METAL:

It is an element which ionizes by the loss of electron to form positive ion easily.

NON METALS:

It is an element which ionizes by the gain of electrons to form negative ion easily.

Differences Between Metals And Non Metals

METALS	NON METALS
PHYSICAL DIFFERENCES	
1. Metals are solids except mercury, with high melting points and boiling points.	1. About half of the non metals are gases. They have low melting and boiling points.
2. Metals have characteristic luster, known as metallic luster and can be polished.	2. Non metals do not have luster like metals and cannot be polished.
3. They on hitting with hammer give off notes i.e. they are sonorous.	3. They are not sonorous and break on hitting
4. They are malleable and ductile that is they can be convert into sheets and wires	4. They are neither malleable nor ductile.
5. They have relatively high densities.	5. They have relatively low densities.
6. Metals have great tensile strength and can with stand stress and strain	6. They are usually brittle and break easily when subjected to stress or strain.
7. They are good conductors of heat and electricity.	7. They are generally bad conductors of heat and electricity.
8. Some common metals are iron (Fe), Copper (Cu), aluminium (Al) and chromium (Cr).	8. Some common examples of non metals are sulphur (S) carbon (C) oxygen (O_2) Nitrogen (N_2) and chloride (Cl_2)
CHEMICAL DIFFERENCES	
• Oxides of metals are basic in character.	• Oxides of non metals are acidic in character.
• When dissolved in water form alkali solution.	• When dissolved in water form acidic solution.
• Metals ionize by the loss of electrons to form +ve ions.	• Metals ionize by the gain of electrons to form –ve ions.
• Metals have few electrons in their valence shells so have greater tendency to lose electrons during chemical reactions to form electrovalent or ionic compounds and form +ve ion.	• Non metals have more electrons in their valence shells so have greater tendency to accept electrons during chemical reactions to form electrovalent or ionic compounds and form –ve ion.

CHEMICAL PROPERTIES OF METALS:

1. REACTION WITH ACID:

Metals which are more electropositive than hydrogen react with dilute acids to produce salts and hydrogen gas by the loss of electrons

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2$$

$$2Al + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2$$

2. REDUCING AGENT:

Metals are generally reducing agents because they have greater tendency to donate their electron readily during chemical reaction.

$$\underset{\text{metal}}{2Na} + \underset{\text{nonmetal}}{Cl_2} \longrightarrow 2Na^{+1}Cl^{-1}$$

$$\underset{\text{metal}}{4Al} + \underset{\text{nonmetal}}{3S_2} \longrightarrow 2Al_2^{+3}S_3^{-2}$$

3. NATURE OF CHLORIDES:

Metallic chlorides are electrovalent i.e. ionic compounds. They are non volatile crystalline solids. They are good electrolytes. They have high melting point and are generally soluble in water.

$$Na^{+1}Cl^{-1} \quad [Na + \tfrac{1}{2} Cl_2 \longrightarrow Na^+Cl^-]$$

4. NATURE OF HYDRIDES:

Metals form very few compounds with hydrogen. However very electropositive metals like Na, K, Ca etc. combine with hydrogen to form ionic hydrides.

For Example:

$$Na^+H^- \quad [Na + \tfrac{1}{2} H_2 \longrightarrow Na^+H^-]$$

These metallic hydrides are salt like ionic solids. They are good electrolytes, soluble in water, but they react with water to liberate H_2 gas. This reaction is known as hydrolysis.

