

8

EXTRACTION OF METALS

WHAT WE HAVE LEARNT

- **More than eighty of elements in the periodic table are metals.**
- **Metals form compounds easily as they are highly reactive.**
- **Metals exist as positive ions in their compounds.**
- **Majority of the metals present in the earth's crust are compounds.**
- **Conductivity of heat and electricity, metallic lustre, malleability and ductility are some important properties of metals.**
- **Metals play a vital role in our daily life because of their various properties.**
- **Many metals are essential for the sustenance of life.**
- **Alloying prevents corrosion.**

EXTRACTION OF METALS

Metals have been a part of human life for at least about 8000 years. The evolution of civilized society began with tools made of metals. Metals like iron, copper and aluminium form the basis of modern industry as well as technology. Metals have different and diversified uses in every walk of life. Metals are found in nature either in elemental form or in the form of compounds along with other materials. The compounds from which metals are separated are called ores. After removing the impurities from the ores pure metal is extracted from the compounds. Metallurgy is an important area of chemistry. Physical methods as well as complex chemical methods are used in concentration of ores and extraction of metals from their compounds. Though each metal has a particular method of refining, many steps in the processes are similar. Different methods are used for the extraction of metals depending on the nature of the ore. Extraction is done by the most simple method using the least amount of chemicals. We will examine the basis of these processes which are industrially and economically beneficial to us.

Most metals are seen in nature as compounds. Can you say why? The least reactive metals like gold, silver and platinum occur in the free state. Metals form compounds with electronegative elements or their radicals.

Note the name and composition of some metallic compounds given below. (Table 8.1).

Metallic compounds occur in the earth's crust as minerals. Some examples for minerals are given in table 8.1.

Many minerals contain the same metal. Find out the oxidation state of the metal in each compound. These metallic ions are to be reduced in order to get pure metals from their compounds. But the process of producing pure metal from minerals is not very easy. Minerals which are used for the commercial production of metals are called ores.

On the basis of the availability of the ore, quantity of the metal contained in the ore and the simplicity of the method of production, the ore is selected.

Metal	Compound	Composition formula
Sodium	Rock salt Chile salt petre	NaCl NaNO₃
Potassium	Carnalyte Sylvin	KCl Mg Cl₂.6H₂O KCl
Magnesium	Magnetite Dolomite	MgCO₃ MgCO₃ . CaCO₃
Calcium	Gypsum Lime stone/marble	CaSO₄ . 2H₂O CaCO₃
Aluminium	Bauxite Cryolite	Al₂O₃ . 2H₂O Na₃AlF₆
Iron	Magnetite Haematite Iron pyrites	Fe₃O₄ Fe₂O₃ FeS₂
Copper	Copper pyrites Malachite Cuprite	CuFeS₂ Cu(OH)₂ CuCO₃ Cu₂O
Zinc	Zinc blende Calamine	ZnS ZnCO₃

Table 8.1

Concentration of the ore

The ores obtained from the crust of earth will contain gravel, sand and earthy impurities. These impurities are known as gangue. The gangue is to be removed to get pure metal. Depending on the nature of ore and gangue, different methods are used for removing the impurities. This process is known as concentration of ores. Some important methods used for concentration are given below:

1. Washing in a stream of water

When the density of impurities is less than that of the ore, this method can be used. When powdered ore is washed in a stream of water, the floating impurities will be washed away and the ore will remain underneath.

2. Froth floatation

If the density of the ore is less than that of impurities this method is used. Powdered ore is added to a mixture of pine oil and water. This is

stirred by a strong current of air. Pine oil forms froth and the ore wetted by pine oil floats with it. This can be easily removed.

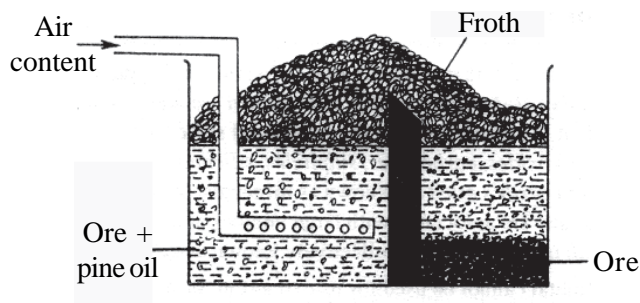


Figure 8.1

This method is used for the concentration of sulphide ores.

3. Magnetic separation

If the ore is magnetic, it can be separated from the impurities by passing through a magnetic field. The magnetic ore is attracted towards the magnet.

