12. Periodic classification of elements

Have you ever visited a library? There are thousands of books in a large library. If you ask for a book in general it is very difficult to trace. Whereas if you ask for a particular book, the library staff can locate it very easily. How is it possible? In library the books are classified into various categories and sub categories. They are arranged on shelves accordingly. Therefore locating books become very easy.

As on date one hundred and eighteen elements are known. It is difficult to identify each and every element individually and to know its property and uses. Therefore they have been classified on the basis of their similarities in properties. One of the important instincts of mankind is to be systematic. Scientists felt the necessity to group elements of similar characteristics together so that if the properties of one of them are known, those of the others could be guessed and related.

Henry Gwyn-Jeffreys Moseley, an English physicist (1887–1915), used X-rays to determine the atomic numbers of the elements.

When a large number of elements were discovered, several attempts were being made to arrange them on the basis of their properties, nature, character, valency, etc., (Real credit for preparing the periodic table goes to Mendeleev).

12.1. MODERN PERIODIC LAW

A large number of scientists made attempts to eliminate the drawbacks of Mendeleev's periodic table. In 1912, Moseley, an English physicist measured the frequencies of X-rays emitted by a metal, when the metal was bombarded with high speed electrons. He plotted square roots of the frequencies against atomic numbers. The plot obtained was a straight line. He found that the square root of the frequency of the prominent X-rays emitted by a metal was proportional to the atomic number and not to the atomic weight of the atom of that metal.

MORE TO KNOW

Atomic number is number of protons in the nucleus or number of electrons revolving around the nucleus in an atom.

Moseley suggested that atomic number (Z) should be the basis of the classification of the element. Thus, he gave modern periodic law as follows:

Modern periodic law states that **"the physical and chemical properties of elements are the periodic function of their atomic numbers."**

Thus, according to the modern periodic law, if elements are arranged in the increasing order of their atomic numbers, the elements with similar properties are repeated after certain regular intervals.

12.2. MODERN PERIODIC TABLE

Based on the modern periodic law, a number of forms of periodic table have been proposed from time to time but general plan of the table remained the same as proposed by Mendeleev. The table which is most commonly used and which is based upon the **electronic configuration of elements** is called the **long form of the periodic table**. This is called the **modern periodic table.**

12.2.1. Description of modern or long form of the periodic table

Long form of the periodic table is a chart of elements in which the elements have been arranged in the increasing order of their atomic numbers. This table consists of **horizontal rows called periods and vertical columns called groups**.

12.2.3. Study of periods

The **horizontal rows are called periods**. There are **seven** horizontal rows in the periodic table.

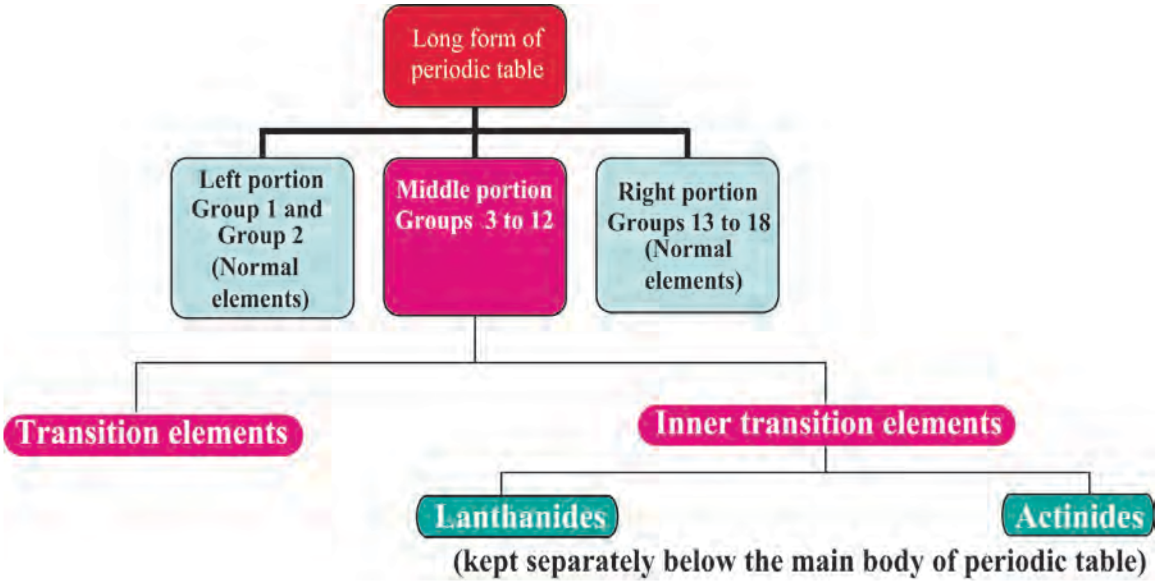
MORE TO KNOW

The modern periodic table has also been divided into four blocks known as s,p,d and f blocks.

- **First period** (Atomic number 1 and 2): This is the shortest period. It contains only two elements (Hydrogen and Helium).
- **Second period** (Atomic number 3 to 10): This is a short period. It contains eight elements (Lithium to Neon).

Third period (Atomic number 11 to 18): This is also a short period. It contains eight elements (Sodium to Argon).

12.2.2. Different portions of long form of periodic table



- **Fourth period** (Atomic number 19 to 36):

  This is a long period. It contains eighteen elements (Potassium to Krypton). This includes 8 normal elements and 10 transition elements.

- **Fifth period** (Atomic number 37 to 54): This is also a long period. It contains 18 elements (Rubidium to Xenon). This includes 8 normal elements and 10 transition elements.

- **Sixth period** (Atomic number 55 to 86): This is the longest period. It contains 32 elements (Ceasium to Radon). This includes 8 normal elements, 10 transition elements and 14 inner transition elements (Lanthanides).

- **Seventh period** (Atomic number 87 to 118): As like the sixth period, this period also can accomodate 32 elements. Till now only 26 elements have been authenticated by IUPAC

12.2.4. Study of groups

- Vertical columns in the periodic table starting from top to bottom are called groups. There are 18 groups in the periodic table.
- First group elements are called alkali metals.
- Second group elements are called alkaline earth metals.
- Groups three to twelve are called transition elements .
- Group 1, 2 and 13 - 18 are called normal elements or main group elements or representative elements .
- Group 13 is Boron family.
- Group 14 is Carbon family.
- Group 15 is Nitrogen family.
- Group 16 elements are called chalcogen family (except polonium).
- Group 17 elements are called halogen family.
- Group 18 elements are called noble gases or inert gases.
- The Lanthanides and actinides which form part of the group 3 are called inner transition elements.

