Physical Properties of Metals and Non-metals (भौतिक गुण) (धातु) (अधातु)

The resistance offered by a substance against cutting or scratching. (अवरोध) (काटना) (घिसना)

Only defined for solids (ठोस)

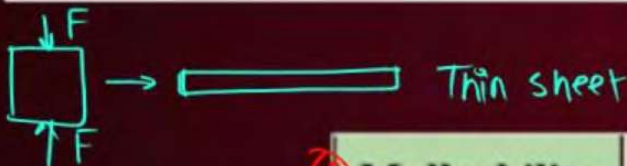
Property	Metals	Non-metals
① Hardness	Generally, hard Exception: ① Lithium, Sodium and Potassium (cut with a knife (soft metals)) ② Mercury	Generally, soft Exception: Diamond **(Naturally hardest substance and a form of C)**
② Lustre	Lustrous	Generally, non-lustrous / dull Exception: Iodine and Graphite (Form of C)

The ability of metals to reflect light due to which they have a shiny surface.

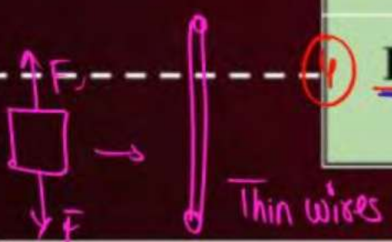
Physical Properties of Metals and Non-metals

The ability of metals to be converted into thin sheets on application of compressive forces.

(दबाव)



	Metals	Non-metals
3 **Malleability**	Generally, malleable Exception: Mercury → liquid state at room temp. (25°C)	Non-malleable
4 **Ductility**	Generally, ductile Exception: Mercury	Generally, non-ductile Exception: Carbon fibre



The ability of metals to be converted into thin wires on application of tensile forces. (खिंचाव)

Physical Properties of Metals and Non-metals

Produce deep ringing sound when struck hard

M.P. State at room temp. (25°C)

Ga → 29.7°C SOLID

Cs → 28.4°C SOLID

melts on human palm (37°C)

Property	Metals	Non-metals
5 Sonority	Sonorous	Non-sonorous
6 Electrical conductivity	Good electrical conductors	Generally poor electrical conductors Exception: Graphite (form of C)
7 Thermal conductivity or Heat conduction	Generally good thermal (heat) conductors Exception: Lead & Mercury	Generally poor thermal conductors Exception: $\boxed{\text{Diamond}}$
8 Melting point	High melting point Exception: Gallium and Caesium, Mercury	Generally, low melting point Exception: Graphite & Diamond

Fun Fact!

- Gold is the most malleable metal.
- Platinum is the most ductile metal. *(Gold according to NCERT)*
- Diamond is the best conductor of heat among all elements.
- Silver is the best conductor of heat in case of metals.
- Order of electricity conduction in case of metals will be:

Silver > Copper > Gold > Aluminium

How Reactivity Series Was Built?!

REACTION OF METALS WITH OXYGEN	EXAMPLES
• Metal + Oxygen → Metal oxide	$2Cu + O_2 \rightarrow 2CuO$ (Black) (Copper) (Copper(II) oxide) — Shiny brown
	$4Al + 3O_2 \rightarrow 2Al_2O_3$ (Aluminium) (Aluminium oxide)

metal oxides

MBA → Basic, amphoteric

both

Neutralisation Rxn

Metal oxide	+	Acid	→	Salt	+	Water
$Al_2O_3(s)$ Base	+	6 dil. $HCl(aq)$ Strong Acid	→	$2AlCl_3(aq)$ (Aluminium chloride)	+	$3H_2O(l)$

Metal oxide	+	Base	→	Salt	+	Water
$Al_2O_3(s)$ Acid	+	$2NaOH(aq)$ Strong base	→	$2NaAlO_2(aq)$ (Sodium aluminate)	+	$H_2O(l)$

- Metal oxides are **basic** and **amphoteric** in nature.
- Basic metal oxides: **Na_2O, K_2O, CaO** etc.
- Amphoteric metal oxides: **Al_2O_3, ZnO** etc.

Non-metal + Oxygen $\rightarrow$ Non-metal oxide

$$C + O_2 \rightarrow CO_2$$

$$S + O_2 \rightarrow SO_2$$

$$N_2 + O_2 \rightarrow 2NO$$

Non-metal oxide

- Acidic
  - CO_2, NO_2, SO_2, SO_3 etc.
- Neutral
  - H_2O, CO, NO, N_2O etc.

How Reactivity Series Was Built?!

