EXTRACTION OF METALS

A metal is an element (except hydrogen) which loses electron(s) to positive ions.

Physical properties of metal compared to non-metal.

	property	meaning	metals	non-metals
1	Thermal conductivity	Able to conduct heat	high	low
2	Electrical conductivity	Able to conduct electricity	high	low
3	Lustre	Shiny and can be polished	high	low
4	Sonority	Able to make a ringing sound when struck	high	low
5	Ductility	Able to be made into thin wire	high	low
6	Tensile strength	strength under stress	high	low
7	Malleability	Able to be made into sheets	high	low
8	Density	Mass per unit volume	high	low

physical strength is the tensile strength of the metal. physical strength results from the way atoms are arranged in a substance.

- There are metals with high tensile strength like iron, copper and aluminium. Other metals have little tensile strength like sodium and potassium.

Chemical strength is the reactivity of the metal. Chemical reactivity depends on the way electrons are arranged in an atom. Potassium and sodium have got very low tensile strength but chemically they have the greatest chemical strength.

Chemical properties of metals.

Chemical properties of metals depend on the reactivity series

1 Reaction with air / oxygen.

Almost all metals react with oxygen to form metal oxide. But different metals react with oxygen at different intensities.

- Potassium, sodium, calcium, magnesium, zinc, iron burn in air or oxygen to form oxide.

eg. $4Na + O_2 \rightarrow 2Na_2O$

- Lead and copper react with oxygen on heating but they do not burn.
- Less reactive metals than copper like silver, gold and platinum do no react with oxygen.

Notice that

- Sodium metal is always kept immersed in kerosene oil, Because, if ~~kept~~ in it open, it reacts so vigorously with oxygen present in air that it catches fire.
- Aluminium reacts so readily with the oxygen in air a protective oxide is formed on its surface. This usually prevents any further reaction.

2 Reaction of Metals with water

Metals react with water to produce metal hydroxide (or metal oxide) and hydrogen gas. Also the reactions depend on reactivity of the metal.

- potassium, sodium and calcium react with cold water to produce their hydroxides and hydrogen gas.

$2Na + 2H_2O \rightarrow 2NaOH + H_2$.

- Magnesium, zinc and iron react with hot water (steam) to produce oxide and hydrogen gas.

$Mg + H_2O \rightarrow MgO + H_2$.

3 Reactions of metals with Dilute acids

- Potassium and sodium react extremely violently with rapid effervescence and splashing → (should not be tried)
- Calcium, Magnesium, Zinc, iron react slowly with bubbles of hydrogen.
- Copper, silver, Gold and platinum do not react with dilute acids.

5 Reaction of metals with hydrogen.

Only a few metals like Na, K, Ca and Mg react with hydrogen to form metal hydrides.

$2Na + H_2 \rightarrow 2NaH$

$Ca + H_2 \rightarrow CaH_2$.

6 Displacement reactions

A more reactive metal, higher in the reactivity series, can displace a less reactive metal from its compound.

eg. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

~~Metal~~ Extraction of Metals

An ore is a naturally occurring mineral from which a metal can be extracted economically.

→ Some minerals contain a high percentage of the particular metal and the metal can be extracted from them.

- An ore contains a good percentage of metal and there are no objectionable impurities in it.

Therefore, All the ores are minerals but all the mineral are not ores.

Extraction of metals is the process of obtaining pure metal from its ore.

The abundance of chemical elements in the Earth's crust

- Oxygen 45%
- Silicon 27%
- Aluminium 8%
- Iron 5.8%
- Calcium 5.1%
- Magnesium 2.8%
- Sodium 2.3%
- Potassium 1.7%
- Titanium 0.8%
- All others 1.4%.

Ores are those minerals from which metal are extracted conveniently and profitably.