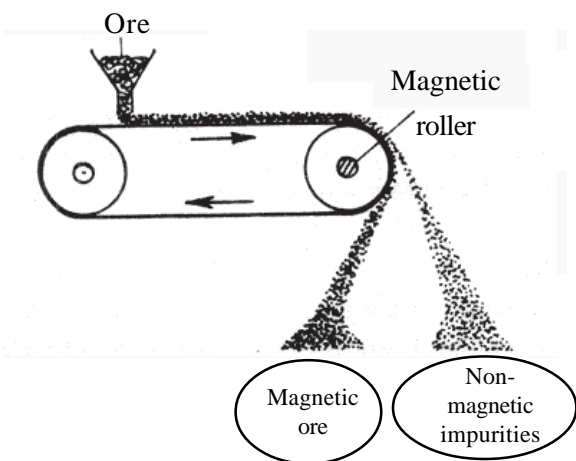


Figure 8.2

4. Leaching

This method is used when the impurities are insoluble but the ore is soluble in a solvent. When powdered ore is added to the solvent, the ore reacts with the solvent; but the impurities remain unaffected. This type of

concentration is known as leaching. The following reaction shows the concentration of bauxite.



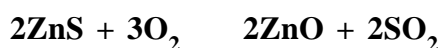
Bauxite reacts with sodium hydroxide to form sodium aluminate. Fill up the table below:

Ore	Method of concentration	Explanation
Copper glance		
Bauxite		
Haematite		
Zinc blende		

Table 8.2

5. Roasting

The ore is crushed and heated in a strong blast of air. The ores are converted into their oxides. The ore is oxidised by the oxygen present in the air.



6. Calcination

When ores such as calcium carbonate is heated either in the absence of air or in controlled air stream, the following reaction takes place.



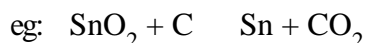
Volatile impurities are removed by this method.

Extraction of metals

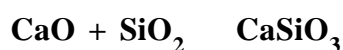
Next step is the extraction the metal from the concentrated ore. Depending on the nature of the ores there are different methods for the extraction of metals.

1. Smelting

Ores after roasting or calcination is mixed with coke or charcoal and heated strongly. Metals like zinc, iron, nickel, lead, tin etc. are prepared by this method.



The ores thus obtained may still contain certain impurities which can be removed by adding flux. If the gangue is acidic (eg. SiO_2) basic flux such as lime (CaO) is used. If the gangue is basic (eg: SeO) acidic flux (eg. SiO_2) is used. The flux reacts with gangue to form slag. The slag floats over the molten metal as its density is less than that of the molten metal.



2. Reduction with aluminium

Metals like manganese, chromium, vanadium etc. cannot be extracted by heating with carbon as they form their carbides. Such metals

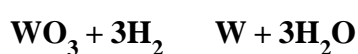
can be prepared by reducing their oxides with aluminium.



This method can be used for preparing metals which are less electropositive than aluminium.

3. Reduction with Hydrogen

If other reducing agents are not effective, hydrogen is used.



Refining of metals

The metals produced by the above methods will still contain impurities. The process of removal of impurities from a crude metal is the third step in the production of metals.

1. Liquation

Metals with low melting point (eg: lead, tin) are heated on the sloping hearth of a furnace and allowed to flow away from infusible impurities.

