Occurrence of metals in nature: Metals occur in nature in free state or in combined state. A metal is said to occur native or free when it is found in nature in the metallic state. For example, gold may be found in nature as metal. This is because gold when left exposed to air practically does not undergo any change. It is not reacted upon by moisture, oxygen and carbon dioxide of the air. Thus, those metals which remain unaffected by moisture, oxygen and carbon dioxide of the air can occur native or free. In other words, the unreactive metals occur in nature in Free State because of their low reactivity towards chemical reagents. Another example of an unreactive metal is silver. The reactive metals, i.e, the metals which react with moisture, oxygen, carbon dioxide or other chemical reagents, are not found in nature in free state, but in combined state in the form of compounds.

Minerals: Metal – bearing substances, found in the earth crust, are called minerals. In other words, the solid compounds of metals occurring in nature are called minerals. For example, NaCl, KCl, $CaCO_3$, $MgCO_3$, ZnS, Cu_2S, Fe_2S, etc. which are found in nature are minerals.

Ores: The minerals from which metals can be obtained on a commercial scale are called ores. In other words, the minerals from which metals can be extracted profitably are called ores. Both bauxite ($Al_2O_3.2H_2O$) and clay ($Al_2O_3.2SiO_2.2H_2O$) are minerals of aluminium. However, it is bauxite that is chiefly used to obtain aluminium commercially. So bauxite, not clay, is an ore of aluminium.

Thus:

(i) All ores are minerals, but all minerals are not ores.

(ii) An ore is rich in the amount of the metal. The amount of foreign materials or impurities is low in an ore.

Different types of ores: The different types of ores that are used in the extraction of metals are listed below.

1. Oxides: Copper, aluminium, Zinc, tin, iron .etc. occur as oxides.
2. Sulphides: silver, copper, zinc, mercury, lead, iron, etc., occur as Sulphides.
3. Carbonates: Sodium, copper, calcium, magnesium, zinc, lead, iron etc., occur as carbonates.
4. Sulphates: Sodium, Calcium, magnesium, lead etc., occur as sulphates.
5. Halides: Sodium, calcium, silver etc., occur as halides.
6. Phosphates: Calcium occurs as phosphates.

METALLURGY: The process of extracting metals from their ores and refining them for use is known as metallurgy. In other words, the process of obtaining a metal from its ores is called metallurgy of the metal.

Principles of metallurgy: The extraction of a metal from its ore depends upon the reactivity of the metals.

1. Metals at the top of the activity series (K,Na,Ca,Mg,etc.) are highly reactive. They do not occur in the free state. They are extracted by the electrolysis of the molten ore.
2. Metals in the middle of the activity series (Zn,Fe,Pb,etc.)are moderately reactive. These are obtained by roasting and calcination of their sulphide or carbonate ore.
3. Metals at the bottom of the activity series (Au,Ag,Pt,Cu) being the least reactive are found in the free state. Copper and silver also occur as their sulphide or oxide ores. These are obtained by the process of roasting.

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Metallurgical operations: The various steps used in metallurgy are listed below.

1. Enrichment or dressing of the ore
2. Conversation of the enriched ore into the oxide of metal.
3. Extraction of metal from the metal oxide
4. Refining or purification of the metal

Enrichment or dressing of an ore: removal of unwanted material (gangue) from the ore is called enrichment or concentration of ore. The undesirable impurities like soil, sand etc found in ore are called gangue or matrix. The process used for removal of gangue from an ore is based on the difference between the physical and chemical properties of the gangue and ore. Enrichment or dressing of an ore is carried out by the following methods.

1. Levigation: The powered ore is washed in a jet of water. The lighter, rocky and earthy impurities are washed away by water, while heavier ore particles are left behind to settle down at the bottom. This process is also called hydraulic washing.

2. Froth floatation: Sulphide ores of copper, lead and zinc are generally concentrated by this method. The finely powdered ore is mixed with water and a small amount of oil in a tank. Air is blown into the mixture. A froth or scum is produced at the surface. The ore particles are carried by the froth to the surface. The earthy impurities sink to the bottom. The froth along with the ore is removed. An acid is added to break up the froth. The concentrated ore is filtered and dried.

3. Liquation: This process is used to concentrate the ore whose melting point is lower than that of the impurities. Stibnite, an ore of antimony, is concentrated by this method. The impure ore is heated. The ore melts and flows along the surface. The impurities are left behind.

4. Magnetic separation: This method is used when the magnetic properties of the ore and the impurities are different. For example, tinstone, an ore of tin, contains wolfram as an impurity that is magnetic. To remove this impurity, the ore is finely powdered to make the magnetic and the nonmagnetic particles distinctly separate.

5. Leaching or chemical separation: in this method, the powered ore is treated with a suitable solvent. The ore dissolves in it while the impurities remain undissolved. For example, the bauxite ore contains Fe_2O_3, SiO_2, etc., as impurities. The ore is powered and treated with a solution of sodium hydroxide. Al_2O_3 and SiO_2 present in the ore dissolve, forming sodium aluminate and sodium silicate respectively. The impurities are left behind undissolved.

