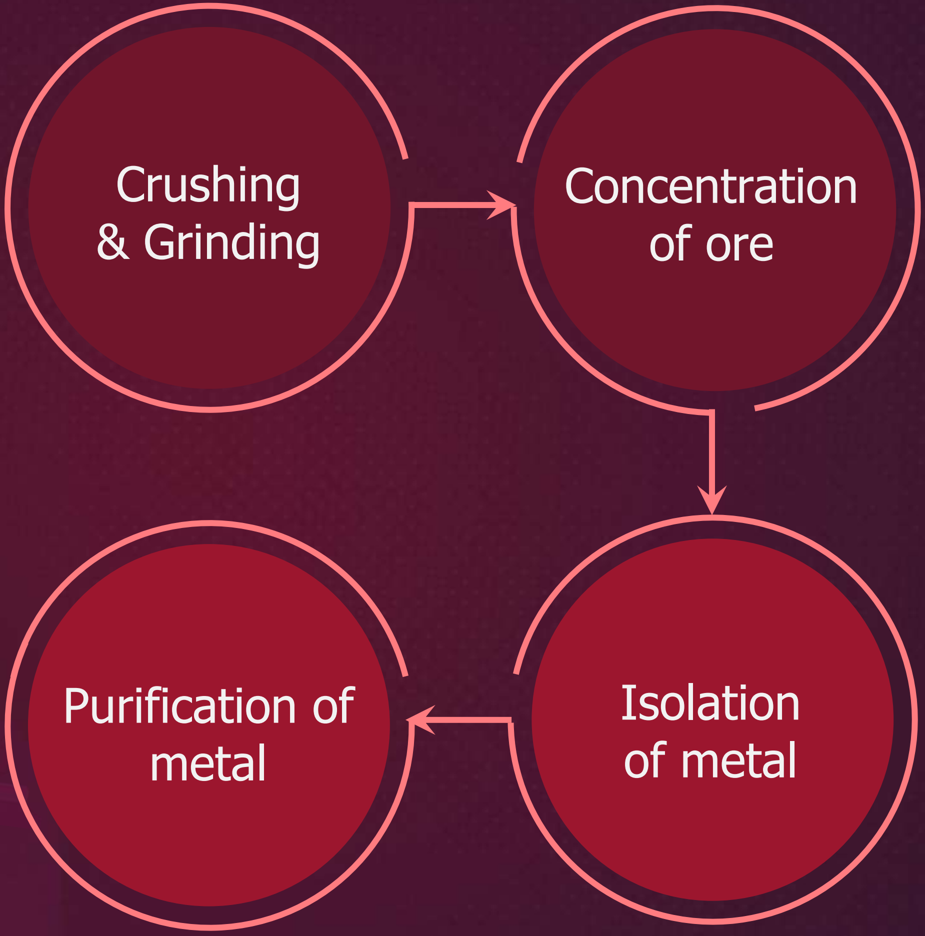
Ores of **Cu, Au, Ag,** and more

Electrometallurgy

Metallurgy that deals with the application of **electric current** either for **electrolytic deposition** or as a source of **heat.**

Ores of **Na, Mg, Al,** and more

Steps involved in extraction and isolation of metals from ores!



Crushing and Grinding

Also known as **pulverisation** of ore

The ore is first **crushed** by **jaw crushers.**

And ground to **powder** in **ball mills** and **stamp mills.**

Concentration of Ore

Removal of **unwanted material** from ore

Also known as **dressing** or **benefaction**

Concentration of ore **depends** on the difference in the **physical properties** of:

1. **Components** of metal
2. **Gangue**

Gangue

An ore usually **contaminated** with **earthly** or **undesired materials** known as **gangue**.

Concentration or Dressing of Ore

Concentration of ore involves

- Physical methods
  - Hydraulic washing
  - Magnetic separation
  - Froth floatation process
- Chemical methods
  - Leaching

Hydraulic Washing

Principle

This method is based on **differences** in the **gravity** of **ore** and the **gangue** particles.

Also known as **gravity separation** method

An **upward stream** of running **water** is used to wash the powdered ore.

Lighter gangue particles are **washed** away

Heavier ores are **left** behind

Magnetic Separation

Principle

This method is based on the **differences** in the **magnetic properties** present in the ore particles.

It is generally used to **separate magnetic impurities** from **non-magnetic ores.**

Tin stone, SnO_2 (non-magnetic) is separated from magnetic impurity $FeWO_4 + MnWO_4$.

Wolframite

Magnetic Separation

Powdered ore is allowed to move over **magnetic roller** and **falls down.**

Magnetic material makes a **new heap.**

Because it is held to roller for **longer time**

Froth Floatation Process

Principle

This method is based upon **differential wetting** of:

Ore - - - - By - - - → **Oil**

Impurity - - - - By - - - → **Water**

It is generally used to **remove gangue** from **sulphide ores.**

Steps of Froth Floatation Process

1. Preparation of suspension of powdered ore
2. Addition of collectors and froth stabilisers
3. Agitation of mixture

Preparation of Suspension of Powdered Ore

Fine powder + Water

Slurry

Collectors and Froth Stabilisers

Collectors are the compounds that **enhance non-wettability** of mineral particles.

Examples: **Pine oil, crude coal, tar,** and more

Froth stabilisers are the compounds that **reduce** the **surface tension** of **water.** They also produce a **stable froth.**

Examples: **Aniline, cresol,** and more

Agitation of Mixture

A **rotating paddle** agitates the mixture and **draws air** in it.

It forms **froth** that causes **ore** particles

Froth is **light** and can be **skimmed off.**

Dried and **ore** particles are **recovered**

Froth Floatation Process

If **two sulphide ores** are **present**, a particular ore can be **obtained** by using **depressants.**

Depressants are **substances** that are added to **suppress** the **floating characteristic** of the ore particles.

Example: **NaCN/KCN**

Froth Floatation Process

Example

In this example, NaCN or KCN helps to keep ZnS in aqueous solution by forming a water soluble complex while PbS can be obtained in the froth.