(Reaction of Metals with oxygen)

(stored in kerosene because they react even at room temp. in air)

(25°C)

Metal	At Room Temperature	On Strong Heating
K	Forms K_2O and burns	lilac / pale purple flame → Burns and forms K_2O
Na	Forms Na_2O and burns	golden flame → Burns and forms Na_2O
Ca	Forms protective layer of CaO on Ca	bright white flame: Burns and forms CaO
Mg	Forms protective layer of MgO on Mg	bright white flame: Burns and forms MgO
Al	Forms protective layer of Al_2O_3 on Al	bright white flame: Burns and forms Al_2O_3
Zn	Forms protective layer of ZnO on Zn	blue flame ← Burns and forms ZnO
Fe	Forms protective layer of Fe_3O_4 ($FeO.Fe_2O_3$) on Fe	Sparkles ← Powdered iron burns vigorously
Pb	Forms protective layer of PbO on Pb	Don't burn but forms PbO
Cu	On low heating forms CuO (black) on Cu	Don't burn but forms CuO
Ag, Au and Pt	NO REACTION	NO REACTION

How Reactivity Series Was Built?!

REACTION OF METALS WITH COLD WATER	OBSERVATIONS

- The metal that reacts at a lower temp. is more reactive than the one that doesn't react or react slowly.
- Only **K, Na and Ca** reacts with cold water.

Metal	+ Cold water →	Metal hydroxide	+ Hydrogen gas
$2Na(s)$	$+ 2H_2O(l) \rightarrow$	$2NaOH(aq)$	$+ H_2(g)$ + heat
$2K(s)$	$+ 2H_2O(l) \rightarrow$	$2KOH(aq)$	$+ H_2(g)$ + heat

(i) Evolved hydrogen gas catches fire.

(ii) H_2 gas immediately catches fire in case of K. It means speed of reaction of K with H_2O is greater than Na with H_2O.

So, $\boxed{\textbf{reactivity of K > Na.}}$

(iii) Metal oxides formed in these cases are soluble in water and forms metal hydroxides.

ex: $Na_2O + H_2O \rightarrow 2NaOH$

Metal	+ Cold water →	Metal hydroxide	+ Hydrogen gas
$Ca(s)$	$+ 2H_2O(l) \rightarrow$	$Ca(OH)_2(aq)$	$+ H_2(g)$ + heat

(i) Evolved hydrogen gas doesn't catch fire.

(ii) The tiny bubbles of hydrogen gas formed stick to the surface of the calcium, and hence it starts floating on the water.

Conclusion: Order of reactivity → K > Na > Ca

How Reactivity Series Was Built?!

REACTION OF METALS WITH HOT WATER

- Only **K, Na, Ca and Mg** reacts with hot water.

Metal	+	Hot water	→	Metal hydroxide	+	Hydrogen gas
$Mg(s)$	+	$2H_2O(l)$	→	$\boxed{Mg(OH)_2(aq)}$	+	$H_2(g)$ + heat

OBSERVATIONS

(i) Evolved hydrogen gas doesn't catch fire.

(ii) The tiny bubbles of hydrogen gas formed stick to the surface of the ~~calcium~~ magnesium, and hence it starts floating on the water.

(iii) Speed of reaction of metals with hot water follows the below order:

$$\boxed{K > Na > Ca > Mg}$$

How Reactivity Series Was Built?!

REACTION OF METALS WITH STEAM	OBSERVATIONS
• **K, Na, Ca, Mg, Al, Zn and Fe** reacts with steam.	(i) Evolved hydrogen gas doesn't catch fire. (ii) We can only arrange those metals that react with cold or hot water in decreasing order of their reactivity which is: $\boxed{\textbf{K > Na > Ca > Mg}}$

$$\text{Metal} + \text{Steam} \rightarrow \text{Metal oxide} + \text{Hydrogen gas}$$

