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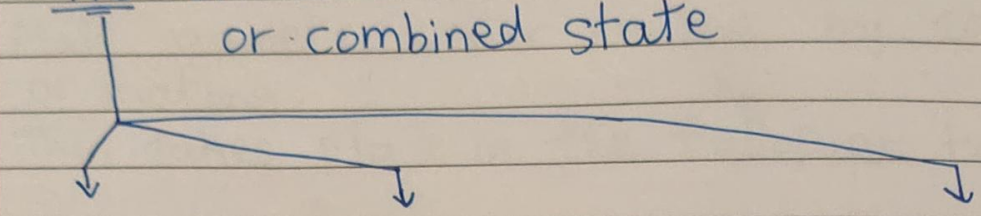
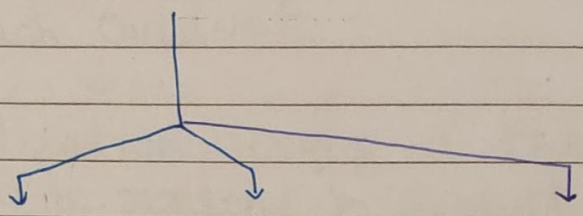
METALS & NON-METALS

»» 118 elements on earth's crust in free or combined state



Metals (90)
Fe
Al
Cu
etc.

Non-Metals (22)



Non. Metals	Halogens	Inert gases
Carbon (g)	Fl (g)	He
Nitrogen (g)	H (g)	Ne
Oxygen (g)	Cl (g)	Ar
F (s)	Br (l)	Kr
S (s)	I (s)	Xe
Se (s)	At (s)	Rn

Metalloids (7)

Metalloids ←

1. Germanium (Ge)
2. Boron (B)
3. Silicon (Si)
4. Polonium (Po)
5. Arsenic (As)
6. Tellurium (Te)
7. Antimony (Sb)

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Transition Metals

- Their two outermost shells are incomplete.
- Eg - Iron, Zn, Copper

PHYSICAL PROPERTIES

Property	Metals	Non-Metals
Hardness	Generally hard	Generally soft (S, P)
Exceptions:	• Na, K, Li (can be cut with knife)	• Diamond (hardest)
State	Solid at room temp.	Exist in all 3 states 11 - gaseous 1 - liquid (Bromine) 10 - solid
Exceptions:	• Mercury (liquid) • Gallium (evaporates on palm)	—
Lustre	Shining surface, highly polished	No lustre, dull appearence
Exceptions:	• Lead (dull)	• Diamond, iodine, graphite (lustrous)
Melting and boiling points (M.P. & B.P.)	High (due to strong bonds) Eg - Tungsten (highest melting point)	Low (weak forces, vaporize at low temp.)
Exceptions:	• Gallium, caesium have ~~high~~ low M.P.	• B, Si, C, etc. (solid) have high B.P.; Diamond (both high)

Property	Metals	Non-metals
Density	High (sink)	Low
Exceptions:	• Na, K (are alkali → ∴ float) stored in kerosene	• Iodine, Diamond (high density)
Malleability (sheets)	Beaten into sheets (without cracking) ∴ High (gold, silver are most malleable)	Break easily ∴ Low malleability
Exceptions:	• Zn, Hg	—
Ductility (wires)	Drawn into wires (without breaking) ∴ Highly ductile Gold is most ductile (1gm gold → 2km long wire) Tungsten - invisible wire	Non ductile
Exceptions:	• Zinc, Mercury, Gallium	• Carbon fibres (strong and light) used in sports, aerospace, military equipments
Brittleness	Hard, not brittle	Brittle (break into pieces)
Exceptions:	• Zinc	
Conduction of heat and electricity	Good conductors Eg - Silver (best conductor of electricity)	Poor conductors
Exceptions:	• Lead and mercury (poor conductors of heat and electricity)	• Graphite (good conductor of electricity)