12.3. CHARACTERISTICS OF MODERN PERIODIC TABLE

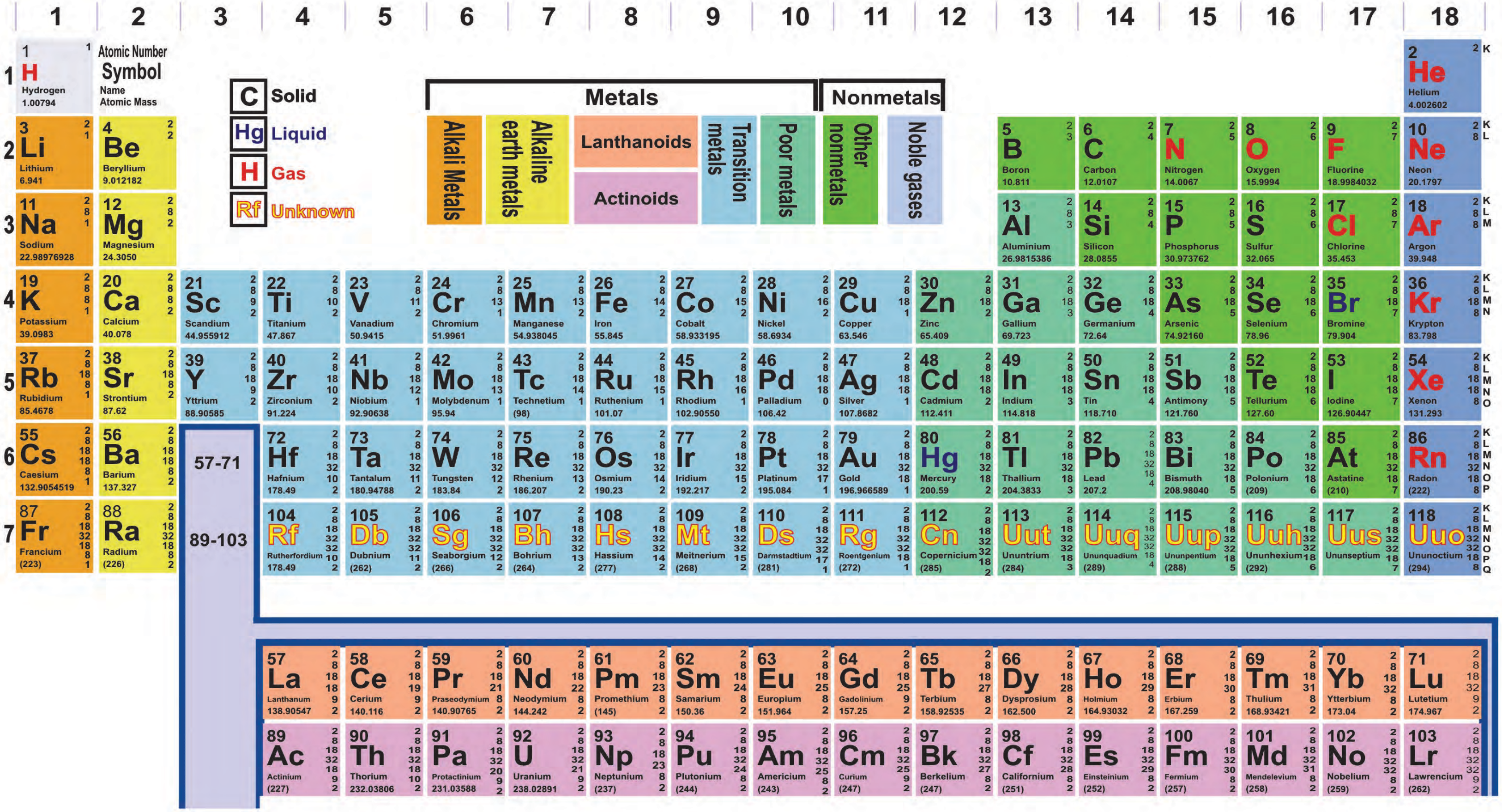
12.3.1. Characteristics Of Periods

- In a period, the electrons are filled in the same valence shell of all elements.
- As the electronic configuration changes along the period, the chemical properties of the elements also change.
- Atomic size of the elements in a period decrease from left to the right.
- In a period, the metallic character of the element decreases while their non-metallic character increases.

12.3.2. Characteristics of Groups

- The elements present in 2 and 18 groups differ in atomic number by 8,8,18,18,32.
- The elements present in 13 – 17 groups differ in atomic number by 8,18,18,32.
- The elements present in 4 - 12 groups differ in atomic number by 18,32,32.

MODERN PERIODIC TABLE



C Solid
Hg Liquid
H Gas
Rf Unknown

Metals: Alkali Metals, Alkaline earth metals, Lanthanoids, Actinoids, Transition metals, Poor metals