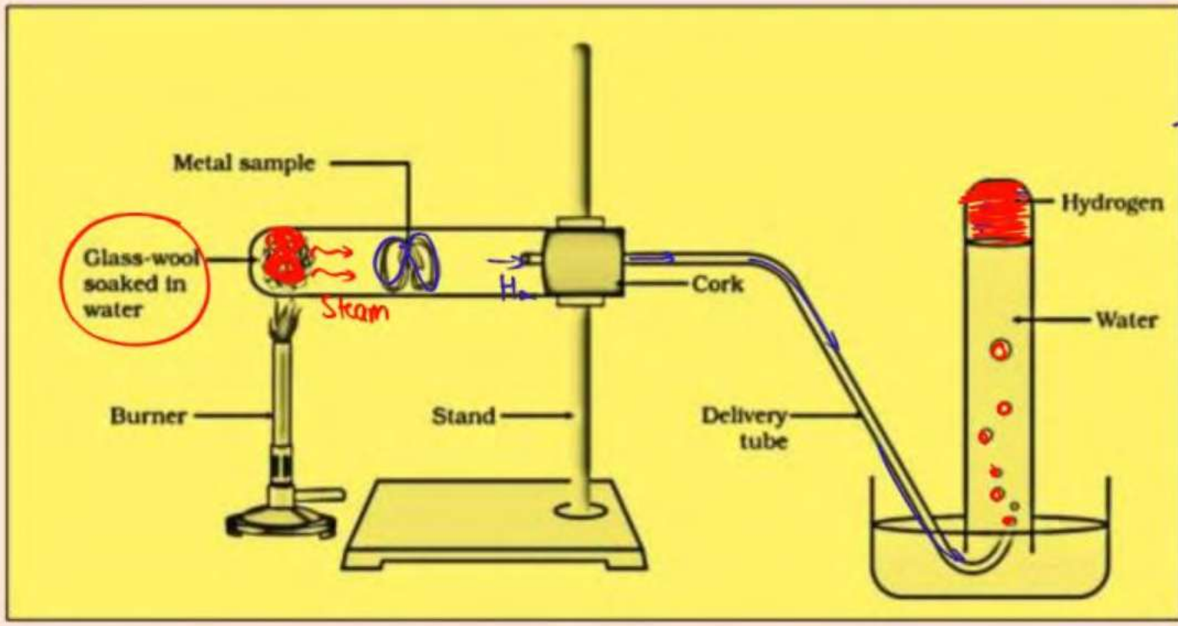
$$2Al(s) + 3H_2O(g) \rightarrow Al_2O_3(s) + 3H_2(g)$$

$$Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$$

$$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$$

How Reactivity Series Was Built?!

REACTION OF METALS WITH STEAM



→ downward displacement of water

→ (i) H_2 is insoluble in H_2O

(ii) H_2 is lighter than H_2O

How Reactivity Series Was Built?!

REACTION OF METALS WITH DILUTE ACIDS	OBSERVATIONS
• Metal + Dil. Acid. → Salt + Hydrogen Gas ***(when reactivity of metal > hydrogen of acid)*** **<u>Important to Remember</u>** • In case of nitric acid, only magnesium and manganese react with very dilute nitric acid to form salt and hydrogen gas. • When other metals react with nitric acid, hydrogen gas is not evolved. Nitric acid being a strong oxidising agent oxidises the hydrogen gas to water and itself gets reduced to oxides of nitrogen like $NO/NO_2/N_2O$. • **Aqua regia**, which in Latin means '**royal water**' is a mixture of *concentrated nitric acid and hydrochloric acid in the ratio of 1:3* by volume. It is a highly corrosive and fuming liquid. It is one of the few reagents that can dissolve gold and platinum.	• When magnesium, aluminium, zinc, iron and lead reacts with dilute hydrochloric acid, the rate of formation of hydrogen bubbles follows the order Mg > Al > Zn > Fe > Pb. • We can only arrange those metals that react with dilute acids in decreasing order of their reactivity which is: **K > Na > Ca > Mg > Al > Zn > Fe > Pb** Cu, Ag, Au & Pt don't react with dil. acids

How Reactivity Series Was Built?!

REACTION OF METALS WITH SALT SOLUTION OF OTHER METALS

(i) $Ag\,(s) + Cu(NO_3)_2\,(aq) \rightarrow$ No Reaction
(ii) $Au\,(s) + Cu(NO_3)_2\,(aq) \rightarrow$ No Reaction

(I), (II) & (III) → Reactivity of Cu > Ag & Au

Reaction of copper with silver nitrate solution: When a copper wire is introduced in the colourless solution of silver nitrate, the solution starts turning blue due to the formation of copper nitrate.

$$\underbrace{Cu(s)}_{\text{Shiny brown}} + \underbrace{2AgNO_3(aq)}_{\text{Colourless}} \rightarrow \underbrace{Cu(NO_3)_2(aq)}_{\text{Blue soln}} + \underbrace{2Ag(s)}_{\text{Silvery grey}}$$

Hence, reactivity of Cu > Ag.

(IV)
Ag: free as well as combined state
Au: always free state

Reactivity Series of Metals

Kudi Naal Car Maango Alto Zisko Fir Lekar Hum Chale Mathura Sath Ghumne Prateek

(it can lose electron like metals)

K	Reactivity (↓)	Potassium
Na		Sodium
Ca		Calcium
Mg		Magnesium
Al		Aluminium
Zn		Zinc
Fe		Iron
Pb		Lead
H		**Hydrogen**
Cu		Copper
Hg		Mercury
Ag		Silver
Au		Gold
Pt		Platinum