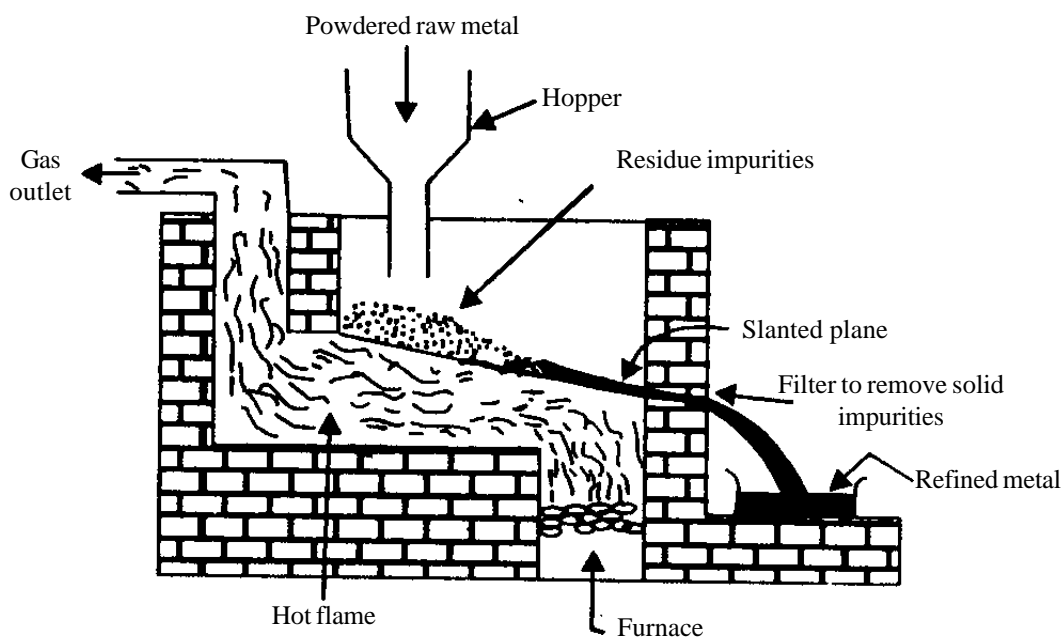


Figure 8.3

2. Distillation

Volatile metals when heated strongly distil over leaving behind the impurities (eg: mercury, zinc).

3. Electrolysis

Highly electropositive metals are refined by electrolysis. The metal to be refined is taken as the anode. Any suitable substance can be used as cathode. A compound of the metal is used as the electrolyte. When electrolysed, pure metal gets deposited on the cathode.

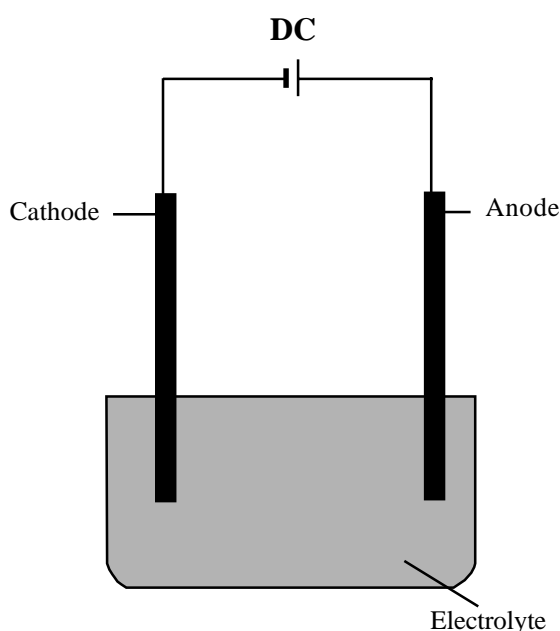


Figure 8.4

The reactions taking place in the electrodes in the refining of metal M is given below:



Prepare a note on the refining of copper in your science diary.

Anode : impure copper

Cathode : pure copper

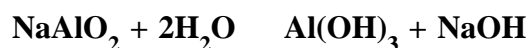
Electrolyte : Copper sulphate solution

Which are the different steps involved in the production of fine metal from its ore? Make a note of the different methods involved in each steps.

Extraction of aluminium

Bauxite is the ore of aluminium. It is an oxide of aluminium. This ore is concentrated by leaching. Which is the solvent used for the leaching of bauxite? Write down the equation representing the chemical change. We have seen that the compound formed is sodium aluminate (NaAlO_2).

Sodium aluminate is soluble in water. This solution is filtered off and a little aluminium hydroxide is added. Aluminium hydroxide precipitates out from NaAlO_2 .



The Al(OH)_3 thus obtained is heated strongly to get unhydrous alumina (Al_2O_3).



Aluminium is obtained by the electrolysis of alumina.

Can you say why electrolysis is used here? Discuss with reference to the points given below:

- **Position of aluminium in the electro chemical series.**
- **Electro positive character of aluminium.**

Aluminium is obtained by the electrolysis of alumina dissolved in fused cryolite. The figure showing the electrolysis of alumina is given below:

The chemical reaction during electrolysis is shown below:



Can you say which element gets deposited in each electrode?

