8. Metallurgy

- Physical properties of metals
- Chemical properties of metals
- Chemical properties of nonmetals
- Metallurgy: Various concepts.
- Physical properties of nonmetals
- Reactivity series of metals
- Ionic compounds.

Earth was born about 4.5 billion years ago. Various formative processes have been taking place in the core of the earth and its surroundings since its creation till today. These have resulted in the formation of various ores, liquids and gases.

Think about it Which method do we use when we want to study many things together and at the same time?

The substances around us are in the form of some or the other elements or their compounds. In the beginning, elements were classified in accordance with their chemical and physical properties into the types metals, nonmetals and metalloids, and these are in use even today. You have studied their characteristics in the last standard. We are going to get more information about them in this lesson.

Can you tell? What are the physical properties of metals and nonmetals?

Physical properties of metals

Metals exist mainly in solid state. The metals namely, mercury and gallium exist in liquid state at room temperature. Metals possess luster. The metallic luster goes on decreasing due to exposure to atmospheric oxygen and moisture and also in presence of some reactive gases.

We know that metals have the properties namely, ductility and malleability. Similarly, all metals are good conductors of heat and electricity. Generally, all metals are hard. However, the alkali metals from group 1 such as lithium, sodium and potassium are exceptions. These metals can be cut with knife as they are very soft. Metals have high melting and boiling points. For example, tungsten metal has the highest melting point (3422 ^{0}C). On the contrary, the melting and boiling points of the metals such as sodium, potassium, mercury, gallium are very low. A sound is produced when certain metals are struck. This is called sonority. These metals are known as sonorous metals.

Physical properties of nonmetals

When properties of nonmetals are considered, it is found that some nonmetals are in solid state while some are in gaseous state. Exception is the nonmetal bromine which exists in liquid state. Nonmetals do not possess luster, but iodine is the exception as its crystals are shiny. Nonmetals are not hard. Diamond which as an allotrope of carbon is the exception. Diamond is the hardest natural substance. Nonmetals have low melting and boiling points. Nonmetals are bad conductors of electricity and heat. Graphite, an allotrope of carbon, is an exception, as it is a good conductor of electricity.

Chemical properties of metals

Metals are reactive. They lose electrons easily and become positively charged ions. That is why metals are called electropositive elements.

Do you know ?

Substances which are good conductors of heat are usually good conductors of electricity as well. Similarly bad conductors of heat are also bad conductors of electricity. The exception is diamond which is bad conductor of electricity but good conductor of heat.

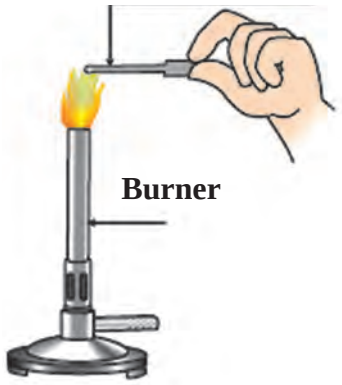
Try this.

Apparatus : Pair of tongs or spatula, knife, burner, etc.

Chemicals : Samples of aluminium, copper, iron, lead, magnesium, zinc and sodium.
(**Note:** Use sodium carefully, in presence of teacher)

Procedure : Hold the sample of each of the above metals at the top of the flame of a burner with the help of a pair of tongs, or a spatula.

1. Which metal catches fire readily?
2. How does the surface of a metal appear on catching fire?
3. What is the colour of the flame while the metal is burning on the flame?



8.1 Combustion of metal

Reactions of Metals:

a. Reaction of metals with oxygen

Metals combine with oxygen on heating in air and metal oxides are formed. Sodium and potassium are very reactive metals. Sodium metal combines with oxygen in the air even at room temperature and forms sodium oxide.

$$4Na(s) + O_2\,(g) \longrightarrow 2Na_2O(s)$$

On exposure to air sodium readily catches fire. Therefore, to prevent accident in the laboratory or elsewhere it is kept in kerosene. Oxides of some metals are soluble in water. They react with water to form alkali.

$$Na_2O\,(s) + H_2O\,(l) \longrightarrow 2NaOH\,(aq)$$

We know that magnesium oxide is formed on burning magnesium ribbon in the air. Magnesium oxide reacts with water to form an alkali, called magnesium hydroxide.

$$2Mg(s) + O_2\,(g) \longrightarrow 2\,MgO(s)$$

$$MgO + H_2O \longrightarrow Mg(OH)_2$$

b. Reaction of metals with water

Apparatus : Beakers.

Chemicals : Samples of various metals (Important note : Sodium metal should not be taken), water.

Procedure : Drop a piece of each of the metal in separate beakers filled with cold water.

1. Which metal reacts with water?
2. Which metal floats on water? Why? Prepare a table with reference to the above procedure and note your observations in it.

Sodium and potassium metal react rapidly and vigorously with water and liberates hydrogen gas.

$$2Na\ (s) + 2H_2O\ (l) \longrightarrow 2NaOH\ (aq) + H_2(g) + heat$$

$$2K(s) + 2H_2O\ (l) \longrightarrow 2KOH\ (aq) + H_2(g) + heat$$

On the other hand, calcium reacts with water slowly and less vigorously. The hydrogen gas released in this reaction collects on the surface of the metal in the form of bubbles and the metal floats on water.

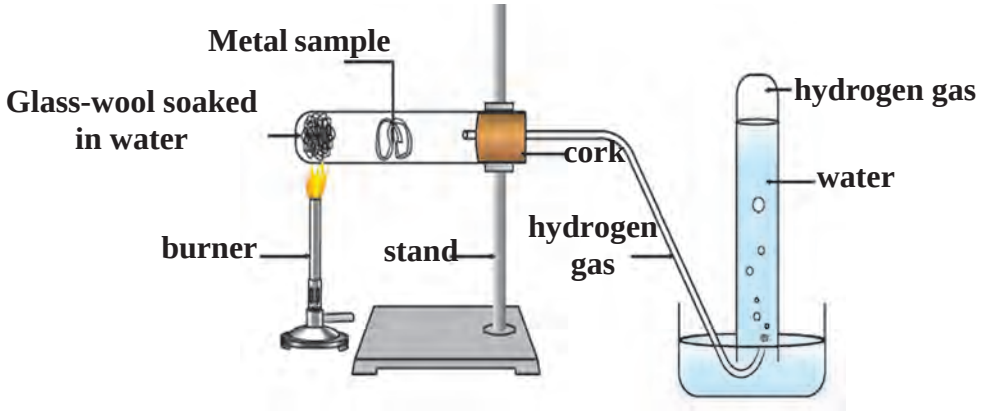
$$2Ca(s) + 2H_2O\ (l) \longrightarrow 2Ca(OH)_2(aq) + H_2(g)$$

