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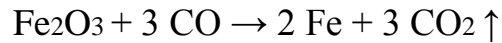
a) **Discuss different reactions in the blast furnace.**

Reactions in the blast furnace

Following chemical reactions take place in different zones of the blast furnace.

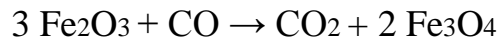
(i) **Zone of reduction** – (300°C to 800°C - i.e. dull red heat)

This is the uppermost zone of the blast furnace. It is called the zone of reduction. Here, the iron oxide from the charge is reduced by carbon monoxide to spongy iron.

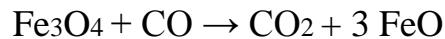


The reduction of Fe_2O_3 actually takes place in following three stages.

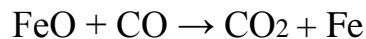
a) Conversion of ferric oxide to ferrous - ferric oxide



b) Conversion of ferrous – ferric oxide to ferrous oxide.



c) Conversion of ferrous oxide to metallic iron.



When the spongy iron falls in the middle region (zone of heat absorption), limestone,

CaCO_3 decomposes to give CaO (lime) and CO_2 . Lime thus obtained acts as a flux.

It combines with silica to form a fusible (meltable) slag.



(ii) **Zone of heat absorption** – (800°C to 1200°C – i.e. bright red heat)

This is the middle part or zone of the blast furnace. In this zone, the ascending CO_2 is reduced to carbon monoxide when it reacts with carbon (coke).



As the reaction is endothermic, the temperature in this region falls and comes in the range 800°C – 1000°C.

(iii) Zone of combustion – (1300°C to 1500°C – i.e. white heat)

This is the zone near the tuyeres . Here the carbon burns to form CO₂ producing tremendous amount of heat. $C + O_2 \rightarrow CO_2 \uparrow + 97 \text{ kcal}$

The heat evolved raises the temperature to 1500°C. As the hot gases go up and meet the descending charge, the temperature falls slowly to about 1300°C.

(iv) Zone of fusion – (1500°C to 1900°C)

In this zone, the spongy iron melts and dissolves some carbon, phosphorus and silica. The molten iron collects at the bottom of the furnace while the fusible slag floats on it and protects the iron from oxidation. The layers of molten iron and slag are withdrawn through separate tapping holes from time to time. The process is economical as it is continuous one. The waste gases containing about 25% CO, 15% CO₂, 56% N₂ and 4% H₂ are let out through the outer pipe. These are burnt with air to produce heat which is used for preheating the air blast passed through the tuyeres. The blast furnace can work day and night for years together. Iron so obtained is known as **Pig Iron**. It is remelted in a vertical furnace (known as cupola) and can be cast or poured into moulds. It is then called **cast iron**. Thus cast iron is obtained after remelting pig iron.

b) Mention the different applications of alumina in modern industry

Alumina can be used in different fields as the following: Furnace components, Catalyst substrates, Electronics substrates, Electrical insulators, Cutting tools, Bearings, Spark Plugs, Arc lamp tubes, Laser hosts, Gem stones, Catalyst pellets, *Alumina coatings*, Oxidation protection of aluminum and aluminum alloys, Capacitors, Transistors, Bioceramics *Alumina fibers*, Thermal insulators, Fire

retardation, Ceramics and glasses, Electrical insulators, Porcelains, Durable glasses.

c) Give the names, composition and uses of any three alloys of iron

Alloy Steels

N	Metal added	Alloy Steel	Composition	Properties	Uses
1	Manganese	Manganese steel	12 to 15 % Mn	Very hard and resistant to wear	For rock crushing machinery, armour plates, rail road tracks
2	Nickel steel	Nickel steel	3.2 % Ni	Increased elasticity and hardness	For making armour plates, cables, automobile parts
3	Chromium	Chromium steel	11.5 % Cr	Resists corrosion	For utensils, cycle and automobile parts
4	Nickel	Invar	36 % Ni	Coefficient of expansion equals that of glass	For clock pendulums and measuring tapes
5	Chromium	Chromium steel	1.5 to 2 % Cr	Extremely hard	For cutting tools and crushing machinery, armour piercing bullets
6	Vanadium and chromium	Chromium – vanadium steel	0.15 %V + 1% Cr	Good tensile strength	For springs, shafts, axles and frames
7	Tungsten	Tungsten steel	14 to 20% W	Extremely hard and strong	For drills and high speed tools
8	Molybdenum	Molybdenum steel	0.3 to 3 % Mo	Retains hardness even at high temperature	For cutting tools and axles

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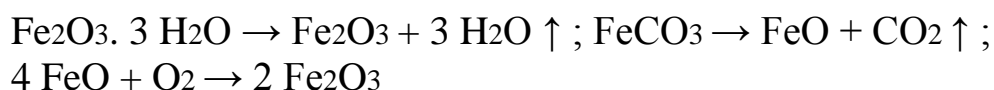
a) **Discuss the steps which used in the manufacture of cast iron.**

Washing and concentration or dressing of the ore

Haematite ore is washed with water. It is subjected to magnetic separation. The ore being magnetic in nature, falls apart as a separate heap. This way the ore becomes rich in oxide of iron. It is then broken into small pieces of 1” to 2” size, screened and shifted. This helps to remove gangue. Due to washing, silicious impurities are removed. The ore is thus concentrated.