Property	Metals	Non-metals
Solubility	Do not dissolve in any liquid solvent	Dissolve Eg - Iodine in chloroform Sulphur in carbon disulphide
Sonority	Produce ringing sound ∴ Highly sonorous	Not sonorous

Group 1 - Alkali metals
Group 2 - Alkaline Earth metals
Group 3 ┐
4 │
5 │
6 │
7 ├ Transition elements
8 │
9 │
10 │
11 │
12 ┘
Group 13 - Boron family
14 - Carbon family
15 - Nitrogen family
16 - Oxygen family

Group 17 - Halogens
Group 18 - Zero group (Noble gases)

CHEMICAL PROPERTIES

Metals	Non-Metals
» 1/2/3 electrons in last orbit	» 5/6/7 electrons in last orbit
» Electron donors	» Electron acceptors
» Form +ve ions: Cations	» Form -ve ions: Anions
» Electropositive elements	» Electronegative elements
» Form basic oxides	» Form acidic oxides
Examples:	Examples:
» $Na + O_2 \rightarrow Na_2O$ $Na_2O + H_2O \rightarrow NaOH$	» $C + O_2 \rightarrow CO_2$ $CO_2 + H_2O \rightarrow H_2CO_3$
» $K + O_2 \rightarrow K_2O$ $K_2O + H_2O \rightarrow KOH$	» $S + O_2 \rightarrow SO_2$ $SO_2 + H_2O \rightarrow H_2SO_4$
» $Mg + O_2 \rightarrow MgO$ $MgO + H_2O \rightarrow Mg(OH)_2$	» $N + O_2 \rightarrow NO_2$ $NO_2 + H_2O \rightarrow HNO_3$
» $Ca + O_2 \rightarrow CaO$ $CaO + H_2O \rightarrow Ca(OH)_2$	
Exception:	Exception:
CrO_3, Mn_2O_7 acidic oxides	H_2O, CO, NO, N_2O Neutral (neither acidic nor basic)

⋙ They ionise by loss of electrons, hence reducing agents. $Na \rightarrow Na^+ + e^-$	⋙ They ionise by gain of electrons, hence oxidising agents $Cl + e^- \rightarrow Cl^-$

Difference between Ionic / Electrovalent Bonds and Covalent Bonds

Ionic Bonds	Covalent Bonds
⋙ Transfer of electrons	⋙ Sharing of electrons
⋙ Good Conductors	⋙ Poor conductors
⋙ High melting and boiling points	⋙ Low melting and boiling points
⋙ Soluble - in water Insoluble - in organic solvents (Kerosene, alcohol, etc.)	⋙ Soluble - organic solvent Insoluble - water
⋙ Generally Solid because of strong bonds	⋙ Generally liquids or gases because of weak bonds
⋙ Eg - NaCl	⋙ H_2O, CO_2

CHEMICAL REACTIONS

K
Na
Ca
Mg
Al
Zn
Fe
Pb
Sn
[H]
Cu
Hg
Ag
Au
Pt

① Metals with Oxygen

Metal + O_2 → Metal oxides
(basic oxides)

- $Na + O_2 \rightarrow Na_2O$
- $Ca + O_2 \rightarrow CaO$
- $Mg + O_2 \xrightarrow{\Delta} MgO$
- $Al + O_2 \xrightarrow{\Delta} Al_2O_3$
- $Cu + O_2 \rightarrow CuO$ (copper blisters burn)

② Metals with Water

Metal + H_2O → Metal hydroxide / oxide

- hydroxides { K, Na, Ca } cold water; { Mg } hot water
- oxides { Al, Zn, Fe } steam
- Pb, [H], Cu, Hg, Ag, Au, Pt — NO REACTION with water

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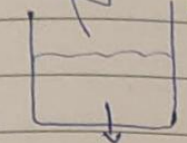
Examples

HYDROXIDE

[1] Na / K



Violent
Exothermic
Combustible

Cold water

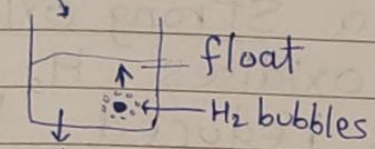
$2K + 2H_2O \rightarrow 2KOH + H_2$
(liliac flame)