The metals; aluminium, iron and zinc do not react with cold or hot water, but they react with steam to form their oxides. Hydrogen gas is released in this reaction.

$$2Al(s) + 3H_2O(g) \longrightarrow Al_2O_3\ (s) + 3H_2(g)$$

$$3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$$

$$Zn(s) + H_2O(g) \longrightarrow ZnO(s) + H_2(g)$$



8.2 Reaction of a metal with water

Try out and think about it

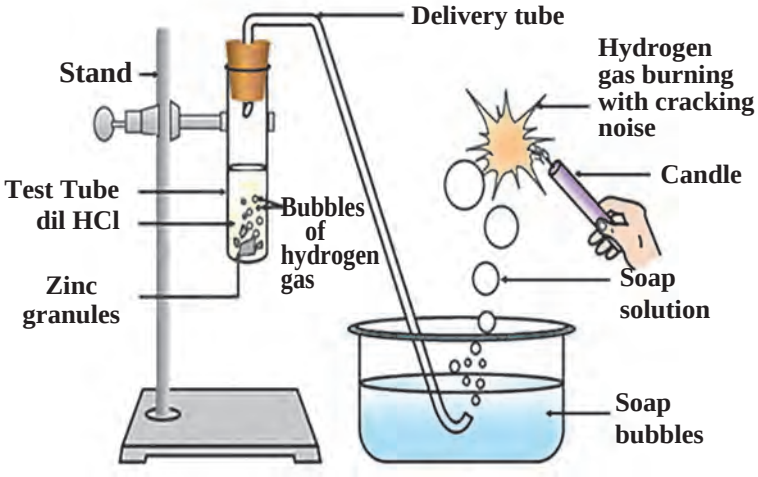
Test whether the metals gold, silver and copper react with water and think over the finding.

c. Reaction of metals with oxygen

In the earlier chapter we have looked into reaction of metals with acids. Are all the metals equally reactive?

When samples of aluminium, magnesium, iron or zinc are treated with dilute sulphuric or hydrochloric acid, sulphate or chloride salts of metals are formed. Hydrogen gas is liberated in this reaction. The reactivity of these metals can be indicated by the following sequence.

Mg > Al > Zn > Fe



8.3 Reaction of metals with dilute acid

$$Mg(s) + 2HCl\ (aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

$$2Al\ (s) + 6HCl\ (aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$$

$$Fe(s) + 2HCl\ (aq) \longrightarrow FeCl_2(aq) + H_2(g)$$

$$Zn\ (s) + HCl\ (aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

d. Reaction of metals with nitric acid

Nitrate salts of metals are formed on reaction of metals with nitric acid. Various oxides of nitrogen (N_2O, NO, NO_2) are also formed in accordance with the concentration of nitric acid.

$$Cu(s) + 4\ HNO_3\ (aq) \longrightarrow Cu\ (NO_3)_2\ (aq) + 2NO_2(g) + 2H_2O\ (l)$$
(Concentrated)

$$3\ Cu(s) + 8HNO_3\ (aq) \longrightarrow Cu\ (NO_3)_2\ (aq) + 2NO(g) + 4H_2O\ (l)$$
(Dilute)

Aqua Regia: Aqua regia is a highly corrosive and fuming liquid. It is one of the few reagents which can dissolve the noble metals like gold and platinum. Aqua regia is freshly prepared by mixing concentrated hydrochloric acid and concentrated nitric acid in the ratio 3:1.

e. Reaction of metals with salts of other metals

Try this.

Apparatus: Copper wire, iron nail, beaker or big test tube etc.
Chemicals: Aqueous solutions of ferrous sulphate and copper sulphate.

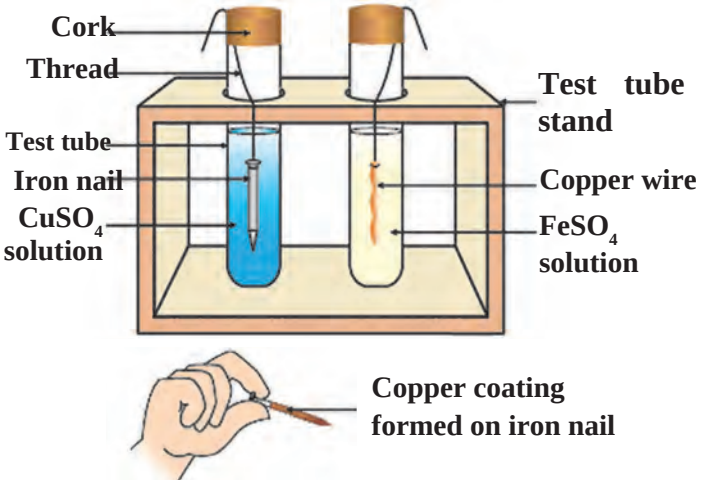
Procedure:

1. Take a clean copper wire and a clean iron nail.
2. Dip the copper wire in ferrous sulphate solution and the iron nail in copper sulphate solution.
3. Keep on observing continually at a fixed interval of time.

a. In which test tube a reaction has taken place?

b. How did you recognize that a reaction has taken place?

c. What is the type of the reaction?



8.4 Reaction of metal with solution of salts of other metals

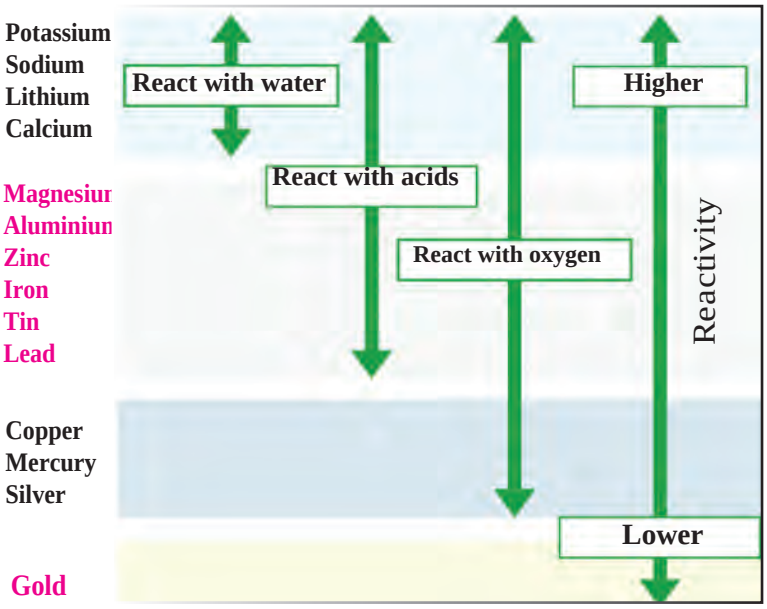
Reactivity series of metals

We have seen that reactivity of all metals is not the same. However, the reagents oxygen, water and acids are not useful to determine the relative reactivities of all the metals, as all the metals do not react with them. The displacement reaction of metals with solutions of salts of other metals serves this purpose. If a metal A displaces another metal B from the solution of its salt then it means that the metal A is more reactive than the metal B.

