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1	85.48	91.67	96.01	92.22	92.78	93.06	86.02	92.62	93.61	93.01	88.89	91.40	348	1	196	1544
10	81.39	85.42	88.48	85.83	86.94	83.92	78.49	86.88	86.11	82.80	81.06	84.99	324	8	185	2043
100	70.76	79.79	78.68	76.39	77.50	69.84	68.61	83.33	74.72	72.85	71.72	74.93	323	13	178	2395
500	62.17	72.08	69.36	66.67	68.61	60.32	54.57	77.32	64.44	61.02	59.34	65.08	313	25	160	3542
1000	57.87	68.13	64.46	61.67	63.33	56.75	49.46	72.95	58.59	55.65	53.28	60.22	310	27	154	4137
2000	52.97	62.50	58.33	55.56	57.22	49.21	43.55	67.48	53.06	50.00	46.46	54.21	302	46	145	5005
3000	49.69	59.17	54.41	51.94	53.61	45.44	42.74	63.38	49.17	46.77	42.42	50.79	297	66	135	6180
4000	47.03	56.67	51.72	49.17	51.11	42.66	37.90	60.38	46.39	44.09	39.39	47.86	296	70	131	6750
5000	44.99	54.38	49.51	47.22	48.89	40.48	36.02	57.65	43.89	41.94	37.12	45.64	286	94	126	7516
6000	43.35	52.17	47.55	45.56	47.22	38.69	34.41	55.45	41.94	40.32	35.10	43.85	266	201	121	8494
7000	41.92	51.04	45.83	43.89	45.56	37.10	33.33	53.55	40.28	38.71	33.59	42.25	254	299	109	10848
8000	40.49	49.79	43.38	42.50	44.44	35.91	31.99	51.63	38.61	37.63	32.32	40.79	245	395	102	12874
9000	39.47	48.54	43.14	41.11	43.06	34.52	30.91	50.27	37.22	36.29	30.81	39.58	239	471	100	13215
10000	38.85	47.71	41.91	40.00	41.94	33.33	29.84	48.90	36.11	35.22	29.80	38.51	231	600	85	18547
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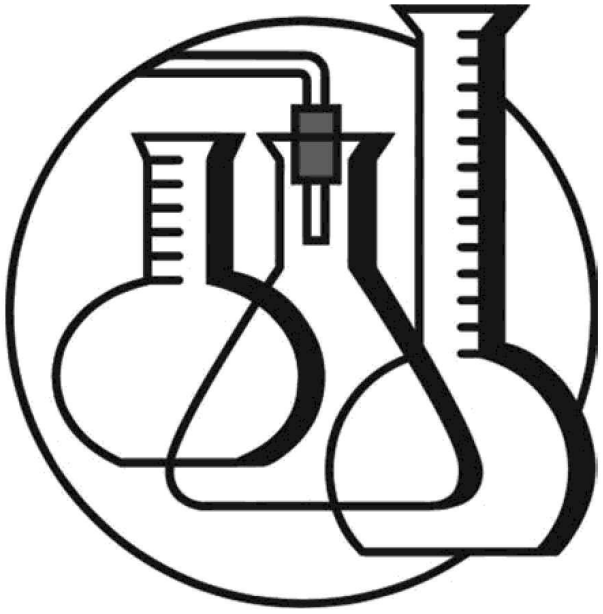


8

Metals and Non-Metals

INTRODUCTION

Metals in nature generally exist in the form of their compounds. The extraction of metals from their respective compounds involves various processes from simple mechanical crushing or grinding to complicated chemical reactions under specific conditions for a better yield. These processes are carried out in well-designed furnaces. Finally, these metals are purified to different extents based on their end use. All these processes come under the purview of **metallurgy**. The properties of metals can be improvised by doping a small amount of another metal or non-metal which makes the same metal usable for a variety of purposes and this area comes under the study of alloy.

Certain useful non-metals like sulphur and carbon, are available in the elemental state under the earth's crust. These non-metals are excavated and refined before using them in various fields. Apart from this, different compounds which consist of various metals and non-metals in different proportions are manufactured in industries in large scale and prepared in the laboratory in small scale depending on their application. The study of these metals, non-metals and their compounds is necessary because of their wide range of applications.

Metallurgy

Some metals like silver, gold, platinum are less reactive and are found in their free states. The other metals being highly reactive are found in their combined states like oxides, carbonates or sulphides. These solid inorganic compounds found in the earth's crust are called minerals.

In certain minerals, the percentage of a particular metal is high and these metals can be extracted from these profitably; such minerals are called **ores**. The impurity associated with the ore is called **gangue**. The process of the extraction of metals from their respective ores is called **metallurgy.**

Metals are extracted from suitable ores through certain **general metallurgical processes** like

(i) Dressing or concentration of ore
(ii) Concentration of ore
(iii) Conversion of ore to oxide
(iv) Extraction of metal
(v) Refining

(i) **Dressing of ore:** The ores are in the form of huge rocks. In this process, the rocks are broken down into small pieces and ground to powder. This powdered form of ore is used for further metallurgical processes.

(ii) **Concentration of ore:** The ore is associated with huge amounts of impurities like sand, other metal compounds, and certain non-metals. The impurities that are associated with the ore is called gangue. In this process, certain amount of gangue is removed from the ore, thus increasing the concentration of metal in the ore. The process by which the gangue is removed depends on the type of ore and gangue.

(a) **Magnetic separation:** This process is carried out for those ores in which either the ore or the gangue is magnetic in nature. The powdered ore is made to fall on a rubber belt which moves horizontally over two pulleys of which one is a strong map net. Magnetic components are retained on the belt and is collected as a separate heap after coming out of the magnetic influence.

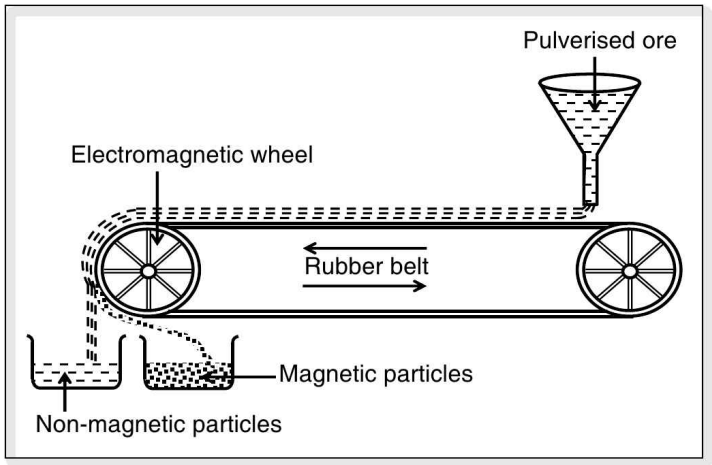


Figure 8.1 Electromagnetic separation

(b) Gravity separation: The ores in which the specific gravity difference between the ore and gangue is high is concentrated by gravity separation. This is generally applicable for iron ore. The ore is taken on a sloping table with ridges and washed with water. The water washes away the lighter gangue particles leaving behind the concentrated ore. This method of separation is applicable to all types of ores except sulphide ores.

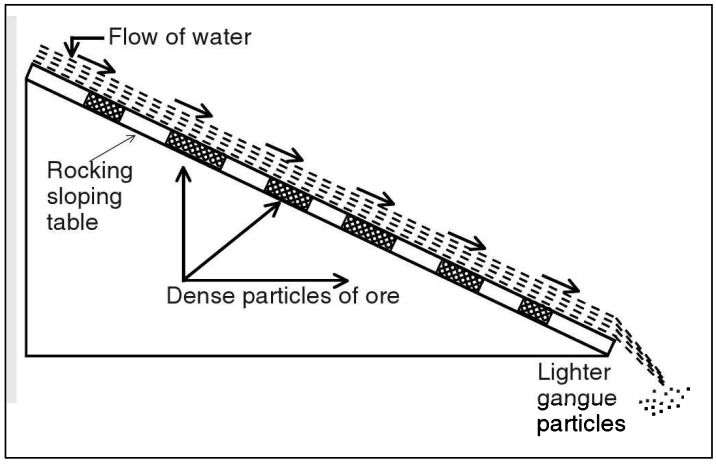


Figure 8.2 Concentration of ore by Gravity Process

(c) **Froth floatation:** This process is generally followed for sulphide ores. The ore is taken in a tank with oil and water and mixed thoroughly by blowing air. Bubbles of oil are formed. The ore sticks to these bubbles and rises up while the gangue sticks to the water and settles at the bottom. The froth along with the ore is separated.

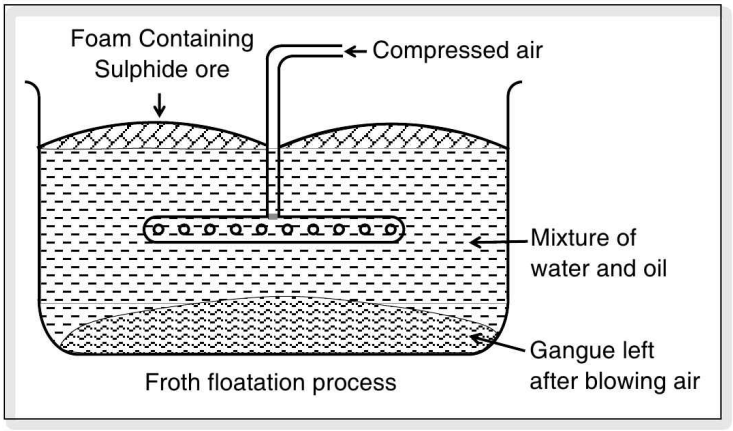


Figure 8.3 Froth floatation process

(iii) **Conversion of ore to oxide:** The conversion of ore to oxide is carried out by two methods.

(a) Roasting: This is generally carried out for sulphide ores. The ore is heated to a temperature below the fusion point of the ore where the ore reacts with the oxygen present in air and forms metal oxide and sulphur dioxide.

$MS + O_2 \rightarrow MO + SO_2$

Volatile impurities present in the ore are removed during this process.

(b) Calcination: This process is carried out specifically for carbonate ores. The main purpose of this process is the removal of CO_2 from the ore. Hence the ore is heated to its decomposition temperature and gets converted to the oxide form. Along with CO_2, volatile impurities are also removed in this process. Apart from carbonate ores, hydrated ores are also subjected to calcination for the removal of water of crystallization.

$MCO_3 \rightarrow MO + CO_2$

(iv) **Extraction of metal:** The oxide ores obtained from the above process are reduced to metals by smelting. During this process flux (a material which combines with gangue) is added. This converts the gangue to slag (the fusible material gangue forms when flux reacts with it), which is separated from the ore. The metal so obtained in this process is not 100% pure and needs to be further purified.

(v) **Purification or refining of metals:** Different methods of the refining of metals are followed for different metals. The method of refining generally depends upon the type of impurities present within the metal.

(i)	Distillation	Iron, Mercury	The metal is strongly heated above its boiling point in the absence of air. The metal vapourizes, leaving behind the impurities. The vapours are cooled in earthen retorts, to get the metal in the solid or in the liquid form.

(Continued on following page)

(ii)	Liquation	Lead, Tin (metals with low melting point)	The metal is taken on the upper part of the sloping hearth and heated above its melting point. The metal melts, flows down the hearth and is collected at the bottom.
(iii)	Polling	Copper with cuprous oxide as impurity	Molten copper is stirred with wooden poles. These poles emit wood gas which reduces copper oxide to copper.
(iv)	Oxidation	Iron with oxidizable impurities	Oxygen is blown through molten metal where the impurities get converted to gaseous oxides and are removed. $C + O_2 \rightarrow CO_2 \uparrow$ $S + O_2 \rightarrow SO_2 \uparrow$
(v)	Electrolytic refining	Aluminium	A block of impure metal is taken as anode and a thin strip of pure metal as cathode. The electrolyte is the soluble salt of the metal. On passing the current, the metal ions from the anode dissolve in the electrolyte, go towards the cathode and get discharged there. Electrolysis continues and the cathode becomes a thick block of pure metal.

The extraction of all the metals from the ores follows one of the above processes.

Metallurgy of iron

Iron is a highly reactive metal and is generally found in the oxide state. The most common ores of iron are

Haematite	Fe_2O_3
Limonite	$Fe_2O_3.H_2O$
Magnetite	Fe_3O_4
Siderite	$FeCO_3$
Iron pyrites	FeS_2
Magnetite	Fe_3O_4

Iron is generally extracted from haematite, limonite, siderite. Among these haematite and limonite are the most preferred ores.