Nonmetals: Other nonmetals, Noble gases

Group Numbers

PERIODS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	1 H Hydrogen 1.00794 1	Atomic Number Symbol Name Atomic Mass																2 He Helium 4.002602 2	K
2	3 Li Lithium 6.941 2 1	4 Be Beryllium 9.012182 2 2											5 B Boron 10.811 2 3	6 C Carbon 12.0107 2 4	7 N Nitrogen 14.0067 2 5	8 O Oxygen 15.9994 2 6	9 F Fluorine 18.9984032 2 7	10 Ne Neon 20.1797 2 8	K L
3	11 Na Sodium 22.98976928 2 8 1	12 Mg Magnesium 24.3050 2 8 2											13 Al Aluminium 26.9815386 2 8 3	14 Si Silicon 28.0855 2 8 4	15 P Phosphorus 30.973762 2 8 5	16 S Sulfur 32.065 2 8 6	17 Cl Chlorine 35.453 2 8 7	18 Ar Argon 39.948 2 8 8	K L M
4	19 K Potassium 39.0983 2 8 8 1	20 Ca Calcium 40.078 2 8 8 2	21 Sc Scandium 44.955912 2 8 9 2	22 Ti Titanium 47.867 2 8 10 2	23 V Vanadium 50.9415 2 8 11 2	24 Cr Chromium 51.9961 2 8 13 1	25 Mn Manganese 54.938045 2 8 13 2	26 Fe Iron 55.845 2 8 14 2	27 Co Cobalt 58.933195 2 8 15 2	28 Ni Nickel 58.6934 2 8 16 2	29 Cu Copper 63.546 2 8 18 1	30 Zn Zinc 65.409 2 8 18 2	31 Ga Gallium 69.723 2 8 18 3	32 Ge Germanium 72.64 2 8 18 4	33 As Arsenic 74.92160 2 8 18 5	34 Se Selenium 78.96 2 8 18 6	35 Br Bromine 79.904 2 8 18 7	36 Kr Krypton 83.798 2 8 18 8	K L M N
5	37 Rb Rubidium 85.4678 2 8 18 8 1	38 Sr Strontium 87.62 2 8 18 8 2	39 Y Yttrium 88.90585 2 8 18 9 2	40 Zr Zirconium 91.224 2 8 18 10 2	41 Nb Niobium 92.90638 2 8 18 12 1	42 Mo Molybdenum 95.94 2 8 18 13 1	43 Tc Technetium (98) 2 8 18 14 1	44 Ru Ruthenium 101.07 2 8 18 15 1	45 Rh Rhodium 102.90550 2 8 18 16 1	46 Pd Palladium 106.42 2 8 18 18 0	47 Ag Silver 107.8682 2 8 18 18 1	48 Cd Cadmium 112.411 2 8 18 18 2	49 In Indium 114.818 2 8 18 18 3	50 Sn Tin 118.710 2 8 18 18 4	51 Sb Antimony 121.760 2 8 18 18 5	52 Te Tellurium 127.60 2 8 18 18 6	53 I Iodine 126.90447 2 8 18 18 7	54 Xe Xenon 131.293 2 8 18 18 8	K L M N O
6	55 Cs Caesium 132.9054519 2 8 18 18 8 1	56 Ba Barium 137.327 2 8 18 18 8 2	57-71	72 Hf Hafnium 178.49 2 8 18 32 10 2	73 Ta Tantalum 180.94788 2 8 18 32 11 2	74 W Tungsten 183.84 2 8 18 32 12 2	75 Re Rhenium 186.207 2 8 18 32 13 2	76 Os Osmium 190.23 2 8 18 32 14 2	77 Ir Iridium 192.217 2 8 18 32 15 2	78 Pt Platinum 195.084 2 8 18 32 17 1	79 Au Gold 196.966589 2 8 18 32 18 1	80 Hg Mercury 200.59 2 8 18 32 18 2	81 Tl Thallium 204.3833 2 8 18 32 18 3	82 Pb Lead 207.2 2 8 18 32 18 4	83 Bi Bismuth 208.98040 2 8 18 32 18 5	84 Po Polonium (209) 2 8 18 32 18 6	85 At Astatine (210) 2 8 18 32 18 7	86 Rn Radon (222) 2 8 18 32 18 8	K L M N O P
7	87 Fr Francium (223) 2 8 18 32 18 8 1	88 Ra Radium (226) 2 8 18 32 18 8 2	89-103	104 Rf Rutherfordium 178.49 2 8 18 32 32 10 2	105 Db Dubnium (262) 2 8 18 32 32 11 2	106 Sg Seaborgium (266) 2 8 18 32 32 12 2	107 Bh Bohrium (264) 2 8 18 32 32 13 2	108 Hs Hassium (277) 2 8 18 32 32 14 2	109 Mt Meitnerium (268) 2 8 18 32 32 15 2	110 Ds Darmstadtium (281) 2 8 18 32 32 17 1	111 Rg Roentgenium (272) 2 8 18 32 32 18 1	112 Cn Copernicium (285) 2 8 18 32 32 18 2	113 Uut Ununtrium (284) 2 8 18 32 32 18 3	114 Uuq Ununquadium (289) 2 8 18 32 32 18 4	115 Uup Ununpentium (288) 2 8 18 32 32 18 5	116 Uuh Ununhexium (292) 2 8 18 32 32 18 6	117 Uus Ununseptium 2 8 18 32 32 18 7	118 Uuo Ununoctium (294) 2 8 18 32 32 18 8	K L M N O P Q

57 La Lanthanum 138.90547 2 8 18 18 9 2	58 Ce Cerium 140.116 2 8 18 19 9 2	59 Pr Praseodymium 140.90765 2 8 18 21 8 2	60 Nd Neodymium 144.242 2 8 18 22 8 2	61 Pm Promethium (145) 2 8 18 23 8 2	62 Sm Samarium 150.36 2 8 18 24 8 2	63 Eu Europium 151.964 2 8 18 25 8 2	64 Gd Gadolinium 157.25 2 8 18 25 9 2	65 Tb Terbium 158.92535 2 8 18 27 8 2	66 Dy Dysprosium 162.500 2 8 18 28 8 2	67 Ho Holmium 164.93032 2 8 18 29 8 2	68 Er Erbium 167.259 2 8 18 30 8 2	69 Tm Thulium 168.93421 2 8 18 31 8 2	70 Yb Ytterbium 173.04 2 8 18 32 8 2	71 Lu Lutetium 174.967 2 8 18 32 9 2
89 Ac Actinium (227) 2 8 18 32 18 9 2	90 Th Thorium 232.03806 2 8 18 32 18 10 2	91 Pa Protactinium 231.03588 2 8 18 32 20 9 2	92 U Uranium 238.02891 2 8 18 32 21 9 2	93 Np Neptunium (237) 2 8 18 23 8 2	94 Pu Plutonium (244) 2 8 18 32 24 8 2	95 Am Americium (243) 2 8 18 32 25 8 2	96 Cm Curium (247) 2 8 18 32 25 9 2	97 Bk Berkelium (247) 2 8 18 32 27 8 2	98 Cf Californium (251) 2 8 18 32 28 8 2	99 Es Einsteinium (252) 2 8 18 32 29 8 2	100 Fm Fermium (257) 2 8 18 32 30 8 2	101 Md Mendelevium (258) 2 8 18 32 31 8 2	102 No Nobelium (259) 2 8 18 32 32 8 2	103 Lr Lawrencium (262) 2 8 18 32 32 9 2

- The elements present in a group have the same number of electrons in the valence shell of their atoms.
- The elements present in a group have the same valency.
- The elements present in a group have identical chemical properties.
- The physical properties of the elements in group such as melting point, boiling point, density vary gradually.
- Atomic radii of the elements present in a group increases downwards.

12.3.3. Advantages of the Modern Periodic Table

- The table is based on a more fundamental property ie., atomic number.
- It correlates the position of the element with its electronic configuration more clearly.
- The completion of each period is more logical. In a period as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached.
- It is easy to remember and reproduce.
- Each group is an independent group and the idea of sub-groups has been discarded.
- One position for all isotopes of an element is justified, since the isotopes have the same atomic number.
- The position of eighth group (in Mendeleev‘s table) is also justified in this table. All transition elements have been brought in the middle as the properties of transition elements are intermediate between left portion and right portion elements of the periodic table.
- The table completely separates metals from non-metals. The non-metals are present in upper right corners of the periodic table.
- The positions of certain elements which were earlier misfit (inter-changed) in the Mendeleev’s periodic table are now justified because it is based on atomic number of the elements.
- Justification has been offered for placing lanthanides and actinides at the bottom of the periodic table.

12.3.4. Defects in the Modern Periodic Table

- Position of hydrogen is not fixed till now.
- Position of lanthanides and actinides has not been given inside the main body of periodic table.
- It does not reflect the exact distribution of electrons of some of transition and inner transition elements.