Formation of Ionic Compounds / Electrovalent Compounds

metal

$$\underset{(2,8,1)}{Na} \rightarrow \underset{(2,8)}{Na^{1+}} + e^-$$

Cation

$$\underset{(2,8,7)}{Cl} + e^- \rightarrow \underset{(2,8,8)}{Cl^{1-}}$$

Anion

Non-metal

metal

$$\underset{(2,8,2)}{Mg} \rightarrow \underset{(2,8)}{Mg^{2+}} + 2e^-$$

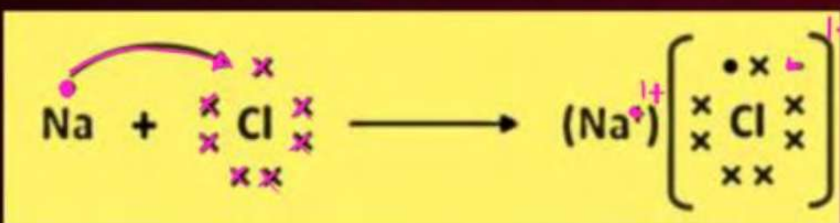
cation

$$\underset{(2,8,7)}{Cl} + e^- \rightarrow \underset{(2,8,8)}{Cl^-}$$

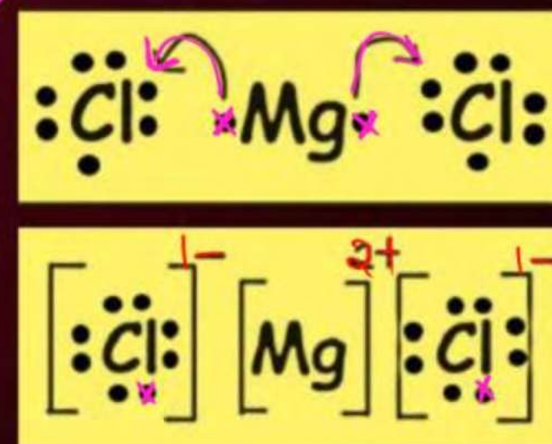
anion

non-metal

Lewis Electron Dot Structure - NaCl



Lewis Electron Dot Structure – $MgCl_2$



Properties of Ionic Compounds

(i) **Physical nature**	Generally, brittle solids and breaks into pieces when pressure is applied.
(ii) **Melting and boiling points**	High melting and boiling points as a sufficient amount of energy is required to break the strong electrovalent bonds. strong electrostatic force of attraction b/w oppositely charged ions
(iii) **Solubility**	Generally, Soluble in water and insoluble in solvents like kerosene, petrol and more.
(iv) **Electrical conductivity** (because ions are free to move)	Conducts electricity in molten and aqueous form. It does not conduct electricity in solid form as the ions are immobile in the solid state.

Important Terms in Metallurgy

- Metals occur naturally in the form of elements (free state) or compounds (combined state) in the earth's crust (major source) or seawater (minor source) and are called **minerals**.
- The minerals from which metals can be extracted economically and conveniently are called **ores**. Thus, all ores are minerals but all minerals are not ores.
- The earthly and rocky impurities that are associated with the mineral are called **gangue or matrix**.

Important Terms in Metallurgy

Common steps

- **Crushing and grinding of ore:** This involves converting the ore to powdered form.
- **Concentration/Dressing/Enrichment of ore:** This involves removing gangue or matrix from ore due to their differences in physical or chemical properties.
- **Roasting:** Sulphide ores are heated in excess of oxygen (from air) below melting point of metal to convert to metal oxide. Sulphur dioxide gas is evolved.
- **Calcination:** Carbonate ores are heated in absence of oxygen below melting point of metal to convert to metal oxide. Carbon dioxide gas is evolved.

Ores of Some Common Metals

Metal	Name of the ore	Chemical formula of ore
(a) Sodium (Na)	Rock salt	$NaCl$
(b) Aluminium (Al)	Bauxite	$Al_2O_3.2H_2O$
(c) Zinc (Zn)	(i) Zinc blende (ii) Calamine	(i) ZnS (ii) $ZnCO_3$
(d) Iron (Fe)	(i) Haemetite (ii) Magnetite (iii) Iron pyrite (iv) Siderite	(i) Fe_2O_3 (ii) Fe_3O_4 (iii) FeS_2 (iv) $FeCO_3$
(e) Copper (Cu)	(i) Copper glance (ii) Cuprite (iii) Copper pyrite	(i) Cu_2S (ii) Cu_2O (iii) $CuFeS_2$
(f) Mercury (Hg)	Cinnabar	HgS
(g) Lead (Pb)	Galena	PbS

Important to Remember

K, Na, Ca, Mg, Al	Metals of high reactivity *(always exists in combined state or in the form of compounds)*
Zn, Fe, Pb	Metals of medium reactivity *(always exists in combined state or in the form of compounds)*
Cu, Hg, Ag	Metals of low reactivity *(always exists in free state as well as combined state)*
Au, Pt	Metals of least reactivity *(always exists in free state or in the form of elements)*

All Steps – Metals of Low Reactivity

(Sulphide Ore discussion in course)