Metal A + Salt solution of metal B ⟶ Salt solution of metal A + Metal B

Answer from your observations in the previous activity 8.4, which metal is more reactive, copper or iron?

In the previous activity, iron has displaced copper from copper sulphate. It means that metallic iron is more reactive than metallic copper.



8.5 Reactivity series of metals.

Scientists have developed the reactivity series by doing many experiments of displacement reaction. The arrangement of metals in the increasing or decreasing order of reactivity is called the reactivity series of metals. Metals are divided into the following groups according to their reactivity.

1. Highly reactive metals.
2. Moderately reactive metals.
3. Less reactive metals.

f. Reaction of metals with nonmetals

Noble gases (like helium, neon, argon) do not take part in the chemical reactions. So far, we have seen from the reactions of metals that cations are formed by oxidation of metals. If we look into the electronic configuration of some metals and nonmetals, it will be seen that the driving force behind a reaction is to attain the electronic configuration of the nearest noble gas with complete octet. Metals do this by losing electrons while nonmetals do this by gaining electrons. The outermost shell of noble gases being complete, they are chemically inert.

You have seen in the last standard that the ionic compound sodium chloride is formed as sodium metal gives away one electron while the nonmetal chlorine takes up one electron.

$2\,Na + Cl_2 \longrightarrow 2\,NaCl$
(Metal) (nonmetal) (ionic compound)

Similarly, magnesium and potassium form the ionic compounds $MgCl_2$ and KCl, respectively.

Chemical properties of nonmetals

Nonmetals are a collection of elements having less similarity in physical and chemical properties. Nonmetals are also called electronegative elements, as they form negatively charged ions by accepting electron. Some examples of chemical reactions of nonmetals are as follows.

1.Reaction of nonmetals with oxygen:

Generally, nonmetals combine with oxygen to form acidic oxides.
In some cases, neutral oxides are formed.

$C + O_2 \xrightarrow{\text{Complete combustion}} CO_2$ (Acidic)

$2C + O_2 \xrightarrow{\text{Partial Combustion}} 2CO$(Neutral)

$S + O_2 \xrightarrow{\text{Combustion}} SO_2$ (Acidic)

2. Reaction of nonmetals with water : Generally, nonmetals do not react with water, except the halogens. For example, chlorine on dissolving in water gives the following reaction.

$$Cl_2(g) + H_2O(l) \longrightarrow HOCl(aq) + HCl(aq)$$

3. Reaction of dilute acids with nonmetals : Generally, nonmetals do not react with dilute acids, halogens are exception to this. For example, chlorine reacts with dilute hydrobromic acid by the following reaction.

$$Cl_2(g) + 2HBr(aq) \longrightarrow 2HCl(aq) + Br_2(aq)$$

4. Reaction of nonmetals with hydrogen :

Nonmetals react with hydrogen under certain condition (such as proper temperature, pressure, use of catalyst, etc.)

$$S + H_2 \longrightarrow H_2S$$
$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Use your brain power ! In the reaction between chlorine and HBr a transformation of HBr into Br_2 takes place. Can this transformation be called oxidation? Which is the oxidant that brings about this oxidation?

Ionic compounds

The compounds formed from two units, namely cation and anion are called ionic compounds. The cation and anion being oppositely charged, there is an electrostatic force of attraction between them. You know that, this force of attraction between cation and anion is called as the ionic bond. The number of cations and anions in a compound and the magnitude of the electric charge on them is such that the positive and negative charges balance each other. As a result, an ionic compound is electrically neutral.

Ionic compounds are crystalline in nature. The surfaces of all the particles of a crystalline substance have a definite shape and are smooth and shiny. The regular arrangement of ions in the solid ionic compounds is responsible for their crystalline nature. The arrangement of ions is different in different ionic compounds, and therefore the shapes of their crystals are different. The main factor that determines the general arrangement of ions in a crystal is the attractive force between oppositely charged ions and the repulsive force between similarly charged ions. Because of this the general crystalline structure has negative ions arranged around a positive ion and positive ions arranged around a negative ion. Two of the important factors responsible for a certain crystal structure are as follows.

1) Size of the positively and negatively charged ions.
2) Magnitude of the electrical charge on the ions.

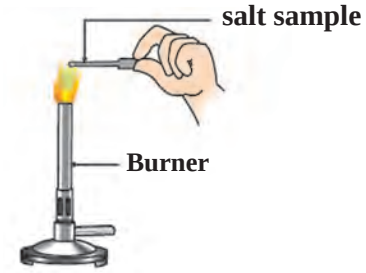
The electrostatic attraction in the neighbouring ions with opposite charges is very strong. That is why the melting points of ionic compounds are high. Also, the ionic compounds are hard and brittle.

Properties of ionic compounds

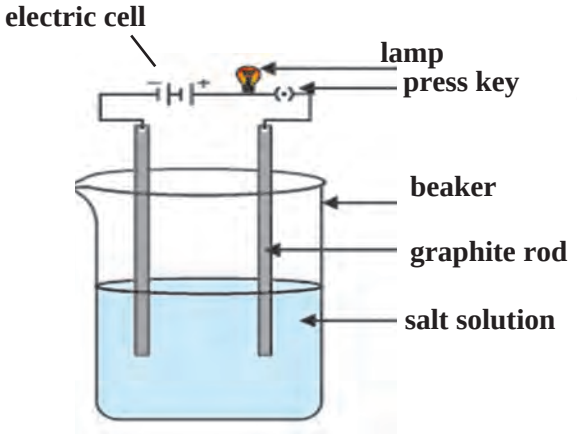
Try this.

Apparatus: Metal spatula, burner, carbon electrodes, beaker, cell, lamp, press key, electrical wires, etc.
Chemicals: Samples of sodium chloride, potassium iodide and barium chloride, water.