The manufacturing of pig iron is the first step in the metallurgy of iron. This pig iron is further converted to cast iron which is used for the manufacture of steel and wrought iron.

(i) **Dressing and concentration of ore:** The ore is crushed to make smaller pieces from large chunks.

The crushed ore is concentrated by the process of magnetic separation and further concentration is done by gravity separation process.

(ii) **Conversion to oxide:** The concentrated ore is converted to oxide form by the process of roasting which involves heating the ore in the presence of excess of air.

On roasting, the carbonate ore decomposes to oxide giving out carbon dioxide. This process is also associated with other advantages like

(a) the removal of moisture and other volatile impurities.

(b) the removal of impurities like sulphur, phosphorous, arsenic, antimony in the form of gaseous oxides.

(c) the conversion of ferrous oxide to ferric oxide.

(d) inducing porosity in the mass, thus rendering the metal to easy reduction.

(iii) **Reduction of oxide to metal:** The reduction of oxide to metal is carried out with carbon in a blast furnace by the process called smelting.

Smelting in blast furnace

Blast furnace is a huge chimney like structure about 30 m high and 8 m in diameter. It is made of iron plates and lined internally with refractory bricks. On top, it has a double cup and cone arrangement. Below this, there is an outlet for waste gases. A hearth is present at the bottom to collect cast iron and slag, and has separate outlets for each. Hot compressed air is blown into the furnace through pipes called tuyeres which are placed above the hearth.

The ore is mixed with coke, and limestone approximately in the ratio of 8 : 4 : 1. This mixture is called charge.

The charge is lowered into the furnace from the top through the cup and cone arrangement and various reactions take place in the furnace at different levels.

(a) Lower region (1500°C–2000°C)

Coke combines with the heated air coming from the tuyeres and burns to form carbon dioxide. The reaction, being highly exothermic increases the temperature in this zone to 2000°C.

$$C + O_2 \rightarrow CO_2 + 97 \text{ kcal.}$$

This region is also called the combustion zone.

(b) Middle region or fusion zone (1500°C–1000°C)

The carbon dioxide formed in the lower layer moves to the middle layer where it is reduced to carbon monoxide.

$$CO_2 + C \rightarrow 2CO - 39 \text{ kcal}$$

At such a high temperature, the limestone added decomposes into calcium oxide and carbon dioxide.

$$CaCO_3 \rightarrow CaO + CO_2 - 43 \text{ kcal}$$

The calcium oxide(quick lime) formed reacts with impurities like sand in the ore and converts them to slag.

$$CaO + SiO_2 \rightarrow CaSiO_3$$

The slag, calcium silicate goes towards the hearth present at the bottom of the furnace. As the reactions in the middle region are endothermic, the temperature of this zone decreases.

(c) Upper region or reduction zone (1000°C–500°C)

The carbon monoxide formed in the middle region moves to the upper region where it reduces the iron oxide to iron.

$$FeO + CO \xrightarrow{750-600^\circ C} Fe + CO_2$$

$$Fe_3O_3 + 3CO \rightarrow \xrightarrow{600-400^\circ C} 2Fe + 3CO_2$$

The iron formed here melts due to high temperature and then, due to its high density, settles down. Both the slag (calcium silicate) and iron settle down in the hearth. Iron being heavier forms the bottom layer with slag on top. From here, iron and slag are tapped through separate outlets.

The iron obtained from this process is called the pig iron. This is not 100% pure and acts as the basic raw material for cast iron and steel.

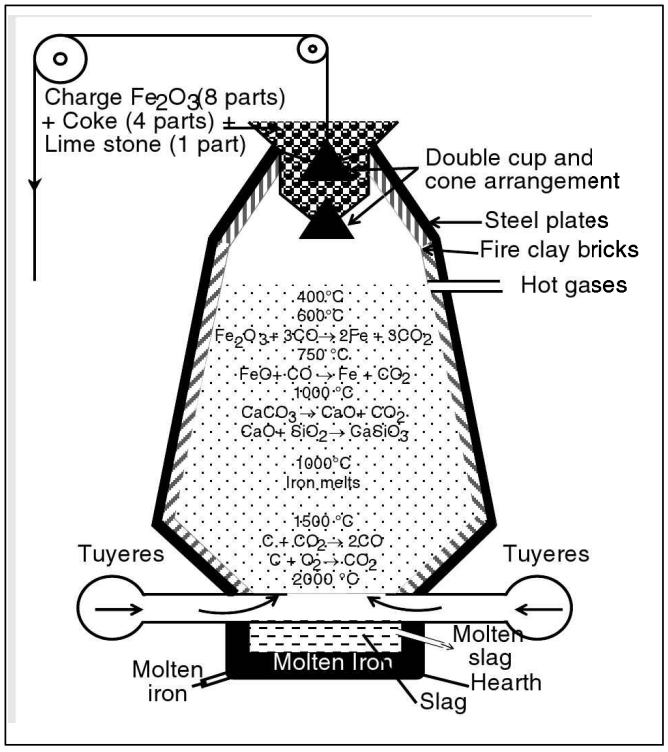


Figure 8.4

Cast iron

This is obtained by re-melting pig iron in a vertical furnace called cupola and thereby gets refined. It is then poured into suitable moulds where it solidifies. This re-melted pig iron is called cast iron.

Wrought iron

This is a comparatively purer form of iron. Cast iron is taken in a reverberatory furnace and stirred at high temperature. This process is called puddling. Most of the impurities are lost during this process due to the high temperature. Iron at this stage is in a semi solid state. This on cooling gives wrought iron.

Steel

Steel is an **alloy of iron** with some amount of carbon in it. The carbon added increases the hardness of iron. Thus steel is harder than iron and the hardness increases with increase in the carbon content. The manufacture of steel is carried out by many processes. The best quality is the however obtained by the **open-hearth process**.

Open-hearth process for making special type of steel

As the name suggests, the shape of the furnace is like a hearth the top of which is open. The charge is pig iron and steel scrap. The process can be carried out in two ways depending on the impurities present in the raw material.

Acid process: In this process, the furnace is lined with acidic refractories, i.e., silica brick.

Basic process: In this process, the furnace is lined with magnesite or dolomite. Basic process is adopted if phosphorus is present as an impurity.

Along with pig iron, steel scrap is added as raw material in this process. To promote the oxidation of the impurities, small amount of iron ore is added to provide additional oxygen.

The temperature on the top of the hearth is generated by hot fuel gas which burns on the hearth and produces a temperature of 1600°C to 1650°C. Carbon starts getting oxidized. Sulphur gets oxidized to sulphur dioxide, silicon to silicon dioxide and phosphorous to phosphorous pentoxide. The silica and phosphorous pentoxide react with manganese and calcium oxide to form slag.

$C + O_2 \rightarrow CO_2$

$2CO_2 + C \rightarrow 2CO$

$P + O_2 \rightarrow P_2O_5$

$Si + O_2 \rightarrow SiO_2$

$MnO + SiO_2 \rightarrow MnSiO_3$

$CaO + P_2O_5 \rightarrow 2Ca_3 (PO_4)_2$

The final composition of steel is adjusted by adding ferrosilicon and/or ferromanganese alloy. Thus in this process temperature and composition can be controlled. It is a very lengthy process and takes about 5 to 15 hours.

Raw materials used in open-hearth process have low content of phosphorous and sulphur in them, hence the steel made by this process is of better quality.

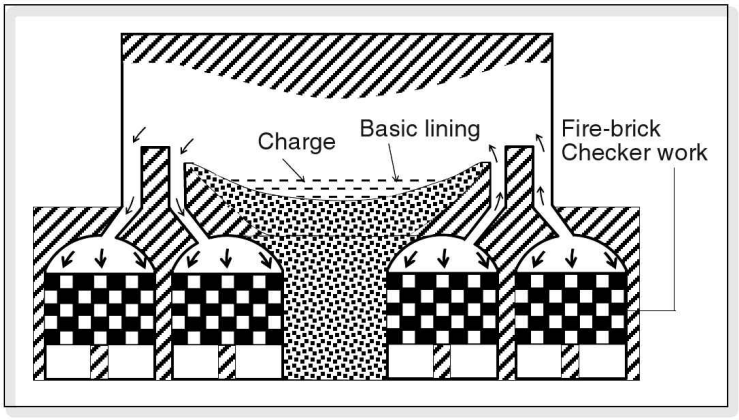


Figure 8.5 An open hearth furnace

Alloying of metal changes its physical properties and thus makes it useful for a variety of purposes depending on the composition of the alloy.

Another important aspect of alloy is prevention of corrosion. Stainless steel, a unique alloy of iron does not get corroded at all.

Corrosion of iron can be prevented in many other ways.

The most common ones are

(i) **Galvanization:** The process of coating a layer of zinc on the metal is called galvanization.

(ii) **Electroplating:** In this process, one metal is deposited over the other metal through an electrolytic process. The metal to be coated is taken as the cathode and the metal with which it is coated is taken as anode. On passing electricity, the anode dissolves in the electrolyte which is generally a salt solution of the anodic metal. The metal ions move towards the cathode where they are discharged and get deposited on the cathode, thus forming a coating over it.

Metals thus have various applications in the from of elements, compounds, alloys etc. Similarly, non-metals also play a very important role in various fields due to their specific properties. Which makes, the study of non-metals also equally significant as that of metals.

Non-metals

Carbon

It is one of the most important non-metallic elements. It is invariably present in all the living organisms in the form of biomolecules.

Occurrence

Carbon occurs both in the free state and in the combined state.

Free state

Carbon exists as the native element in the form of coal in the earth's crust. It occurs in a very small amount in the form of its allotropic forms like diamond and graphite.

Combined state

In the combined state, carbon exists in the form of oxides, (carbon dioxide, carbon monoxide), carbonates (metal carbonates) and many organic compounds (proteins, carbohydrates, etc).

Allotropy

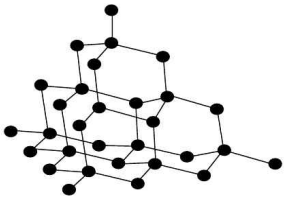
Allotropy is the phenomenon in which an element exhibits different physical forms with similar chemical properties. The different physical forms exhibited by the element are called allotropes. Carbon exhibits various allotropic forms which have a wide variety of applications. The allotropic forms are broadly classified into **crystalline forms and amorphous forms**.

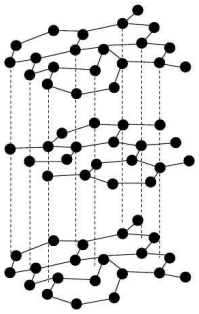
(i) **Crystalline forms**: In these allotropic forms, the carbon atoms have a well defined regular geometrical arrangement.

☛ *Example* Diamond, Graphite

Comparative study of diamond and graphite

Structure	Diamond has a regular tetrahedral arrangement. This is due to the bonding of each atom of carbon with four other carbon atoms covalently, forming a single unit of crystal. These crystal units lie in different planes accounting for a rigid three dimensional structure. Carbon has a valency of four and each carbon is bonded to four other carbon atoms forming a tetrahedral unit. These tetrahedral units lie in different planes, thus forming a rigid three dimensional structure.	In graphite, each carbon atom is bonded covalently to three other carbon atoms resulting in the arrangement of hexagonal rings in a single plane. The forces of attraction between the atoms of two single crystals, in the parallel planes are weak. Each carbon is bonded to three carbon atoms only leaving behind one free valency. A three dimensional arrangement of hexagonal rings is resulted. These rings lie on a single plane. The entire structure is such that the layers of hexagonal rings are arranged parallel to each other.





Appearance	A pure diamond is a colourless, transparent, crystal. It is the hardest among naturally occuring solids.	Graphite is a dark grey, very soft solid with metallic lustre.
Conduction	It is a good conductor of heat and bad conductor of electricity.	It is a bad conductor of heat and good conductor of electricity.
Refractive index	It has a high refractive index of 2.5.	It is opaque.
Solubility	It is insoluble in common solvents.	It is insoluble in common solvents.
Density	Density of diamond is 3.5 gm/cm^3, which is the densest form of carbon.	Density is 2.25 gm/cm^3.
Melting Point	The melting point of diamond is about 3700°C.	It has a melting point of about 3600°C.