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2$$

CHEMICAL PROPERTIES OF NON METALS:

1. REACTION WITH ACIDS:

Non metals do not react with dilute acids, but some of non metals get oxidized into their oxides or some oxy-acids, with hot concentrated acids.

$$C + 2HNO_{3\,(conc)} \xrightarrow{hot} CO_2 + 4NO_2 + 2H_2O$$

$$S + 6HNO_{3\,(conc)} \xrightarrow{hot} H_2SO_4 + 6NO_2 + 2H_2O$$

$$S + 2H_2SO_{4\,(conc)} \xrightarrow{hot} 3SO_2 + 2H_2O$$

2. OXIDIZING AGENT:

Non metals are generally oxidizing agents. They have tendency to accept electrons easily during chemical reactions.

$$\underset{\text{non-metal}}{Cl_2} + \underset{\text{metal}}{2Na} \longrightarrow 2Na^{+1}Cl^{-1}$$

3. NATURE OF CHLORIDES:

Non metals form covalent chlorides by sharing of electrons which are usually volatie liquids, easily hydrolyzed in water in most of the cases.

$$PCl_3 \quad [2P + 3Cl_2 \longrightarrow 2PCl_3]$$

PCl_3 is hydrolyzed in water to form phosphorous acid and HCl.

$$PCl_3 + 3H_2O \longrightarrow H_3PO_3 + 3HCl$$

4. **NATURE OF HYDRIDES:**
   Non metals combines with hydrogen to form stable covalent hydrides by the sharing of electrons, such as NH_3, H_2S, HCl etc. They are mostly gases and are generally non electrolytes.

DEFINITIONS

MINERALS:

The combined form of metals with less definite chemical impurities is known as "minerals".

ORES:

Minerals when mixed with earthy materials are known as "Ores". An ore is mostly consists of a mixture of minerals with worthless rocky materials. These rocky materials present in ores are called "gangue particles".

For Example:

- Haematite (Fe_2O_3), Iron pyrite (FeS_2O) are the common ores of iron.
- Cuperite (Cu_2O), Copper pyrite ($CuFeS_2$) are the common ores of copper.

METALLURGY:

The extraction of metals from its ore is called "metallurgy". It is the science and technology to extracting metals from their natural sources i.e. ores are making them for practical use.

STEPS OF METALLURGY

1. **Preliminary Preparation:**
   An ore is usually cashed and grinded for the preliminary preparation.
2. **Concentration Of The Ore:**
   Concentration of the ore is preformed only for sulphide ore. "Forth Floatation Process" is a very sophisticated technique of the concentration of the ore. This process involves the mixing of finely divided ore with impurities with water and oil, especially pine oil or creosote oil. Air is blown in the mixture and the oil forming froth which floats on the surface and then the froth is skimmed off that contains the sulphide ore, while the gangue particles present in the ore sink at the bottom. The forth is washed and dried, and is called "concentrated ore",
3. **Roasting Of The Concentrated Ore:**
   The concentrated ore is roasted in a furnace in air to remove the sulphur, carbon and other impurities from the ore. S and C are removed as SO_2 and CO_2 gases respectively, leaving behind the oxides of metals. Arsenic and antimony present are also burnt off in the process of roasting. The oxides are easier to deal with as compared to sulphides and carbonates.

$$4CuFeS_2 + 5O_2 \xrightarrow{\text{roasting}} 2Cu2S + 2FeO + 2FeS + 4SO_2$$

4. **Smelting Of The Ore:**
   In this process, the roasted ore is mixed with sand i.e. silica (SiO_2) and coke (C). The ore is now heated strongly until it melts. The remaining impurities present react with silica to form "slag" of molten silicate. The slag is removed from the top of the molten mass and is discarded. The remaining molten mass left is called matte.

5. Reduction:

This process is applied to get free metals, in which a reducing agent or electron donor must be presented to supply electrons three main methods, depending upon the nature of the particular metal.

i. Chemical Reduction:

The less electropositive metals like Pb, Fe, Sn, Zn etc are usually obtained by reducing their oxides with coke or CO, which are cheaply available. For example, in case of Zn, its ore Zinc blend (ZnS) is first oxidized or converted into its oxides in the process of roasting. The oxide of Zinc is then reduced by heating it with coke.