$2Na + 2H_2O \rightarrow 2NaOH + H_2$
(golden yellow flame)

∴ Kept in Kerosene

HYDROXIDE

[2] Ca



cold water

$Ca(OH)_2$

$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

⋙ Reaction not so violent
⋙ No fire
⋙ H_2 does not burn

[3] Al, Zn, Fe

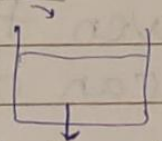
React with steam
Form oxides

OXIDES

$Al + H_2O \rightarrow Al_2O_3 + H_2$
$Zn + H_2O \rightarrow ZnO + H_2$
$Fe + H_2O \rightarrow Fe_2O_3 + H_2$

HYDROXIDE

[4] Mg



hot water

$Mg + H_2O \xrightarrow{\text{(hot)}} Mg(OH)_2 + H_2$

Q Why is Cu used to make hot water boilers but not steel/iron?

③ Metals with Acids

Metal + Acid → Salt + H_2

Metals react with HCl / H_2SO_4, but not with HNO_3

↓ Why?

»» Because it is a strong oxidising agent, so it oxidises H_2 to H_2O and gets reduced to any nitrogen oxide (NO_2 / NO / N_2O)

- But Mg and Mn react with HNO_3 to give H_2 gas.

»» $Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$

$Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2\uparrow$

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$

AQUA REGIA (Royal Water)

Conc. HCl : Conc. HNO_3

3 : 1

»» It can dissolve gold, even though neither of these acids can do so alone.

»» It is highly corrosive

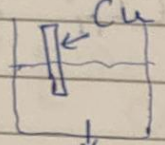
»» Highly fuming liquid

④ Metals with other metal Salts

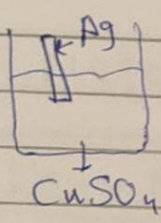
Metal A + Salt B → Salt A + Metal B

↳ Displacement reaction

Examples:



$Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$



No reaction ($Ag + CuSO_4$) | similarly No reaction ($Cu + FeSO_4$)

$Mg + CuSO_4 \rightarrow MgSO_4 + Cu$

Many other examples ...

⑤ Metals with Non-Metals

Metal + Non-Metal → Salt

(ionic compounds)

»» Example : $2Na + Cl_2 \rightarrow 2NaCl$

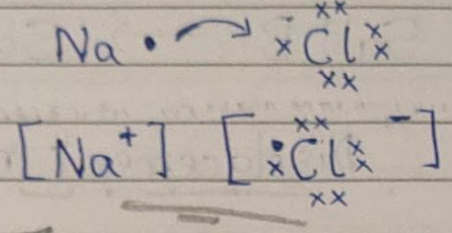
* Electron dot structure

① NaCl

>>7

K L M K L M

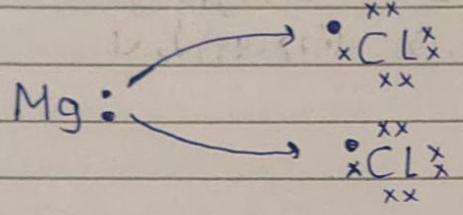
Na_{11} = 2 8 1 Cl_{17} = 2 8 7



② $MgCl_2$

K L M K L M

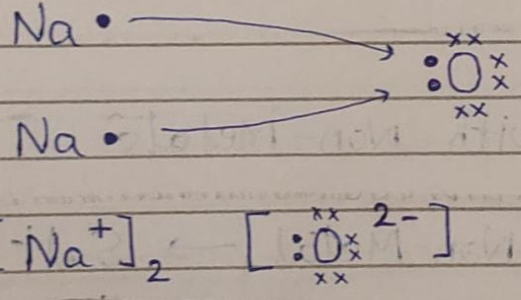
Mg = 2 8 2 Cl_{17} = 2 8 7



③ Na_2O

K L M K L

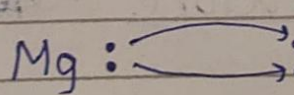
Na_{11} = 2 8 1 O_8 = 2 6



④ MgO

K L M K L

Mg_{12} = 2 8 2 O = 2 6



CHEMICAL REACTIONS OF NON-METALS

① Non-Metals with Oxygen

Non-Metal + O_2 ⟶ Non-metallic oxides

»» $C + O_2 \rightarrow CO_2$ (Acidic oxide)