(ii). **Amorphous allotropes of carbon:** In these forms of carbon, the carbon atoms are not arranged in an orderly manner.

☛ *Example* Coke, wood, charcoal, sugar, lamp black, animal charcoal. etc.

Comparative study of amorphous allotropes

Coke	Coke is prepared by heating coal in the absence of air up to a temperature of 1300°C in huge iron retorts.	It is a grayish black porous solid.	(i) It is used as a household fuel. (ii) It is used extensively in the extraction of metals like copper and lead, from their oxides and sulphide ores as it is an excellent reducing agent. (iii) It is used in the manufacture of graphite and calcium carbide. (iv) It is used in the manufacture of water gas and producer gas.
Lamp black	Lamp black is prepared by burning mustard oil, turpentine oil, petroleum in the absence of oxygen. A clean dry glass slide is placed over the flame of mustard oil lamp. After some time a deep black powdery substance is coated on the slide, which is known as lamp black.	Lamp black is light, powdery black substance, having a velvet touch. It has an oily feel due to the presence of vapours of some amounts of oil.	(i) Lamp black is used as stabilizing filler for rubber in making tyres and plastics. (ii) It is used as a black pigment in inks and paints. (iii) It is used for making black shoe polishes. (iv) It is used in the manufacture of black carbon papers and carbon ribbons for type-writers.

Wood charcoal	A dry hard glass test tube is half filled with wood shavings. The wood shavings are heated in the absence of air using Bunsen burner. Wood shavings get charred, giving off fumes. The charred product formed is wood charcoal.	It is a brittle grey solid and can adsorb gases and liquids.	(i) It is used as a house hold fuel. (ii) For small scale extraction of metals. (iii) As a deodorant. (iv) In gas masks.
Sugar charcoal	It is prepared by the destructive distillation of sugar.	It is a thick black residue.	(i) It is used for extracting metals from their oxides. (ii) It is used as an adsorbent material in place of activated charcoal.
Animal charcoal	Animal bones contain organic matter and calcium phosphate. The crushed fine powder of the animal bones if subjected to destructive distillation produces residue. This residue is called bone charcoal.	It has less percentage of carbon and has the property of adsorption. It has high adsorptive capacity for mercury, arsenic, etc.	(i) Bone charcoal is used to remove colour from sugar cane juice by adsorbing impurities. (ii) It is used in the extraction of yellow phosphorous.

Compounds of Carbon

Carbon, in nature, exists largely in the form of compounds. These compounds exist invariably in the form of organic and inorganic compounds. Some of the important inorganic compounds of carbon are

(i) **Oxides of carbon:** Carbon reacts with oxygen to form two types of oxides, namely carbon monoxide and carbon dioxide.

(a) Carbon monoxide: It is prepared by passing carbon dioxide over heated coke.

$$CO_{2(g)} + \underset{\text{(red hot)}}{C} \rightarrow 2CO_{(g)} - Q$$

Carbon monoxide is a very harmful gas. On breathing, it combines with blood, reacts with haemoglobin forming carboxy haemoglobin thus decreasing the oxygen carrying capacity of the blood.

Uses

(i) It is used in the preparation of fuel gases.
(ii) It is used as reducing agent.
(iii) It is used in the preparation of metal carbonyls.

(b) Carbon dioxide: This is prepared by treating hydrochloric acid with limestone.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

Carbon dioxide gas plays a very important role in the atmosphere.

Uses

(i) It is used in the photosynthesis of plants
(ii) It also traps the heat radiation and keeps the earth warm.

The characteristic feature of carbon dioxide gas is seen when it is passed through lime. A milky white precipitate of calcium carbonate is formed, which dissolves on excess passage of carbon dioxide due to the formation of soluble calcium bicarbonate

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$$

(ii) **Carbonates and bicarbonates:** Carbonates and bicarbonates are another important class of compounds of carbon.

All carbonates except sodium and potassium carbonates on thermal decomposition give carbon dioxide. All bicarbonates on heating undergo decomposition to give carbon dioxide. Thus carbonates and bicarbonates act as sources, for the preparation of carbon dioxide.

Nitrogen

Nitrogen is an inactive element and is present in maximum proportion in air. The significance of nitrogen in air is to dilute the activity of oxygen thereby allowing natural processes like respiration and combustion to take place at a moderate rate.

Occurrence

Free state

Nitrogen exists in the free state in the atmospheric air. It is the major constituent of air comprising 78% by volume and 75% by weight.

Combined state

Nitrogen occurs in the combined state in various forms. It is present in the form of minerals like nitre (KNO_3) and chile salt petre ($NaNO_3$). Nitrogen is present in major amounts in organic matter such as proteins, nucleic acids, enzymes and various compounds of biological importance.

Preparation

In the industries, nitrogen is manufactured by isolation from the atmospheric air as it contains nitrogen in abundance. This is done by fractional distillation of liquid air.

Laboratory method of preparation of nitrogen gas

Principle: Ammonium chloride reacts with sodium nitrite to give ammonium nitrite which decomposes thermally to give nitrogen gas.

$$NH_4Cl + NaNO_2 \rightarrow NH_4NO_2 + NaCl$$

$$NH_4NO_2 \rightarrow N_2 + 2H_2O$$

Procedure

Equimolar solutions of ammonium chloride and sodium nitrite are taken in a round bottom flask and heated gently. Ammonium nitrite is formed which decomposes to give nitrogen which is collected by the downward displacement of water.

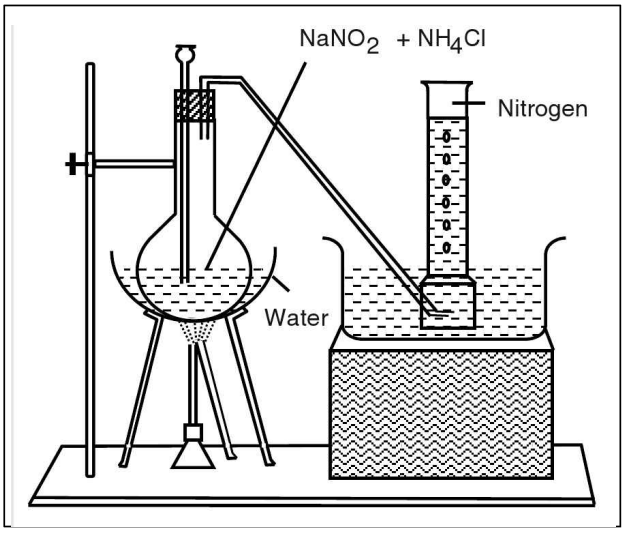


Figure 8.6 Preparation of nitrogen

Physical properties

Physical properties of nitrogen

Solubility	Slightly soluble in water (2.3 vol in 100 vol)
Density	Slightly lighter than air. Vapour density of air = 14.4 Vapour density of N_2 = 14.0
Liquefaction	It can be liquefied to a colourless liquid which boils at –195.8°C
Solidification	It can be solidified under high pressure to a white snow like mass which melts at –209.8°C.
Nature	It is a chemically nonreactive gas. Due to this nonreactive nature, it is used in (i) the filling of electric bulbs to prevent the oxidation of the filament present in it. (ii) and in the preservation of food stuffs

Chemical properties

Reaction with non metals (i) Hydrogen	Nitrogen reacts with hydrogen at high temperature and pressure to give ammonia gas. $N_2 + 3H_2 \rightarrow 2NH_3$
(ii) Oxygen	Nitrogen and oxygen react in equal volumes to form nitric oxide $N_2 + O_2 \rightarrow 2NO$
Reaction with metals (i) magnesium	Magnesium reacts with nitrogen to form magnesium nitride $3Mg + N_2 \rightarrow Mg_3N_2$
(ii) Calcium	$3Ca + N_2 \rightarrow Ca_3N_2$
(iii) Aluminium	$2Al + N_2 \rightarrow 2AlN$
Reaction with compounds (i) Calcium carbide	Heating calcium carbide with nitrogen at 800°C to 1000°C forms a mixture of calcium cyanamide and graphite $CaC_2 + N_2 \xrightarrow[}{\downarrow 800°C} CaCN_2 + C$

Uses

(i) Filling of electric bulbs

(ii) Manufacture of fertilizers

(iii) Storage of canned food

Compounds of nitrogen

Since nitrogen is the most essential element for the growth of plants and most of the plants are incapable of absorbing nitrogen directly from the atmosphere, the manufacture of useful compounds from nitrogen has lot of industrial significance. The most important compounds are ammonia and nitric acid which form the basic raw materials for the manufacture of a number of fertilizers.

Laboratory preparation of ammonia

Principle: Ammonium chloride on reaction with an alkali like calcium hydroxide liberates ammonia gas.

$$NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3\uparrow$$

Process: Ammonium chloride and calcium hydroxide are taken in 1 : 3 ratio by weight in a round bottom flask and heated gently. The gas evolved is passed through a delivery tube which is connected to the bottom of a tower packed with quick lime. The gas passes through this tower and is collected in an inverted gas jar by downward displacement of air.

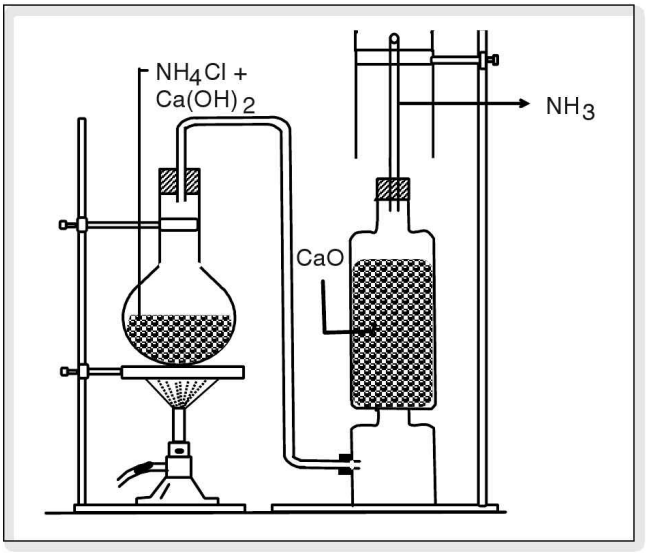


Figure 8.7 Preparation of ammonia

Physical properties

Colour	Colourless
Odour	Pungent smell, causes burning sensation in the upper part of nasal track and brings tears to eyes.
Taste	Bitter in taste
Physiological nature	Poisonous, damages respiratory system
Density	It is lighter than air (vapour density 8.5)
Solubility	Highly soluble in water, so it cannot be collected by the downward displacement of water. 1300 vol of NH_3 can be dissolved in 1 vol. of H_2O at STP.
Boiling point	–33.4°C.
Freezing point	–78°C.

Chemical properties

With non-metals (i) Oxygen	A burning match stick when introduced into a jar containing ammonia and oxygen burns with a pale blue flame. $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$ When the above mixture of ammonia and oxygen is passed over heated platinum, nitric oxide and water vapour are formed with the evolution of heat. $4NH_3 + 5O_2 \xrightarrow[900°C]{Pt} 4NO + 6H_2O$ $2NO + O_2 \rightarrow 2NO_2$ $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$
(ii) Chlorine	1) Limited amount of Cl_2 White dense fumes of ammonium chloride are formed along with nitrogen. $8NH_3 + 3Cl_2 \rightarrow 6NH_4Cl + N_2$ 2) Excess amount of Cl_2 Nitrogen trichloride and HCl are formed. $NH_3 + 3Cl_2 \rightarrow NCl_3 + 3HCl$
With metals	On reaction with active metals corresponding amides are formed. $2NH_3 + 2Na \rightarrow 2NaNH_2 + H_2$ $2NH_3 + 2K \rightarrow 2KNH_2 + H_2$
With acids	Ammonia being slightly basic reacts with acids to form salts. $NH_3 + HCl \rightarrow NH_4Cl$ $NH_3 + HNO_3 \rightarrow NH_4NO_2$ $2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$
Reducing Property	When Ammonia is passed over hot cupric oxide, gets reduced to copper. $CuO + 2NH_3 \rightarrow N_2 + 3Cu + 3H_2O$

Uses

(i) Manufacture of fertilizers

(ii) As a laboratory reagent

(iii) Manufacture of rayon, plastic, rubber, etc.

(iv) In the preparation of explosives like ammonal (NH_4NO_3 + Al powder) and amatol (NH_4NO_3 + 20% TNT)

Phosphorous

Phosphorous is an important element and is used in the elemental state and in the compound form. It is one of the essential nutrients required in larger amounts (macro nutrient) for plants. It plays a role in photosynthesis.