MORE TO KNOW

The last element authenticated by IUPAC is Cn112 [Copernicium]. However, the number of elements discovered so far is 118.

12.4. METALLURGY

Individually you are great in your aspect.You will become the GREATEST IF YOU ARE ALLOYED TOGETHER.
Unity is strength.

INTRODUCTION

Metallurgy is as old as our civilization. Copper was the first metal to be used for making utensils, weapons and for other works. Metals play a significant role in our life. They constitute the mineral wealth of a country which is the measure of prosperity.

Metals like titanium, chromium, manganese, zirconium etc. find their applications in the manufacture of defence equipments. These are called **strategic metals**. The metal uranium plays, a vital role in nuclear reactions releasing enormous energy called nuclear energy. Copper, silver and gold are called **coinage metals** as they are used in making coins, jewellery etc.

MORE TO KNOW

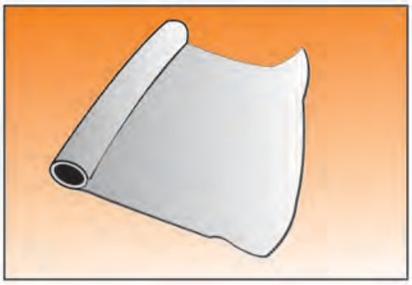
Purity of gold is expressed in carat.

24 carat gold = pure gold.

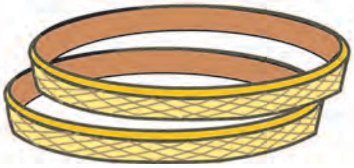
For making ornaments 22 carat gold is used which contains 22 parts of gold by weight and 2 parts of copper by weight. The percentage of purity is $\frac{22}{24}$ x 100=91.6% (**916 Make gold**)

From one gram of gold, nearly 2km of wire can be drawn. Its an amazing fact indeed!

Vietnameses Craft Work in silver



Aluminium foil



Bangles

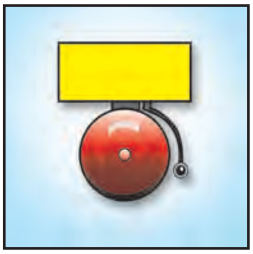
MORE TO KNOW

THE VITALITY OF METALS FOR THE TOTALITY OF LIFE

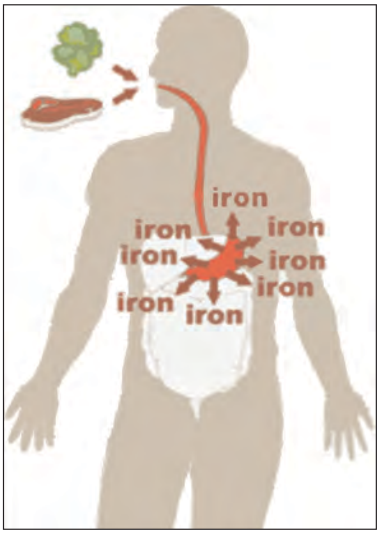
Metals in minute amounts are essential for various biological purposes. **Fe** – a constituent of blood pigment (haemoglobin).

Ca - a constituent of bone and teeth. **Co** - a constituent of vitamin B-12

Mg - constituent of chlorophyll.



METALS AROUND US



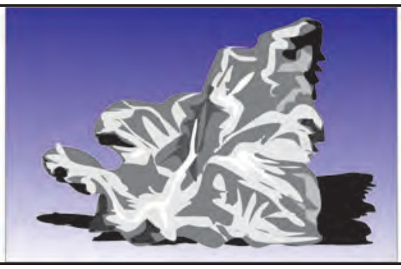
12.4. TERMINOLOGIES IN METALLURGY

12.4.1. Minerals: A mineral may be a single compound or complex mixture of various compounds of metals which are found in earth.

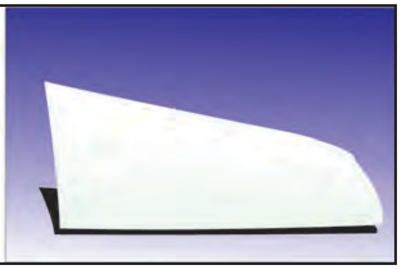
12.4.2. Ores: The mineral from which a metal can be readily and economically extracted on a large scale is said to be a ore.

For example, clay ($Al_2O_3.2SiO_2.2H_2O$) and bauxite ($Al_2O_3.2H_2O$) are the two minerals of aluminium. But aluminium can be profitably extracted only from bauxite. Hence **bauxite is an ore of aluminium and clay is its mineral**.

Gold



Silver



Aluminium

12.4.3. Differences between minerals and ores

- Minerals contain a low percentage of metal while ores contain a large percentage of metal.
- Metals cannot be extracted easily from mineral. On the other hand,ores can be used for the extraction of metals.
- All minerals cannot be called as ores,but all ores are minerals.

Mining: The process of extracting the ores from the earth crust is called mining.

Metallurgy: Various steps involved in the extraction of metals from their ores as well as refining of crude metal are collectively known as metallurgy.

Gangue or Matrix: The rocky impurity, associated with the ore is called gangue or matrix.

Flux: It is the substance added to the ore to reduce the fusion temperature

Slag: It is the fusible product formed when flux reacts with gangue during the extraction of metals.

Flux + Gangue → Slag

Smelting: Smelting is the process of reducing the roasted oxide to metals in the molten condition.

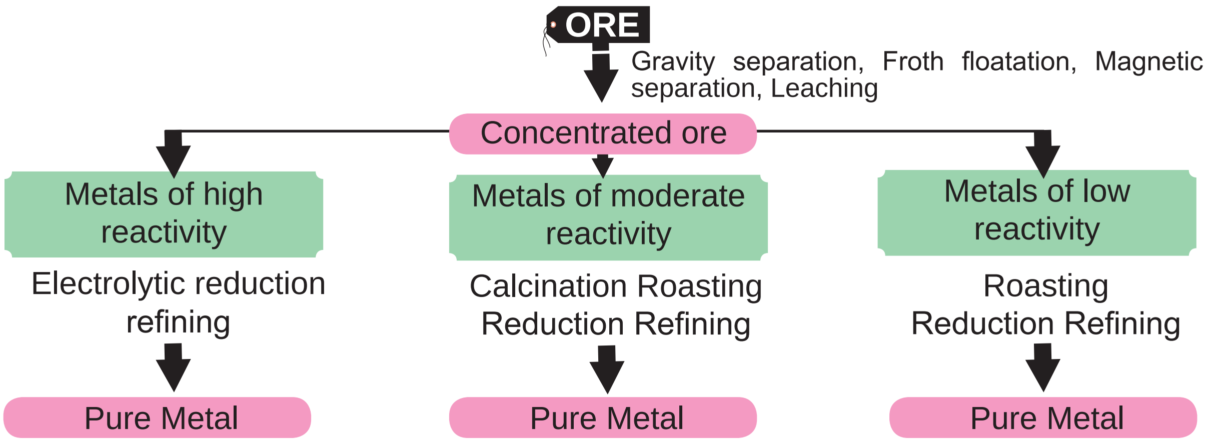
12.5. OCCURRENCE OF METALS

Nearly 80 metallic elements are obtained from mineral deposits on or beneath the surface of the earth.Metals which have low chemical reactivity are found in **free state, or in native state.**

Gold, silver and platinum are examples of metals that are partly found in a free state. Most of the other metals are found in a combined state in the form of their oxide ores, carbonate ores , halide ores, sulphide ores, sulphate ores and so on.