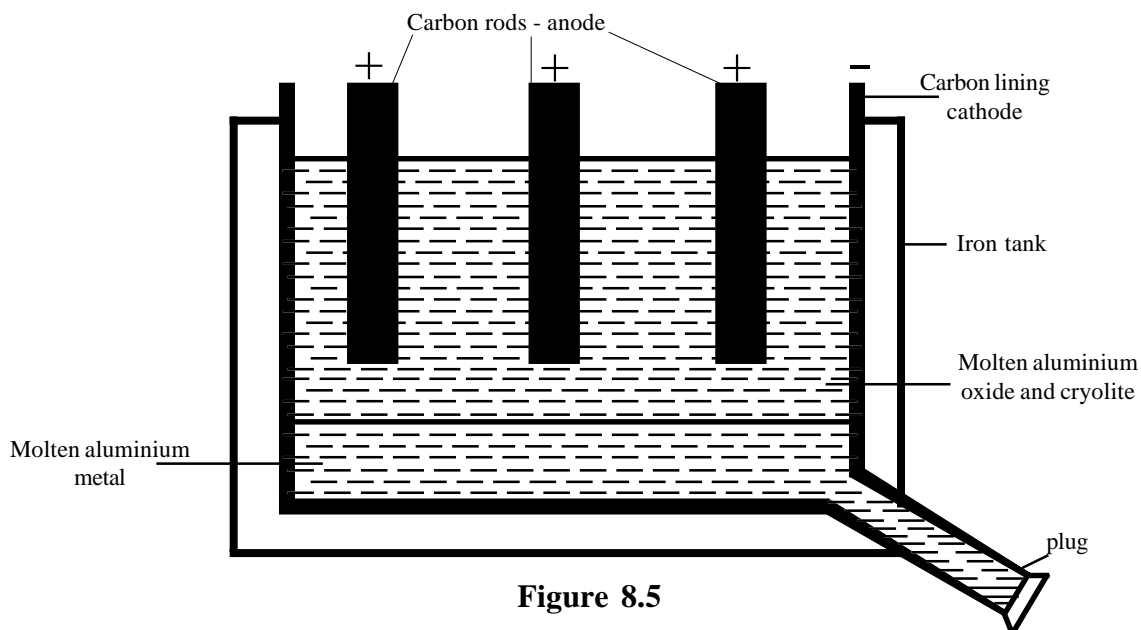


Figure 8.5

- Which ion is attracted towards the anode?
- Which ion is attracted towards the cathode? Which is the element deposited? Write down the equation.
- Write down the equation showing the reaction between the carbon anode and the oxygen liberated.

The properties and uses of aluminium are given below. Which property is made use of in each of the following cases? Make a note in your Science diary.

Properties of Aluminium

- Silvery white in colour
- density 2.6 g/cm^3
- comparatively less hard
- reducing property
- conducts heat
- reflects heat and light
- conducts electricity

Uses of Aluminium

- to make utensils
- to make automobile parts
- to make ice cube tray
- to make electrical wires
- to make roofs
- to use in reflecting telescope
- to obtain metals from Cr_2O_3 , Mn_2O_3

Extraction of Iron

Iron is the most important metal among the transition elements. Also it is the most abundantly produced metal now a days.

What are the minerals of iron? Magnetic substances like haematite, magnetite etc. are the ores of iron.

Which method can be used for the concentration of these ores? Can you give reasons?

Iron ore is converted into iron in blast furnace. Iron is produced by reducing Fe_2O_3 using coke.

The gangue found in iron ore is usually silica (SiO_2). Which flux can be used to remove this gangue?

Write down the reaction between silica and the flux. What is the compound formed?

The reactions taking place inside the blast furnace are given below:

- Which part of the blast furnace has the highest temperature?
- Which compound acts as the reducing agent? How is it formed?