Occurrence

Phosphorous, being highly reactive, doesn't exist in the free state. In the combined state, it exists in the form of phosphates, in inorganic as well as organic matter.

Inorganic compounds

Chlorapatite	$3Ca_3(PO_4)_2.CaCl_2$
Fluorapatite	$3Ca_3(PO_4)_2.CaF_2$
Phosphorite	$Ca_3(PO_4)_2$

Organic matter

It is found in phosphoproteins of yolk, bone marrow, brain, nervous system, bones, teeth, etc.

Preparation

Phosphorous is prepared by the electrolytic reduction of mineral phosphate.

Procedure

The mineral phosphate (calcium phosphate) is mixed with sand and coke. This mixture is taken in an electric furnace with carbon electrodes. The mixture is electrically heated up to 1775K.

The following reactions take place

$$2Ca_3(PO_4)_2 + 6SiO_2 \rightarrow \quad 6CaSiO_3 + P_4O_{10}$$

(sand) (slag)

$$P_4O_{10} + 10C \rightarrow P_4 + 10CO$$

The slag formed settles at the bottom and is removed. Phosphorous vapours and carbon monoxide gas formed are let out of the furnace from the top. The subsequent cooling of these vapours under water results in the condensation of phosphorous into solid phosphorous.

Purification

The phosphorous obtained is purified using potassium dichromate in an acidic medium. The impurities are oxidized and removed as vapours or slag. Pure liquid phosphorous settles at the bottom where it is collected, filtered through chamois leather and sent through water cooled pipes for solidification.

Allotropy

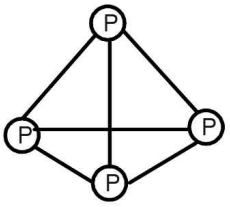
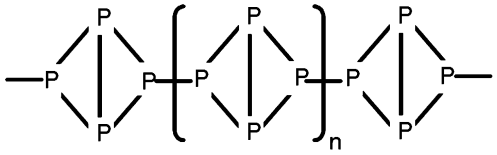
The phenomenon of the existence of an element in more than one form is called allotropy and the different forms of the element are called allotropes. Allotropes have almost same chemical properties but different physical properties.

Phosphorous exists in two important allotropic forms.

(i) White phosphorous.

(ii) Red phosphorous.

Comparative study of white phosphorous and red phosphorous

State	Soft solid	Brittle powder
Colour	White initially, gradually changes to yellow	Dark red
Odour	Garlic smell	Odourless
Density	1.82 gm/cm^3	2.1 gm/cm^3
Melting Point	317 K	–
Boiling Point	553.5 K	Sublimes at 565K
Ignition temperature	308 K	533K
Physiological nature	Poisonous	Non-poisonous
Atomicity	Four	Exists as chains
Structure	 Isolated tetrahedral P_4 units	 Chains of tetrahedral P_4 units linked to each other by P–P bonds.

Chemical properties

(i) With air/oxygen	Phosphorous reacts with oxygen to form two types of oxides P_2O_3 and P_2O_5 $P_4 + 3O_2 \xrightarrow[\text{supply}]{\text{Limited}} 2P_2O_3$ $P_4 + 5O_2 \xrightarrow[\text{excess}]{} 2P_2O_5$ These oxides with (excess) water produce oxyacids like HPO_3 H_3PO_4, H_3PO_3 and $H_4P_2O_7$
(ii) With chlorine	Phosphorous reacts with chlorine to form PCl_3 and PCl_5. $P_4 + 6Cl_2 \xrightarrow[\text{supply}]{\text{Limited}} 4PCl_3$ $P_4 + 10Cl_2 \xrightarrow{\text{Excess}} 4PCl_5$
(iii) With NaOH	Phosphorous when boiled with NaOH produces a colourless, poisonous gas phosphine $P_4 + 3NaOH + 3H_2O \rightarrow PH_3 + 3NaH_2PO_2$

Uses

(i) Red phosphorous is used in making safety matches.
(ii) Used in making phosphor bronze, an alloy of phosphorous, copper and tin.
(iii) Used in making rat poison (Zinc phosphide).
(iv) Used in making fertilizers.

Phosphorous plays a very vital role in the growth of plants. It is available to plants in the form of phosphate. One of the important constituent of fertilizers is phosphorous. It is given to plants in the form of calcium phosphate, super phosphate of lime, and lime nitrogenous phosphate.

Super phosphate of lime is a widely used phosphatic fertilizer which is prepared by treating calcium phosphate with concentrated sulphuric acid.

$$Ca_3(PO_4)_2 + H_2SO_4 \rightarrow \underbrace{2CaSO_4 + Ca(H_2PO_4)_2}_{\text{Super phosphate of lime}}$$

Oxygen

Oxygen is one of the most important non-metals. It plays a very important role in the life of most of the living organisms.

Occurrence

Oxygen is found in the free state and in the combined state.

Free state

Oxygen is present in free state in the atmospheric air. It comprises about 21% by volume and about 23% by mass of the total air. Water in oceans and other water bodies also contains some amount of oxygen in the dissolved state. Due to the presence of this dissolved oxygen in water, all aquatic species are able to survive in water.

Combined state

Water is the most important compound which contains oxygen in the combined state. Plants and animals also contain 50%–70% of oxygen in the combined state. 50% of oxygen is present in the form of silicates, carbonates, limestone and other ores.

Laboratory preparation of oxygen

In the laboratory, oxygen is prepared by the thermal decomposition of potassium chlorate or lead nitrate or potassium permanganate. The oxygen gas released is collected by the downward displacement of water.

$$2\,KClO_3 \xrightarrow[MnO_2]{\Delta} 2KCl + 3O_2 \uparrow$$

$$2Pb\,(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2 \uparrow$$

$$2KMnO_4 \xrightarrow{\Delta} K_2MnO_4 + MnO_2 + O_2 \uparrow$$

Physical properties

Colour	Colourless
Taste	No characteristic taste
Odour	No characteristic odour
Physiological nature	Non-poisonous
Density	Vapour density = 16
Solubility	Slightly soluble in water
Liquefaction	–183°C at atmospheric pressure.
Boiling and freezing point	Boiling point is –183°C Freezing point is –218.4°C
Action on litmus	Neutral

Chemical properties

(i) **With metals**	Metals react with oxygen to form basic or amphoteric oxides. $2Ca + O_2 \rightarrow 2CaO$ } basic $2Mg + O_2 \rightarrow 2MgO$ } $4Al + 3O_2 \rightarrow 2Al_2O_3$ (amphoteric)
(ii) **With non-metals**	Non-metals react with oxygen to form basic or neutral oxides. $S + O_2 \rightarrow SO_2$ $C + O_2 \rightarrow CO_2$ $2H_2 + O_2 \rightarrow 2H_2O$

If a few drops of acid is added to water, it can be decomposed into its components, i.e., hydrogen and oxygen by passing electricity through it. This process is called **electrolysis of water** and is used for the industrial preparation of hydrogen and oxygen.

Electrolysis of water

If a little amount of sulphuric acid is added to water, the water is called acidulated water. When this is subjected to electrolysis, water decomposes to give hydrogen and oxygen. Hydrogen is liberated at the cathode and oxygen is liberated at the anode.

$$2H_2O \xrightarrow{\text{Electric current}} 2H_{2(g)} + O_{2(g)}$$

Experiment 1

Acidulated water is taken in a rectangular tank. Platinum plates are inserted into the tank which are connected to the opposite terminals of the battery. When high voltage is passed through the tank, water electrolyses to give hydrogen gas at the cathode and oxygen gas at the anode.

Advantages

(i) The process is comparatively economical and can be used especially in places where the electricity is available at cheaper rates.

(ii) Hydrogen gas is obtained as a bi-product.

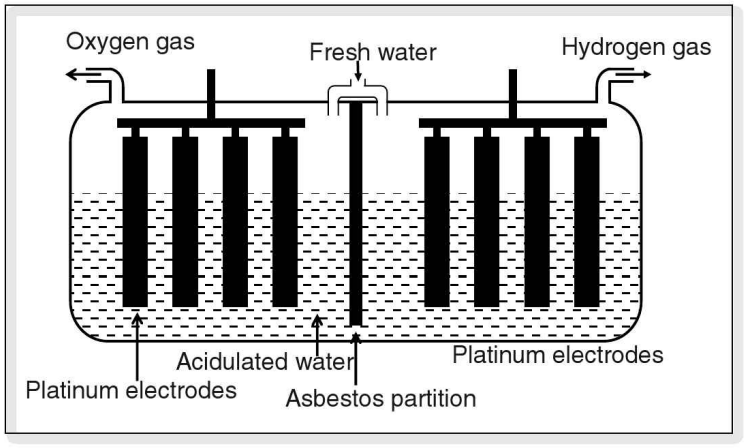


Figure 8.8 Industrial electrolysis of water

Properties of oxygen

Uses of oxygen

(i) Respiration of living organisms.

(ii) Combustion or burning of fuels.

(iii) Manufacture of H_2SO_4 and HNO_3 in industry.

(iv) Explosive: For blasting big rocks in mines, a mixture of coal, petroleum jelly and liquid oxygen is used in the form of cartridge.

(v) Metal extraction: Used in blast furnace for the extraction of iron.

(vi) Welding: A mixture of oxygen and hydrogen on burning gives oxy-hydrogen flame which is at a temperature of 2800°C. In place of hydrogen, when acetylene is used, it becomes oxy-acetylene flame which gives a still higher temperature of 3300°C. Both are used for welding purposes.

(vii) Stimulant for breathing: A mixture of 95% oxygen and 5% CO_2 is called carbogen. It is used for aiding breathing in patients with breathing problems.

(viii) As anaesthetic: A mixture of N_2O and oxygen is used as anaesthetic during surgical operations.

(ix) Rocket fuel: Liquid oxygen is used.

(x) Artificial respiration: Oxygen cylinders are carried by mountaineers, astronauts, miners, divers, submariners, aviators, firemen etc.

Sulphur

Sulphur is an important non metallic element. It reacts with metals thus destroying their metallic properties. Hence its name is derived from the Sanskrit word "sulvari" which means enemy of copper.

Occurrence

In nature, sulphur occurs in both free and combined state.

Free State

Sulphur in the free state is found in the earth's crust in the volcanic regions.

Combined state

Sulphur in the combined state is found in organic matter in the form of many biomolecules (insulin, glucosinolates of plants and animals, natural gas, etc) and in inorganic matter in the form of sulphides (cinnabar–HgS, galena–PbS, Iron pyrites–FeS) and sulphate (gypsum– $CaSO_4.2H_2O$, Epsom salt–$MgSO_4.7H_2O$)

☛ *Extraction* Sulphur is extracted from the earth's crust by the following process:

Frasch process

This process is used to extract sulphur j250which lies 150–400 m below the earth's crust.This process is also called Louisiana process as large deposits of it are found in Louisiana. A direct mining is not possible as sulphur is present in layers of quick sand and gravel.

Process: In this process, three concentric pipes of diameters 25 mm, 76 mm and 152 mm are drilled through the ground to the sulphur deposits. Super heated steam (170°C) under pressure is sent through the outer most pipe. This melts the sulphur below (m.p of sulphur = 112°C). Hot compressed air (up to 35 atm) is sent through the innermost pipe, which froths up the molten sulphur below. The sulphur foam formed rises up the middle pipe and is collected.

Advantage

The sulphur extracted in this process is 99·5% pure and doesn't need further purification.