Froth containing ZnS and PbS $\xrightarrow{\text{Depressant}}$ **Soluble** complex of ZnS

Depressant: **NaCN/KCN**

$PbS(s) + NaCN \longrightarrow$ **No reaction**

$ZnS(s) + 4NaCN \longrightarrow [Zn(CN)_4]^{2-} + 4Na^{+} + S^{2-}$

Concentration or Dressing of Ore

Concentration of ore involves

- Physical methods
  - Hydraulic washing
  - Magnetic separation
  - Froth floatation process
- **Chemical methods**
  - **Leaching**

Chemical Methods: Leaching

It is generally used if the ore is **soluble** in a **suitable solvent**.

Leaching of

- Alumina
- Silver and gold

Leaching of Alumina

From **bauxite ($Al_2O_3.2H_2O$)**

Principal **ore of aluminium**

Impurities present in bauxite → **SiO_2, TiO_2,** and **Fe** oxides

Leaching of Alumina

Step 1

Digesting powdered ore with **aqueous NaOH**

At **473-523 K** and **35-36 bar**

$$\underbrace{Al_2O_3(s) + Fe_2O_3 + SiO_2 + TiO_2}_{\text{Impurity}} + 2NaOH + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq) + \text{Impurities}$$

Sodium aluminate

Leaching of Alumina

Step 2

Aluminate is **neutralised** by passing CO_2

$$2Na[Al(OH)_4]\,(aq) + 2CO_2\,(g) \longrightarrow Al_2O_3.xH_2O \downarrow + 2NaHCO_3$$

Precipitate

Leaching of Alumina

Step 3

Sodium silicate remains in the **solution**

Hydrated alumina is **filtered**, **dried** and **heated.**

$$Al_2O_3.xH_2O \xrightarrow{1470K} Al_2O_3\,(s) + xH_2O\,(g)$$

Pure alumina

Leaching of Gold and Silver

Step 1

Metal is **leached** with dil. **NaCN** or **KCN.**

In the presence of O_2

$$4M\,(s) + 8CN^{-}(aq) + 2H_2O\,(aq) + O_2\,(g) \longrightarrow 4[M(CN)_2]^{-} + 4OH^{-}\,(aq)$$

M = Ag or **Au**

Leaching of Gold and Silver

Step 2

Pure metal is **obtained** by replacement.

$$2[M(CN)_2]^{-}\,(aq) + Zn\,(s) \longrightarrow [Zn(CN)_4]^{2-}\,(aq) + 2M(s)$$

Isolation of Metal

For **isolation**, concentrated ore must be converted to a **particular form**.

Which is **suitable** for **reduction**

Steps Involved in the Isolation of Metal

Step 1	Conversion of ore to oxide
Step 2	Reduction of oxide to metal

Conversion of Ore to Oxide

Sulphide ores, carbonate ores and hydrated ores → **Oxide ore**

Easy to reduce

Generally, the conversion of an ore is carried out by

- Calcination
- Roasting

Calcination

Generally used for **carbonate ores**

High temperature

$$\text{Concentrated ore} \xrightarrow{\Delta} \text{Metal oxide}$$

In the **absence** or **limited supply** of air

Calcination

EXAMPLES

1 Metal carbonate $\xrightarrow{\Delta}$ Metal oxide + $CO_2\uparrow$

$$ZnCO_3\,(s) \xrightarrow{\Delta} ZnO\,(s) + CO_2\uparrow(g)$$

Calamine

$$CaCO_3.MgCO_3\,(s) \xrightarrow{\Delta} CaO\,(s) + MgO\,(s) + 2CO_2\uparrow(g)$$

Dolomite

Calcination

EXAMPLES

2 Hydrated ores → Anhydrous oxides

$Fe_2O_3.3H_2O \xrightarrow{\Delta} Fe_2O_3 + 3H_2O\uparrow$

Limonite

$Al(OH)_3 \xrightarrow{\Delta} Al_2O_3 + 3H_2O\uparrow$

3 **Impurities** like **S, As, and Sb** are removed in the form of elemental **vapours**.

4 The products of **calcination** are always **porous**.

Roasting

Generally used for **sulphide ores**

$$\text{Concentrated ore} \xrightarrow[\text{Excess air}]{\Delta} \text{Metal oxide}$$

High temperature below melting point of metal

Roasting occurs in **reverberatory furnaces**

Roasting

1 Metal sulphide + O_2 $\xrightarrow{\Delta}$ Metal oxide + $SO_2\uparrow$

$$2ZnS\,(s) + 3O_2 \xrightarrow{\Delta} 2ZnO\,(s) + 2SO_2\uparrow(g)$$

$$2PbS\,(s) + 3O_2 \xrightarrow{\Delta} 2PbO\,(s) + 2SO_2\uparrow(g)$$

$$2Cu_2S\,(s) + 3O_2 \xrightarrow{\Delta} 2Cu_2O\,(s) + 2SO_2\uparrow(g)$$

Occurs in **reverberatory furnaces**

Roasting

2 Sometimes,

Lower oxidation state → **Higher oxidation state**

$$2\overset{\mathrm{II}}{\mathrm{Fe}}\mathrm{O} + \frac{1}{2}\mathrm{O_2} \xrightarrow{\Delta} \overset{\mathrm{III}}{\mathrm{Fe_2}}\mathrm{O_3}$$

Roasting

3 The **impurities** like **organic matter, S, As** are removed by **roasting** in the form of their **volatile oxides**.

4 The product of **roasting** are always **porous**

5 **Hydrous** ores become **anhydrous** through roasting.

Reduction of Oxide to Metal

C or CO or any other metal

Metal oxide $\xrightarrow{\text{Reducing agent}}$ Metal

$$M_xO_y + yC \longrightarrow xM + yCO$$

Some metal oxides get **reduced** easily while others are **difficult** to **reduce**,

But **heating** is required in any case.