Exceptions [»» $C + \frac{1}{2}O_2 \rightarrow CO$ (Neutral)

CO, H_2O, NO, N_2O

Neutral oxides

② Non-Metals with Water

✕ **Non-Metal + H_2O ⟶ NO REACTION**

③ Non-Metals with Acid

✕ **Non-Metal + Acid ⟶ NO REACTION**

④ Non-metals with Salt so

N.M. + Salt →

»» $2NaBr + Cl_2 \rightarrow 2NaCl + Br$

CORROSION

»» It is a slow process of eating away of metals by the reaction of air, moisture or chemicals.

① **Rusting of Iron**

»» $Fe_2O_3 \cdot x H_2O$

>>>

② **Tarnishing of Silver**

»» $Ag + H_2S \rightarrow Ag_2S$

③ **Formation of green coating over copper**

»» $CuCO_3 \cdot Cu(OH)_2$

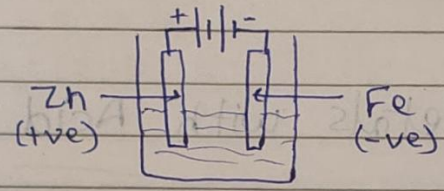
* ADVANTAGE

»» Al and Zn form a layer of oxide (impervious protective layer) and prevents metal from further corrosion

* PREVENTING

1. Galvanisation

»» Coating of thin layer of zinc over iron or steel.



IMP 2. Alloying

»» Homogenous mixture of 2 or more metals or metals with non-metals

»» Improves the properties (hardness and strength) of metals

- Examples
  - (a) Brass - Cu + Zn
    (70%) (30%)

(b) Stainless steel - Ni (Nickel) + Cr (Cromium) + Fe

(c) Bronze - Cu + Sn (tin)

(d) Solder - Pb + Sn

(e) Amalgam (any metal + Hg mercury)
- Sodium mercury amalgam
- Silver mercury amalgam
  - used in dentistry

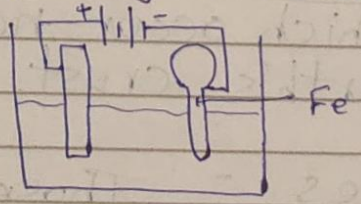
3. Greasing / Oiling

4. Electroplating

Tin plating
»» Layer of tin on iron, steel or copper
(Sn on Fe/Cu/steel)

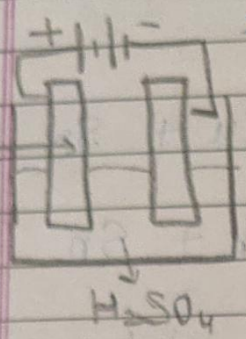
Chromium Plating
»» Layer of cromium on iron for shine, durability and to prevent rusting
(Cr on Fe)

- Cathode - Metal on which electroplating is to be done



5. Painting

6. Anodising



»» The process of forming a thick layer of oxide on the surface of the metals like Zn, Al, etc. which prevents and protects the metal from further oxidation.

»» In this process, a clean metal is taken at anode and dil. H_2SO_4 is taken as an electrolyte.

»» When electric current is passed, O_2 is liberated, which reacts with the metal to form layers of oxide on its surface.

METALLURGY (Extraction of metals from its ores)

»» The branch of science and technology concerned with the properties of metals and their production and purification.