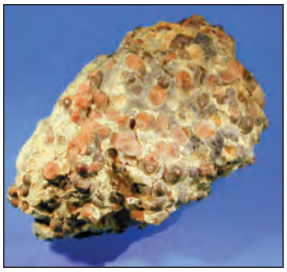
Oxide Ores	Carbonate Ores	Halide Ores	Sulphide Ores
Bauxite ($Al_2O_3.2H_2O$)	**Marble ($CaCO_3$)**	**Cryolite (Na_3AlF_6)**	**Galena (PbS)**
Cuprite (Cu_2O)	**Magnesite ($MgCO_3$)**	**Fluorspar (CaF_2)**	**Iron pyrite (FeS_2)**
Haematite (Fe_2O_3)	**Siderite ($FeCO_3$)**	**Rock salt (NaCl)**	**Zinc blende (ZnS)**

Flow Chart (Extraction of Metal from its ore)



12.6. METALLURGY OF ALUMINIUM, COPPER AND IRON

12.6.1. Metallurgy of aluminium



Symbol : Al
Colour : Silvery white
Atomic number : 13
Electronic configuration:2, 8, 3
Valency : 3
Atomic mass : 27

Position in the periodic table: period=3, group=13 (III A)

Aluminium is the most abundant metal in the earth's crust. Since it is a reactive metal it occurs in the combined state. The important ores of aluminium are as follows:

Name of the ore	Formula
Bauxite	$Al_2O_3.2H_2O$
Cryolite	Na_3AlF_6
Corundum	Al_2O_3

The chief ore of aluminium is bauxite ($Al_2O_3.2H_2O$).

Extraction of aluminium from bauxite involves two stages:

I. Conversion of Bauxite into Alumina by Baeyer's Process

The conversion of Bauxite into Alumina involves the following steps:

i.Bauxite ore is finely grounded and heated under pressure with concentrated caustic soda solution at 150°C to obtain sodium meta aluminate.

$$\underset{\text{Bauxite}}{Al_2O_3.2H_2O} + 2NaOH \xrightarrow{150^{\circ}C} \underset{\text{Sodium Meta aluminate}}{2NaAlO_2} + 3H_2O$$

ii.On diluting sodium meta aluminate with water, aluminium hydroxide precipitate is obtained.

$$NaAlO_2 + 2H_2O \rightarrow NaOH + Al(OH)_3$$

iii.The precipitate is filtered, washed, dried and ignited at 1000°C to get alumina.

$$2Al(OH)_3 \xrightarrow{1000^{\circ}C} Al_2O_3 + 3H_2O$$

2.Electrolytic reduction of Alumina by Hall's process

Aluminium is produced by the electrolytic reduction of fused alumina (Al_2O_3) in the electrolytic cell.

Cathode : Iron tank lined with graphite

Anode : A bunch of graphite rods suspended in molten electrolyte

Electrolyte : Pure alumina + molten cryolite + fluorspar (fluorspar lowers the fusion temperature of electrolyte)

Temperature : 900-950°C

Voltage used : 5-6V

The overall equation for aluminium extraction is

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

Aluminium deposits at cathode and oxygen gas is liberated at anode

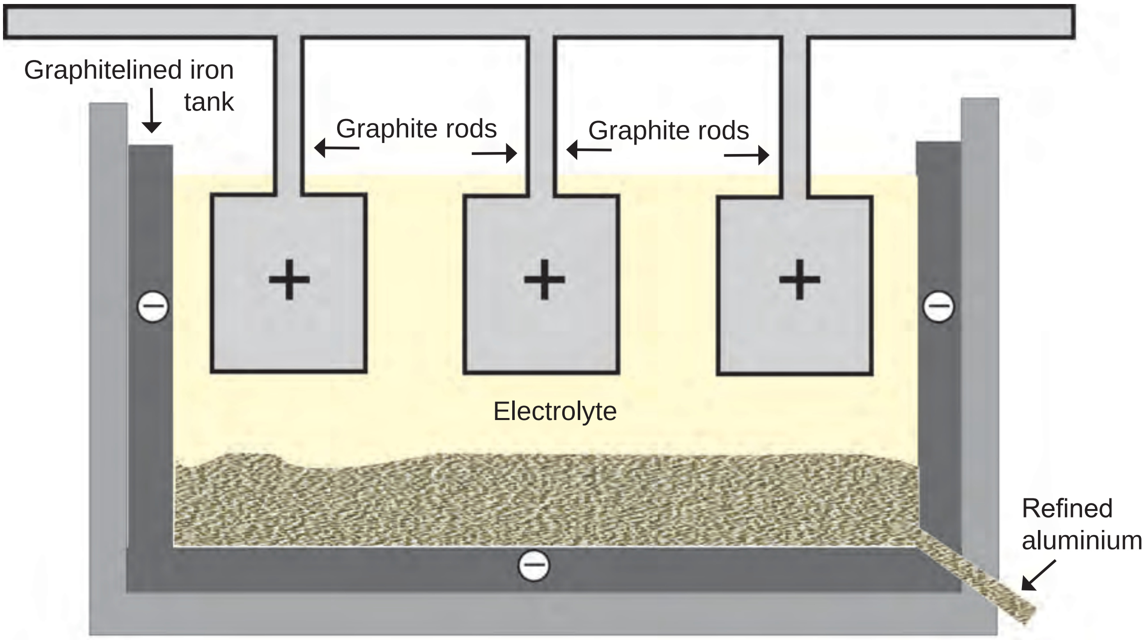


Fig 12.6.3 Electrolytic refining of aluminium

Properties of Aluminium

Physical properties:

i. It is a silvery white metal.
ii. It has low density and it is light
iii. It is malleable and ductile.
iv. It is a good conductor of heat and electricity.