Recall

Gibb's energy change

$\Delta G = \Delta H - T\Delta S = -RT \ln k$

ΔH: Enthalpy change
ΔS: Entropy change
T: Temperature
k: Equilibrium constant

ΔG = -ve → Reaction proceeds (**spontaneous**)

ΔG = 0 → Reaction at **equilibrium**

ΔG = +ve → Reaction does **not** occur (**non-spontaneous**)

Now Let's Study a **Diagram** which Helps in Predicting the **Feasibility** of **Thermal Reduction** of an Ore!

Ellingham Diagram

It is a graph that **provides** the basis for considering the choice of **reducing agent** in **reduction** of **oxides**.

Ellingham Diagram

1 Generally, it **consist of the plots** of

$\Delta_f G^o$ vs **T**

For formation of **oxides**

$$2xM\,(s) + O_2\,(g) \longrightarrow 2M_xO\,(s)$$

2 The slope of the graph of $xM \longrightarrow M_xO$ is **positive.**

As **ΔG increases** with **increases** in temperature.

Slope of the line of carbon is unique due to entropy factor.

Ellingham Diagram

3

Generally, **free energy** follows a **straight line, except** when the material **melt** or **vaporise** when there is **large change** in **entropy** associated with change in state.

↓

Slope of line **changes**

Hg ⟶ **HgO** line changes slope at **356 °C**

Hg boils

Mg ⟶ **MgO** line changes slope at **1120 °C**

Mg boils

Ellingham Diagram

Below which
ΔG = −ve

4

There is a **point** in the curve of the graph above which M_xO **decomposes** on its own.

So, M_xO is **stable**

Ellingham Diagram

5

In most of the processes, one **metal** is used to **reduce** the **oxide** of **another metal** at particular temperature

So, any metal can **reduce** the oxide of another metal which **lies above** it in the **Ellingham diagram**.

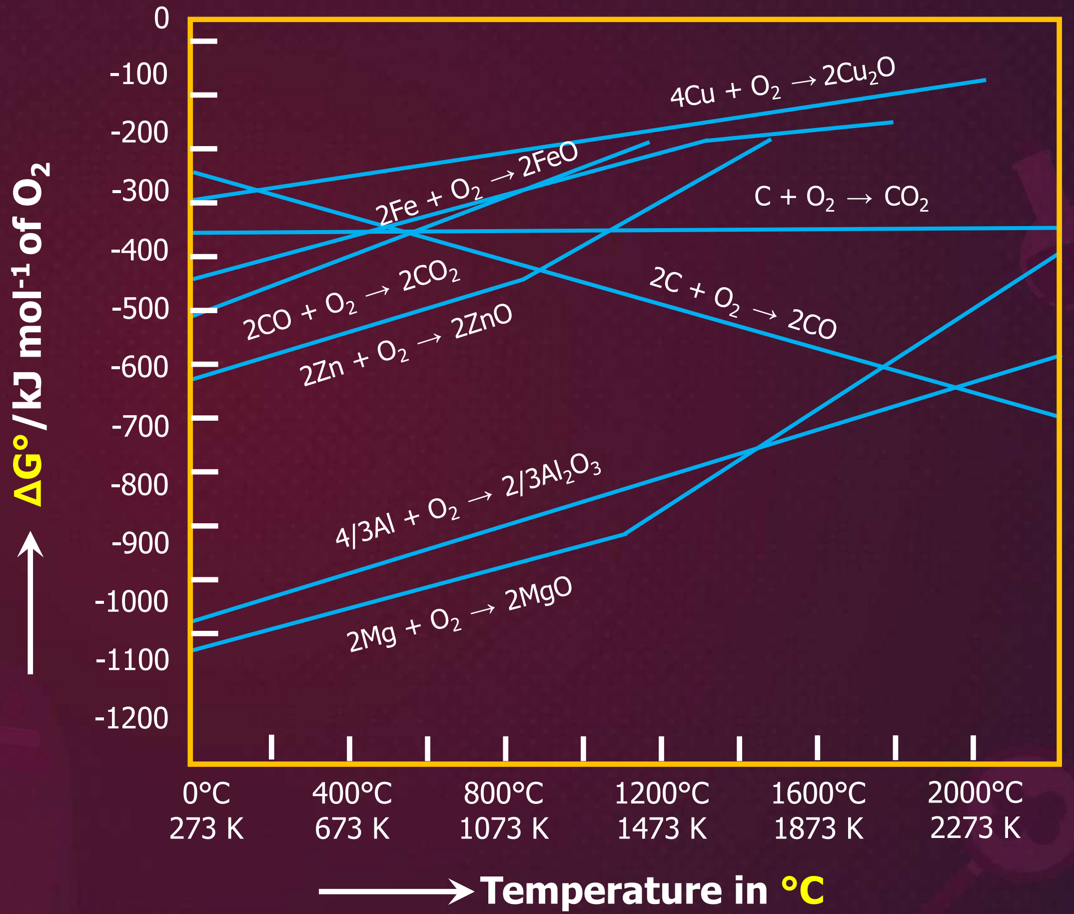
Al reduces the oxides of **Zn, Fe, Ti**

BUT,

It **cannot** reduce **MgO** at a temperature below **1500°C**

Ellingham Diagram

Larger the **difference** between the upper and lower lines, **easier** the **reduction.**



Applications of Ellingham Diagram

Extraction of

- **Fe** from its oxide
- **Cu** from **Cu_2O**
- **Zn** from **ZnO**

Extraction of Fe from Its Oxides

1. **Crushing** and **grinding** ✓
2. **Concentration** ✓ — By **calcination** or **roasting**
3. **Isolation/Extraction** of metal

The ore is mixed with **limestone** and **coke** — In blast furnace

Let’s See What Exactly Occurs in Blast Furnace!