Procedure: Observe the above samples. Place sample of one of the above salts on the spatula and heat it on flame of the burner. Repeat the procedure using the other salts. As shown in the figure, assemble an electrolyte cell. Assemble an electrolytic cell by using a beaker and connecting the carbon electrodes to the positive and negative terminal of the cell. Dip the electrodes in solution of any one of the salts. Do you see the lamp glowing? Check this with all the other salts as well.



a. To heat salt sample



b. To check conductivity of salt solution

8.6 To verify the properties of ionic compounds

5. The ionic compounds cannot conduct electricity when in solid state. In this state the ions cannot leave their places. However, in the fused/molten state they can conduct electricity, as in this state the ions are mobile. The aqueous solutions of ionic compounds conduct electricity as they contain the dissociated ions. On passing current through the solution the ions move to the oppositely charged electrodes. Due to the electrical conductivity in fused and dissolved state the ionic compounds are called electrolytes.

General properties of ionic compounds

1. The attractive force between the positively and negatively charged ions is strong Therefore, the ionic compounds exist in solid state and are hard.
2. The ionic compounds are brittle and can be broken into pieces by applying pressure.
3. The intermolecular force of attraction is high in ionic compounds and, large energy is required to overcome it. Therefore, the melting and boiling points of ionic compounds are high. (see table 8.7)
4. Ionic compounds are water soluble. This is because the water molecules orient in a particular manner around the ions separated by dissociation process. As a result of this a new force of attraction is established between the ion and the surrounding water molecules, replacing the original intermolecular attraction; and aqueous solutions of ionic compounds are formed. Ionic compounds are however, insoluble in solvents like kerosene and petrol. This is because unlike water a new attractive force can not be established in these solvents.

Compound	ionic/ nonionic	Melting point ^{0}C	Boiling point ^{0}C
H_2O	nonionic	0	100
$ZnCl_2$	ionic	290	732
$MgCl_2$	ionic	714	1412
NaCl	ionic	801	1465
NaBr	ionic	747	1390
KCl	ionic	772	1407
MgO	ionic	2852	3600

8.6 Melting and boiling points of some ionic compounds

Metallurgy

The science and technology regarding the extraction of metals from ores and their purification for the use is called metallurgy.

Occurrence of metals

Most metals being reactive do not occur in nature in free state but are found in combined state as their salts such as oxides, carbonates, sulphides and nitrates. However, the most unreactive metals that are not affected by air, water and other natural factors like silver, gold, platinum, generally occur in free state. The compounds of metals that occur in nature along with the impurities are called minerals.

The minerals from which the metal can be separated economically are called ores. Ores contain many types of impurities such as soil, sand and rocky substances along with the metal compounds. These impurities are called gangue. Metals can be extracted from their ores by means of various methods of separation. The process of extraction of metal in pure state from the ores is also a part of metallurgy.

Ores are taken out from the mines and the gangue is usually separated from the ore at the site itself by various methods. Then the ores are carried out to the place where metals are produced. There metals are extracted in pure form. Then metals are further purified by different methods of purification. This entire process is called metallurgy.

Basic principles of metallurgy

Pure metal is obtained from the ore by the following stages.

1. Concentration of ores

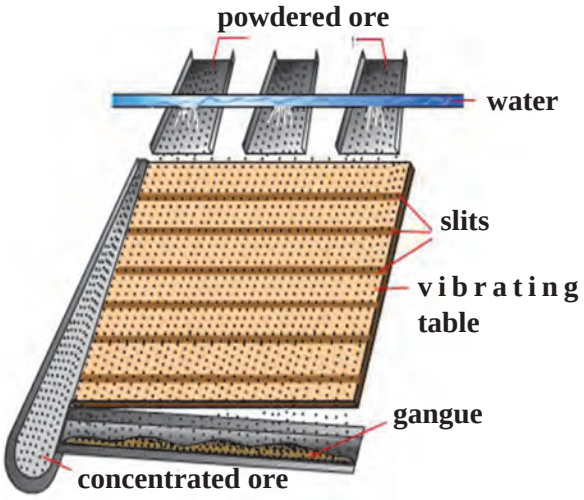
The process of separating gangue from the ores is called concentration of ores. In this process the concentration of the compound of the desired metal is increased. Various ways are used for this purpose. However, exact way to be used depends upon the physical properties of the metal present in the ores and the gangue. It also depends upon the reactivity of the metal and the facilities available for the purification. Various factors that could be responsible for the environmental pollution are also considered. Some general methods for the concentration of ores are as follows.

a. Separation based on gravitation

The heavy particles of ores can be easily separated from the light particles of gangue by the gravitational method. The processes to carry out this separation are as follows.

i. Wilfley table method

In this method of separation, the Wilfley table is made by fixing narrow and thin wooden riffles on inclined surface. The table is kept vibrating continuously. Powdered ore obtained from lumps of the ore using ball mill is poured on the table and a stream of water is also released from the upper side. As a result, the lighter gangue particles are carried away along with the flowing water, while the heavier particles in which proportion of minerals is more and proportion of gangue is less, are blocked by the wooden riffles and get collected on the slits between them.

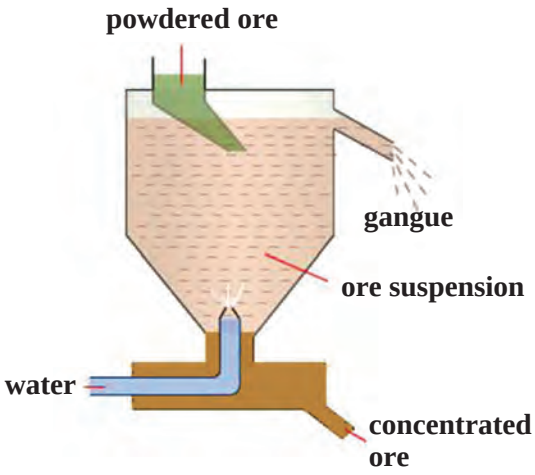


8.8 Wilfley table method

ii. Hydraulic separation method

The hydraulic separation method is based on the working of a mill. There is a tapering vessel similar to that used in a grinding mill. It opens in a tank-like container that is tapering on the lower side. The tank has an outlet for water on the upper side and a water inlet on the lower side.