<u>Extraction of metals (at the bottom of the Activity Series) of Low Activity</u>:
These metals, being less reactive, can be obtained by reducing their oxides to metals by heating alone.

1. Cinnabar: (HgS) is an ore of mercury, when heated in air, it first changes into oxide and then into mercury metals. e.g.

$2HgS(s) + 3O_2(g) \longrightarrow 2HgO(s) + 2SO_2(g)$

$2HgO(s) \longrightarrow 2Hg(l) + O_2(g)$

2. Copper glance (Cu_2S): when it is heated in air, partially oxidized and the oxidized product reacts with the remaining. e.g.

$2Cu_2S(s) + 3O_2(g) \longrightarrow 2Cu_2O(s) + 2SO_2(g)$

$2Cu_2O(s) + Cu_2S(s) \longrightarrow 6Cu(s) + SO_2(g)$

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Extraction of Metals (At the middle of the activity Series) of Medium Reactivity:
The metals in the middle of the activity series as iron,zinc,lead,copper etc. are moderately reactive. These metals are usually present as sulphides or carbonates in nature. These sulphides or carbonates are first converted into oxides because it is easy to exact metals from its oxide. Sulphides are converted into oxides by roasting and carbonates are converted into oxides by calcinations. The metal oxides thus obtained are then reduced to the corresponding metals by reduction using suitable reducing agents such as carbon. Chemical Reactions involved in the extraction of zinc are as follows:

Roasting: It is the process in which carbonate ore is heated below its melting point in the presence of air to convert it into metal oxide. e.g.

$2ZnS(s) + 3\ O_2(s) \longrightarrow 2ZnO(s) + 2SO_2(g)$

Calcination: It is the process in which carbonate ore is heated below its melting point in the absence of air to convert it into metal oxide.

$ZnCO_3\ (s) \longrightarrow ZnO(s) + CO_2\ (g)$

Reduction of oxide: It is the process of conversion of metal oxide ore into metal. It can be done by heating the oxides.

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

Sometimes displacement reactions can also be used to reduce metal oxide. The highly reactive metals such as sodium, calcium, aluminum etc, are used as reducing agents because they can displace metals of lower reactivity from their compounds, e.g. reaction of manganese dioxide with aluminum powder.

$3MnO_2\ (s) + 4\ Al(s) \longrightarrow 3Mn\ (l) + 2Al_2O_3(s) + Heat$

These displacement reactions are highly exothermic. The amount of heat produced is so high that the metals are produced in the molten state.

The reaction of iron (III) oxide (Fe_2O_3) with aluminum to produce iron is used to join railway tracks or cracked machine parts. This process is called thermite welding.

$Fe_2O_3(s) + 2Al(s) \longrightarrow 2Fe\ (l) + Al_2O_3\ (s) + Heat$

This reaction of metal oxide to form metal by using aluminum powder as a reducing agent is known as thermite reaction. The mixture of iron oxide and aluminium powder is called thermite.

Exaction of Metals (At the top of the activity Series) of High Reactivity: These metallic compounds agent cannot be reduced by carbon or any other reducing agent due to their high affinity with oxygent. Therefore, electrolytic reduction is employed for these metals e.g. Na, Ca etc

Electrolytic Reduction: The salts of these metals as chlorides in molten form are electrolysed. Metal is deposited at the cathode and chlorine is liberated at the anode. The reaction are:

At cathode: $Na^+ + e^- \longrightarrow Na$ (Reduction)

At anode: $2Cl^- \longrightarrow Cl_2 + 2e^-$ (oxidation)

Similarly, aluminum is obtained by the electrolytic reduction of molten aluminium oxide also called alumina.

At cathode: $Al_3^+ + 3e^- \longrightarrow Al$ (Reduction)

At anode: $O_2^- \longrightarrow 1/2O_2 + 2e^-$(oxidation)

Refining of Metals: It is the process of purification of the metal obtained after reduction. Various methods for refining are employed, but the most common one is the electrolytic refining.

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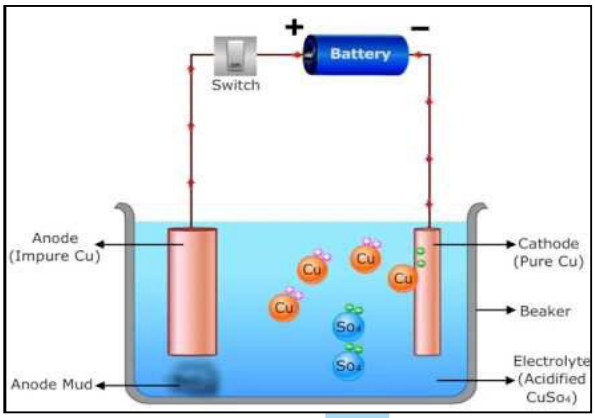
Electrolytic Refining: Many metals like Sn, Ni, Ag etc are refined electrolytically. Process: In this process, a thick strip of impure metals is used as anode and a thin strip of pure metal is used as an electrolyte. A solution of metal salt (to be refined) is used as an electrolyte. When electric current is passed, metal ions from the electrolyte are reduced to the metal which get deposited on the cathode. An equivalent amount of pure metal from the anode gets oxidized to metal ion and goes into the solution. And from solution it goes to cathode and deposit. This cycle is repeated until whole of the metal ion from impure rod is dissolved and deposited on cathode. The soluble impurities go into the solution, whereas the insoluble impurities settle down below anode and are known as anode mud, e.g. in electrolytic refining of crude copper.