Blast Furnace

Hot air is blown in from the **bottom** of **blast furnace**

Coke is burnt to produce a **high temperature** at the **lower** portion of furnace only

Up to **2200K**

CO and **heat** move to the **upper** part of the furnace

The **temperature** is **lower** in the **upper** part

Hence, **Fe oxides** get **reduced** at

Lower temperature range

Higher temperature range

Depending upon the **point of intersection** in the **Ellingham diagram**

Blast Furnace

At **500-800K (lower temperature),** the following reactions occur

$$3Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 + CO_2$$

$$Fe_3O_4 + 4CO \longrightarrow 3Fe + 4CO_2$$

$$Fe_2O_3 + CO \longrightarrow 2FeO + CO_2$$

At **900-1500K (higher temperature),** the following reactions occur

$$C + CO_2 \longrightarrow 2CO$$

$$FeO + CO \longrightarrow Fe + CO_2$$

Types of Iron

Iron may be

- Pig iron
- Cast iron
- Wrought iron

Pig Iron

The **iron** obtained from **furnace**

P, **S**, **Si**, **Mn**

Contains **4% carbon** and
a small amount of **impurities**

Can be **cast**
into a variety
of **shapes**

Known as **Pig iron**

Cast Iron

Preparation

Pig Iron → **Cast iron**

Melt

Scrap **Fe** and coke

Using **hot air blast**

Lower carbon content (**3%**), **hard**, and **brittle**

Wrought Iron

Prepared from **cast iron**

By **oxidising impurities** in a **reverberatory** furnace lined with **haematite**

Haematite oxidises **C** to **CO**

$$Fe_2O_3 + 3C \longrightarrow 2Fe + CO$$

Limestone is added as **flux**

S, **Si**, **P** are **oxidised** and passed into **slag**

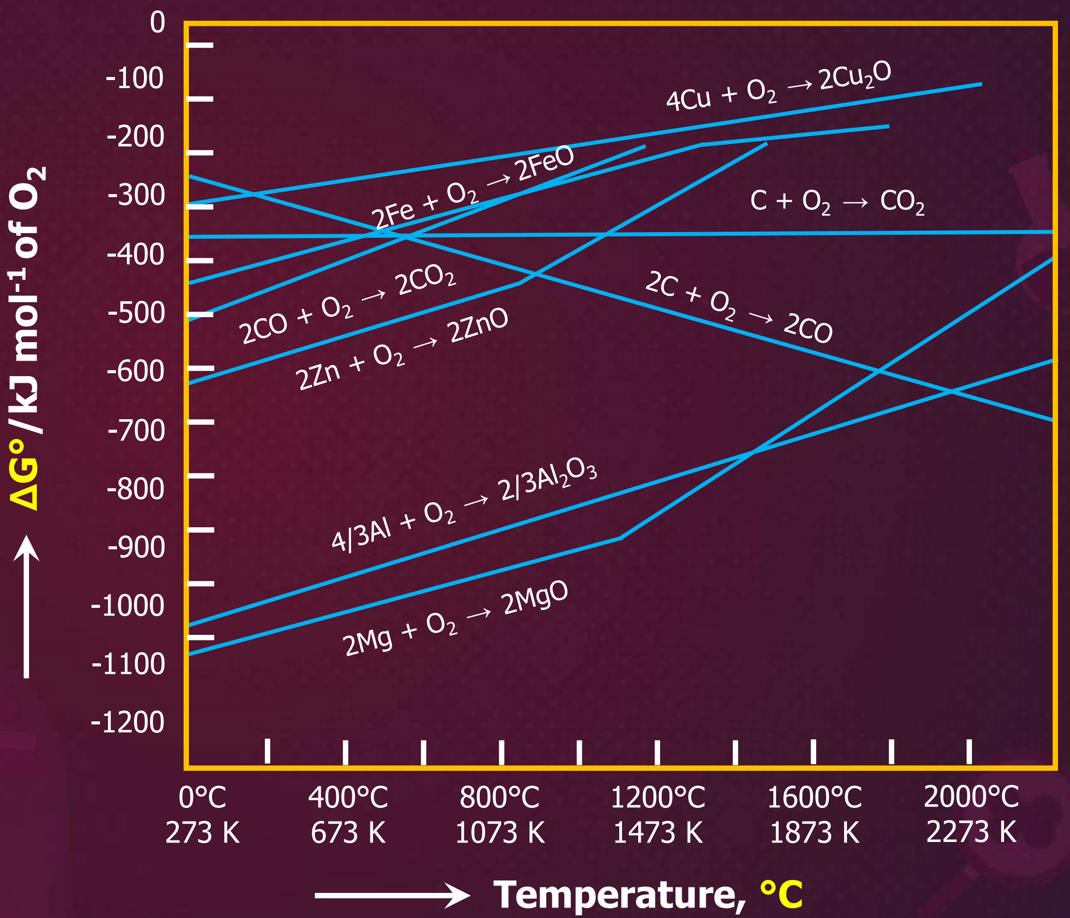
Hence, **iron metal** is removed

It consists of around **99.4% iron** by mass.

Extraction of Cu From Cu_2O

The **sulphide ores** of **Cu** are **roasted** as

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$



Extraction of Cu From Cu_2O

Hence, it is easy to **reduce** the oxide ores of **copper** directly to the **metal**

By just **heating** with **coke**

As $C \rightarrow CO$ and $C \rightarrow CO_2$ are at much lower positions

$$Cu_2O + C \longrightarrow 2Cu + CO$$

Actually, the ore is **heated** in a **reverberatory furnace** after mixing with **silica.**

$$\underset{\textbf{Impurity}}{FeO} + SiO_2 \longrightarrow \underset{\textbf{(Slag)}}{FeSiO_3}$$

Extraction of Cu From Cu_2O

Copper ore is produced as **copper matte.**

Contains Cu_2S and **FeS**.

Copper matte is then charged to a silica-lined **convertor** with the addition of some **silica**

After that, **hot air blast** is blown to **convert** the remaining **FeS**, **FeO**, and Cu_2S/Cu_2O to **Cu**

Reactions Involved in the Extraction of Cu

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

$$FeO + SiO_2 \longrightarrow FeSiO_3 \text{ (Slag)}$$

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$

The **solid copper** obtained has a **blistered** appearance

Due to SO_2 **evolution**

It is known as **Blister copper**

Blister Copper

Extraction of Zn from ZnO

Requires **higher temperature** than Cu

Reduction of ZnO is done using coke

For **heating** oxide, it is made into **brickettes** with **coke** and **clay**.