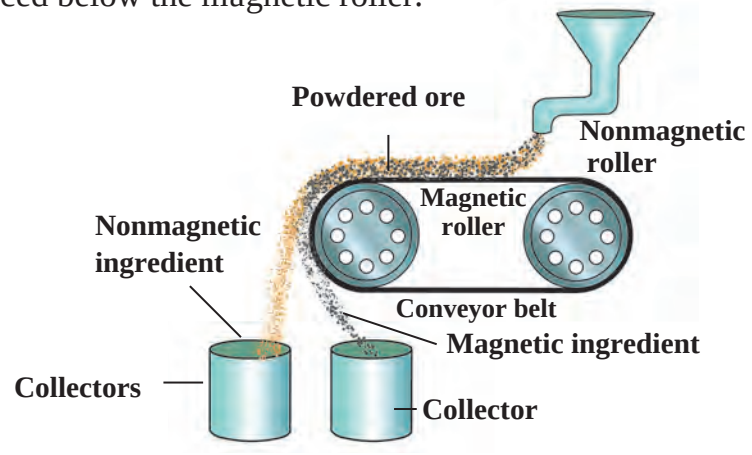
Finely ground ore is released in the tank. A forceful jet of water is introduced in the tank from the lower side. Gangue particles are lighter and therefore they flow out along with the water jet from the outlet on the upper side of the tank and get collected separately. At the same time the heavy particles of the ore are collected at the bottom from the lower side of the tank. In short, this method is based on the law of gravitation, wherein particles of the same size are separated by their weight with the help of water.



8.9 Hydraulic separation

b. **Magnetic separation Method :** This method requires an electromagnetic machine. The main parts of this machine are two types of iron rollers and the conveyor belt moving continuously around them. One of the rollers is nonmagnetic while the other is electromagnetic. The conveyor belt moving around the rollers is (nonmagnetic) made up of leather or brass. The powdered ore is poured on the conveyor belt near the nonmagnetic roller. Two collector vessels are placed below the magnetic roller.

The particles of the nonmagnetic part in the ore are not attracted towards the magnetic roller. Therefore, they are carried further along the belt and fall in the collector vessel places is away from the magnetic roller. At the same time the particles of the magnetic ingredients of the ore stick to the magnetic roller and therefore fall in the collector vessel near the magnetic roller.



8.10 Magnetic separation

In this way the magnetic and nonmagnetic ingredients in the ore can be separated depending on their magnetic nature. For example, cassiterite is a tin ore. It contains mainly the nonmagnetic ingredient stannic oxide (SnO_2) and the magnetic ingredient ferrous tungstate ($FeWO_4$). These are separated by the electromagnetic method.

c. Froth floatation method

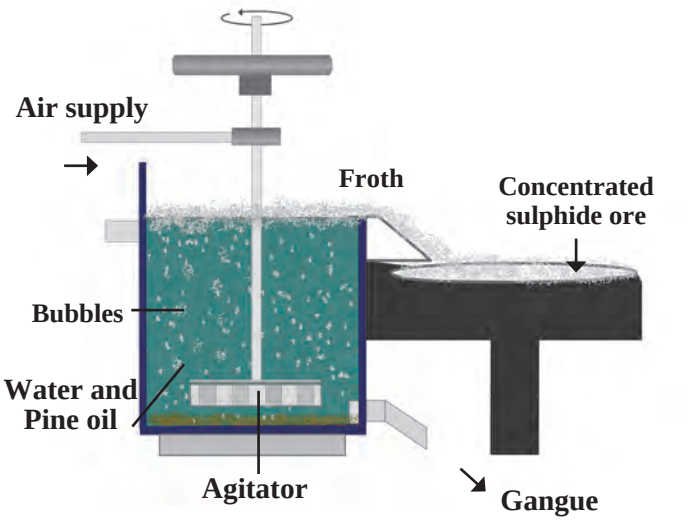
The froth floatation method is based on the two opposite properties, hydrophilic and hydrophobic, of the particles. Here the particles of the metal sulphides, due to their hydrophobic property, get wetted mainly with oil, while due to the hydrophilic property the gangue particles get wetted with water. By using these properties certain ores are concentrated by froth floatation method.

Internet my friend

Collect the information about the different steps of metal extraction & explain it in the class.

Collect the related videos.

In this method the finely ground ore is put into a big tank containing ample amount of water. Certain vegetable oil such as pine oil, eucalyptus oil is added in the water for the formation of froth. Pressurised air is blown through the water. There is an agitator rotating around its axis in the centre of the floatation tank. The agitator is used as per the requirement. Bubbles are formed due to the blown air. Due to agitation a foam is formed from oil, water and air bubbles together, due to the agitating. This foam rises to the surface of water and floats. That is why this method is called froth floatation process.



8.11 Froth floatation method

Particles of certain sulphide ore float with the foam on water as they preferentially get wetted by the oil. For example, this method is used for the concentration of zinc blend (ZnS) and copper pyrite ($CuFeS_2$)

d. Leaching

The first step in the extraction of the metals aluminium, gold and silver from their ores is the method of leaching. In this method the ore is soaked in a certain solution for a long time. The ore dissolves in that solution due to a specific chemical reaction. The gangue, however, does not react and therefore does not dissolve in that solution. So it can be separated. For example, concentration of bauxite, the aluminium ore, is done by leaching method. Here bauxite is soaked in aqueous NaOH or aqueous Na_2CO_3 which dissolves the main ingredient alumina in it.

Do you know ?

Water does not stick to colocasia leaves. Similarly, water does not stick to wax. On the other hand common salt or soap stick to water that is, they get wetted by water.

Can you recall? What is the electronic definition of oxidation and reduction?

During the extraction of metals from their ores, metal is obtained from the cation of metal. In this process the metal cation is to be reduced. How to bring about the reduction depends upon the reactivity of the metal. We have already learnt about the reactivity series of metals.

2. Extraction of metals

a. Extraction of reactive metals

The metals at the top of the reactivity series are highly reactive. Their reactivity decreases down the series. For example, potassium, sodium, aluminium are reactive metals. Reactive metals have large capacity to form cations by losing the electrons in their outermost shell. For example, reactive metals react vigorously with dilute acids to give hydrogen gas. Highly reactive metals burn by reacting with oxygen from air at room temperature. Their extraction has to be done by electrolytic reduction. For example, the metals sodium, calcium and magnesium are obtained by electrolysis of their molten chloride salts. In this process metal is deposited on the cathode while chlorine gas is liberated at the anode. The electrode reactions during the electrolysis of molten sodium chloride to get metallic sodium are as shown below.

Cathode reaction $Na^+ + e^- \longrightarrow Na$ (Reduction)

Anode reaction $2\,Cl^- \longrightarrow Cl_2 + 2e^-$ (Oxidation)

Use your brain power !

Write the electrode reaction for electrolysis of molten magnesium chloride and calcium chloride.

We are now going to see how aluminium is obtained by electrolytic reduction of aluminium oxide in the ore bauxite.