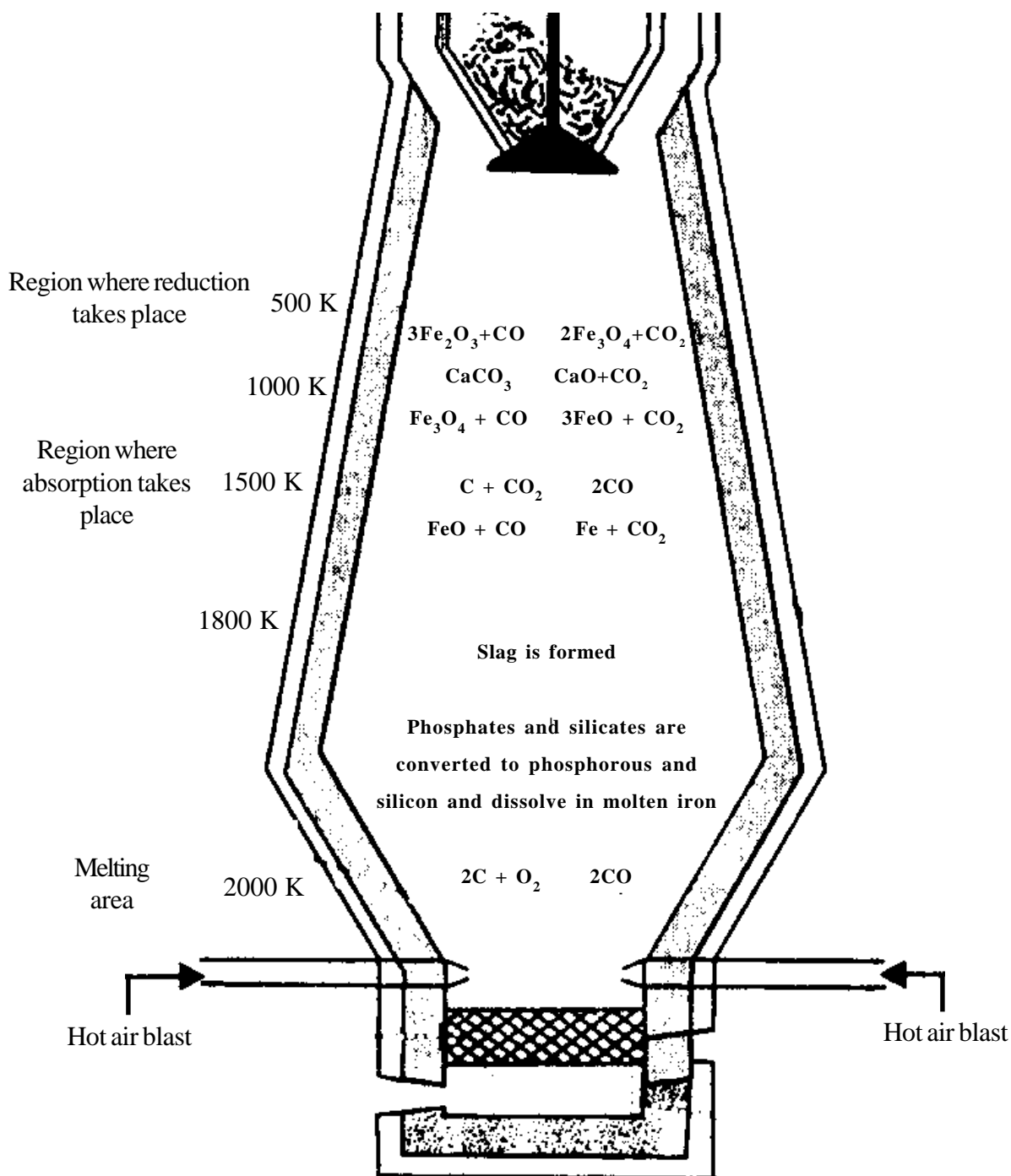


Figure 8.6

- **How is the ore reduced?**
- **Why is lime stone added to the blast furnace?**
- **What are the gangue and flux in this reaction?**
- **Explain why phosphates and silicates present in the ore get reduced?**

The large chunks of iron obtained from the blast furnace is called pig iron. This may contain impurities like carbon, sulphur, phosphorous etc.

Steel

The impurities contained in pig iron are first removed. Then the required amount of other elements such as carbon is added to produce different types of steel.

Analyse the following table and write a note on the different types of steel, their structure and uses.

	Quantity of carbon	Use
Mild steel	0.05% - 0.2%	To make wires, tubes, agricultural implements, rods
Medium steel	0.21% - 0.6%	To make railway tracks, girders, plates
High carbon steel	0.61% - 1.5%	To make surgical implements, springs, knife, drill

Table 8.3

We have already learnt that besides carbon, the presence of some other metals also has a beneficial value. Try to recall the names of such elements.

Heat treatment of steel

The properties of steel with the same composition can be varied by heating and cooling it under certain conditions. This is known as heat treatment. Properties such as hardness, strength, ductility, malleability, and ability to resist corrosion are improved by heat treatment.

Annealing, hardening and tempering are the important methods of heat treatment of steel. In annealing, steel is heated until it is bright red hot and allowed to cool slowly in air. Steel is made soft by this method.

Hardening increases the hardness of steel. In this method red hot steel is plunged into cold water or oil as quickly as possible.

Hardened steel is heated again and is allowed to cool slowly in air. This method is called tempering.