Reaction

$$ZnO + C \xrightarrow[1673\ K]{Coke} Zn + CO$$

Distilled off and collected by rapid **chilling**

Limitations of Ellingham Diagram

1. The theory assumes (often incorrectly) that the reactants and products are in equilibrium
2. Although the Ellingham diagram predicts the feasibility of the reaction, it does not give any data regarding competing alternative reactions
3. Also the Ellingham diagram does not predict the rates of the reactions

Electrolysis

Electrolysis

Electrochemical principles are governed by the given **equation.**

$$\Delta G^{o} = -nE^{o}F$$

Where, n = Number of **electrons**

E^{o} = **Electrode potential** of **redox** couple

$$\Delta G^{o} = -nE^{o}F$$

ΔG^{o}: **-ve**

$-nE^{o}F$: If **+ve**

Less reactive metal would **come out** of the solution.

More reactive metal will **go** to the solution.

Electrode Potential

$E^{o}_{Cu^{2+}(aq)/Cu(s)} = 0.34 \text{ V}$

$E^{o}_{Fe^{2+}(aq)/Fe(s)} = -0.41 \text{ V}$

$$E^{o}_{cell} = E^{o}_{Cu^{2+}(aq)/Cu(s)} - E^{o}_{Fe^{2+}(aq)/Fe(s)}$$

$$= 0.34 \text{ V} - (-\,0.41) \text{ V}$$

$$E^{o}_{cell} = 0.75 \text{ V}$$

+ve E^{o}

Electrode Potential

Reduction

Oxidation

$$Cu^{2+}(aq) + Fe(s) \longrightarrow Fe^{2+}(aq) + Cu(s)$$

Less reactive

More reactive

Normally discharged at **cathode**

Metallurgy of Some Important Metals

Metallurgy of

- Aluminium
- Copper

Electrometallurgy of Aluminium

In the metallurgy of **aluminium**

Purified Al_2O_3 is mixed with Na_3AlF_6 or CaF_2

Na_3AlF_6 or CaF_2 **lowers** the **melting point** of the mixture and brings conductivity.

Electrometallurgy of Aluminium

The fused matrix is **electrolysed.**

During electrolysis, a **steel vessel** is used where:

- Cathode → **Carbon lining**
- Anode → **Graphite**

$$2Al_2O_3 + 3C \longrightarrow Al + 3CO_2$$

The electrolysis is known as **Hall-Heroult process.**

Electrometallurgy of Aluminium

Reaction

At cathode:

$$\underset{\text{(melt)}}{Al^{3+}} + 3e^- \longrightarrow Al(l)$$

At anode:

$$C(s) + \underset{\text{(melt)}}{O^{2-}} \longrightarrow CO(g) + 2e^-$$

$$C(s) + \underset{\text{(melt)}}{2O^{2-}} \longrightarrow CO_2(g) + 4e^-$$

Formed by the reaction between **C** and O_2 liberated from **anode**

Hydrometallurgy of Copper

Low-grade ores

↓ Hydrometallurgy

High-grade ores

First ore is **leached.**

By using **acid** or **bacteria**

Solution containing Cu^{2+} is treated with scrap **Fe** or H_2.

$$Cu^{2+}(aq) + H_2(g) \longrightarrow Cu(s) + 2H^+(aq)$$

Purification of Metals

A metal **extracted** by any method is usually contaminated with some **impurities**

To obtain a metal of **high purity,** several **techniques** are required.

Refining Techniques

- Distillation
- Liquation
- Bessemerisation
- Poling
- Electrolytic refining
- Zone refining
- Vapour phase refining
- Chromatography

Distillation

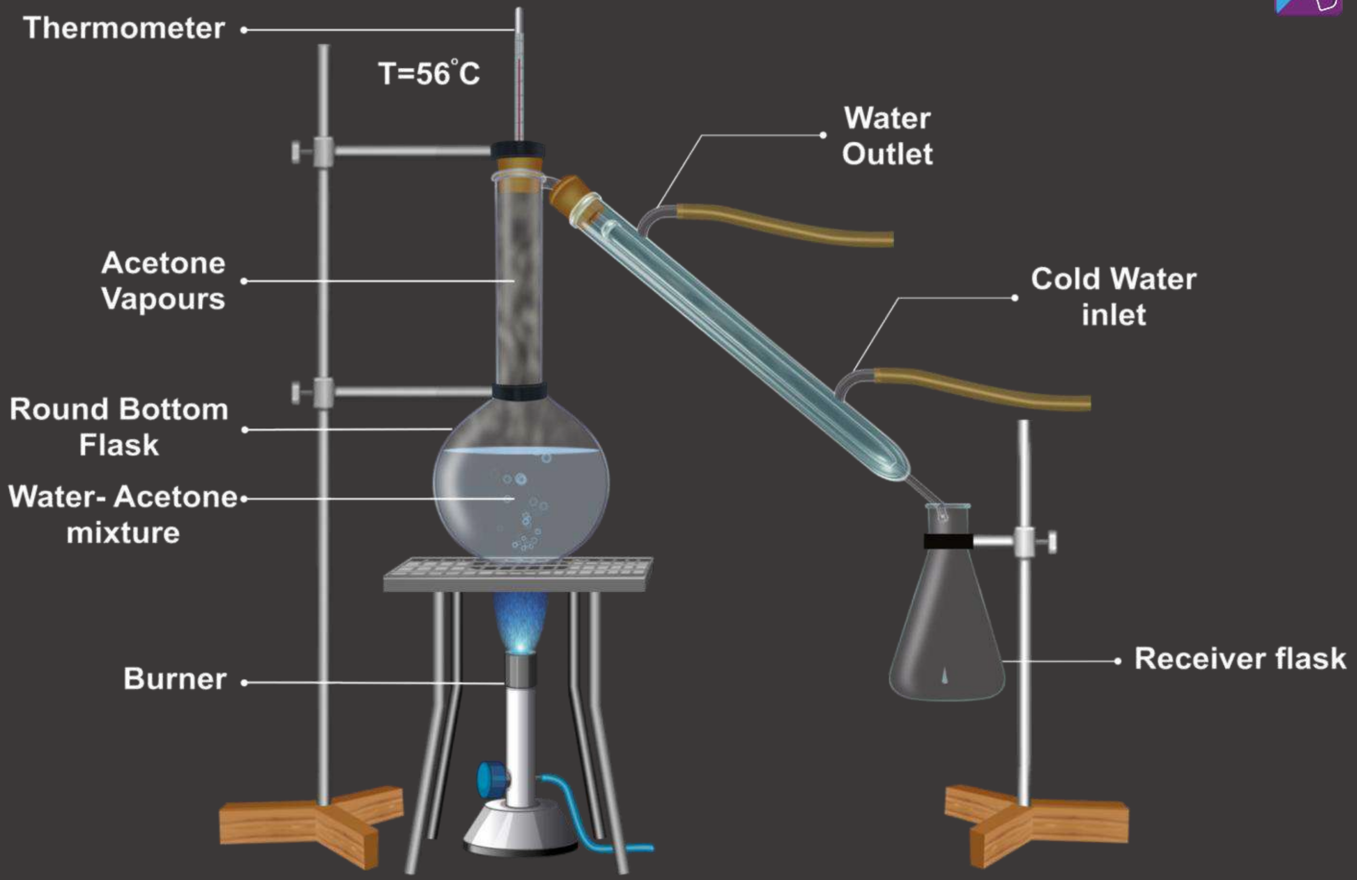
It is very useful for metals with **low boiling** points.