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

$$2ZnS + C \longrightarrow Zn + CO$$

ii. Thermal Reduction:

Some metals are reduced from their ores by direct heating e.g. mercury is obtained by simple heating its ore mercuric sulphide (HgS) in air.

$$HgS + O_2 \longrightarrow Hg + SO_2$$

iii. Electrolytic Reduction:

More electropositive metals like Na, K, Ca, Mg etc. form compounds which are very stable and difficult to reduce chemically. The reduction of these metals occurs by electrolytic reduction process by passing electric current though their molten salts specially chloride slats, for example Na metal is obtained by the electrolytic reduction of molten NaCl, when electric current is passed through the molten mixture of NaCl and $CaCl_2$.Electrolytic reduction process is expensive and is applied when chemical method is not applicable.

$$2Na^+Cl^- \longleftrightarrow 2Na^+ + 2Cl^-$$

CHIEF ORES OF IRON

Iron is the second most abundant metal after aluminum found in the earth crust. Iron has a great industrial importance. It is found in the combined state. Following are some important ores of irons.

- Limonite $Fe_2O_3.3H_2O$ (Hydrated)
- Hematite Fe_2O_3
- Iron pyrite FeS_2
- Siclerite or Spathic $FeCO_3$
- Magnetite Fe_3O_4

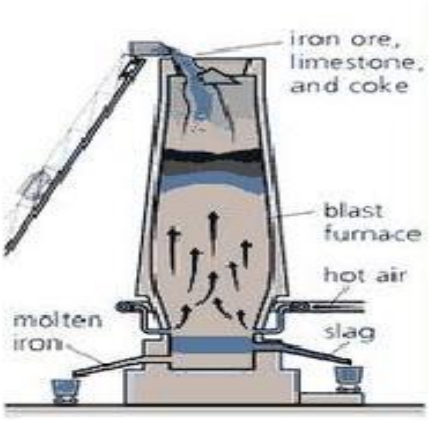
Iron is also present in clay soil as iron silicate. It is an important part of hemoglobin.

EXTRACTION OF IRON

The most important ores from which iron metal is extracted are oxides ores i.e. Haematite (Fe_2O_3) or Limonite ($Fe_2O_3.3H_2O$).

1. Reduction Of Oxides:

The reduction of oxide ores takes place in a blast furnace. This involves the crushing of oxides ore to produce lumps, which are then pre heated using hot gases from the blast furnace. This removes water and other volatile impurities present in the ore.



2. Roasting Of Iron Ore:

The toasted iron ores charged with coke and lime stone ($CaCO_3$) which are fed from the top of the furnace, while a blast of hot air is introduced into it from the bottom through small pipes known as tayeres.

3. Oxidation Of Coke:

The temperature inside the furnace varies from about 2000°C near the bottom to about 200°C at the top. The blast of the hot air oxidized the coke to CO_2 with the liberation of lot of heat.

$$C + O_2 \longrightarrow CO_2 \qquad \Delta H = -394 KJ/mole$$

The reaction is highly exothermic and raises the temperature of the furnace. CO_2 gas rises up the furnace and reacts with more coke to produce CO gas

$$CO_2 + C \xrightarrow{heat} 2CO \qquad \Delta H = +173 KJ/mole$$

4. Formation Of Free Iron:

CO gas thus produced then reduced the iron oxide ore to free iron metal in the upper parts of the furnace. Here the temperature is between 477°C to 727°C.

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

5. Formation Of Calcium Silicate And Calcium Aluminates:

The lime stone which has been introduced together with coke decomposes at high temperature to yield calcium oxide (CaO) which then combines with silica (SiO_2) and aluminum oxide (Al_2O_3) present as impurities to form calcium silicate ($CaSiO_3$) and calcium aluminates ($CaAl_2O_4$).

$$CaCO_3 \longrightarrow CaO + CO_2$$
$$CaO + SiO_2 \longrightarrow CaSiO_2$$
$$CaO + Al_2O_3 \longrightarrow CaAl_2O_4$$

6. Slag Formation:

The mixture of $CaSiO_3$ and $CaAl_2O_4$ remains molten at the furnace temperature and is known as "Slag". It is a useful by product which is used for cement manufacturing making of road material light weight building materials.