Some common ores

	Metal	Name of ore	Formula.
1	Sodium	Rock salt	NaCl
2	Aluminium	Bauxite	$Al_2O_3 \cdot 2H_2O$
		Cryolite	Na_3AlF_6
3	Magnesium	Dolomite	$MgCO_3 \cdot CaCO_3$
		Epsom salt	$MgSO_4 \cdot 7H_2O$
4	Calcium	Dolomite	$CaCO_3 \cdot MgCO_3$
		Gypsum	$CaSO_4 \cdot 2H_2O$
		Fluorspar	CaF_2
5	Copper	Cuprite	Cu_2O
		copper glance	Cu_2S
		Copper pyrites	$CuFeS_2$
6	Iron	Haematite	Fe_2O_3
		Magnetite	Fe_3O_4
		Iron pyrite	FeS_2
		Copper pyrites	$CuFeS_2$
		Siderite	$FeCO_3$
		Zinc blende	ZnS
7	Zinc		

Methods of Extracting metals

The Methods employed in extracting metals depend on its reactivity. The more reactive the metal, the more difficult it is to extract from its compound.

metal	method of extraction
Potassium	Electrolysis
Sodium	
Calcium	
Magnesium	
Aluminium	
Zinc	Heat with carbon or carbon monoxide
Iron	
Lead	
Copper	Roasting in air
Silver	Occur naturally (Found uncombined) native
Gold	

* Stages / Procedures of extracting metals.

Metals can be extracted from their ores by the following processes. These procedures are especially for moderate reactive metals

1 Concentration of the Ore

This is the removal of unwanted materials such as sand clay etc from the ore.

It is also known as enrichment of the ore, or benefi cation of the ore.

This process can be carried out by any method eg washing with running stream of water, Magnetic separation or froth floatation process.

2 Conversion of concentrated ore into metal oxide (Roasting in air).

Roast It is easier to obtain metals from their metal

oxides as compared to other compounds.

(i) Roasting is the process of strongly heating the ore in the excess supply of air below its melting point

eg. $2ZnS + 3O_2 \rightarrow ZnO + 2SO_2$

$2PbS + 3O_2 \rightarrow PbO + 2SO_2$.

(ii) Calcination is the process of heating the ore in a limited supply of air below its melting point.

eg $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

3 Reduction of oxides to metals

The process of converting metal oxides into metals is called reduction. This process is sometimes known as extraction. The method employed depends on the reactivity of the metal.

4 Purification of the ~~ore~~ metal

The methods obtained by above methods is usually impure. ~~The~~ it is to be purified.

- The method used for refining / purifying of metal depends on the nature of metal and impurities present in it.

Example of methods to purify metals are distillation and electrolytic refining.

Sodium metal is not used in the construction of bridge Explain

Why iron is not usually recommended in construction of steam pipes and boilers?

- Because when hot, iron will react with steam to form the ~~tet~~ Triiron tetroxide (Fe_3O_4) which can easily be washed away as result the pipes or boilers will wear out.

(i) Extraction of Sodium by Down's Process

Principal ores; - Sodium chloride (rock salt)
(chile salt petre) - Sodium nitrates (~~Soda ash~~)
- Sodium carbonates (soda ash).

On industrial scale sodium metal is extracted by Down's process.

- Down's process takes place in Down's cell.
Down's cell consists of a rectangular container of steel. Inside of the tank is lined with firebric ks.
- Anode is a graphite rod which projects centrally up through the base of the cell. Cathode is the ring of iron which surrounds the graphite anode.
- The anode and cathode are separated from each other by steel mesh or gauze to prevent sodium and chlorine coming into contact and forming sodium chloride.

Sodium chloride has a high melting point (800°C) so calcium chloride is added to reduce the melting point to about 600°C.

At the cathode, sodium ions are discharged and sodium is formed

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

At the anode the chloride ions are discharged to form chlorine gas

$$2Cl^- \rightarrow Cl_{2(g)} + 2e^-$$

Q. Give reason why sodium is kept under kerosene.

Question

During electrolysis calcium is also obtained but it does not mix with sodium. Explain.

- During electrolysis calcium is also obtained at cathode but sodium and calcium are separated from each other due to difference in densities.

$Na = 0.67\ g/cm^3$ $Ca = 2.54\ g/cm^3$

SA. Sodium catches fire vigorously on reaction with oxygen at room temperature if kept in open. Therefore sodium is kept under kerosene.