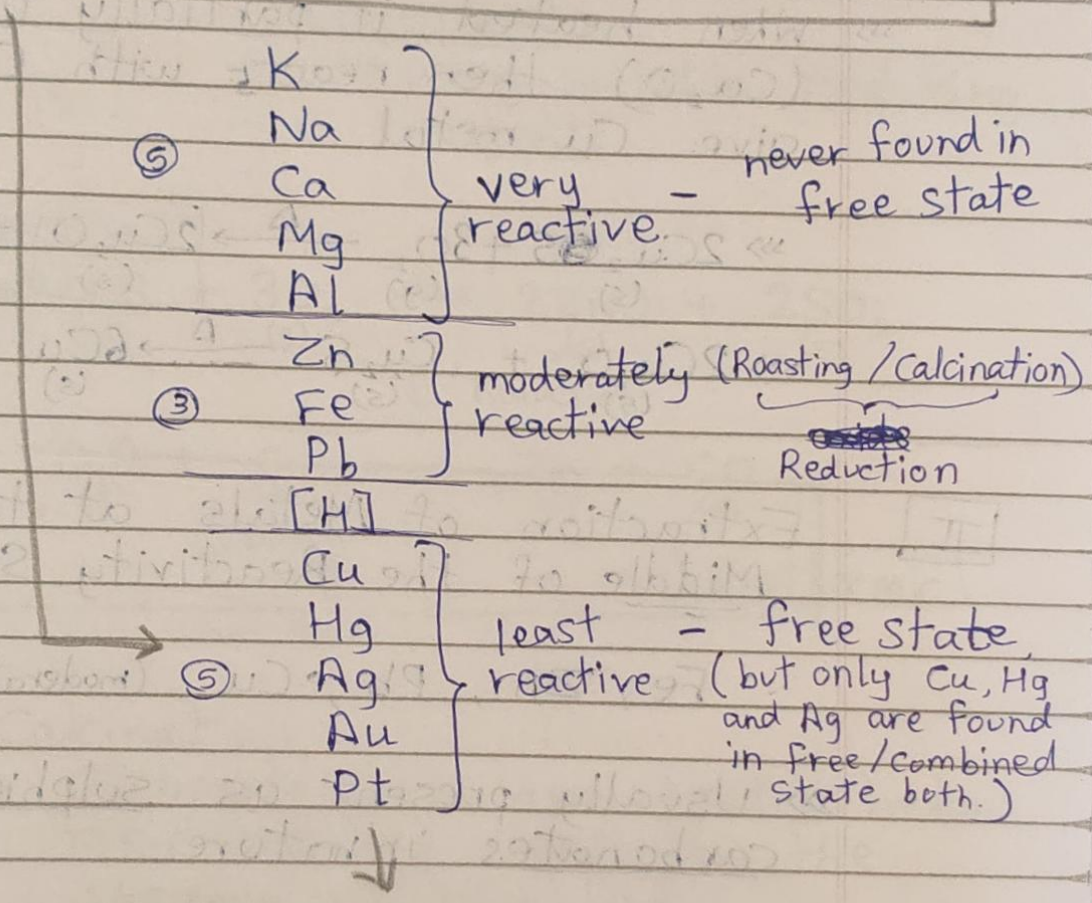
- Minerals - The elements of compounds which occur naturally in the earth's crust.

- Ores :- Those minerals which contain a very high percentage of a particular metal, which can

be profitably (with low cost & minimum effort) extracted

- Gangue - Impurities present in the ores in the form of sand, soil, dust, mud, etc.

I. Extraction of Metals at the Bottom of the Series



» They are less reactive and can be obtained by reducing their oxides, just by heating alone.

1. **Cinnabar** (HgS) Ore of Mercury

»» $2HgS_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2HgO_{(s)} + 2SO_{2(g)}$

$2HgO_{(s)} \xrightarrow{\Delta} 2Hg_{(l)} + O_{2(g)}$

2. **Copper glance** (Cu_2S) Ore of copper

»» When heated, it partially oxidises (Cu_2O), then reacts with Cu_2S to give Cu metal.