7. Flue Gas:

The gas leaving the furnace is known as the "flue gas". It contains N, CO, CO_2 and fine solid particles including carbon particles. The emission of flue gas is a source of environmental pollution.

8. Pig Iron:

The molten iron metal obtained from the blast furnace is run into sand mould where it cools down to solid blocks called "Pig iron". It is hard brittle and melts at 1227°C. It may also be used directly to make steel. It is about 96% iron and 4% carbon, with small amount of other impurities such as silica, sulphur, phosphorous and manganese.

9. Cast Iron:

Pig iron is re-melted mixed with scrap steel and then cooled in mould to form "Cast iron". It is used for making the gates, pipes, lamp posts, engine blocks stoves etc. It is brittle and difficult to weld because of the impurities.

TYPES OF IRON

- **PIG IRON:**

  Pig iron is quite impure, which is directly obtained from the blast furnace. The presence of impurities lowers the melting point of pig iron from 1530°C to 1200°C. It is hard and prattle so it has limited industrial uses. The impurities of the pig iron are given in the form of table.

IMPURITY	% IMPURITIES IN PIG IRON
Carbon	3 – 5
Silicon	1 – 2
Sulphur	0.05 – 0.01
Phosphorous	0.05 – 1.5
Manganese	0.50 – 1.0

- **CAST IRON:**

  It is obtained from pig iron which is re-melted with some scrap steel and cooled in moulds of required shapes. It has slightly a lower percentage of impurities than pig iron, and almost has the same properties as pig iron. It is brittle so difficult to weld or forged. It is used for machinery objects which do not require greater tensile strength e.g. tools, lamps posts, rail rings, gas pipes, base of Bunsen burner, engine block etc.

- **WROUGHT IRON:**

  It is the purest commercial iron, and contains only about 0.1% of carbon. It is obtained by heating the cast iron in a furnace with hematite (Fe_2O_3). During this process C and S are oxidized and are removed as CO_2 and SO_2 respectively.

  $$2Fe_2O_3 + 3C \longrightarrow 4Fe + 3CO_2$$
  $$2Fe_2O_3 + 3S \longrightarrow 4Fe + 3SO_2$$

  At the same time P and Si present are converted into phosphate and silicates of iron and are removed as a slag from the semi molten mass of iron. Wrought iron is almost pure iron.

Therefore it is soft but very tough and malleable. It can be shaped by hammering at about 500°C to 1000°C before its melting point. It can easily be welded and forged. It is used for making nails, chains, iron rods, sheets and horse shoes.

- **STEEL:**

It is an alloy of iron with carbon and other elements such as nickel, manganese, chromium, tungsten and vanadium. It is manufactured from pig iron. About 90% of pig iron is converted into steel. The main impurities of mild steel are given below in the table.

IMPURITY	% IMPURITIES IN STEEL
Carbon	0.15
Silicon	0.03
Sulphur	0.05
Phosphorous	0.05
Manganese	0.50

There are several methods of making steel. The most important methods are:

- The basic oxygen process
- Open hearth process
- The electric arc process.

However they are all based on the same general principle of removing the impurities of C, Si, S, P and Mn from the molten pig iron and to obtain steel of desired compositions.

STAINLESS STEEL:

Definition:

Stainless steel is term applied to the alloy of iron with chromium and nickel containing very low percentage of carbon which shows resistance to corrosion.

Composition:

Stainless steel contains 0.15 – 2.0% of carbon. In addition, some metals chromium or nickel is added to give the steel of desired quality and property.

Properties:

1. It is hard, heat resistant and has high tensile strength and it is practically non oxidisable.
2. It gives resistance to corrosion and usually considered as rust proof.

TYPES OF STEEL (CARBON STEEL)

There are three types of stainless steel according to %ages different constituents.