Step I
Crushing and Grinding of Ore

Powdered Ore

Step II
Concentration of Ore

Concentrated Ore

Step III
Roasting (Sulphide Ore)

metal oxide

Step IV
Auto-reduction
(Conversion of metal oxide to metal)

metal

Step V
Refining/Purification of Metal

Extraction of Metals of Low Reactivity

Cu_2S: Copper Glance

HgS: Cinnabar

Step III: Roasting

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

(from air)

$$2HgS(s) + 3O_2(g) \xrightarrow{\Delta} 2HgO(s) + 2SO_2(g)$$

(from air)

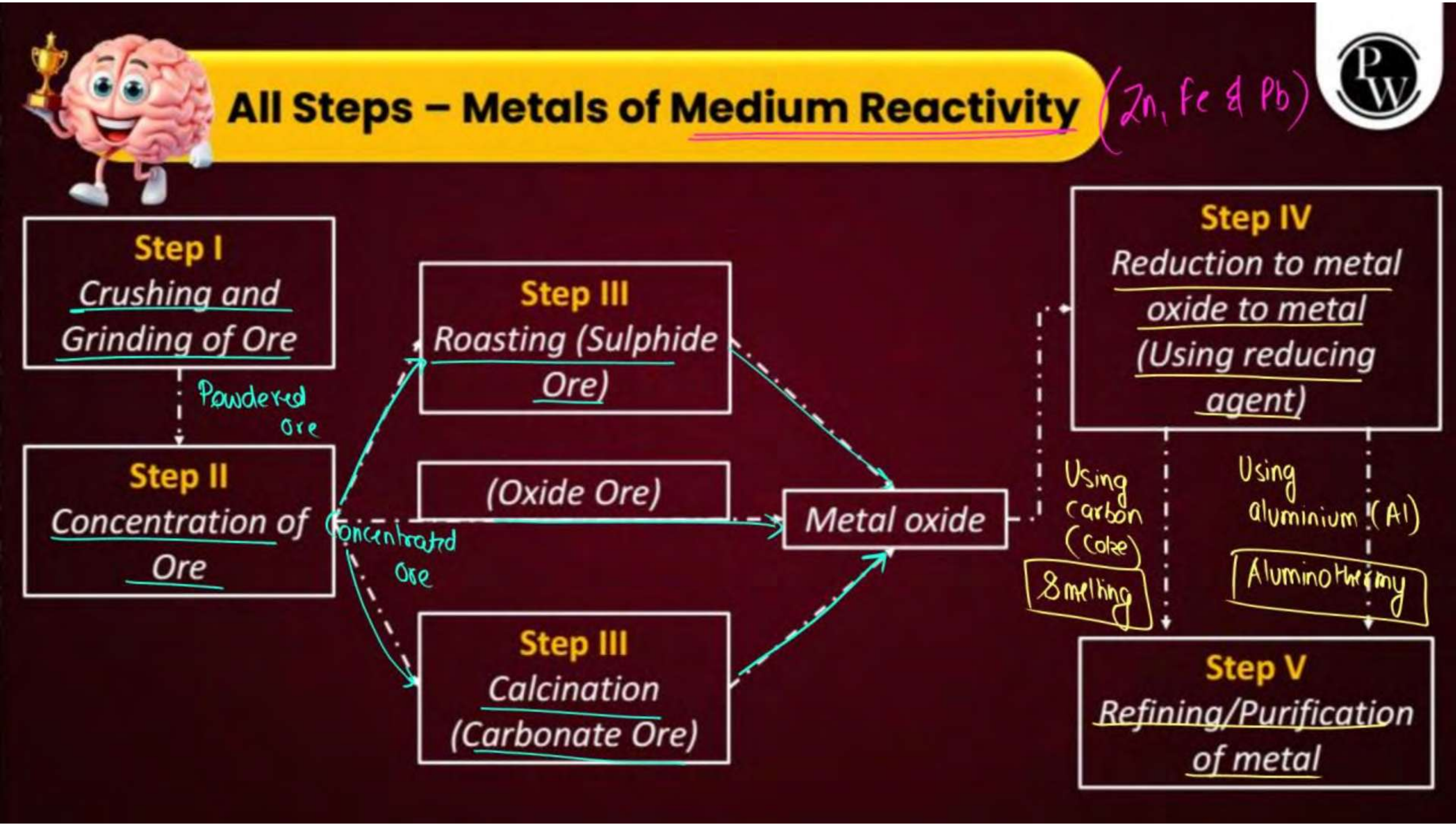
Step IV: Auto-reduction

$$2Cu_2O(s) + Cu_2S(s) \xrightarrow{\Delta} 6Cu(s) + SO_2(g)$$

$$HgS(s) + 2HgO(s) \xrightarrow{\Delta} 3Hg(l) + SO_2(g)$$

$$2HgO(s) \xrightarrow{\Delta} 2Hg(l) + O_2(g)$$

Step V - Refining / Purification of metal


All Steps – Metals of Medium Reactivity
(Zn, Fe & Pb)
Step I
Crushing and Grinding of Ore
Powdered Ore
Step II
Concentration of Ore
Concentrated Ore
Step III
Roasting (Sulphide Ore)
(Oxide Ore)
Step III
Calcination (Carbonate Ore)
Metal oxide
Step IV
Reduction to metal oxide to metal (Using reducing agent)
Using carbon (Coke)
Smelting
Using aluminium (Al)
Aluminothermy
Step V
Refining/Purification of metal