Extraction of Aluminium.

Aluminium Symbol : Al Colour : Silver white
Atomic number : 13 Electronic configuration: 2, 8, 3 Valency : 3

Aluminium being reactive metal does not occur in nature in free state. Aluminium is the third highly abundant element in the earth crust after oxygen and silicon. Aluminium is extracted from its ore bauxite ($Al_2O_3nH_2O$). Bauxite contains 30% to 70% of Al_2O_3 and remaining part is gangue. It is made up of sand, silica, iron oxide etc. There are two steps in the extraction of aluminium.

i. Concentration of bauxite ore:

Bauxite is the main ore of aluminium. Silica (SiO_2), ferric oxide (Fe_2O_3) and titanium oxide (TiO_2) are the impurities present in bauxite. Separation of these impurities is done by leaching process using either Bayer's method or Hall's method. In both these methods finally the concentrated alumina is obtained by calcination.

In the Bayer's process the ore is first ground in a ball mill. Then it is leached by heating with concentrated solution of caustic soda (NaOH) at 140 to 150 ^{0}C under high pressure for 2 to 8 hours in a digester. Aluminium oxide being amphoteric in nature, it reacts with the aqueous solution of sodium hydroxide to form water soluble sodium aluminate. This means that bauxite is leached by sodium hydroxide solution.

$$Al_2O_3 \cdot 2H_2O\,(s) + 2\,NaOH\,(aq) \longrightarrow 2NaAlO_2\,(aq) + 3\,H_2O\,(l)$$

The iron oxide in the gangue does not dissolve in aqueous sodium hydroxide. It is separated by filtration. However, silica in the gangue dissolves in aqueous sodium hydroxide to form water soluble sodium silicate.

Aqueous sodium aluminate is diluted by putting in water and is cooled to 50 ^{0}C. This results in precipitation of aluminium hydroxide.

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

In the Hall's process the ore is powdered and then leached by heating with aqueous sodium carbonate in the digester to form water soluble sodium aluminate. Then the insoluble impurities are filtered out. The filtrate is warmed and neutralised by passing carbon dioxide gas through it. This results in the precipitation of aluminium hydroxide.

$Al_2O_3{\cdot}2H_2O\ (s) + Na_2CO_3(aq) \longrightarrow 2NaAlO_2(aq) + CO_2\uparrow + 2\ H_2O\ (l)$

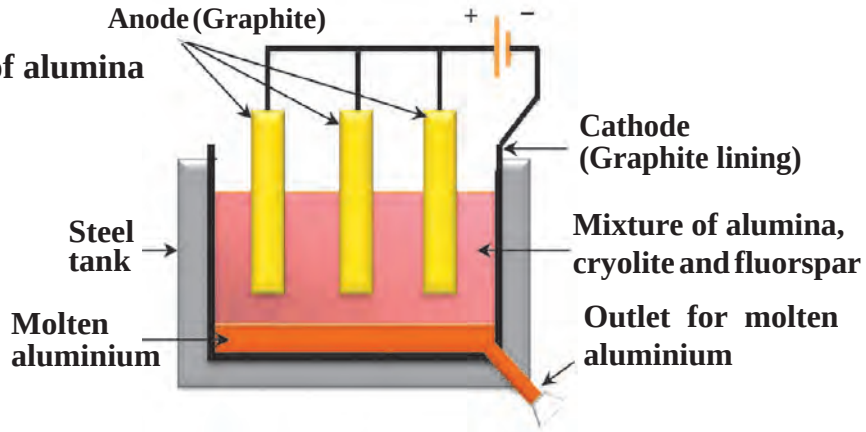
$2NaAlO_2(aq) + 3H_2O + CO_2(g) \longrightarrow 2Al\ (OH)_3\downarrow + Na_2CO_3$

The precipitate of $Al(OH)_3$ obtained in both, Bayer's and Hall's processes is filtered, washed, dried and then calcined by heating at 1000 ^{0}C to obtain alumina.

$2Al(OH)_3 \longrightarrow Al_2O_3 + 3H_2O$

ii. Electrolytic reduction of alumina

a. In this method electrolysis of molten mixture of alumina (melting point > 2000 ^{0}C) is done in a steel tank. The tank has a graphite lining on the inner side. This lining does the work of a cathode. A set of graphite rods dipped in the molten electrolyte works as anode. Cryolite (Na_3AlF_6) and fluorspar (CaF_2) are added in the mixture to lower its melting point up to 1000 ^{0}C.



8.12 Extraction of aluminium

b. Aluminium is deposited on the cathode on passing electric current. Molten aluminium being heavier than the electrolyte, is collected at the bottom of the tank. It is taken out from there from time to time, Oxygen gas is liberated at the anode.

The electrode reactions are as shown below.

Anode reaction $2O^{2-} \longrightarrow O_2 + 4e^-$ (Oxidation)

Cathode reaction $Al^{3+} + 3e^- \longrightarrow Al\ (l)$ (Reduction)

The liberated oxygen reacts with the anodes to form carbon dioxide gas. The anodes have to be changed from time to time as they get oxidised during the electrolysis of alumina.

b. Extraction of moderately reactive metals

Can you tell?

1. What are the moderately reactive metals?
2. In which form do the moderately reactive metals occur in nature?

The metals in the middle of the reactivity series such as iron, zinc, lead, copper are moderately reactive. Usually they occur in the form of their sulphide salts or carbonate. It is easier to obtain metals from their oxides rather than sulphides or carbonates. Therefore, the sulphide ores are strongly heated in air to transform them into oxides. This process is called **roasting**. Carbonate ores are strongly heated in a limited supply of air to transform them into oxides. This process is called **calcination**.

The following reactions occur during roasting and calcination of zinc ore.

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

Calcination $ZnCO_3 \longrightarrow ZnO + CO_2\uparrow$

The zinc oxide so obtained is reduced to zinc by using suitable reductant such as carbon.

$ZnO + C \longrightarrow Zn + CO\uparrow$

Apart from carbon, reactive metals such as sodium, calcium, aluminium are also used as reducing agent for the reduction of metal oxide to obtain the metal. This is because these metals displace a moderately reactive metal from its compound. For example, when manganese dioxide is ignited with aluminium powder the following reaction takes place.