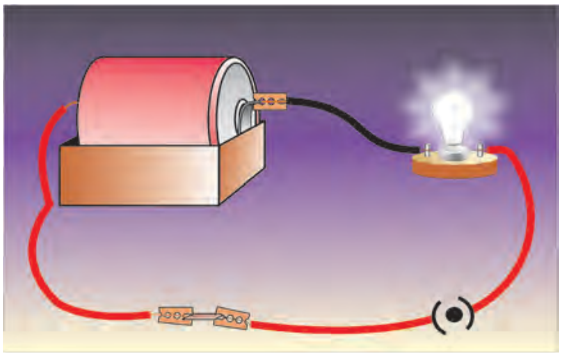


Fig. 12.6.4 Electric conductivity of metal

v. Melting point: 660°C
vi. It can be well polished to produce attractive shiny appearance.

Chemical properties:

1. Reaction with air: It is not affected by dry air. On heating at 800°C, aluminium burns very brightly forming its oxide and nitride.

$4Al + 3O_2 \rightarrow 2Al_2O_3$ (Aluminium Oxide)
$2Al + N_2 \rightarrow 2AlN$ (Aluminium Nitride)

2. Reaction with water: Water has no reaction on aluminium due to the layer of oxide on it. When steam is passed over red hot aluminium, hydrogen is produced.

$$2Al + \underset{\text{Steam}}{3H_2O} \rightarrow \underset{\text{Aluminium Oxide}}{Al_2O_3} + 3H_2\uparrow$$

3. Reaction with alkalis: It reacts with strong caustic alkalis forming aluminates.

$$2Al + 2NaOH + 2H_2O \rightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

4. Reaction with acids: With dilute and con. HCl it liberates H_2 gas.

$$2Al + 6HCl \rightarrow \underset{\text{Aluminium Chloride}}{2AlCl_3} + 3H_2\uparrow$$

Aluminium liberates hydrogen on reaction with dilute sulphuric acid. Sulphur dioxide is liberated with hot concentrated sulphuric acid.

$$2Al + \underset{\text{Dilute}}{3H_2SO_4} \rightarrow Al_2(SO_4)_3 + 3H_2\uparrow$$

$$2Al + \underset{\text{hot \& conc. Sulphuric acid}}{6H_2SO_4} \rightarrow \underset{\text{Aluminium Sulphate}}{Al_2(SO_4)_3} + 6H_2O + 3SO_2\uparrow$$

MORE TO KNOW

MORE TO KNOW

Dilute or concentrated nitric acid does not attack aluminium. But it renders aluminium passive due to the formation of an oxide film on its surface.

5. Reducing action : Aluminium is a powerful reducing agent. When a mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is known as aluminothermic process.

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$$

Uses of Aluminium

USES	FORM	REASON
1.Household utensils	Aluminium metal	It is light, cheap, corrosion resistant, and good conductor of heat.
2.Electrical cable industry	Aluminium wires	It is a good conductor of electricity.
3.Aeroplanes and other industrial parts	Duralumin Al,Cu,Mg,Mn Magnalium Al,Mg	Its alloys are light, have high tensile strength and are corrosion resistant.
4.Thermite welding	Al powder and Fe_2O_3	Its powder is a strong reducing agent and reduces Fe_2O_3 to iron.

AirCraft - An alloy of aluminium

INDUSTRIAL VISIT

Fig 12.6.6

Make an industrial visit to the place where **Thermite welding** is actually done and record your observations on joining the gap between the broken pieces of rails.

12.6.2 Metallurgy of Copper

Symbol : Cu
Atomic mass : 63.55
Atomic number : 29
Electronic configuration : 2, 8, 18, 1
Valency : 1 and 2

Occurrence: It was named as cuprum by the Romans because they used to get it from the island of Cyprus. Copper is found in the **native state** as well as in the combined state.

Ores of copper	Formula
i. Copper pyrite	$CuFeS_2$
ii. Cuprite or ruby copper	Cu_2O
iii.Copper glance	Cu_2S

The chief ore of copper is copper pyrite. It yields nearly 76% of the world production of copper.

Extraction from copper pyrites:

Extraction of copper from copper pyrites involves the following steps.

1.**Crushing and concentration:** The ore is crushed and then concentrated by froth-floatation process.

2.**Roasting:** The concentrated ore is roasted in excess of air. During roasting,

i.moisture and volatile impurities are removed.
ii.copper pyrite is partly converted into sulphides of copper and iron.

$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

3.**Smelting:** The roasted ore is mixed with powdered coke and sand and is heated in a blast furnace to obtain matte and slag. ***(Matte = Cu_2S + FeS)*** The slag is removed as a waste.

4.**Bessemerisation:** The molten matte is transferred to Bessemer converter in order to obtain ***blister copper.*** Ferrous sulphide from matte is oxidised to ferrous oxide which is removed as slag using silica.

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$
$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$
$FeO+SiO_2 \rightarrow FeSiO_3$ (Iron silicate, slag)

5.**Refining:** Blister copper contains 98% pure copper and 2% impurities and are purified by electrolytic refining.

Electrolytic refining.

This method is used to get metal of high degree of purity. For electrolytic refining of copper, we use

Cathode: A thin plate of pure copper metal.

Anode: A block of impure copper metal.

Electrolyte: Copper sulphate solution acidified with sulphuric acid. When electric current is passed through the electrolytic solution pure copper gets deposited at the cathode, impurities settled at the bottom of the anode in the form of sludge called **anode mud**.

Properties

Physical properties: Copper is a reddish brown metal, with high lustre, high density and high melting point (1356^0C).

Chemical properties:

i.**Action of air and moisture:** Copper gets covered with a green layer of basic copper carbonate in the presence of CO_2 and moisture.

$2Cu + O_2 + CO_2 + H_2O \rightarrow CuCO_3.Cu(OH)_2$

ii. Action of Heat: On heating at different temperatures in the presence of oxygen it forms two types of oxides CuO, Cu_2O.

$2Cu + O_2 \xrightarrow{\text{below 1370K}} 2CuO$ (copper II oxide –black)

$4Cu + O_2 \xrightarrow{\text{above 1370K}} 2Cu_2O$ (copper I oxide-red)

iii. Action of Acids: a) with dil.HCl and dil.H_2SO_4

Dilute acids such as HCl and H_2SO_4 have no action on these metals in the absence of air. Copper dissolves in these acids in the presence of air.

$2Cu + 4HCl + O_2 \text{ (air)} \rightarrow 2CuCl_2 + 2H_2O$
$2Cu + 2H_2SO_4 + O_2 \text{ (air)} \rightarrow 2CuSO_4 + 2H_2O$

b) with dil.HNO_3 Copper reacts with dil. HNO_3 with the liberation of Nitric Oxide gas.