Compounds of some metals

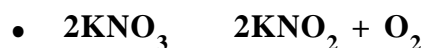
Sodium chloride used for flavouring food is quite familiar to us. We use several other compounds of metals in our daily life. A table showing the uses of some such compounds are given below:

Name of the compound	Formula	Uses
Common salt	NaCl	Used for flavouring food to make freezing mixtures, to melt ice and snow from the roads, to separate soap from glycerine (salting out), in the manufacture of HCl, NaOH, Na ₂ CO ₃
Washing soda	Na ₂ CO ₃ ·10H ₂ O	Used as washing soda and in the manufacture of caustic soda, glass etc.
Baking soda	NaHCO ₃	Used for making baking powder. It is also used in portable type of fire extinguisher.
Salt peter	KCl	Patients suffering from hypertension can use this in food. Also used to make potassium nitrate
Nitre	KNO ₃	Used to make gun powder
Marble	CaCO ₃	Used in the manufacture of glass, cement, quick lime, pottery etc. as a flux in the manufacture of iron, to make tooth paste, to manufacture calcium.
Quick lime	CaO	As a flux in the extraction of metals, as a drying agent, to make soda lime
Slaked lime	Ca(OH) ₂	Used for making mortar and lime plaster, to remove acidity from soil, in the manufacture of bleaching powder
Gypsum	CaSO ₄ ·2H ₂ O	Used in cement to control its setting time, as a filler for paper industry
Plaster of paris	(CaSO ₄) ₂ ·H ₂ O	Used in surgical bandages for making casts, to decorate walls and ceiling
Alum	K ₂ SO ₄ ·Al ₂ (SO ₄) ₃ ·24H ₂ O	Used as a mordant, in the purification of water, in foam fire extinguisher
Copper sulphate	CuSO ₄ ·5H ₂ O	As a fungicide in production of Bordeaux mixture, as an electrolyte
Zinc oxide	ZnO	As pigments in paints, as filler in rubber, in cosmetic powders, creams etc.
Calamine	ZnCO ₃	As an ingredient of calamine lotion

Table 8.4

Analyse the table and try to answer the questions given below:

- Why is sodium chloride used to melt ice and snow from roads?



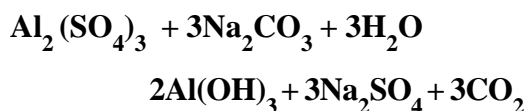
Based on the above equation try to explain why KNO_3 is used in gun powder?

- When made into a paste with water plaster of paris sets in a few minutes to form a firm mass. Which use can be related to this property of plaster of paris?
- Add a little baking soda to dilute hydrochloric acid. Show a glowing match

stick to the gas evolved. What do you observe?

Carry out the following experiment and find out which property of the compound is made use of in the reaction

- CaO is used in the extraction of metals. Can you explain the chemistry behind it?
- NaHCO_3 is used along with alum in foam fire extinguisher. Try to explain the reason with reference to the equation given below:



SUMMARY

- Ores are minerals used for industrial manufacture of metals.
- Concentration, extraction and purification are the three stages in production of metals.
- Aluminium is manufactured by the electrolysis of purified bauxite dissolved in cryolite.
- As aluminum is relatively less heavy and is a good conductor of heat and electricity, it has a number of uses.
- Iron which is the most important transition element is used to make steel.
- By adding other suitable elements to cast iron, steel is made.
- Annealing, hardening and tempering are heat treatment used to improve the qualities of steel.

MORE ACTIVITIES FOR YOU

1. Alloys are more useful than pure metals. Discuss the point with reference to steel.
2. What are the substances used in blast furnace while iron is prepared?
3. Give two advantages of steel compared to cast iron?
4. Prepare a table showing the uses of aluminium and the property made use of in each?
5. A wire fence is supported with steel poles. Though the poles are painted every year the bottom of it is found to have rusted
 - a. Which substances promote the rusting of the iron poles?
 - b. How is rusting prevented by painting?
 - c. That part of the pole which is in contact with the earth is found to have rusted more. Explain the reason for this.
 - d. Can you suggest some other method to prevent rusting?
6. Four test tubes contain solutions and rods as shown below:

Test tube 1	Test tube 2
Silver is placed in zinc sulphate solution	Zinc is placed in silver nitrate solution
Test tube 3	Test tube 4
Zinc rod is placed in magnesium sulphate solution	Copper is placed in silver nitrate solution

In which test tube do the following changes take place?

 - a. Zinc atoms pass into the solution as zinc ions.
 - b. Silver ions get deposited as silver
 - c. No change takes place
 - d. Metal atoms get oxidised
 - e. Write down the equation showing chemical change occurring in any one of the test tubes.

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