»» $2Cu_2S_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2Cu_2O_{(s)} + 2SO_{2(g)}$

»» $2Cu_2O_{(s)} + Cu_2S_{(s)} \xrightarrow{\Delta} 6Cu_{(s)} + SO_{2(g)}$

II. Extraction of Metals at the Middle of the Reactivity Series

Fe, Zn, Pb, Cu (moderately reactive)

»» Usually present as sulphides or carbonates in nature

»» They are first converted into oxides [as it is easy to extract metals from oxides]

>>

Two Methods

ROASTING (for sulphides)
- heat strongly
- Abundant air

CALCINATION (for carbonates)
- heat strongly
- Limited air

REDUCTION
↳ using suitable reducing agents

① Roasting

$$2ZnS_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2ZnO_{(s)} + 2SO_{2(g)}$$

⇓ Reduction

$$ZnO_{(s)} + C_{(s)} \longrightarrow Zn_{(s)} + CO_{(g)}$$

[Coke]

[Exothermic]

② Calcination

» Carbonate ores are heated below their melting points in the absence of air.

↓

Convert to metal oxide

$$ZnCO_{3(s)} \xrightarrow{\Delta} ZnO_{(s)} + CO_{2(g)}$$

(Reduction)

$$ZnO_{(s)} + C_{(s)} \rightarrow Zn_{(s)} + CO_{(g)}$$

» Sometimes, displacement reactions can be used to reduce metal oxides.

» Highly reactive metals (Na/Ca/Mg/Al) are used as reducing agents

- $3MnO_{2(s)} + 4Al_{(powder)(s)} \rightarrow 3Mn_{(l)} + 2Al_2O_{3(s)}$

[melts to due highly exothermic reaction] ∴ liquid

- $Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow 2Fe_{(l)} + Al_2O_{3(s)}$

[molten]

» It is known as Thermit Welding (Al usage)

» Used in railway tracks or cracked machine parts in welding.

Definition :» The reaction of metal oxide to form metals by using Aluminium (Al) powder as a reducing agent is known as THERMIT REACTION.

Reactivity series = Activity series

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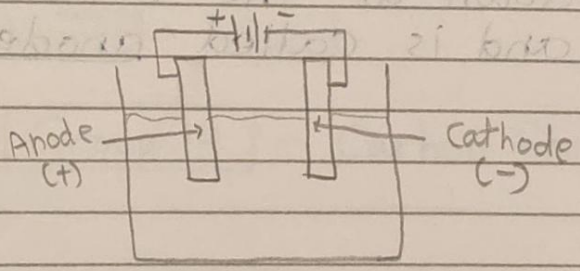
III. Extraction of Metals towards the Top of the Reactivity Series

K, Na, Ca, Mg, Al (very reactive)

» Cannot be obtained from compounds by heating with carbon

★ » Carbon cannot reduce oxides to their respective metals
↓ because
these metals have more affinity for O_2 than C

∴ They are obtained by ELECTROLYTIC REDUCTION



Na, Ca, Mg
» Undergo electrolysis of their molten chlorides

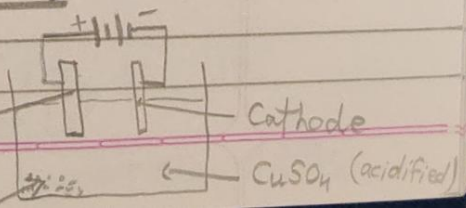
Eg - NaCl

At Cathode — $Na^+ + e^- \rightarrow Na_{(s)}$

At Anode — $2Cl^- \rightarrow Cl_2 + 2e^-$

Electrolytic Refining

- Anode - Impure Cu
- Cathode - Pure Cu



1. Impure metal is placed at anode.
2. Pure metal strip is at cathode.
3. Sol^{n} of metal salt - electrolyte.
4. On passing electric current, the pure metal from anode dissolves in the electrolyte.
5. The equivalent amount of pure metal from electrolyte is deposited on the cathode.
6. The soluble impurities go into the solution (dissolve).
7. The insoluble impurities settle down at the bottom of the anode and is called anode mud.