$3Cu + 8HNO_3\text{(dil)} \rightarrow 3Cu(NO_3)_2 + 2NO\uparrow + 4H_2O$

c) with con.HNO_3 and con.H_2SO_4

Copper reacts with con. HNO_3 and con. H_2SO_4 with the liberation of nitrogen dioxide and sulphur dioxide respectively.

$Cu + \underset{\text{(conc.)}}{4HNO_3} \rightarrow Cu(NO_3)_2 + 2NO_2\uparrow + 2H_2O$

$$Cu + \underset{\text{(conc.)}}{2H_2SO_4} \rightarrow CuSO_4 + SO_2\uparrow + 2H_2O$$

iv. Action of chlorine: Chlorine reacts with copper, resulting in the formation of copper (II) chloride.

$Cu + Cl_2 \rightarrow CuCl_2$

v. Action of alkalis: Copper is not attacked by alkalis.

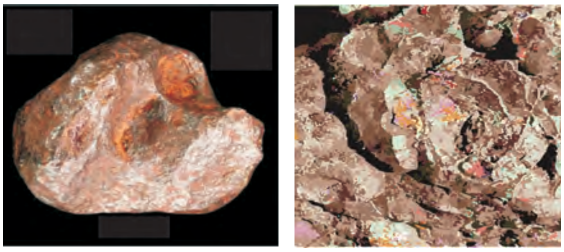
Uses

- It is extensively used for making electric cables and other electric appliances.
- It is used for making utensils, containers, calorimeters, coins.
- It is used in electroplating.
- It is alloyed with gold and silver for making coins and jewels.

PROJECT

Students may be asked to submit a project report on the important applications of copper in everyday life along with the samples.

12.6.3 METALLURGY OF IRON



Symbol :	Fe
Colour :	Greyish white
Atomic mass :	55.9
Atomic number:	26
Valency :	2 & 3
Electronic configuration :	2, 8, 14, 2

Occurrence:

Iron is the second most abundant metal after aluminium. It occurs in nature as oxides, sulphides and carbonates. The ores of iron are given in the following table:

Ores of iron	Formula
I.Red haematite	Fe_2O_3
ii.Magnetite	Fe_3O_4
iii.Iron pyrites	FeS_2

Extraction of Iron from haematite ore (Fe_2O_3)

1.Concentration by gravity separation

The powdered ore is washed with stream of water. As a result, the lighter sand particles and other impurities are washed away and heavier ore particles settle down.

2.Roasting and calcination

The concentrated ore is strongly heated in a limited supply of air in a reverberatory furnace. As a result, moisture is driven out and sulphur, arsenic, phosphorus impurities are oxidised off.

3.Smelting (in Blast furnace)

The **charge** consisting of roasted ore, coke and limestone in the ratio **8 : 4 : 1** is smelted in a blast furnace by introducing it through the **cup and cone** arrangement at the top. There are three important regions in the furnance.

i.The lower region(combustion zone)-temperature is at 1500^0C.

In this region, coke burns with oxygen to form CO_2 when the charge comes in contact with the hot blast of air.

$$C + O_2 \xrightarrow{1500^\circ C} CO_2 + \text{heat}$$

It is an exothermic reaction since heat is liberated.

ii.The middle region (fusion zone)-The temperature prevails at 1000^{0}C.In this region CO_2 is reduced to CO.

$$CO_2 + C \xrightarrow{1000^\circ C} 2CO$$

Limestone decomposes to calcium oxide and CO_2.

$$CaCO_3 \xrightarrow{\blacktriangle} CaO + CO_2$$

These two reactions are endothermic due to the absorption of heat. Calcium oxide combines with silica to form calcium silicate slag.

$$CaO + SiO_2 \rightarrow CaSiO_3$$

iii.The upper region (reduction zone)- temperature prevails at 400^{0}C. In this region carbon monoxide reduces ferric oxide to form a fairly pure spongy iron.

$$Fe_2O_3 + 3CO \xrightarrow{400^\circ C} 2Fe + 3CO_2$$

The molten iron is collected at the bottom of the furnace after removing the slag.

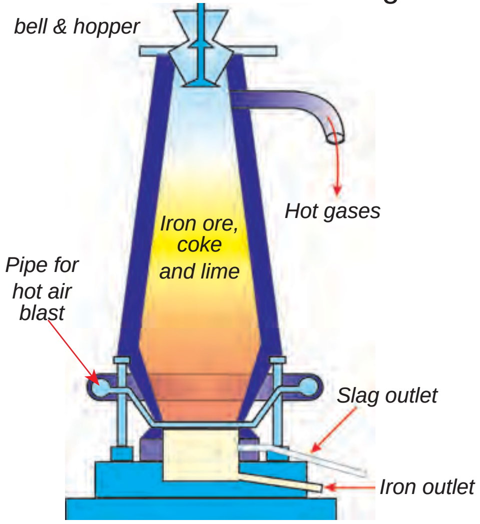


Fig. 12.8.3 Blast furnace

The iron thus formed is called **pig iron**. It is remelted and cast into different moulds. This iron is called **cast iron.**

MORE TO KNOW

CALCINATION AND ROASTING

CALCINATION: It is a process in which ore is heated in the absence of air. As a result of calcinations the carbonate ore is converted into its oxide.

ROASTING: It is a process in which ore is heated in the **presence of excess of air**. As a result of roasting the sulphide ore is converted into its oxide.

MORE TO KNOW

Depending upon the carbon content iron is classified into 3 types.

Pig iron with carbon content of 2- 4.5%

Wrought iron with carbon content <0.25%

Steel with carbon content of 0.25-2%.

Physical properties

- It is a heavy metal of specific gravity 7.9 g/cc
- It is a lustrous metal and greyish white in colour.
- It has high tensility, malleability and ductility.
- It is a good conductor of heat and electricity.
- It can be magnetised.

Chemical properties

1.Reaction with air or oxygen: Only on heating in air, iron forms magnetic oxide

$3Fe + 2O_2 \rightarrow Fe_3O_4$ (black)

2.Reaction with moist air: When iron is exposed to moist air, it forms a layer of brown hydrated ferric oxide on its surface. This compound is known as rust and the phenomenon of forming this rust is known as rusting.

$$4Fe + 3O_2 + \underset{\text{(Moisture)}}{3H_2O} \rightarrow 2Fe_2O_3.3H_2O\text{(Rust)}$$

3.Reaction with steam: When steam is passed over red hot iron,magnetic oxide of iron is formed.

$3Fe + 4H_2O\text{(steam)} \rightarrow Fe_3O_4 + 4H_2\uparrow$

4.Reaction with chlorine: Iron combines with chlorine to form ferric chloride.