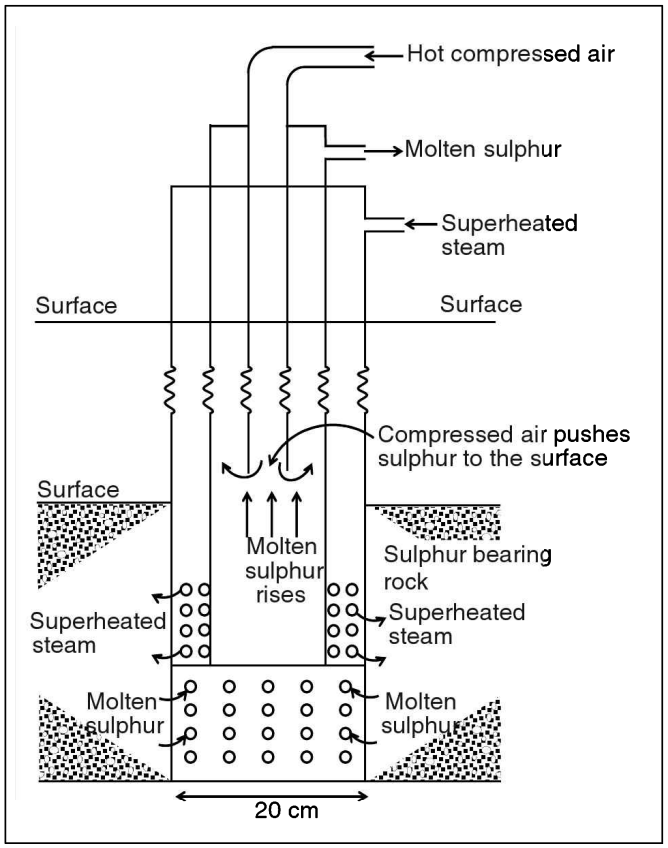


Figure 8.9 The Frasch process for extracting sulphur

Allotropes

Allotropes of sulphur

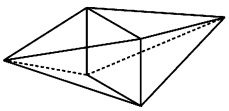
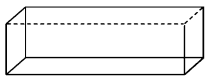
The phenomenon of the existence of an element in more than one physical form is called allotropy; and the other forms of the same element are called allotropes. Sulphur exists in different allotropic forms. Allotropes have same chemical properties but different physical properties.

The three main allotropic forms of sulphur are:

(i) Rhombic sulphur
(ii) Monoclinic sulphur
(iii) Plastic sulphur

Rhombic sulphur and monoclinic sulphur are crystalline whereas plastic sulphur is amorphous.

Comparative study of the allotropic forms of sulphur

Other names	Octahedral sulphur, Alpha-sulphur	Prismatic sulphur, Beta-sulphur	Gamma-sulphur
Preparation	Roll sulphur is dissolved in carbon disulphide. This is allowed to evaporate slowly by slight heating. Rhombic sulphur crystals are left behind.	Roll sulphur is heated on an evaporating dish till it melts to pale yellow liquid. This on cooling forms a crust on the surface. Holes are pierced on the crust and the molten sulphur is drained out. Needle shaped sulphur (monoclinic sulphur) crystals are left behind.	Roll sulphur is heated to above 300°C till it turns to dark brown, this is poured into cold water and the sulphur formed is plastic sulphur.
Colour	Pale yellow	Amber	Dark brown
Shape/ structure	Octahedral 	Needle shaped 	Amorphous
Density	2.08 g/cm^3	1.98 g/m^3	1.92 g/cm^3
Solubility	Soluble in carbon disulphide	Soluble in carbon disulphide	Insoluble in carbon disulphide
Melting point	112.8°C	119°C	No sharp melting point
Conductivity	Sulphur is a bad conductor of heat and electricity		
Boiling point	Sulphur boils at 444°C		

Rhombic sulphur is the most stable form at normal temperature. Monoclinic sulphur and plastic sulphur change to rhombic form on long standing.

Transition between rhombic sulphur and monoclinic sulphur

Rhombic sulphur is stable below 95.6°C and above this temperature, it changes to monoclinic sulphur. Conversely, monoclinic sulphur is stable above 95.6°C, but changes to the rhombic variety below this temperature. Hence 95·6°C is called transition temperature of these two allotropes of sulphur.

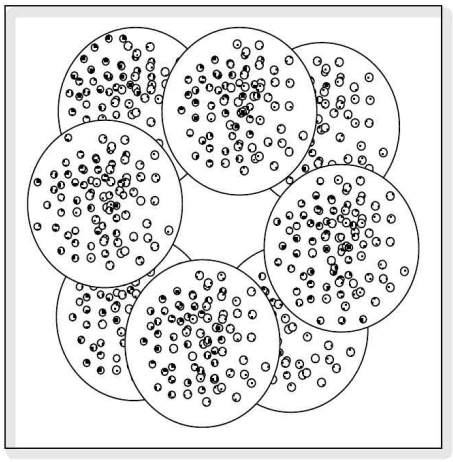


Figure 8.10

Puckered ring structure of sulphur

Both rhombic and monoclinic sulphur exists in the form of S_8 molecules. These S_8 molecules are in the form of a ring. It forms a crown shaped molecule with four atoms on the top and four atoms at the bottom. (Fig 8.10)

The rhombic form and the monoclinic form differ in the arrangement of these S_8 puckered rings. In rhombic sulphur, these rings fit snugly into each other while in monoclinic sulphur the rings are stacked one on top of the other.

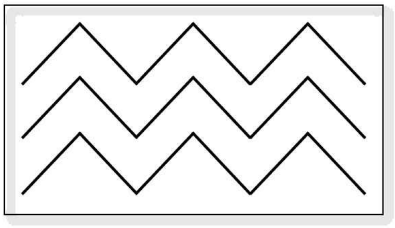


Figure 8.11 Rhombic sulphur

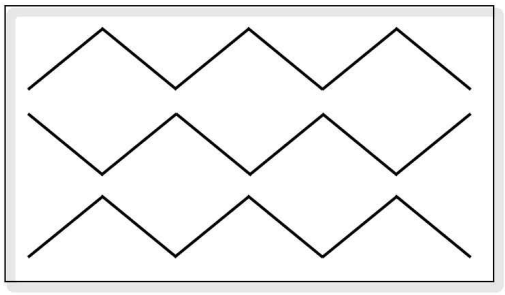


Figure 8.12 Monoclinic sulphur

Action of heat on sulphur

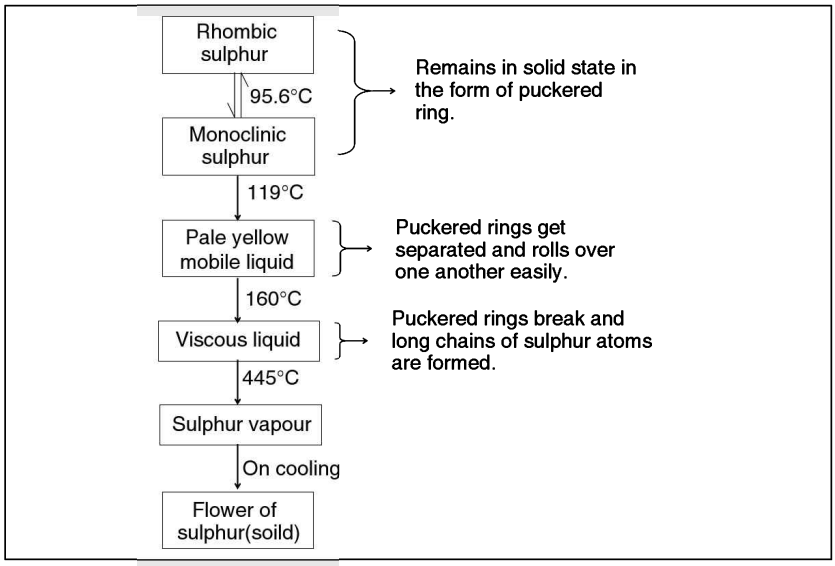


Figure 8.13

Chemical properties

With non-metals	
(i) Oxygen	Sulphur reacts with oxygen above 300°C giving two oxides. $S + O_2 \xrightarrow{800°C} SO_2$ (Sulphur dioxide) $S + O_2 \rightarrow 2SO_3$ (trace amounts) (Sulphur trioxide)
(ii) Hydrogen	Boiling sulphur with hydrogen gas evolves a gas with a bad smell. $H_2 + S \rightarrow H_2S$ (Hydrogen sulphide)
(iii) Carbon	Sulphur vapours when passed over red hot coke forms carbon disulphide $C + S \rightarrow CS_{2(l)}$ (red hot) (carbon disulphide)
With metals	Sulphur vapours when passed over the heated surface of the metals gives the corresponding metal sulphides. $Zn + S \rightarrow ZnS$ $Fe + S \rightarrow FeS$
With acids	Sulphur is oxidized to sulphuric acid and reduces nitric acid to nitrogen dioxide $S + HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$

Uses

Sulphur has a wide variety of uses in various industries.

Rubber industry: It is used for the vulcanization of rubber to make it hard and elastic.

Chemical industry: Used in making chemicals like sulphuric acid, carbon disulphide, etc.

Explosive industry: Sulphur along with charcoal and nitre is used in making gun powder.

Pharmaceutical industry: Sulphur due to its excellent fungicidal activities is used as a fungicide.

Compounds of sulphur

Sulphur forms a wide range of compounds which have applications in various fields.

Sulphur dioxide

This is an oxide of sulphur where one atom of sulphur is associated with two atoms of oxygen.

It is found in exhaust emissions of internal combustion engine, in the industrial areas where coal and petroleum are used as fuels. In nature it is found in volcanic gases.

Preparation

Laboratory preparation of SO_2

Sulphur dioxide is prepared in the laboratory by heating copper turnings with concentrated sulphuric acid.

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + 2H_2O + SO_2\uparrow$

Properties

Physical properties

Colour	Colourless
Odour	Pungent and suffocating
Taste	Sour
Vapour density	32 (2.2 times heavier than air)
Solubility in water	Fairly soluble
Boiling point	–10°C
Freezing point	–76°C
Physiological nature	Poisonous

Chemical properties

Acidic nature (i) With litmus (ii) Reaction with water	Sulphur dioxide is acidic in nature and can change blue litmus to red. Sulphur dioxide with water forms unstable sulphurous acid. $H_2O + SO_2 \rightarrow H_2SO_3$
Reducing property	Sulphurdioxide when passed through chlorine water reduces the chlorine to hydrogen chloride. $SO_2 + Cl_2 + H_2O \rightarrow HCl + H_2SO_4$
Bleaching property	Sulphur dioxide is a good bleaching agent. This on reaction with moisture or water, produces nascent hydrogen which helps in the bleaching action. $SO_2\uparrow + H_2O \rightarrow H_2SO_4 + 2[H]$ (reducing agent) The nascent hydrogen produced on being exposed to moisture acts as the bleaching agent. It reduces the coloured matter to colourless. This reaction is reversible. The colourless product on exposure to atmospheric oxygen can get oxidized and thus regains its colour. Coloured vegetable + [H] → Colourless product + Water (Bleached product)

Hydrogen sulphide

Hydrogen sulphide gas is well known for its rotten egg smell. In free state it is present in volcanic gases, water of springs, in the air near and around industrial area.

Though the gas has bad smell and pollutes atmosphere, it is still prepared in the laboratory due to its certain unique properties and uses.

Laboratory preparation of hydrogen sulphide

Principle: Ferrous sulphide on reaction with hydrochloric acid gives ferrous chloride, liberating hydrogen sulphide gas.

$FeS + 2HCl \rightarrow FeCl_2 + H_2S \uparrow$

Physical Properties

Colour	Colourless
Odour	Smell of rotten eggs
Taste	Sour taste
Solubility	Fairly soluble in water
Vapour density	17 (1.2 times heavier than air)

Chemical properties

Acidic nature	It can change blue litmus to red It reacts with a base to form salt and water $NaOH + H_2S \rightarrow NaHS + H_2O$ (Sodium hydrogen sulphide) $NaOH + NaHS \rightarrow Na_2S + H_2O$ (Sodium sulphide)
Reducing Property (i) With oxygen	Hydrogen sulphide undergoes combustion during which it reduces oxygen to water. $2H_2S + O_2 \rightarrow 2S + 2H_2O$ It however does not support combustion.
(ii) With chlorine	Chlorine on reaction with hydrogen sulphide is reduced to hydrogen chloride. $H_2S + Cl_2 \rightarrow 2HCl \uparrow + S$
(iii) With $FeCl_3$	H_2S reduces ferric chloride to ferrous chloride $FeCl_3 + H_2S \rightarrow FeCl_2 + HCl + S$

(Continued on following page)

(iv) With acids	H_2S on reaction with Conc. H_2SO_4 and HNO_3 reduces these to their respective oxides. $H_2SO_4 + H_2S \rightarrow SO_2 + S + 2H_2O$ (Conc) $2HNO_3 + H_2S \rightarrow 2NO_2 + S + 2H_2O$

Uses

The most important application of hydrogen sulphide gas is in analytical chemistry.