1. Mild steel (Low carbon steel) (13% Cr, 5%Ni)
2. Medium Steel (Medium carbon steel) (17%Cr, 2(6)% Ni)
3. Hard steel (High carbon steel) (18%Cr, 6(8)%Ni)

DIFFERENCE BETWEEN WROUGHT IRON AND STEEL

WROUGHT IRON	STEEL
Wrought iron is the purest commercial iron.	Steel is an alloy of iron with C and other elements.
It is soft, but very tough and malleable.	It is hard, tough and strong.
Iron rusts when exposed to moist air.	It does not rust.

COPPER

OCCURRENCE:

Copper is very useful and important metal. It is relatively un – reactive. It is found generally in the combined states. The most important ores of copper are:

- Copper pyrite $CuFeS_2$
- Copper glance CuS
- Cuprites Cu_2O
- Mala chite $CuCO_3.Cu(OH)_2$ (green)
- Azurite $[2CuCO_3.Cu(OH)_2]$ (blue)

EXTRACTION OF COPPER

Copper metal is usually extracted from its sulphide ores, such as copper pyrite ($CuFeS_2$) which contains about 6% copper. Extraction of copper from copper pyrite involves the following processes.

1. Concentration Of The Ore Froth Floatation:

The pyrite ore is first purified by concentration of the ore by the process of froth floatation. In this process the ore is crushed and is mixed with water and pine oil or creosote oil. Air is blown into the mixture, oil forms froth with sulphide ore, which floats to the surface, the gangue particles in ore, settle down. The sulphide ore particles tend to get coated with oil and are carried to the surface along with the froth. The froth along with the mineral particles is skimmed off and is dried to get concentrated ore. The gangue particles are left behind.

2. Roasting:

This enriched concentrated ore is then roasted in an open hearth furnace in air, port of sulphur and other furnace in arsenic and antimony are burnt off and are removed as their oxides.

$$4CuFeS_2 + 5O_2 \xrightarrow{\text{roasted}} 2Cu_2S + 2FeO + 2FeS + 4SO_2$$

3. Smelting:

The roasted ore is then changed into a blast furnace together with a little coke and silica (SiO_2). In the process of smelting sulphide ore is oxidized to oxide of iron, which combines with silica to form slag as iron silicate ($FeSiO_3$). The slag is removed which floats on the surface at regular interval and is discarded.

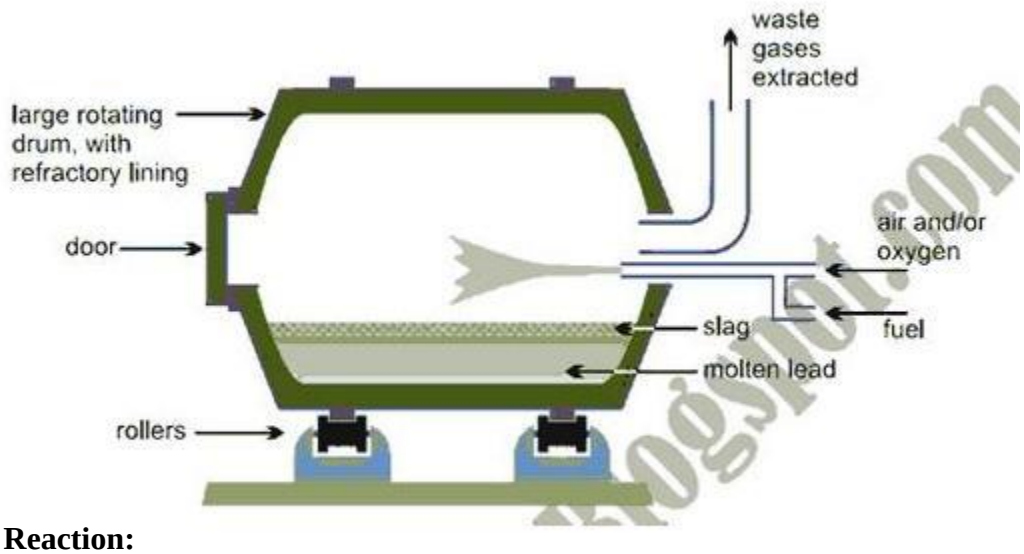
$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$

$$FeO + SiO_2 \longrightarrow FeSiO_3$$

The molten mass below the slag comprises of cuperous sulphide (Cu_2S) mixed with some ferroud sulphide (FeS) known as “matte”.