Extraction of Metals of Medium Reactivity

Step I & IInd → same

ZnS: Zinc Blende

$ZnCO_3$: Calamine

Step III: Roasting

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

(from air)

Step III: Calcination

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

Step IV: Smelting

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

(coke)

Step V: Refining of metal

Extraction of Metals of Medium Reactivity

Reduction of metal oxide by Al → Aluminothermy

The below reactions are examples of displacement, exothermic and redox reactions.

Removal of oxygen - Reduction - Oxidising agent

Pyrolusite $3MnO_2(s) + 4Al(s) \xrightarrow{\Delta} 3Mn(l) + 2Al_2O_3(s) + heat$

molten form

Addition of oxygen - OXIDATION - Reducing agent

$Fe_2O_3(s) + 2Al(s) \xrightarrow[\text{Mg ribbon}]{\text{Ignited by}} 2Fe(l) + Al_2O_3(s) + Heat$

reddish-brown oxide

Silvery grey metal powder

Molten / fused form

This reaction is also classified as a thermite reaction and is used for welding the broken parts of *iron machinery, railway tracks* etc.

K
Na
Ca
Mg
Al
C
Zn
Fe
Pb

can reduce metals below it

All Steps – Metals of High Reactivity

(K, Na, Ca, Mg, Al)

Ores exists as oxides or chlorides

'In syllabus'

Step I

Crushing and Grinding of Ore

Powdered Ore

Step II

Concentration of Ore

Concentrated Ore

Step III

$\boxed{\textit{Electrolytic Reduction}}$

Pure metal

Extraction of Metals of High Reactivity

→ Electrolytic Reduction of Molten NaCl

OIL RIG Lekar Tum Bhangra PAO NCR mein

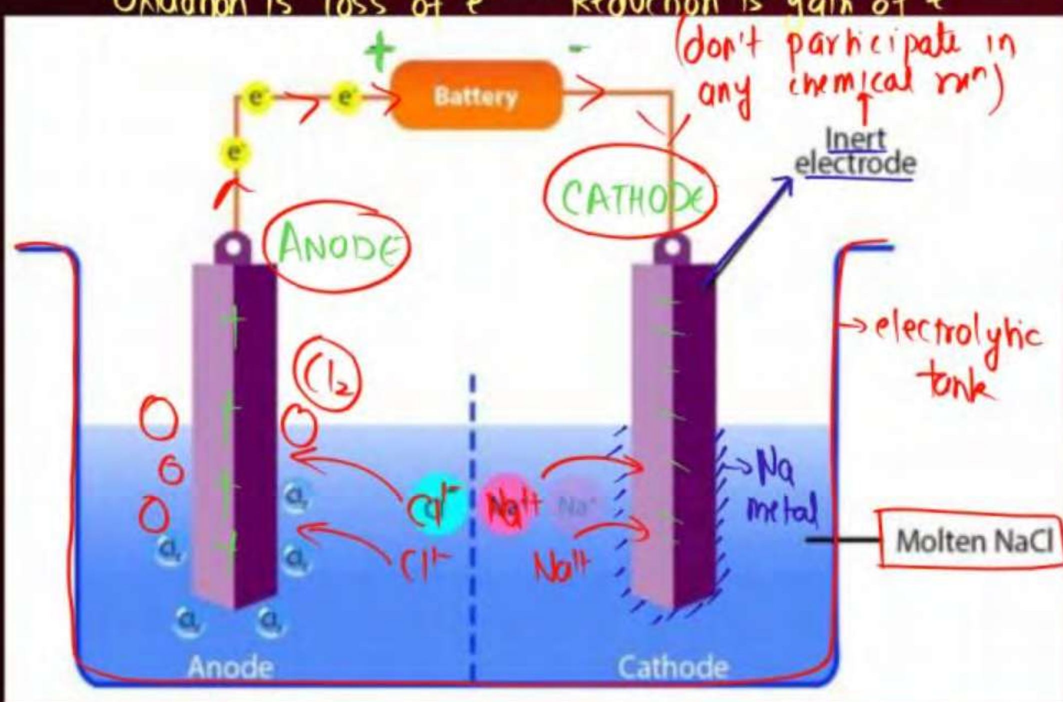
→ Name of ore: Rock salt (NaCl)