Hydrogen sulphide on reaction with aqueous solutions of metal salts convert them to metal sulphides. These metal sulphides are in the form of precipitates. The colour of the precipitate depends upon the nature of metal ion. Therefore, hydrogen sulphide is mainly used for the detection of metal cations present in the metal salts.

$$Pb(NO_3)_2 + H_2S \rightarrow \underset{\text{(Black precipitate)}}{PbS} + 2HNO_3$$

$$CuSO_4 + H_2S \rightarrow \underset{\text{Black precipitate)}}{CuS} + H_2SO_4$$

$$ZnSO_4 + H_2S \rightarrow \underset{\text{(White precipitate)}}{ZnS} + H_2SO_4$$

$$MnSO_4 + H_2S \rightarrow \underset{\text{(Flesh coloured)}}{MnS} + H_2SO_4$$

This is the major use of hydrogen sulphide gas.

Chlorine

Chlorine is not only a member of the halogen family, but also considered as the typical halogen. It is diatomic and highly reactive gas. Chlorine generally exists in a combined state rather than in a free state.

Chlorine was first synthesized by Scheele and the elemental nature was established by Davy.

Laboratory method of preparation

Oxidation of hydrochloric acid: Hydrochloric acid on oxidation with MnO_2 or $KMnO_4$ or $K_2Cr_2O_7$ gives chlorine gas. Oxidation of HCl by MnO_2 is the most common method employed for the preparation of chlorine gas in laboratory.

Principle

When manganese dioxide is heated with concentrated HCl. HCl gets oxidized to chlorine gas.

$$MnO_{2+}4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$$

Physical properties

Colour	Greenish Yellow
Odour	pungent smell
Solubility	Sparingly soluble in water
Density	Heavier than air. Vapour density 35.5
Atomicity	2

Chemical properties

With non-metals (i) Phosphorous	Chlorine reacts with phosphorous to form phosphorous trichloride which further reacts with chlorine to produce phosphorous pentachloride $2P + 3Cl_2 \rightarrow 2PCl_3$ $PCl_3 + Cl_2 \rightarrow PCl_5$
(ii) Hydrogen	Chlorine has a very high affinity towards hydrogen. It reacts with hydrogen to form hydrogen chloride. $H_2 + Cl_2 \rightarrow 2HCl$ Chlorine reacts with hydrogen in hydrocarbon to form carbon and hydrogen chloride. $C_{10}H_{16} + 8Cl_2 \rightarrow 10C + 16HCl$
With metals	Chlorine reacts with most of the metals. $2Na+Cl_2 \rightarrow 2NaCl$. E.g.: Burning magnesium ribbon reacts with chlorine gas to form. $MgCl_2$ with the evolution of light energy $Mg + Cl_2 \rightarrow MgCl_2$
With water	Chlorine dissolves in water forming a mixture of hydrochlolric acid and hypochlorous acid. This reaction is responsible for the bleaching action of chlorine since HOCl dissociates giving nascent oxygen. $Cl_2 + H_2O \rightarrow HCl + HOCl$ $HOCl \rightarrow HCl + [O]$

Uses

(i) Used in the manufacture of bleaching powder.

Bleaching powder is one of the most important compounds of chlorine which is widely used for the purification of drinking water owing to its disinfectant action. It is prepared by treating slaked lime with chlorine gas.

$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$

(ii) For bleaching wood pulp, cotton, paper, silk, rayon, etc.

(iii) For preparing poisonous gas like mustard gas (ClC_2H_4-S-C_2H_4Cl), phosgene ($COCl_2$) tear gas (CCl_3NO_2).

(iv) In the preparation of hydrochloric acid.

(v) In the extraction of metals like platinum, gold, titanium, etc.

(vi) In the manufacture of chloroform ($CHCl_3$),carbon tetrachloride (CCl_4), dichloro diphenyl trichloroethane (DDT) etc. and also in rubber, plastic and paint industries.

(vii) In the purification of drinking water.

test your concepts

Very short-answer type questions

1. What is metallurgy?
2. During calcination carbonate ores are converted to _____.
3. In electroplating process the metal to be coated is taken as _____.
4. What type of oxides do metals form?
5. _____ is used for making shoe polishes.
6. Discuss any three uses of wood charcoal.
7. What is meant by allotrophy?
8. Name the different allotropes of sulphur.
9. _____ is amorphous form of sulphur.
10. Discuss any two uses of carbon monoxide.
11. How is nitrogen isolated from liquid air?
12. The impurities that are associated with the ore are called _____.
13. Which is the purest form of iron? How is it useful?
14. What are the catalyst and promoter used in the manufacture of ammonia during Haber's process?
15. What are the various explosives that can be prepared from ammonia?
16. Non-metals react with oxygen to form _____ or _____ oxides.
17. Discuss three important uses of graphite.
18. How nitric acid reacts with sulphur?
19. What is the colour of the precipitate formed when H_2S is made to react with lead nitrate?
20. Write the reaction of sulphuric acid with sodium chloride and potassium nitrate.
21. _____ is the chemical name of bleaching powder.
22. Explain the acidic nature of sulphur dioxide based on its reactivity with water.
23. Explain the chemical reaction of chlorine with hydrogen sulphide.

24. List the allotropes of phosphorous.

25. When carbon dioxide is passed through lime water, a milky white precipitate of _____ is formed.

26. What is super phosphate of lime?

27. Geometry of alpha-sulphur is _____.

28. Write the reaction of phosphorous with chlorine.

29. During the manufacture of wrought iron, cast iron is taken in a reverberatory furnace and stirred at high temperature and this process is called _____.

30. _____ is an alloy of phosphorous, copper, tin.

Short-answer type questions

31. Complete the following table giving a comparison between metals and non-metals.

	Parameter	Metals	Non-metals
1.	Melting point and boiling point		
2.	Conductivity		
3.	Tensile strength		
4.	Density		
5.	Formation of ions		
6.	Formation of oxides		

32. What is the basic purpose of roasting and calcination? Compare these two processes.

33. Explain froth floatation process for concentrating sulphide ores.

34. Discuss the action of hydrogen chloride on ammonia.

35. Distinguish between calcination and roasting?

36. Write the balanced equations for the following preparations

(i) ammonium sulphate from ammonia.

(ii) ammonium phosphate from ammonia.

37. Explain with equations the reaction of sulphur with metals and non metals.

38. What are the different processes involved in the dressing of ore? Explain.

39. Differentiate between rhombic sulphur and monoclinic sulphur.

40. In industries, chlorine is used in the manufacture of hydrogen chloride. Explain.

41. How is H_2S used as an analytical reagent?

42. Explain the reaction of ammonia with chlorine.

43. How is ore concentrated in the gravity separation process? Explain.

44. How is chlorine gas prepared?

45. State the reactions that take place at the cathode and anode during the process of electrolytic reduction of alumina.

Essay type questions

46. Describe smelting of iron in blast furnace. Write all the reactions which take place in different zones of blast furnace.

47. Explain with equations how sulphur dioxide is prepared in the laboratory.

48. Describe the structure of diamond.

49. Differentiate between white phosphorous and red phosphorous.

50. Compare cast iron, steel and wrought iron.

CONCEPT APPLICATION

Concept Application Level—1

Direction for questions 1 to 7: State whether the following statements are true or false.

1. Rhombic sulphur is the most stable form of sulphur at normal temperature.
2. The solid, inorganic compounds found in the earth's crust are called minerals.
3. Metals react with oxygen only to form basic oxides.
4. Phosphorous reacts with air and forms P_2O_5.
5. Metallic oxides are produced in calcination and roasting.
6. Colourless gas formed by treating phosphorus with NaOH is phosphine.
7. Burning magnesium ribbon continuously burns in nitrogen atmosphere.

Direction for questions 8 to 14: Fill in the blanks.

8. When carbon dioxide is passed through lime water, a milky white precipitate of _____ is formed.
9. The reduction of metallic oxide in presence of carbon or carbon monoxide in blast furnace is called _____.

10. Silica acts as _____ in the process of extraction of iron from its oxides.

11. In open hearth process for making steel, the final composition of steel is adjusted by adding _____ alloy.

12. Hydrogen sulphide on reacting with aqueous solution of metal salts converts them to _____.

13. Reaction taking place in lower region of blast furnace is associated with _____ of energy.

14. Hardness of steel increases with the increase of _____.

Direction for question 15: Match the entries in column A with the appropriate ones in column B.

15.

A.	Charcoal	( )	a.	Rat poison
B.	Sulphur	( )	b.	Fertilizers
C.	Phosphorous	( )	c.	Fungicides
D.	Chlorine	( )	d.	Gas masks
E.	Nitrogen	( )	e.	Tear gas

Direction for questions 16 to 45: For each of the questions, four choices have been provided. Select the correct alternative.

16. Pig iron obtained from blast furnace cannot be used for making tools because

(1) high percentage of impurities decrease malleability.

(2) high percentage of impurities Increase malleability.

(3) low carbon content increases hardness.

(4) low carbon content decreases hardness.

17. Which of the following is the gaseous product obtained in roasting?

(1) SO_2 (2) O_2 (3) SO_3 (4) H_2S

18. Which of the following reactions does not take place in the smelting process?

(1) $FeO + CO \rightarrow Fe + CO_2$. (2) $CaO + SiO_2 \rightarrow CaSiO_3$.

(3) $C + CO_2 \rightarrow 2CO$. (4) $Fe_2O_3.H_2O \rightarrow Fe_2O_3 + H_2O$.

19. Which of the following helps in the bleaching action of sulphurdioxide?

(1) H_2 (2) O_2 (3) [H] (4) O

20. Graphite is generally used as a refractory material in electric furnaces because

(1) of its high melting point. (2) it has a layered structure.

(3) Both (1) and (2). (4) it is lustrous.

21. Reaction: $FeCl_3 + H_2S \rightarrow FeCl_2 + HCl + S$ in the above reaction

(1) H_2S is the reducing agent
(2) $FeCl_3$ undergo oxidation
(3) H_2S acts as oxidizing agent
(4) $FeCl_3$ acts as reducing agent

22. Which would quickly absorb oxygen?

(1) Alkaline solution of pyrogallol
(2) lime water
(3) Conc. H_2SO_4
(4) Alkaline solution of $CuSO_4$.

23. Which of the following changes takes place during the process of calcination of ore?

(1) Thermal decomposition of ore takes place
(2) The mass become porous
(3) Moisture is removed
(4) All the above

24. Which of the following substance is used as lining in Bessemer converter in case of acidic process?

(1) Quick lime
(2) Silica
(3) Slacked lime
(4) Caustic potash

25. The sulphide ores which involve roasting as one of the steps of extraction are concentrated by certain method. Identify the main principle involved.

(1) Adsorption of ore particles to pine oil.
(2) Specific gravity difference between ore and gangue.
(3) Attraction of ore or gangue particles towards the magnet.
(4) Coagulation of gangue particles by the addition of pine oil.

26. Which of the following properties of diamond is not attributed to its rigid giant polymeric tetrahedral structure?

(1) Good thermal conductivity
(2) Good abrasive nature
(3) Poor electrical conductivity
(4) Both (1) and (2)

27. Which of the following oxides react to form slag in open hearth process?

(1) CaO, CO
(2) P_2O_5, CaO
(3) P_2O_5, SiO_2
(4) CaO, CO_2

28. Which of the following negative radical is present in bleaching powder?

(1) Hypochlorite
(2) Chlorate
(3) Chloride
(4) Both (1) and (3)

29. Which of the following compositions is used as a fertilizer?

(1) $CaCN_2 + C$
(2) $CaC_2 + C$
(3) $Ca_3N_2 + C$
(4) $AlN + C$

30. Which of the following salt of calcium is used in the preparation of super phosphate of lime?

(1) $Ca_3(PO_3)_2$
(2) $Ca_3(PO_4)_2$
(3) $Ca(HPO_4)_2$
(4) $CaSO_4$

31. General metallurgical processes are given below. Arrange them in correct sequence.

(a) Conversion of ore to oxide

(b) Refining

(c) Dressing of ore

(d) Extraction of metal

(e) Concentration of ore

(1) eadbc (2) ceadb (3) decba (4) becda

32. Reactions involved in the smelting of iron in the blast furnace are given below. Arrange them in the correct sequence.