$3\ MnO_2 + 4\ Al \longrightarrow 3Mn + 2Al_2O_3 + heat$

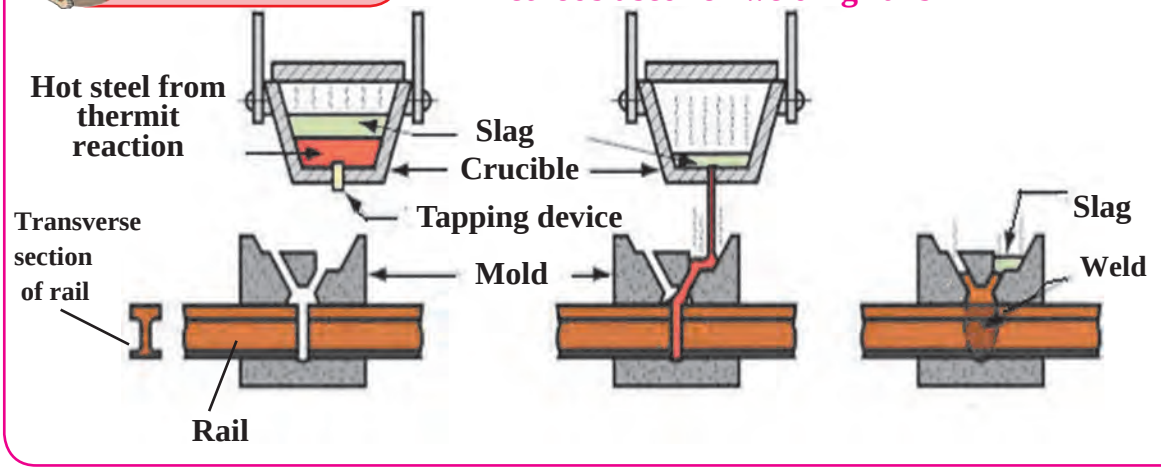
Identify the substances undergone oxidation and reduction in this reaction.

The heat evolved in the above reaction is so large that the metal is formed in the molten state. Another similar example is the thermit reaction. Here, iron oxide reacts with aluminium to form iron and aluminium oxide.

$Fe_2O_3 + 2\ Al \longrightarrow 2\ Fe + Al_2O_3 + heat$

Do you know ?

Methods used for welding rails



8.13 Thermit Welding

c. Extraction of less reactive metals

The metals at the bottom of the reactivity series of metals are less reactive. That is why they are found in free state in nature. For example gold, silver, platinum. The reserves of copper in free state are very few. Presently copper is found mainly in the form of Cu_2S.

Copper is obtained from Cu_2S ore just by heating in air.

$2Cu_2S + 3O_2 \longrightarrow 2\ Cu_2O + 2SO_2\uparrow$

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

Collect information

Collect the information regarding how mercury is extracted from its ore cinnabar and write the corresponding chemical reaction.

3. Refining of metals

Metals obtained by the various reduction processes described above are not very pure. They contain impurities. The impurities need to be separated to obtain pure metal. Electrolysis method is used to obtain pure metals from impure metals.

Corrosion of metals

Can you recall?

1. What is meant by corrosion?
2. Have you seen the following things?

Old iron bars of buildings, copper vessels not cleaned for long time, silver ornaments or idols exposed to air for long time, old abandoned vehicles fit to be thrown away.

Think about it

1) Why do silver articles turn blackish while copper vessels turn greenish on keeping in air for a long time?
2) Why do pure gold and platinum always glitter?

Rusting of iron articles causes large financial loss. Thus corrosion of iron, that is, rusting is a big problem.

1. Iron reacts with moist air and a deposit of reddish substance ($Fe_2O_3 \cdot H_2O$) is formed on it. This substance is called rust.
2. Carbon dioxide in moist air reacts with the surface of copper vessel. Copper loses its luster due to formation of greenish layer of copper carbonate ($CuCO_3$) on its surface. This is called patination of copper.
3. On exposure to air, silver articles turn blackish after some time. This is because of the layer of silver sulphide (Ag_2S) formed by the reaction of silver with hydrogen sulphide in air.
4. By oxidation of aluminium, a thin layer of aluminium oxide forms on it.

Blackened silver vessel

Rusted shackles

The copper cladded statue of Liberty made 300 years ago has turned green.

8.14 Effects of corrosion

Prevention of corrosion

Can you tell?

1. Which measures would you suggest to stop the corrosion of metallic articles or not to allow the corrosion to start?
2. What is done so to prevent rusting of iron windows and iron doors of your house?

Various methods are used to protect metals from corrosion. Special attention is paid in almost all the methods so that iron does not rust. We can lower the rate of the process of rusting of iron. Corrosion of metals can be stopped by keeping metals isolated from a direct contact with air. The prevention of corrosion can be achieved by various ways. Some of these methods are as follows.

1. To fix a layer of some substance on the metal surface so that the contact of the metal with moisture and oxygen in the air is prevented and no reaction would occur between them.

2. To prevent corrosion of metals by applying a layer of paint, oil, grease or varnish on their surface. For example, corrosion of iron can be prevented by this method.

Use your brain power !

Can we permanently prevent the rusting of an iron article by applying a layer of paint on its surface?

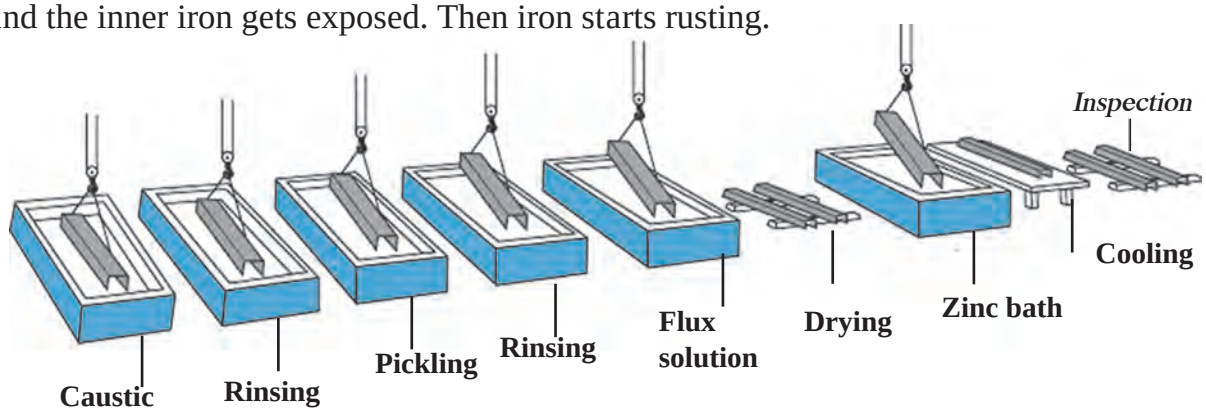
We cannot protect the articles permanently from rusting by painting them. The method of painting is suitable for short time. If there is a scratch on the paint on the surface of the article and if a small surface of the metal comes in contact with air, the process of rusting starts below the layer of the paint.