(ii) Preliminary roasting and calcinations

The concentrated ore is roasted and calcined with a little coal in shallow kiln (furnace) in excess air. Following changes take place during roasting and calcinations. (i) Moisture escapes as steam and organic matter present burns off to give CO₂ and sulphur and arsenic are oxidized to form their volatile oxides SO₂ and As₂O₃ respectively. (ii) Ferrous oxide is converted to ferric oxide which avoids formation of ferrous silicate in the slag during smelting and (iii) The mass becomes porous and thus makes it more suitable for reduction to metallic iron. Following reactions take place.



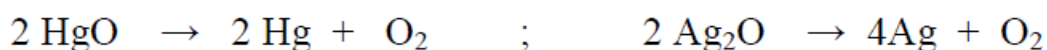
(iii) Reduction or smelting in a Blast Furnace

The roasted and calcined ore (8 parts) is mixed with coke (4 parts) which acts as a reducing agent and limestone (1 part) which acts as a flux. The mixture is introduced in a tall **Blast Furnace**. The blast furnace has two functions (i) to reduce the ore to metallic iron and (ii) to remove the impurities in the form of slag.

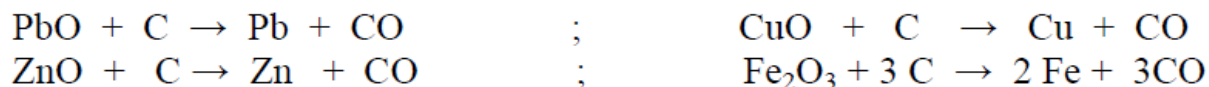
b) Explain the methods which used in reduction of oxides to metals.

One or more of the following methods can be used to obtain a metal from its oxide.

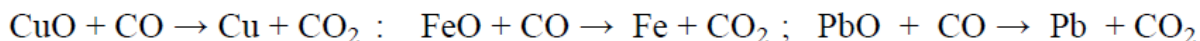
(i) **Heating** - Less reactive metals like silver and mercury can be obtained by heating their oxides alone. These metals are placed at the bottom of the electrochemical series.



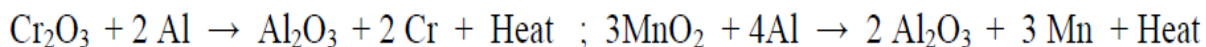
(ii) **Carbon reduction** - Some metals like lead, copper, zinc and iron can be obtained by reducing their oxides by carbon. When the oxides of these metals are heated with coke, the oxides are reduced to a metal. Carbon has more affinity for oxygen than the metals have it for oxygen hence carbon extracts the oxygen leaving behind the free metal.



(iii) Use of **carbon monoxide** - Oxides of metals like PbO, CuO, FeO can be reduced by carbon monoxide at high temperature to give the corresponding metals.



(iv) Use of aluminium - Oxides of metals like ZnO, Cr₂O₃ and MnO₂ cannot be reduced by carbon because these metals have a greater affinity for oxygen than carbon. An active metal like aluminium (in the form of powder) is required to reduce the oxides of these metals. The reduction of a metal oxide by heating with aluminium is called aluminothermy. In this process, lot of heat is evolved and hence the metal may melt in the container. It is tapped from the bottom of the container.



(v) **Electrolysis** - The metals like iron, zinc, lead, chromium, manganese lie in the middle of the electrochemical series. They are somewhat active. So their oxides can be reduced by carbon or carbon monoxide or reactive metals like aluminium or sodium, calcium. But the metals like sodium, magnesium, calcium, aluminium which are placed in the top of the electrochemical series i.e. which are very active, cannot be obtained by the reduction of their oxides by ordinary reducing agents. So they are obtained by passing an electric current through the purified molten ore. An electric current is passed through the molten oxide or chloride of the metal. The metal gets deposited at the cathode from where it is separated.

c) Mention the different applications of iron in our modern life.