4. Reduction:

The molten copper matte Cu_2S with some unreacted FeS is carried out to a converter called “Bessemer Converted” where it is treated with some silica by blowing hot air. The iron sulphide that escapes during smelting is oxides to FeO, forming a slag with silica by blowing hot air. The blast of hot air converts Cu_2S partially to Cu_2O which then reacts with remaining Cu_2S to give metallic copper on reduction in the molten state.



Chemical Reaction:

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

$$FeO + SiO_2 \longrightarrow FeSiO_3$$

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

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

5. Blister Copper:

The molten copper is poured into sand moulds. On cooling thus solidified in sand moulds and is known as blister copper. It is produced during solidification on cooling due to the escape of dissolved SO_2 gas. It is about 98% pure copper. Blister copper contains impurities of iron, zinc, lead, silver, gold etc. Due to the presence of impurities, blister copper is not suitable for electrical work.

6. Refining Of Blister Copper:

Blister copper is refined by the electrolytic process. In this process block of impure copper are used as anode and very thin sheets of pure copper act as cathode. These electrodes are suspended in copper sulphate ($CuSO_4$) solution, acidified with little amount of dilute sulphuric acid (H_2SO_4).

The electrolysis is carried out at 50°C by passing current of 1.3 volts, which helps to deposit pure copper metal at cathode by dissolving blister copper anode forming Cu^{+2} ions. The impurities of less active metal like Zn, Ag, Au etc are left over un dissolved and fall at bottom of the cell as "anode mud".

Reaction:

At Anode

$$Cu \longrightarrow \underset{\text{Blister copper}}{Cu^{+2}} + 2e^-$$

At Cathode:

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

Pure Copper Metal

The electrically refined copper is 100% pure. Blister copper is refined because it has impurities of Fe, Zn, Pb, Ag, Au etc. which reduce the conductivity of copper.

ALLOYS

DEFINITION:

An alloy is a substance prepared by adding other metals or non – metals to a baser metal, so as to obtain certain desirable qualities.

EXPLANATION:

An alloy can be considered as a uniform mixture of two or more metallic elements or non metallic elements like carbon or silicon. The component elements do not undergo any chemical changes during the process of alloying. The percentage composition of the component elements may vary according to the quality desired.

Metals readily form alloys since metallic bond is non – specific. The presence of small quantities of a second element in the metal frequently increases its strength. The uses of a particular metal are governed by its chemical and physical properties. In most cases, a pure metal does not possess all the desired properties necessary. These short comings of the metals are usually eliminated by allowing the metals with one or more other substances usually metals or carbon e.g. pure iron is soft and is useless for many purposes. If however it is alloyed with Si, C, Mn, Cr, Ni or V etc, the resultant alloys are very useful.

SOME COMMON ALLOYS

BRONZE:

This is a very common alloy of baser metal copper. Bronze contains 90 – 95% copper and 5 – 10% tin. It is strong enough to resist chemical attacks. It is an attractive alloy and used for making coins, medals, sculptures and also for general metallic work.

BRASS:

Brass is an alloy of baser metal copper. It contains 60 – 80% copper and 20 – 24% Zn. It is stronger and malleable than copper. It is of yellow color and has low melting point is more attractive in appearance, and used for making moving parts of clocks and watches, nuts and bolts, rods, tubes, musical instruments, ornaments, household, furniture and for general metal work.

NICHROME:

It is an alloy that contains 60% nickel, 25% iron and 15% chromium. Nichrome is heat resistant and electrical resistant. It is used in making of wires.