(a) $CaCO_3 \rightarrow CaO + CO_2 + 43$ kcal

(b) $CaO + SiO_2 \rightarrow CaSiO_3$

(c) $C + O_2 \rightarrow CO_2 + 97$ kcal

(d) $CO_2 + C \rightarrow 2CO - 39$ kcal

(e) $FeO / Fe_2O_3 + CO \rightarrow Fe + CO_2$

(1) cdabe (2) cadeb (3) edcba (4) bceda

33. Different stages involved in the manufacture of hydrogen gas by Bosch process are given below. Arrange them in the correct sequence.

(a) Removal of unoxidized CO

(b) Preparation of water gas

(c) Removal of CO_2

(d) Removal of water vapour

(e) Removal of CO

(1) cedba (2) cdbae (3) becda (4) bdaec

34. Different stages involved in the nitrogen cycle are given below. Arrange them in correct sequence starting from nitrates.

(a) Conversion of animal protein to excretory product

(b) Conversion of ammonia to nitrites

(c) Conversion of plant protein to animal protein

(d) Conversion of nitrites to nitrates

(e) Conversion of nitrates to plant protein

(f) Conversion of excretory product to ammonia

(1) dbeafc (2) cbdafe (3) efbdca (4) ecafbd

35. Epsom salt is

(1) $MgSO_4.7H_2O$ (2) $KCl.MgCl_2.6H_2O$ (3) Na_3AlF_6 (4) $CaSO_4.2H_2O$

36. Which of the following reactions takes place in the lower region of blast furnace?

(1) $CO_2 + C \rightarrow 2CO - 39$ kcal (2) $C + O_2 \rightarrow CO_2 + 97$ kcal

(3) $FeO + CO \xrightarrow{750-600^\circ C} Fe + CO_2$ (4) $CaO + SiO_2 \rightarrow CaSiO_3$

37. When ammonia reacts with excess chlorine it forms

(1) $NH_4Cl + N_2$ (2) $N_2 + HCl$ (3) $NOCl + HCl$ (4) $NCl_3 + HCl$

38. Water gas is a mixture of

(1) $CO + H_2$ (2) $CO_2 + N_2$ (3) $CO + N_2$ (4) $CO_2 + H_2$

39. Which among the following is used in the manufacture of deodorant?

(1) Lamp black (2) Animal charcoal (3) Sugar charcoal (4) Wood charcoal

40. Which of the following compounds is used as the raw material for many fertilizers?

(1) NH_3 (2) H_2S (3) HCl (4) CO_2

41. Which among the following is widely used in the match industry?

(1) N_2 (2) C (3) P (4) Cl_2

42. Which of the following cannot be concentrated by froth flotation process?

(1) Zinc blende (2) Copper pyrites (3) Iron pyrites (4) Limonite

43. Which of the following changes takes place during the process of calcination of an ore?

(1) Thermal decomposition of the ore takes place (2) The mass become porous

(3) Moisture is removed (4) All the above

44. Assertion (A): Diamond is a good conductor of heat.

Reason (R): In diamond each carbon atom is bonded strongly to four other carbon atoms.

(1) Both A and R are true and R is the correct explanation for A.

(2) Both A and R are true but R is not the correct explanation for A.

(3) A is true but R is false.

(4) A is false but R is true.

45. Assertion (A): Wrought iron is much more malleable than pig iron.

Reason (R): Wrought iron is the purest form of iron.

(1) Both A and R are true and R is the correct explanation for A.

(2) Both A and R are true but R is not the correct explanation for A.

(3) A is true but R is false.

(4) A is false but R is true.

Concept Application Level—2

1. What happens to the conductivity of metals with increase in temperature?

2. Why is the iron obtained from the blast furnace not used for making any articles?

3. An iron piece is kept for some time in concentrated nitric acid and then removed. The iron piece now can neither liberate hydrogen from dilute sulphuric acid nor can it liberate copper to form copper sulphate. Explain with an appropriate reason.

4. During the preparation of artificial diamond can molten copper be used instead of molten iron? Justify.

5. Why are diamonds found in coal mines?

6. H_3PO_4 serves as very important intermediate in fertilizer industry. Justify.

7. Why are the metals sodium and potassium not extracted by the electrolysis of their respective salt solutions?

8. In two containers A and B, NH_3 is allowed to react with Cl_2 under suitable conditions. If the gaseous products formed in A responds to litmus test compare the molar ratio of reactants in both the containers and identify the products formed.

9. Among white phosphorous and red phosphorous which is more preferable for use in match sticks? Give reasons in support of your answer.

10. Turpentine oil when exposed to an atmosphere of chlorine ignites with a black sooty flame. Justify.

11. Two solid non-metals X and Y are taken which are used for the purpose of vulcanization of rubber and for use in sugar industry respectively. A mixture of X, Y and 'Z', which is a salt of an alkali metal of corresponding ic acid of nitrogen can explode on heating even in the absence of oxygen. Justify.

12. "Graphite cannot be used as a lubricant in space". Give reasons.

13. X,Y are the elements which belong to VI A, VII A group or 3rd period. Oxide of an element 'X' and element 'Y' act as a bleaching agents in the presence of water. Explain bleaching action of which one is permanent?

14. What are the different reactions taking place in fusion zone of blast furnace and explain how these reactions affect the temperature of the zone.

15. Phosphor bronze is an alloy of copper with 3·5 to 10% of tin and up to 1% of phosphorous. What is the reason for the addition of phosphorous?

16. Iron exposed to moist air for a long time doesn't liberate hydrogen gas from dilute acids like HCl and $H2SO_4$. Explain.

17. Wrought iron is more malleable than cast iron. Give reasons.

18. Mr. John is working in IICT as a scientist. During the synthesis of a drug in the laboratory by his assistant he found that some impurities were associated with the drug. Mr. John dissolved the drug obtained in the solvent and added charcoal to it. This was then filtered off which on evaporation gave back the pure drug. Then the assistant asked Mr. John the following question 'what is the role of charcoal'? What was Mr. John's answer?

19. A group of students in a school were supposed to demonstrate some experiments in a science exhibition to be conducted on the National Science Day. As a part of planning for the above activity, they gathered in the science laboratory and were discussing their ideas. Smith took a beaker of water and a piece of charcoal. He asked his friends to predict whether it will float or sink in the water. Most of them said that it would float and it actually did. He then asked them whether anybody could make it sink in the water. After a few seconds of silence, Andy came forward and said he could do it by boiling the beaker containing water and charcoal. Then all of them were astonished to see the charcoal slowly sinking in the water. Predict the principle involved in the above experiment.

20. An oxide of a nonmetal 'X' is the mixed anhydride of two oxy acids. Identify 'X' and the other two oxyacids. Also mention how the oxide is formed from the stable hydride of the same element.

21. **(a)** Explains the disadvantage of P_2O_5 as a drying agent though it is known to be a good desiccant.

    (b) How can P_2O_5 be used in the preparation of SO_3?

22. Carbon dioxide and water vapour present in air moderates the temperature of the earth. Explain.

23. Anhydrides of sulphurous acid and carbonic acid produce milkiness when passed through a solution of the same substance 'X'. When chlorine gas is made to react with the same solution 'X', it gives a compound 'Y' having disinfectant action. Identify 'Y' and justify its use for the above purpose.

24. **(a)** Account for the changes observed in the surroundings when carbon dioxide gas comes out of a fire extinguisher.

    (b) Although CO_2 is generally used as a material in fire extinguisher it can not be used to put out fires caused by metals like Na, Mg, K.

25. A practical examination was being conducted for the students. The examiner, in the viva voice, asked Julie the question "Two salts X and Y are given to you. Salt 'X' is obtained by treating potassium with oxy acid of a non metal with suffix ic which has seven electrons in 'M' shell which is the valence shell. Salt 'Y' is formed between lead and oxy acid of a non metal with five electrons in its valence 'L' shell. Both the salts can give oxygen on thermal decomposition. "Which salt do you prefer for the preparation of pure oxygen and why?". When she answered the question correctly, examiner was very much impressed and awarded her full marks. What was the answer that Julie gave?

Concept Application Level—3

1. Is the property involved in the shining of diamond and lustre of metals the same? Justify.
2. Wrought iron is more malleable than cast iron. Give reasons.
3. Rusted iron is washed with phosphoric acid before soldering. Justify.
4. A bivalent metal forms a salt with the oxy acid of a solid non-metal in which the non-metallic element has +5 oxidation state. The salt formed can not be used as a fertilizer though it contains essential nutrients and is available as mineral in nature. However, the salt when treated with conc. H_3PO_4 gives an important and desirable fertilizer when compared with conc H_2SO_4. Identify the various substances involved and give equations.
5. Burning of coal leads to increase in the acidity of soil. Comment on this statement.
6. Graphite and iodine are the only nonmetals possessing lustre which is actually an important attribute of metals. Comment on the statement with proper justification.
7. How does soda water help in digestion of food after over eating?
8. Metals like platinum, palladium find application in the process of purification of hydrogen. Justify.
9. Mr. Paul, who is working for Asian paints, while constructing a house coated the building with white paint. After a few months his friend Mr. Richard who is working in a chemical laboratory visited the house and noticed a few dark patches on the white paint here and there due to which the building lost its original lustre. He advised his friend to try for restoration of lustre by washing with hydrogen peroxide. Justify the role of hydrogen peroxide.
10. "Metals are good thermal conductors and electrical conductors. How the above said properties vary in case of diamond and graphite, which are allotropes of the non metallic element carbon.

Very short-answer type questions

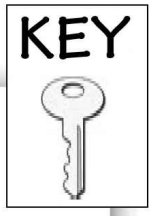
1. Process of the extraction of metals from their respective ores is called metallurgy.
2. Oxide
3. Cathode
4. Basic oxides or amphoteric oxides
5. Lampblack
6. Fuel, deodorant and gas masks
7. Existence of different physical forms of element with almost similar chemical properties.
8. Rhombic sulphur, monoclinic sulphur and plastic sulphur
9. Plastic sulphur
12. Gangue
13. Wrought iron, chains, bolts etc
14. Fe, Mo
15. Ammonal (NH_4NO_3 + Al powder), Amatol (NH_4NO_3 + 20% T.N.T)
16. Acidic, neutral
17. Leads of pencils, moderator in nuclear reactors, making refractory crucibles
18. $S + HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$
19. Black precipitate
20. $H_2SO_4 + 2NaCl \rightarrow Na_2SO_4 + 2HCl$
    $H_2SO_4 + 2KNO_3 \rightarrow K_2SO_4 + 2HNO_3$
21. Calcium chloro hypochlorite
22. $SO_2 + H_2O \rightarrow H_2SO_3$
23. $H_2S + Cl_2 \rightarrow 2HCl \uparrow + S$
24. White and red phosphorous
25. Calcium carbonate
26. $Ca(H_2PO_4)_2H_2O + 2CaSO_4 \cdot 2H_2O$
27. octahedral
28. $2P + 3Cl_2 \rightarrow 2PCl_3$; $PCl_3 + Cl_2 \rightarrow PCl_5$
29. puddling
30. Phosphobronze

Short-answer type questions

33. (i) Set-up
    (ii) Raw materials
    (iii) Procedure
34. $HCl + NH_3 \rightarrow NH_3Cl$
35. Heating of ore in absence and in presence of air respectively.
39. (i) Preparation
    (ii) Colour
    (iii) Structure/shape
    (iv) Melting, boiling points
    (v) Density
40. (i) Principle
    (ii) Process
    (iii) Reaction
42. Colour of product (precipitate)
44. $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

Essay type questions

46. (i) Set-up
    (ii) Raw materials
    (iii) Layers
    (iv) Procedure
    (v) Reactions in various layers.
    (vi) Temperature in various layers
    (vii) Collection of metal
47. (ii) Process
    (iii) Purification
48. (i) Arrangement of carbon atoms
    (ii) Bonds
49. (i) State
    (ii) Colour
    (iii) Odour
    (iv) Melting, boiling points
    (v) Physiological nature
    (vi) Atomicity
    (vii) Structure
50. (i) Composition
    (ii) Preparation



Concept Application Level—1

True or false

1. True
2. True
3. False
4. True
5. True
6. True
7. True

Fill in the blanks

8. calcium carbonate
9. smelting
10. flux
11. ferrosilicon and/or ferromanganese
12. metallic sulphides
13. release
14. carbon content

Match the following

15. A : d
    B : c
    C : a
    D : e
    E : b

Multiple choice questions

16. Choice (1)
17. Choice (1)
18. Choice (4)
19. Choice (3)
20. Choice (1)
21. Choice (1)
22. Choice (1)
23. Choice (4)
24. Choice (2)
25. Choice (1)
26. Choice (3)
27. Choice (2)
28. Choice (4)
29. Choice (1)
30. Choice (2)
31. (i) Dressing of ore
    (ii) Concentration of ore
    (iii) Conversion of ore to oxide
    (iv) Extraction of metal
    (v) Refining

    Choice (2)
32. (i) $C + O_2 + 97$ kcal
    (ii) $CO_2 + C \rightarrow 2CO - 39$ kcal
    (iii) $CaCO_3 \rightarrow CaO + CO_2 + 43$ kcal
    (iv) $CaO + SiO_2 \rightarrow CaSiO_3$
    (v) $FeO / Fe2O_3 + CO \rightarrow Fe + CO_2$

    Choice (1)
33. (i) Preparation of water gas
    (ii) Removal of CO
    (iii) Removal of CO_2
    (iv) Removal of water vapour
    (v) Removal of unoxidized CO

    Choice (3)
34. (i) Conversion of nitrates to plant protein.
    (ii) Conversion of plant protein to animal protein.
    (iii) Conversion of animal protein to excretory product.
    (iv) Conversion of excretory product to ammonia.
    (v) Conversion of ammonia to nitrites.
    (vi) Conversion of nitrites to nitrates.