(ii) Extraction of Iron

The chief iron ores are

(i) Haematite (Fe_2O_3)
(ii) Magnetite (Fe_3O_4)
(iii) siderite ($FeCO_3$)
(iv) Iron pyrites (FeS)
(v) Limonite ($Fe_2O_3 \cdot 3H_2O$)

Iron is extracted mainly from its oxides, haematite (Fe_2O_3) and magnetite Fe_3O_4.

Extraction of iron from haematite

Iron ore, coke and limestone are mixed together and fed into the top of the blast furnace.

Hot air is blasted into the bottom of the blast furnace

At 1000°C – 1600°C

Coke reacts with hot air to form carbon dioxide

$$C_{(s)} + O_2 \rightarrow CO_2$$

(This is an exothermic reaction whereby the heat evolved heat further the furnace)

Heat makes limestone decompose into calcium oxide and carbon dioxide

$$CaCO_3 \longrightarrow CaO + CO_2.$$

Carbon dioxide produced goes up the furnace and reacts with more coke up there producing carbon-monoxide

$$CO_2 + C \rightarrow 2CO$$ (This happens at 800°C/hot

Carbon monoxide is a reducing agent. It rises further up the furnace where it meets iron oxide and starts reducing it producing iron and carbon dioxide

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$ (at 250°C)

Calcium oxide which was produced from the thermal decomposition of limestone is a base. It reacts with impurities of haematite such as silicon dioxide which is acidic forming calcium silicate which is called slag.

$$CaO + SiO_2 \rightarrow CaSiO_3$$

Molten iron and slag produced trickles down and settles at the bottom of the furnace. Iron is denser than slag ~~for~~ so it settles beneath it.

Iron and slag are tapped off separately at regular intervals and pure iron is collected alone.

Calcium silicate produced

- It is used in building roads
- It is used as fertilizers.

(iii) Extraction of Aluminium

Occurrence or main ores

1. Bauxite $Al_2O_3 . 2H_2O$
2. Cryolite Na_3AlF_6.

The main ore from which aluminium is extracted is bauxite.

Stages

1. Purification of bauxite.

(i) Bauxite, an impure form of aluminium oxide, is first treated with sodium hydroxide to obtain pure aluminium oxide, removing impurities such as iron (II) oxide and sand.

$$\underset{\text{Bauxite.}}{Al_2O_3} + 2NaOH \rightarrow \underset{\text{Sodium aluminate}}{NaAlO_2} + H_2O$$

The silica also dissolves forming sodium silicate.

(as impurities)

$$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$$

Undissolved impurities mainly are iron(III) oxide and filtered off.

(ii) A little aluminium hydroxide is added to sodium aluminate in order to precipitate aluminium hydroxide

$$NaAlO_2 + 2H_2O \xrightarrow[\text{hydrolysis}]{Al(OH)_3} Al(OH)_{3(s)} + NaOH_{(aq)}$$

Sodium silicate remains in the solution.

(iii) Precipitate of $Al(OH)_3$ is filtered, washed, dried and heated to give a pure aluminium oxide (alumina).

$$2Al(OH)_3 \rightarrow \underset{\text{Alumina.}}{Al_2O_3} + 3H_2O$$

2 Electrolysis of Purified Bauxite.

The pure aluminium oxide is mixed with cryolite (Na_3AlF_6). Cryolite is added to alumina in order to lower the melting point from 2050°C to about 900°C It is then electrolysed in a rectangular steel tank with carbon lining, which serves as Cathode. Anode is a set of thick carbon rods suspended from ~~the~~ top into the fused Al_2O_3.

$$Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$$

At anode:

Oxide ions get attracted to the anode and discharged

$$2O^{2-} \rightarrow O_2 + 4e^-$$

At Cathode

$$Al^{3+} + 3e^- \rightarrow Al$$

Aluminium ions get attracted to the cathode and discharged and settle at the bottom of the container.