Like **Zn** and **Hg**

An impure metal is **evaporated** to obtain a **pure metal.**

Distillate

Distillation



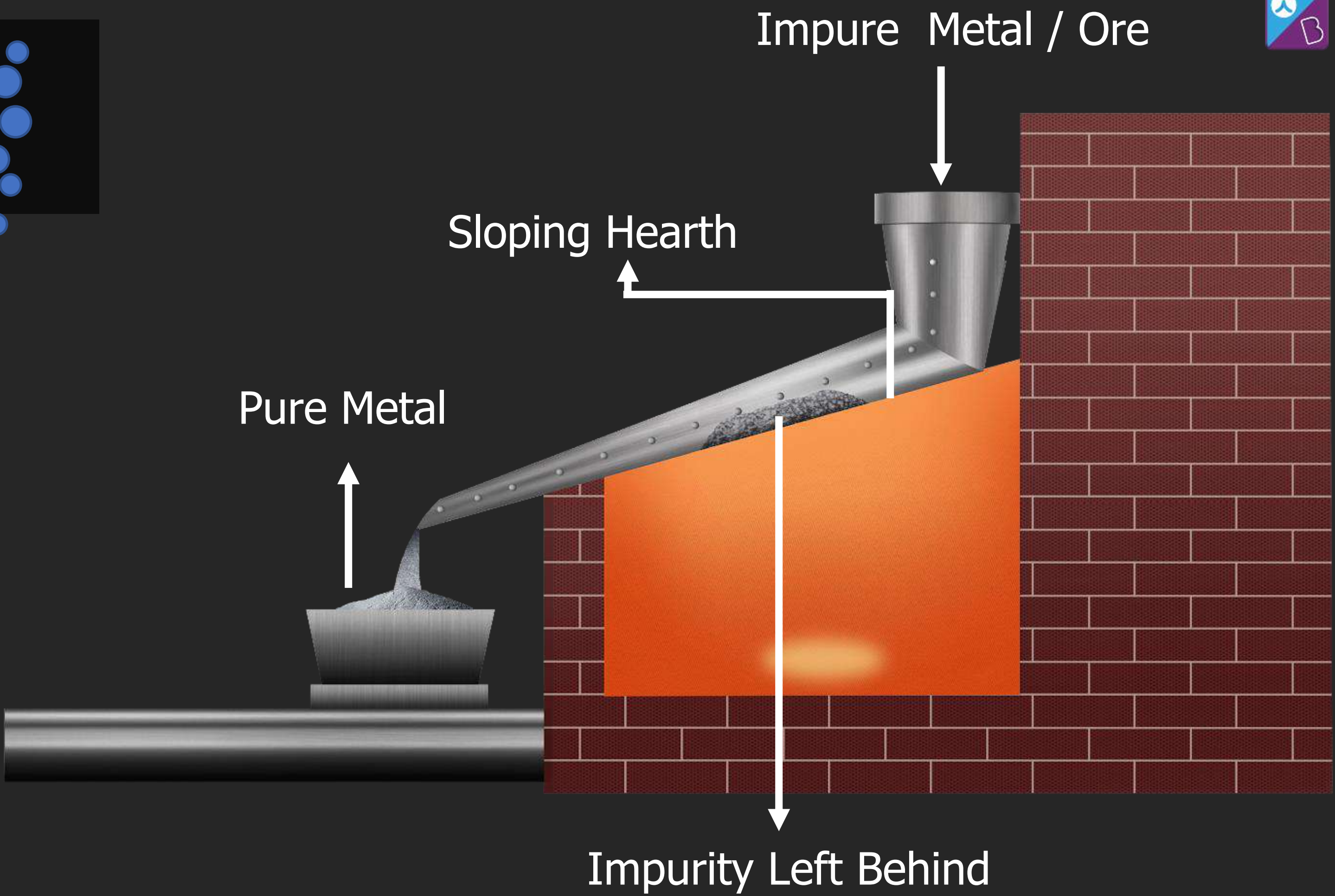
Liquation

Liquation is used for metals with **low melting points.**

Like **Sn**

Metal is made to flow on **sloping surface;** this is how it separates from impurities with **higher melting points.**

Liquation


Impure Metal / Ore
Sloping Hearth
Pure Metal
Impurity Left Behind

Bessemerisation

Method in which **air** is **blown** into **molten metal** mat

Deposited in the **bessemer converter**

In the final stage of **smelting**, **other products** (FeS) are **oxidized** ($FeSiO_3$) and removed as **slag.**