OIL → Oxidation is loss of e^-

RIG → Reduction is gain of e^-

PAO → +ve, anode, oxidation

NCR → -ve, cathode, reduction



- Molten/Fused NaCl: Strong Electrolyte
- $NaCl \rightarrow Na^+ + Cl^-$
- Inert Electrode: Graphite or Platinum

Reaction at cathode (Reduction: Gain of electrons)

$$Na^+ + e^- \rightarrow Na$$

Reaction at anode (Oxidation: Loss of electrons)

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

$Cl^{1-} \rightarrow Cl + e^-$

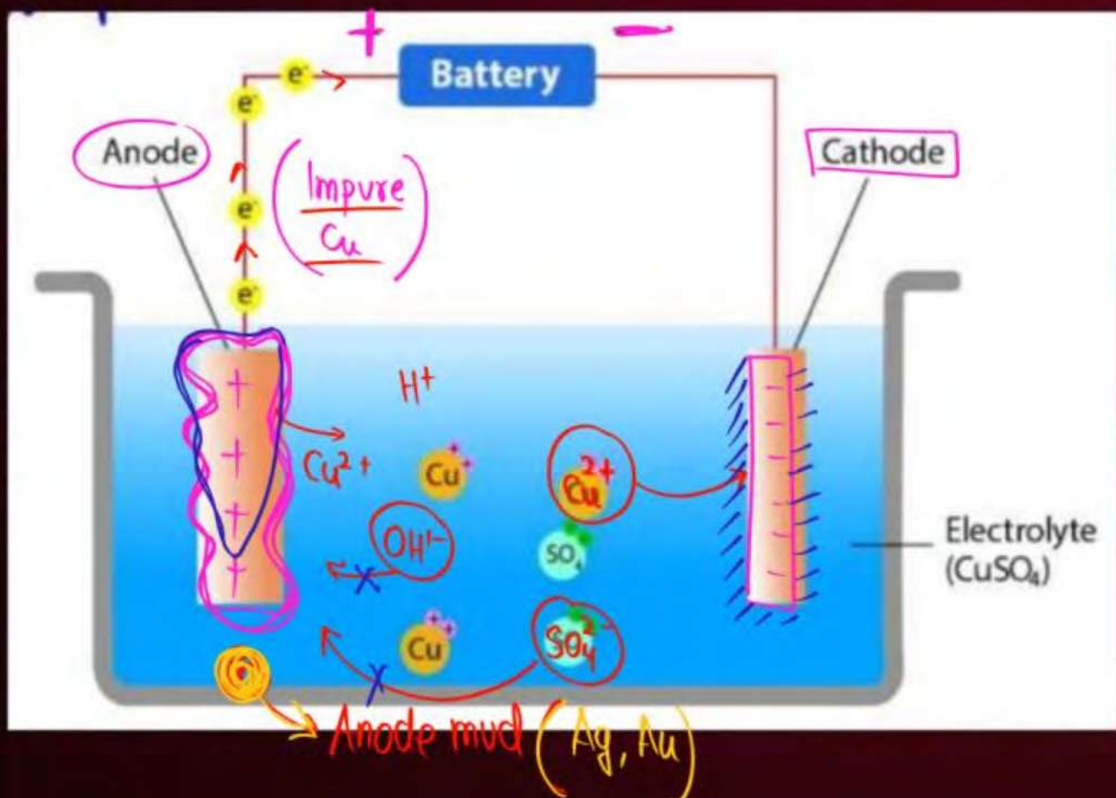
$Cl^{1-} \rightarrow Cl + e^-$

$2Cl^{1-} \rightarrow Cl_2 + 2e^-$

Electrolytic Refining of Metals

for Cu, Zn, Ni, Au etc.

Done for metals such as copper, zinc, tin, nickel etc.



active electrodes

- Anode: Impure Copper
- Cathode: Pure Copper
- Electrolyte: Copper sulphate solution

jis metal ki refining होगी uska salt solⁿ होगा

Reaction at anode (Oxidation: Loss of electrons)

Thinner with time

$$\boxed{Cu \rightarrow Cu^{2+} + 2e^-}$$

Thicker " —

Reaction at cathode (Reduction: Gain of electrons)

$$Cu^{2+} + 2e^- \rightarrow Cu$$

Corrosion and Its Types

CORROSION AND ITS TYPES

- **Meaning of Corrosion:**

(degradation)

It is a surface deterioration process of metals in which they convert to a more stable form, i.e. oxides, sulphides, carbonates and more, due to the attack of atmospheric gases.