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$(ferric chloride)

5.Reaction with acids: With dilute HCl and dilute H_2SO_4 it evolves H_2 gas

$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$

$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2\uparrow$

With conc. H_2SO_4 it forms ferric sulphate

$2Fe + 6H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3SO_2 + 6H_2O$

With dilute HNO_3 in cold condition it gives ferrous nitrate

$4Fe + 10HNO_3 \rightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$

When iron is dipped in conc. HNO_3 it becomes chemically **inert or passive** due to the formation of a layer of iron oxide (Fe_3O_4) on its surface.

Uses of iron

i.**Pig iron** is used in making pipes, stoves, radiators, railings, man hole covers and drain pipes.

ii. **Steel** is used in the construction of buildings, machinery, transmission and T.V towers and in making alloys.

iii.**Wrought iron** is used in making springs, anchors and electromagnets.

12.7 ALLOYS

An alloy is a homogeneous mixture of of a metal with other metals or with non-metals that are fused together.

Alloys are solid solutions. Alloys can be considered as solid solutions in which the metal with high concentration is **solvent** and the metal with low concentration is **solute**. For example, brass is an alloy of zinc(solute) in copper(solvent).

12.7.1 Methods of making alloys:

1.By fusing the metals together.

2.By compressing finely divided metals one over the other.

Amalgam: An amalgam is an alloy of mercury with metals such as sodium, gold, silver, etc.,

MORE TO KNOW

DENTAL AMALGAMS

It is an alloy of mercury with silver and tin metals. It is used in dental filling.

Dental amalgam

12.7.2 Copper Alloys

Name of the alloy	Reason for alloying	Uses
i.Brass(Cu,Zn)	Lusturous,easily cast,malleable, ductile,harder than Cu.	Electrical fittings, medals, hard ware, decorative items.
ii.Bronze(Cu,Sn,Zn)	Hard,brittle,takes up polish.	Statues, coins, bells, gongs.

12.7.3 Aluminium Alloys

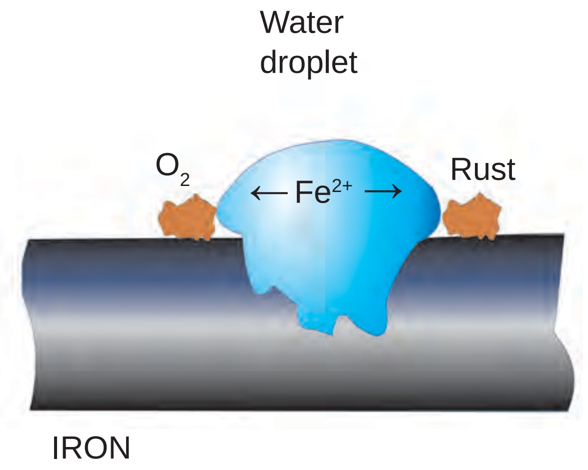
Name of the alloy	Reason for alloying	Uses
i.Duralumin(Al,Mg,Mn,Cu)	Light,strong,resistant to corrosion stronger than aluminium.	Aircraft,tools,pressure cookers
ii.Magnalium(Al,Mg)	Light,hard,tough,corrosion resistant.	Aircraft,scientific instrument

12.7.4 Iron Alloys

Name of the alloy	Reason for alloying	Uses
i.Stainless steel (Fe,C,Ni,Cr)	Lusturous,corrosion resistant,high tensile strength.	Utensils,cutlery,automobile parts.
ii.Nickel steel (Fe,C,Ni)	Hard, corrosion resistant,elastic.	Cables,aircraft parts,propeller.

12.8 CORROSION

Corrosion is defined as the slow and steady destruction of a metal by the environment. It results in the deterioration of the metal to form metal compounds by means of chemical reactions with the environment.



Rusting of iron

MORE TO KNOW

MECHANISM OF CORROSION

Corrosion is a simple electro chemical reaction.

When the surface of iron is in contact with a piece of carbon and water, iron acts as the anode and the carbon acts as a cathode.CO_2 from air dissolves in water to form carbonic acid(H_2CO_3).This acid acts as an electrolyte.

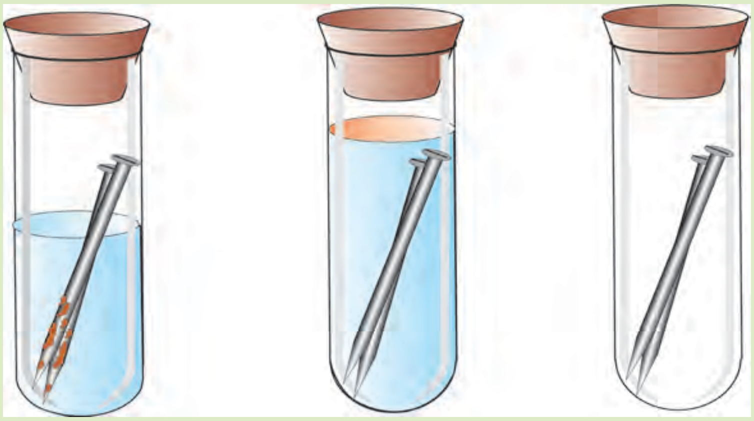
The electrochemical reactions are as follows:

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

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

The Fe^{2+} ions are oxidised to Fe^{3+} ions. The Fe^{3+} ions combine with OH^- ions to form $Fe(OH)_3$.This becomes **rust ($Fe_2O_3.xH_2O$) which is hydrated ferric oxide.**

ACTIVITY 9.1



The conditions for rusting

Take three test tubes provided with rubber corks and label them as A, B and C. Place few iron nails of same size in these tubes. Pour some water in test tube A, some boiled water along with turpentine oil in test tube B and anhydrous $CaCl_2$ in test tube C.Keep them under observation for few days. Notice the changes.

The nails in A are rusted while the nails in B and C are unaffected.

The rusting of nails in A is due to air and water. In B, the oily layer above water does not allow air to come in contact with nails. In C, the substance anhydrous $CaCl_2$ has absorbed moisture completely. This activity shows that rusting of iron requires air and water.

12.8.1 Methods of preventing corrosion:

Corrosion of metals is prevented by not allowing them to come in contact with moisture,CO_2 and O_2.This is achieved by the following methods:

- **By coating with paints:** Paint coated metal surfaces keep out air and moisture.
- **By coating with oil and grease:** Application of oil and grease on the surface of iron tools prevents them from moisture and air.
- **By alloying with other metals:** Alloyed metal is more resistant to corrosion.
- **Example:** stainless steel.
- **By the process of galvanization:** This is a process of coating zinc on iron sheets by using electric current. In this zinc forms a protective layer of zinc carbonate on the surface of iron. This prevents corrosion.
- **Electroplating:** It is a method of coating one metal with another by passing electric current. Example: silver plating, nickel plating. This method not only lends protection but also enhances the metallic appearance.
- **Sacrificial protection:** Magnesium is more reactive than iron. When it is coated on the articles made of steel it sacrifices itself to protect the steel.