Copper metal

Step 1

$$Cu_2S \xrightarrow{\text{Air blast}} Cu_2O$$

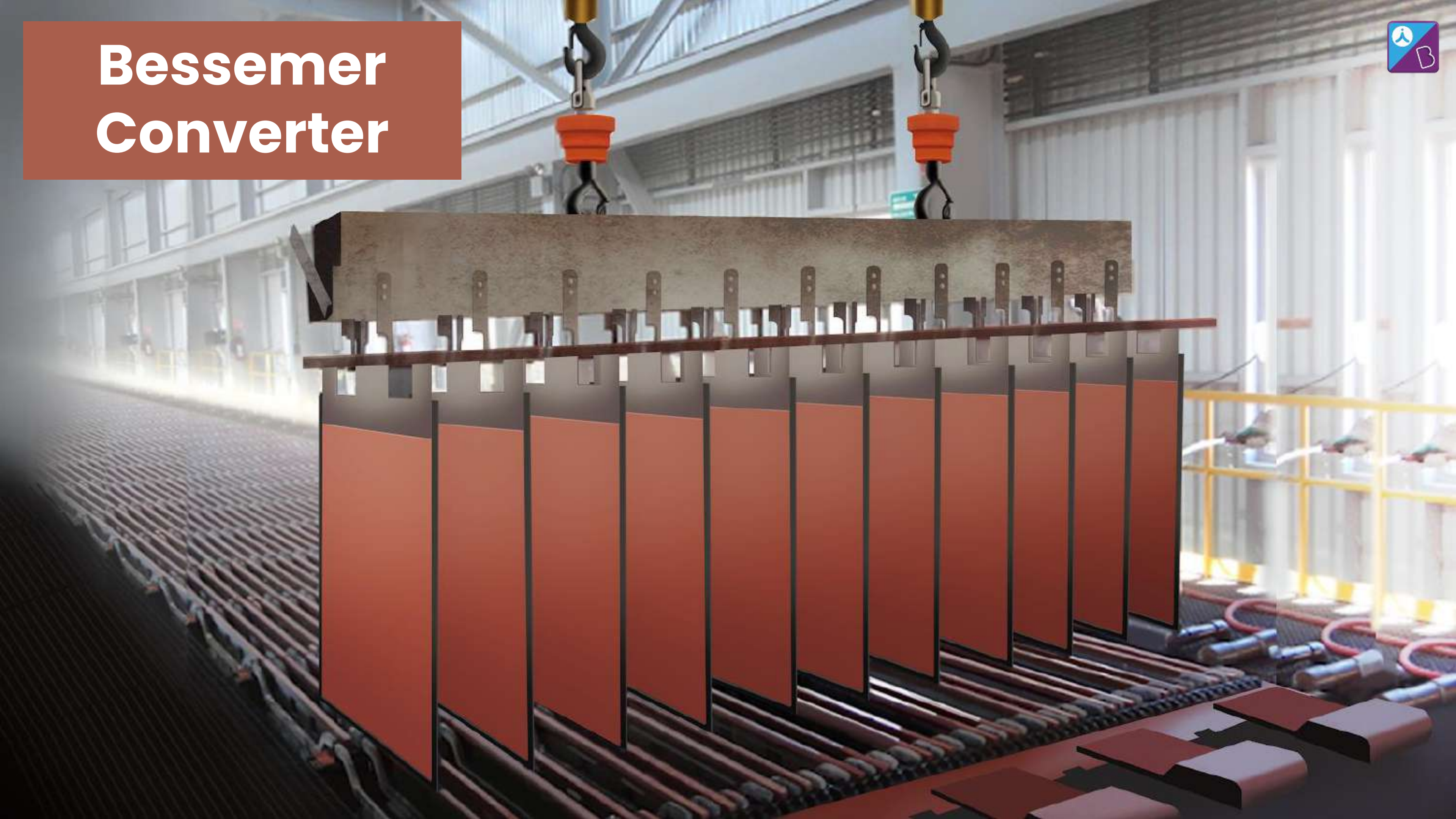
$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$

Step 2

Cu_2O reacts with the remaining **molten Cu**

$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$

Bessemer Converter



Poling

Used for **Cu** and **Sn**

Molten Cu contains **impurity**

Cu_2O

Molten Cu is treated with powdered **anthracite.**

Then stirred with a pole of **green wood.**

Poling

Green wood at higher temperature **liberates hydrocarbon** gases.

These gases are converted into **methane.**

Reduces CuO to Cu

Reaction

Green wood → Hydrocarbon → CH_4

$$4CuO + CH_4 \longrightarrow 4Cu + CO_2 + 2H_2O$$

99.5% pure → **Tough pitch copper**

Electrolytic Refining

In this method

Anode	**Impure** metal
Cathode	Strip of the **same** metal in its **pure form**

Both the electrodes are put in a **suitable electrolytic** bath.

Containing **soluble salt** of same metal

Electrolytic Refining

General reaction

Anode: $M \longrightarrow M^{n+} + ne^{-}$

More basic metal

Cathode: $M^{n+} + ne^{-} \longrightarrow M$

Less basic metal

Copper Refining

Anode	**Impure** copper
Cathode	**Pure** copper strips
Electrolyte	**Acidified** solution of $CuSO_4$

Reactions involved

Anode: $Cu \longrightarrow Cu^{2+} + 2e^-$

Cathode: $Cu^{2+} + 2e^- \longrightarrow Cu$

NOTE

Impurities from **blister copper** deposit as **anode mud**

Contains **Se, Te, Ag, Au, Pt**

Recovery of these metals may meet the **cost** of **refining**.

Zn can also be refined from **electrolytic refining.**

Zone Refining

Principle

Impurities are **more** soluble in the **molten state** than in the **solid metal**.

A **circular mobile heater** is **fixed** at one end of a rod of the impure metal.

The molten zone **moves** along with the **heater** that moves **forward**.