Oxygen gas which ~~re~~volves reacts with carbon from the ~~Cathode~~ anode forming carbon dioxide (CO_2). The ~~cathode~~ anode gets worn away. To solve this, the ~~cathode~~ anode is replaced at regular intervals.

Extraction is a reduction. During extraction, the metallic ion takes up the necessary number of electrons to convert it to the corresponding atom. This process of electron gain is a reduction and the electrons are supplied by the reducing agent concerned in the rxn. or in the case of high reactive metals reduction is brought about by electrolysis. The cathode acts as a reducing region by supplying electrons.

Uses of Aluminium

1. Food containers because it is resistant to corrosion and non-toxic
2. Construction of air-craft bodies because aluminium is very strong and very light and it is resistant to corrosion.
3. Overhead power cables because it conducts electricity, is very light, malleable and ductile.
4. Window frames: resists corrosion, strong, conductor.
5. It is used to make cooking utensils - good heat, it has high melting.

Extraction of Copper

Copper is one of the most popular metals. Native copper occurs in some regions in the world.
The principal ores of copper are

- Copper pyrites ($CuFeS_2$)
- Cuprite (Cu_2O)
- Copper (I) Sulphide (Cu_2S)
- Malachite ($CuCO_3 . Cu(OH)_2$)

Common ore used for the extraction of copper is copper pyrites ($CuFeS_2$).

Copper is mainly extracted from copper pyrites ($CuFeS_2$).

1 Roasting of concentrated ore ($CuFeS_2$) in air,

$$2CuFeS_2 + 4O_2 \rightarrow Cu_2S + 2FeO + 3SO_2$$

copper pyrites — copper(I) sulphide — iron (II) oxide

2 Silicon dioxide is added and the mixture is heated in the absence of air. The iron (II) oxide is converted into iron (II) silicate ($FeSiO_3$) which is run off.

$$FeO + SiO_2 \rightarrow FeSiO_3$$

copper (I) sulphide is then heated in a regulated supply of air.

3. The remaining copper (I) sulphide is then reduced to copper by heating in a controlled amount of air

$$Cu_2S + O_2 \rightarrow 2Cu_{(s)} + SO_{2(g)}$$

4 Copper is then purified by electrolysis.

Copper (II) sulphate solution is used as electrolyte, pure copper is used as cathode and impure copper is used as anode.

- Any impurity fall to the bottom of the cell and collect below the anode in the form of a slime.

The ions present in the solution are

From water; $H^+_{(aq)}$, $OH^-_{(aq)}$

From the copper (II) sulphate Cu^{2+}, SO_4^{2-}

At anode; $Cu_{(s)} \rightarrow Cu^{2+} + 2e^-$

At cathode; $Cu^{2+} + 2e^- \rightarrow Cu_{(s)}$.

Uses of copper

1 In electrical wires because it is a perfect electrical conductor and very ductile.

2 Making alloys such as bronze and brass.

3 Cooking utensils because it conducts heat and it has

high melting point. Also resists corrosion

4. Used as electrodes because it is a good conductor of electricity.

5 It used ~~to~~ in making water pipes it is resistant to corrosion.

6 It is used in making coins and ornaments.

ALLOYS

A mixture of two or more metals or a metal and a non-metal.

Some of Alloys are

Alloy	Composition	Special properties	Uses.
Brass	65% copper 35% zinc	- Harder than copper - Does not corrode	Jewellery, machine bearings, musical instruments
Stainless steel	70% iron 20% chromium 10% nickel Carbon	• Does not rust	Cutlery, domestic appliances, kitchen sinks.
Bronze	90% copper 10% tin	Does not corrode	statues, ornaments
Duralumin	95% aluminium 4% copper 0.5% magnesium 0.5% Manganese	• Increased hardness and tensile strength • light	Aircraft construction bicycle parts
Steel	~~Iron~~ ~~Fe~~ 99% iron 1% Carbon	• Stronger than iron • ~~Above corrosion~~ resistant	Building materials
Cupronickel	75% - copper 25% - nickel	Attractive silver colour.	Coinage metal.