- **Rusting of Iron:**

moisture (H_2O)

O_2

Iron reacts with moist air to form a **reddish-brown layer of hydrated ferric oxide**. (RUST)

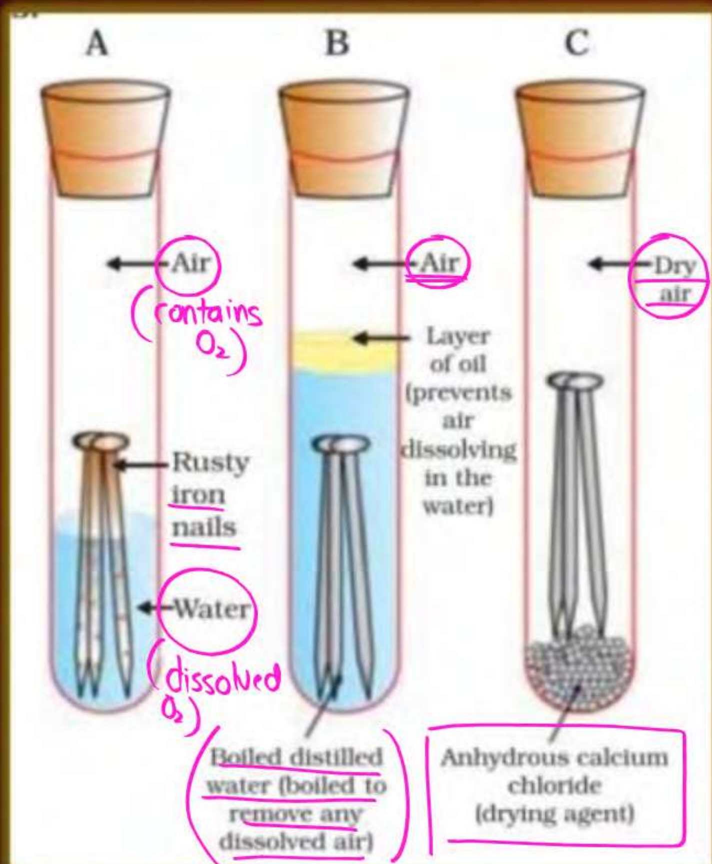
COLOUR OF LAYER AND CHEMICAL EQUATION

'Silvery grey'

Reddish-brown

$$4Fe(s) + 3O_2(g) + xH_2O(g) \rightarrow 2Fe_2O_3.xH_2O(s)$$

Factors Required for Rusting



- **Test Tube A:** Both water and air (contains oxygen) are present. So, rusting will take place.
- **Test Tube B:** Only boiled water (no dissolved air). No rusting can happen.
- **Test Tube C:** Only dry air (no moisture). No rusting can happen.

Corrosion and Its Types

CORROSION AND ITS TYPES	COLOUR OF LAYER AND CHEMICAL EQUATION
• **Tarnishing of Copper:** Copper reacts with moist carbon dioxide gas in air to form a **green layer of copper carbonate hydroxide**. It is also called **patina**.	 Green $2Cu(s) + CO_2(g) + O_2(g) + H_2O(g) \rightarrow CuCO_3.Cu(OH)_2(s)$

(II)

(protective layer)

(because it sticks to metal surface & protects metal underneath)

'Patina'

① Basic copper carbonate

Corrosion and Its Types

CORROSION AND ITS TYPES	COLOUR OF LAYER AND CHEMICAL EQUATION
• **Tarnishing of Silver:** Silver reacts with hydrogen sulphide gas present in the air to form a **black layer of silver sulphide**. It is also called **patina.**	 Black $4Ag(s) + 2H_2S(g) + O_2(g) \rightarrow 2Ag_2S(s) + 2H_2O(g)$

Ways to Prevent Rusting

Type of Protection	What is Being Done?	Temporary/Permanent
(i) Barrier Protection	• Applying a layer of paint, oil or grease on iron	Temporary Solution
(ii) Sacrificial Protection	• Galvanisation *(Applying a layer of zinc on iron)* • Layer of acts as a barrier and zinc being more reactive than iron oxidises itself at place of iron.	Better than barrier but not a permanent solution
(iii) Alloying → to make an alloy (Utensils)	• Stainless Steel *(Mixture of Iron + Nickel + Chromium)*	Permanent Solution

Nickel → provide hardness

Chromium → resistance to corrosion; prevents from getting stains

Ways to Prevent Rusting

(v) amalgam
- Zinc amalgam → Hg + Zn
- Dental amalgam → Hg + Ag/Au

Alloy	Composition	Properties	Important Uses
(i) Brass (पीतल)	**Copper (80%) and Zinc (20%)**	Malleable, strong, resists corrosion	Utensils, screws etc.
(ii) Bronze (कांस्य)	**Copper (90%) and Tin (10%)**	Strong and resists corrosion	Coins, bells etc.
(iii) Steel	**Iron (80-98%), Carbon (.030-1.25%) and Other Metals**	Hard and high tensile strength	Construction
(iv) Solder	**Lead (50%) and Tin (50%)**	Lower melting point than lead and tin	For joining electrical wires together.