    Choice (4)

35. Epsom salt is $MgSO_4 .7H_2O$

Choice (1)

36. Combustion of carbon takes place in lower region of blast furnace.

$C + O_2 \rightarrow CO_2 + 97$ kcal

Choice (2)

37. $NH_3 + 3Cl_2 \rightarrow NCl_3 + 3HCl$
(excess)

Choice (4)

38. Water gas is a mixture of $CO + H_2$

Choice (1)

39. Wood charcoal is used in the manufacture of deodorant.

Choice (4)

40. NH_3 is used as the raw material for the production of many fertilizers.

Choice (1)

41. Phosphorus is widely used in the match industry.

Choice (3)

42. Limonite, $Fe_2O_3.H_2O$ cannot be concentrated by froth flotation process.

Choice (4)

43. During calcination, the thermal decomposition of an ore takes place, mass becomes porous and moisture is removed.

Choice (4)

44. In diamond each carbon atom is bonded to four other carbon atoms and forming rigid three dimensional structure. Hence it is a good conductor of heat.

Choice (1)

45. Wrought iron is the purest from of iron and its carbon content is the least. Hence it is highly malleable.

Choice (1)

Concept Application Level—2

Key points

1. (i) Change of movement of metal kernels with the increase in temperature.

(ii) Cause for flow of current through metals.

(iii) Changes in energy of metal kernels with temperature.

(iv) Effect of movement of metal kernels in flow of electricity.

(v) Relation between flow of electricity and conductivity.

2. (i) Reactions taking place in blast furnace.

(ii) Quality of iron obtained from blast furnace.

(iii) Composition of iron obtained.

(iv) Effect of components on properties of iron.

3. (i) Reactivity of nitric acid

(ii) Reaction of nitric acid with iron.

(iii) Changes in iron.

(iv) Reactivity of iron.

4. (i) Changes involved on solidification.

(ii) Arrangement of carbon atoms in diamond.

(iii) Conditions required for the preparation of diamond.

(iv) Comparison of volume changes during solidification of iron and copper.

5. (i) Composition and conditions in coal mines.

(ii) Conditions necessary for the formation of diamonds.

(iii) Comparison of conditions in coal mines and conditions necessary for diamond formation.

6. (i) Reaction of H_3PO_4 with mineral phosphate and ammonia.

(ii) Composition of phosphate rock.

(iii) Solubility of the major component of the phosphate rock.

(iv) Reaction between H_3PO_4 and the above component.

(v) Solubility of the product formed.

(v) Reaction between H_3PO_4 and ammonia.

(vi) Soluble nature of the product formed.

7. (i) Electropositivity
   (ii) Ions formed during electrolysis of aqueous salt solution.
   (iii) Fate of ions after formation.
   (iv) Discharge of ions at the respective electrodes.
8. (i) Comparison of products obtained in different conditions.
   (ii) Identification of the products formed in A and B.
   (iii) Comparison of the amount of chlorine reacted with ammonia in A and in B.
   (iv) Balanced chemical equations of the above two reactions.
   (v) Calculation of molar ratio of the reactants in the above reactions.
9. (i) Comparison of structure of white phosphorous and red phosphorous.
   (ii) Comparison of ignition temperature of white phosphorous and red phosphorous.
   (iii) Relating ignition temperature to usage as match sticks.
10. (i) Composition of turpentine.
   (ii) Reaction of chlorine with one of the components of turpentine oil.
   (iii) Product formed in the above reaction.
   (iv) Identification of the constituent of turpentine oil which is responsible for the black sooty flame.
11. (i) Identification of X,Y and salt Z .
   (ii) Effect of heat on Z.
   (iii) Nature of the products formed.
   (iv) Reaction of the gaseous product with X and Y.
   (v) Change in pressure and heat content due to above reactions.
12. (i) Layered structure of graphite.
   (ii) Factors that make graphite act as a lubricant.
   (iii) Conditions in space.
   (iv) Relate conditions in space to factors that help graphite to act as a lubricant.
13. (i) Identification of X and Y.
   (ii) Identification of oxide of X.
   (iii) Comparison of process of bleaching by Y and that by oxide of X
   (iv) Comparison of nature of products.
   (v) Effect of atmospheric oxygen on the products.
14. (i) Reactions associated with energy changes.
   (ii) Change in energy that is involved in the reactions taking place in fusion zone.
   (iii) Effect of this change in energy on the temperature of this zone.
15. (i) Bonds formed in the alloy.
   (ii) Reactivity of phosphorous with metals.
   (iii) Nature of products formed.
   (iv) Effect of these products on the physical properties of the alloy.
16. When iron is exposed to moist air for a long time rust formation takes place, that is iron gets converted to $Fe_2O_3.XH_2O$ and hence iron does not liberate hydrogen gas from dil acids like HCl, H_2SO_4.
17. Wrought iron is the purest form of iron. Its carbon content is least. Hence it is highly malleable. While cast iron has relatively more carbon content along with other impurities. Hence it is less malleable.
18. Charcoal has good adsorbing properties. When charcoal is added, it adsorbs the impurities, and when filtered, the impurities are separated from charcoal.

19. Charcoal is porous in nature and air is present in the pores of charcoal. So in the first case it floats on the water. In the second case, on boiling air escapes from its pores and hence its density becomes more thus, it sinks in the water.

20. The oxide of nitrogen which is a mixed anhydride of its oxy acids is NO_2. The oxy acids are HNO_2 and HNO_3. NO_2 can be obtained from the stable hydride NH_3 by it's reaction with oxygen.

$$4NH_3 + 5O_2 \xrightarrow[900\,^\circ C]{Pt} 4NO + 6H_2O$$

$$2NO + O_2 \rightarrow 2NO_2$$

21. **(a)** P_2O_5 is a solid and is a good desiccant since it can absorb moisture from other substances. However, on absorbing moisture, P_2O_5 forms H_3PO_4 which forms a layer on the surface. As a result of this, its desiccating ability decreases and hence, its use for drying is limited.

(b) P_2O_5 is a strong dehydrating agent and hence removes water molecules from inorganic compounds. H_2SO_4 and HNO_3 are converted into their corresponding anhydrides.

$$2H_2SO_4 + P_4O_{10} \rightarrow 2SO3 + 4HPO3$$

22. Air plays a very important role in keeping the temperature of the earth within a certain range. This happens as a result of a phenomenon known as the green house effect. The CO_2 and water vapour of air are transparent to the visible radiation of the sun that warms the earth's surface during day time. The radiated IR radiation by earth is trapped by water vapour and CO_2 which maintains the temperature even during night time. The heat is trapped which keeps the earth warm even during the night. Had there been no CO_2 in the air, the night would have been abnormally cold and life would not have existed on earth.

23. Anhydrides of sulphurous acid and carbonic acid are SO_2 and CO_2 respectively. They produce milkiness on passing through a solution of $Ca(OH)_2$. When Cl_2 gas is made to react with $Ca(OH)_2$, $CaOCl_2$ (bleaching powder) is formed. Bleaching power on dissociation in water gives $Ca(OH)_2$, HCl and HOCl. Hypochlorous acid being unstable decomposes to HCl and nascent oxygen which is responsible for bleaching action.

$$CaOCl_2 + H_2O \rightarrow Ca(OH)_2 + HCl + HOCl.$$

$$HOCl \rightarrow HCl + [O]$$

24. **(a)** Carbon dioxide comes out with great force through a small nozzle from soda acid fire extinguisher. Sudden expansion of CO_2 takes place which leads to reduction in temperature of the carbon dioxide to a great extent and moisture present in air condenses on the carbon dioxide molecules and appears like fog.

(b) Na, Mg and K metals continue to burn in atmosphere of CO_2. It is due to fact that these active metals get oxidized by CO_2 to form respective oxides.

25. Nonmetal with 7 electrons in its valence shell (M shell) is chlorine. The salt which gives oxygen on thermal decomposition should be an alkali metal chlorate. Nonmetal with 5 electrons in its valence shell (L shell) should be nitrogen and the salt which can give oxygen on decomposition should be nitrate. Alkali metal chlorate gives only pure oxygen gas whereas bivalent that is lead metal nitrate gives a mixture of oxygen and NO_2. Since it is difficult to separate O_2 from this mixture, the first one is a preferred method to get pure O_2 gas.

Concept Application Level—3

Key points

1. (i) Structure.
   (ii) Comparison between type of bonding in metal and diamond.
   (iii) Influence of metallic bond on lustre of metals.
   (iv) Optical phenomenon which helps in shine of diamond.
   (v) Influence of arrangement of carbon atoms in diamond.
2. (i) Compare composition of wrought iron and cast iron.
   (ii) Bonding involved in wrought iron and cast iron.
   (iii) Comparing the directionality of bonds.
   (iv) Effect of bonding on physical properties.
3. (i) Comparison of ignition temperatures.
   (ii) Surface of metals to be soldered.
   (iii) Reactivity of phosphoric acid with rust, impurities.
   (iv) Products formed and nature of products.
4. (i) Identification of the oxy acid of solid non-metal which can exhibit the given oxidation state.
   (ii) Identification of salt formed.
   (iii) Solubility of the salt formed.
   (iv) Products obtained when the salt reacts with H_3PO_4 and H_2SO_4 separately.
   (v) Solubility of the products formed.
   (vi) Comparison of the extent of acidity imparted to the soil by both the products.
5. (i) Composition of coal.
   (ii) Origin of coal.
   (iii) Reactivity of various components of coal when burnt.
   (iv) Product formed by these components.
   (v) Reactivity of these components with water (rain).
6. The reason behind the lustre of metals is the presence of free electrons which undergo excitation and deexcitation in the visible region of spectrum. Iodine being larger atom, electrons can undergo excitation and deexcitation in the visible region, since they experience less nuclear forces of attraction. Graphite in the layer lattice structure has free electrons which can show the same trend. Due to these reasons, these two nonmetals exhibit lustre like metals.
7. In soda water, CO_2 dissolves in water to form carbonic acid which creates an acidic medium in the digestive system and helps in digestion of excess food.
8. Metals like platinum, palladium adsorb hydrogen on their surfaces. When the metal is heated after adsorption, hydrogen gas is expelled. Since other impurities do not get adsorbed, pure hydrogen can be obtained through this process.
9. White paint has lead sulphate in it. As the polluted atmosphere has H_2S, it reduces the lead sulphate to lead sulphide which is black in colour. When these walls are washed with hydrogen peroxide, it acts as an oxidizing agent and converts black lead sulphide to white lead sulphate.

   $PbSO_4 + H_2S \rightarrow PbS + H_2SO_4$

   White Black

   $PbS + 4H_2O_2 \rightarrow PbSO_4 + 4H_2O$

   Black White
10. Thermal conductivity and electrical conductivity of metals are attributed to close packing in metals and the presence of free electrons in the metal lattice respectively. Though diamond and graphite are allotropes of carbon, diamond

is a good thermal conductor due to its rigid three dimensional structure, in which carbon atoms are closely and regularly arranged. Diamond is a not good electrical conductor as there are no free electrons in the structure. Graphite on the other hand has free electrons in the layer lattice structure which makes it a good electrical conductor. Graphite is a bad thermal conductor.