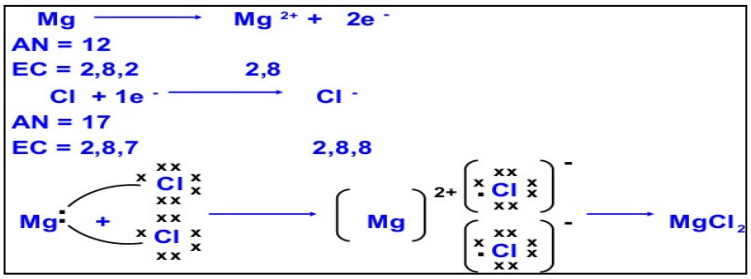
Corrosion: It is the sloe process of eating away of metals by the reaction of atmospheric air and moisture, e.g. rusting of iron, tarnishing of silver, formation of green coating over copper etc.

Prevention of corrosion: Rusting of iron is prevented by galvanizing, by making alloys, painting greasing or oiling and tin- planting and chromium plating which are explained below:

- **Galvanisation**: The process of coating iron and steel objects with a thin layer if zinc id called galvanization. It is done by dipping the object in molten zinc.The galvanized article is protected against rusting even if the zinc coating is broken.
- **Alloying**: It is the method of improving the propertied of a metal by mixing two or more metals.
- **Alloying of gold**: pure gold is very soft. It is called 24 carat gold. To increase the strength and hardness of gold and to make it suitable for making jewellery, alloy of gold is made with silver or copper e.g. 22 carat gold means 22 parts pure gold mixed with 2 parts of Cu or Ag.
- **Alloying of iron**: pure iron is very soft and stretches easily when hot. It is mixed with a small amount of carbon (nearly 0.05%) and it becomes strong. Iron is mixed with many metals to form different alloys.
- **Painting:** Rusting of iron can be easily prevented by coating the surface with a paint which protects iron from air and moisture.
- **Greasing or oiling:** When grease or oil is applied to the surface of an iron object then air and moisture cannot come in contact with it and hence, rust is prevented e.g. tools and machine parts made up of iron are smeared with grease.
- **Tin- planting and Chromium Plating:** Tin and chromium metals are resistant to corrosion. So, when a thin layer of tin metals is deposited on object by electro-planting, then the iron and steel objects are protected from rusting.
- When the coating of metal is done with the help of electricity by making the use of other metal is called electro – plating.

Alloy: An Alloy is a homogeneous mixture of two or more metals or a metal and a non-metal. It is prepared by mixing the metals in molten form and then cooling the mixture. The electrical conductivity and melting point of an alloy is less than that of pure metals, e.g. brass, an alloy of copper and tin (Cu and Sn) is not a good conductor of electricity whereas copper is used for making electric circuits. If an alloy contains mercury as one of its components, it is called amalgam, e.g. sodium- mercury amalgam, silver-mercury amalgam etc.

The Wonder of Ancient Indian Metallurgy: the iron pillar near Qutub Minar in Delhi was built more than 1600 years ago by the iron workers of India. They had developed a process which prevented iron from rusting. For its quality of rust resistance, it has been examined by scientists from all parts of the world.



Ionic or Electrovalent Bond: a chemical bond formed by the complete transfer of electrons from one atom to another is called ionic bond. Such a compound are called ionic compounds. A metal gives electrons to form cations. A non metal gains electron to form anions. It means an ionic bond is formed between a metal and a non metal.

Properties of ionic compounds:

1. Physical nature: they are crystalline solids because of strong forces of attraction between positive and negative ions. These are generally brittle and break into pieces when pressure is applied.
2. Melting and Boiling Points: these compounds have high melting and boiling points as large amount of energy is required to break strong attraction
3. Solubility: these compounds are soluble in water and insoluble in organic solvents like kerosene, benzene, ether and petrol etc. As water is polar in nature it helps in separation of oppositely charged ions from their ionic compounds.
4. Conduction of electricity: the conduction of electricity through the solution involves movement of charged particles. Ionic compounds are good conductor of electricity, but they conduct electricity either in molten form or in aqueous form. In molten form, the electrostatic forces of attraction between the oppositely charged ions become less due to heat. This the reason due to which ions move freely and conduct electricity. They do not conduct electricity in sold form because of absence of fee ions due to rigid structure.

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