Why do new iron sheets appear shiny?

Corrosion can be prevented by putting a layer of noncorrodible metal on a corrodible metal. This can be done in many ways.

1. Galvanizing

In this method a thin layer of zinc is applied to prevent corrosion of iron or steel. For example, shining iron nails, pins, etc. In this method corrosion of zinc occurs first because zinc is more electropositive than iron. After a few rainy seasons the zinc layer goes away and the inner iron gets exposed. Then iron starts rusting.



8.15 Galvanizing process

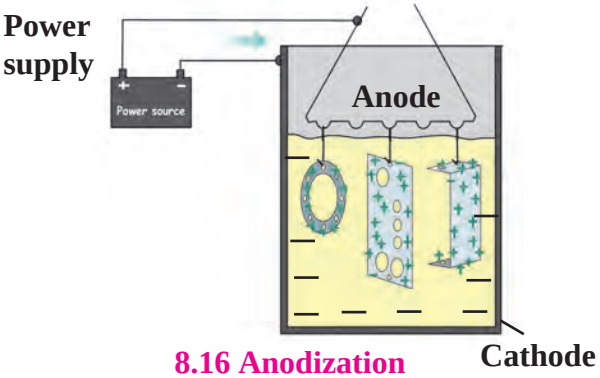
2. Tinning

In this method a layer of molten tin is deposited on metals. We call this as '*kalhaee*'.A greenish layer forms on the surface of a copper or brass vessel. This greenish layer is poisonous. If buttermilk or curry is placed in such a vessel it gets spoiled. Tinning is done to prevent all such damages.

3. Anodization

In this method metals like copper, aluminium are coated with a thin and strong layer of their oxides by means of electrolysis. For this the copper or aluminium article is used as anode. As this oxide layer is strong and uniform all over the surface, it is useful for prevention of the corrosion of the metal.

For example, when aluminium is anodised, the thin layer of aluminium oxide is formed. It obstructs the contact of the aluminium with oxygen and water. This prevents further oxidation. This protection can be further increased by making the oxide layer thicker during the anodization.



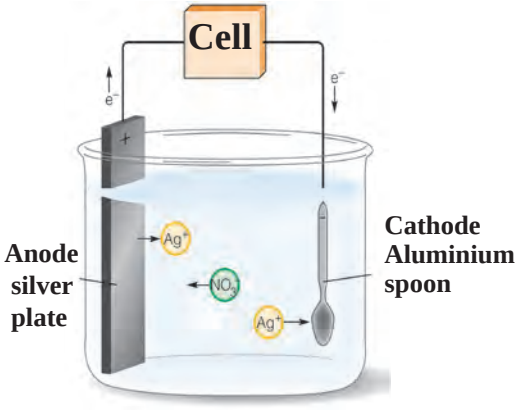
8.16 Anodization

4. Electroplating

In this method a less reactive metal is coated on a more reactive metal by electrolysis. Silver plated spoons, gold plated ornaments are the examples of electroplating.

5. Alloying

Majority of the metallic substances used presently are in the form of alloys. The main intention behind this is to decrease the intensity of corrosion of metals. The homogenous mixture formed by mixing a metal with other metals or nonmetals in certain proportion is called an alloy. For example, bronze is an alloy formed from 90% copper and 10 % tin. Bronze statues do not get affected by sun and rain. Stainless steel does not get stains with air or water and also does not rust. It is an alloy made from 74% iron, 18% chromium and 8% carbon. In recent times various types of alloys are used for minting coins.



8.17 Electroplating

8.18 Coins made from various alloys

Do you know ?

When one of the metals in an alloy is mercury the alloy is called amalgam. For example, sodium amalgam, zinc amalgam, etc. Silver amalgam was earlier used by dentists. Gold amalgam is used for extraction of gold.

Collect information

1. What are the various alloys used in daily life? Where are those used?
2. What are the properties that the alloy used for minting coins should have?

Exercise

1. Write names.

a. Alloy of sodium with mercury.
b. Molecular formula of the common ore of aluminium.
c. The oxide that forms salt and water by reacting with both acid and base.
d. The device used for grinding an ore.
e. The nonmetal having electrical conductivity.
f. The reagent that dissolves noble metals.

2. Make pairs of substances and their properties

Substance	Property
a. Potassium bromide	1.Combustible
b. Gold	2.Soluble in water
c. Sulphur	3.No chemical reaction
d. Neon	4.High ductility.

3. Identify the pairs of metals and their ores from the following.

Group A	Group B
a. Bauxite	i. Mercury
b. Cassiterite	ii. Aluminium
c. Cinnabar	iii. Tin

4. Explain the terms.

a. Metallurgy b. Ores
c. Minerals d. Gangue.

5. Write scientific reasons.

a. Lemon or tamarind is used for cleaning copper vessels turned greenish.
b. Generally the ionic compounds have high melting points.
c. Sodium is always kept in kerosene.
d. Pine oil is used in froth flotation.
e. Anodes need to be replaced from time to time during the electrolysis of alumina.

6. When a copper coin is dipped in silver nitrate solution, a glitter appears on the coin after some time. Why does this happen? Write the chemical equation.

7. The electronic configuration of metal 'A' is 2,8,1 and that of metal 'B' is 2,8,2. Which of the two metals is more reactive? Write their reaction with dilute hydrochloric acid.

8. Draw a neat labelled diagram.

a. Magnetic separation method.
b. Froth floatation method.
c. Electrolytic reduction of alumina.
d. Hydraulic separation method.

9. Write chemical equation for the following events.

a. Aluminium came in contact with air.
b. Iron filings are dropped in aqueous solution of copper sulphate.
c. A reaction was brought about between ferric oxide and aluminium.
d. Electrolysis of alumina is done.
e. Zinc oxide is dissolved in dilute hydrochloric acid.

10. Complete the following statement using every given options.

During the extraction of aluminium……..

a. Ingredients and gangue in bauxite.
b. Use of leaching during the concentration of ore.
c. Chemical reaction of transformation of bauxite into alumina by Hall's process.
d. Heating the aluminium ore with concentrated caustic soda.

11. Divide the metals Cu, Zn, Ca, Mg, Fe, Na, Li into three groups, namely reactive metals, moderately reactive metals and less reactive metals.

Project:

Collect metal vessels and various metal articles. Write detailed information. Write the steps in the procedure that can be done in the laboratory for giving glitter to these. Seek guidance from your teacher.

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