Zone Refining

As heater moves

- **Pure** metal **crystallises** out of melt.
- The **impurities** pass on into the **adjacent** molten zone.

Zone Refining

Process is **repeated** several times and the heater is moved in the **same direction.**

Impurities get concentrated at **one end.**

This end is **cut off**

Ge, **Si**, **B**, **Ga**, **In**, etc.

Semiconductors and other **metals**

Requirements of Vapour Phase Refining

1. A metal should form a **volatile compound** with a **reagent.**

2. The volatile compound should be **easily decomposable.**

For **easy recovery**

Vapour Phase Refining

Vapour phase refining

- Mond's process
- Van Arkel method

Requirements of vapour phase refining

A metal should form a **volatile compound** with a **reagent**.

→

The volatile compound should be **easily decomposable** for **easy recovery**.

Van Arkel Method

Van Arkel method is useful for removing **impurities** from metals like **Zr, Ti.**

Oxygen and **nitrogen**

Van Arkel Method

Step 1

Crude metal is heated in an evacuated vessel with **iodine.**

volatilises

$$Zr + 2I_2 \longrightarrow ZrI_4$$

More covalent

Step 2

Metal iodine is decomposed on **tungsten filament.**

Heated to about **1800 K**

$$ZrI_4 \longrightarrow Zr + 2I_2$$

Pure metal

Mond's Process

Step 1

Ni is **heated** in a stream of CO to form **nickel tetracarbonyl.**

Step 2

The volatile compound is subjected to **higher temperature.**

$$Ni + 4CO \xrightarrow{330\text{-}350\ K} Ni(CO)_4$$

Volatile

$$Ni(CO)_4 \xrightarrow{450\text{-}470\ K} Ni + 4CO$$

Pure metal

Chromatography

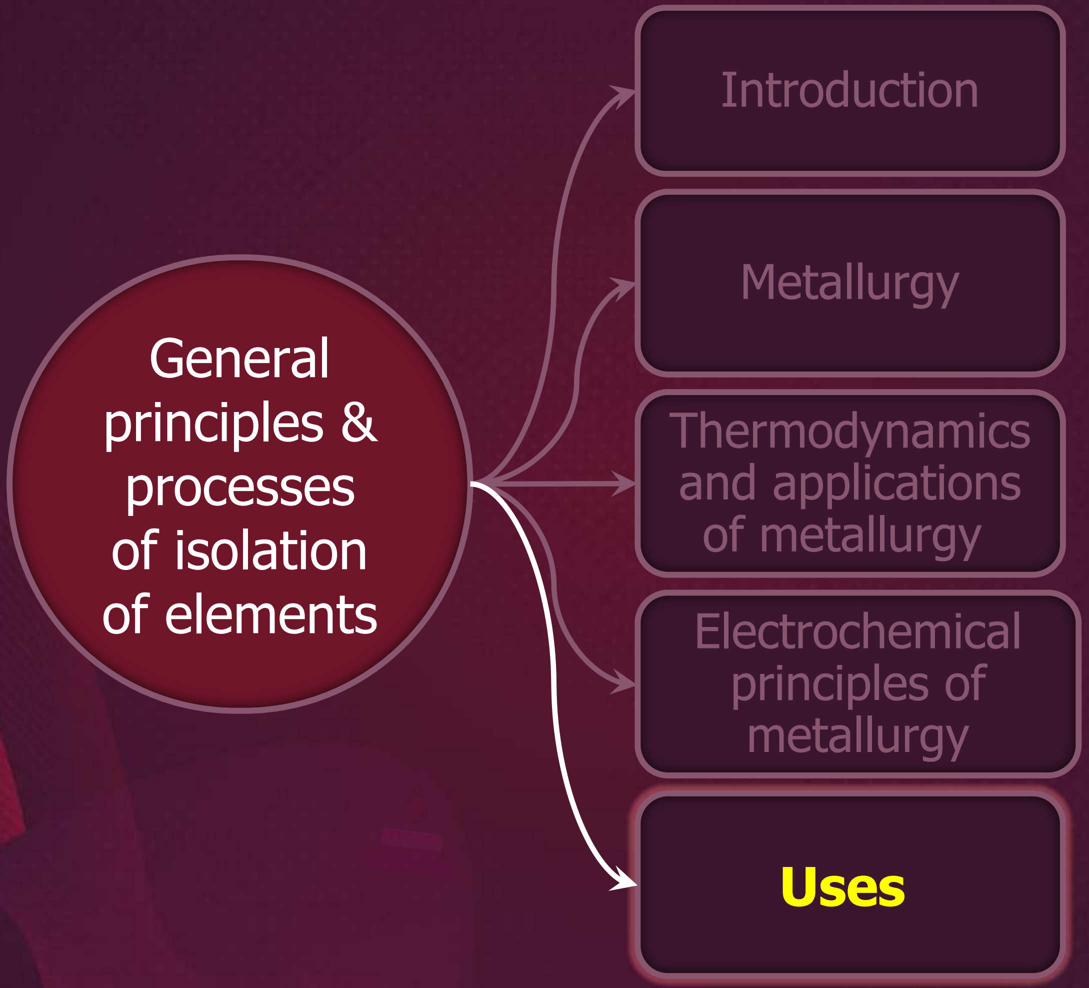
In **chromatography,** a column of Al_2O_3 is prepared in a **glass tube**

The **moving** medium containing a solution of components is in **liquid form**.

Column chromatography

It is very useful for the **purification** of elements that are available in **minute quantities**

Impurities are **not** very different in chemical properties from the element to be **separated**.


General principles & processes of isolation of elements
Introduction
Metallurgy
Thermodynamics and applications of metallurgy
Electrochemical principles of metallurgy
Uses

Wrappers for chocolates

Fine dust of aluminum in paints and lacquers

Electricity conductors of aluminium wire

Brass

Cu + Zn

60%

40%


Coinage Alloy
Cu + Ni


German Silver
Zn: 25-30%
Cu: 25-30%
Ni: 40-50%


Alloys


Cast Iron


Copper wires
for steam


Cast iron


Wrought iron


Chrome iron