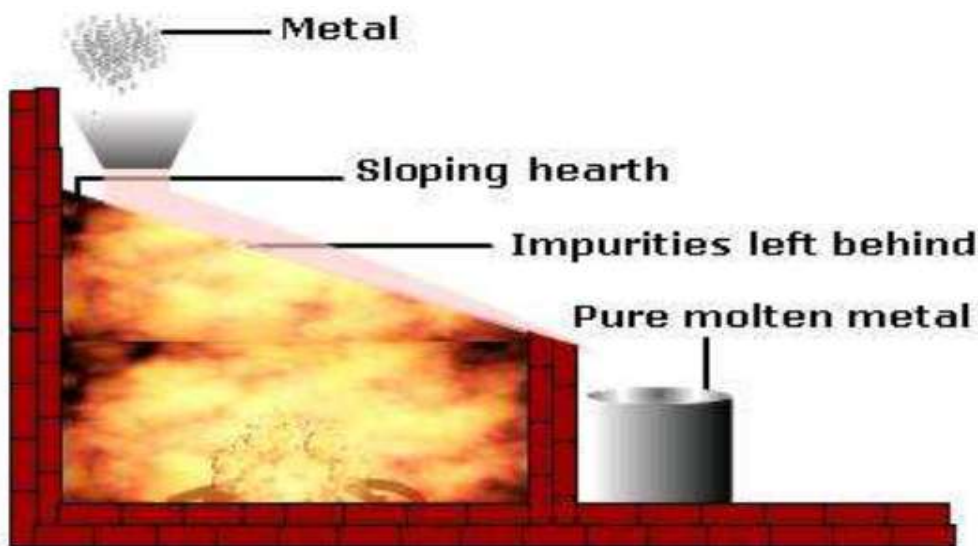
Iron is used in the forms shown below as material of construction for machines, plants, buildings, locomotives, ships, automobiles, railway lines and for many other things. All these forms are obtained from pig iron which is first obtained from the iron ore. White cast iron obtained when molten low silicon, high manganese pig iron is rapidly cooled. Grey pig iron which contains very small amounts of carbon and other impurities but 1.2-3% slag Steel which contain from 0.08 to 0.8% carbon. Major part of cast iron is used to manufacture steel. Cast iron is used for casting metal objects such as pipes, railings, weights, heavier parts of machines etc. Iron is used as material of construction. Hard steel which contain 0.8 to 1.5% carbon. Alloy or special steels which besides carbon contain one or more metals such as Ni, Cr, W, V, Mo, Mn.

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- a) Mention different methods which used in refining of metals with explain **ONLY ONE** method.

Refining of metals:

(i) **Liquation** - It is a technique for separating constituents of an ore, a metal, or an alloy by partial melting. The technique is used when the melting temperature of the metal is lower than that of the impurity and the impurities are not miscible with the metal. Metals like Bi, Sn, Pb, Hg etc. are purified by this technique. The sloping floor of the reverberatory furnace is used to melt the crude metal, when pure metal flows down and impurities are left behind.



Electro-refining - Electro-refining of metals is a process of obtaining pure metal from the impure one by the process of electrolysis.

Process - The process of electro-refining of metals involves the following steps: (i) The electrolyte is usually an aqueous solution of the salt of the metal with some corresponding acid, if necessary. (ii) A thick block of impure metal is made as the

anode. (iii) A thin rod or sheet of pure metal is made as the cathode. (iv) The metal cations being positive, migrate towards the cathode and get discharged. (v) At anode, the atoms of the metal lose electrons, form cations and enter the solution. (vi) The less electropositive impurities in the anode, settle down at the bottom and are removed as anode mud while the more electropositive impurities pass into the solution. (vii) Anode finally disintegrates while the cathode gains in weight due to

Fig.1 - Hydraulic washing

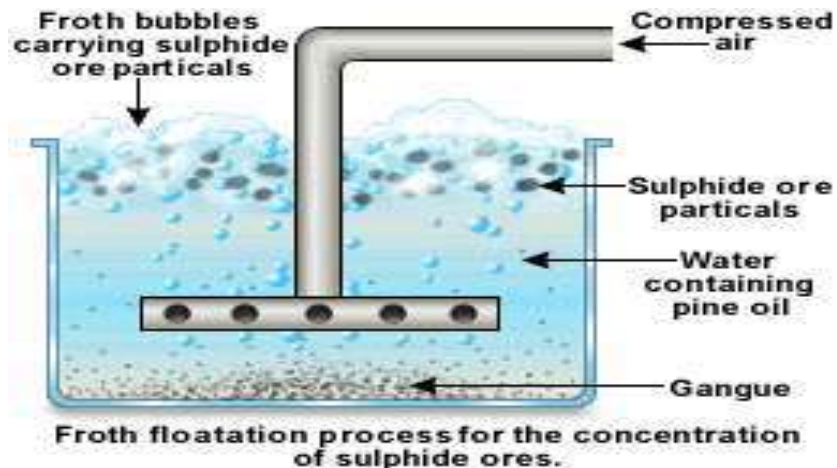
the collection of pure metal. This way pure metal is obtained.

Distillation - Metals like zinc and mercury which boil at low temperature are purified by this method. The impure metal is taken in iron retort and heated strongly above the boiling point of the metal. At the boiling point, vapours of the metal are produced which are led to a condenser. By condensation of the vapours, pure metal is obtained.

) **Hydraulic washing (Gravity separation):** In this process, the ore particles are poured over a hydraulic classifier which is a vibrating inclined table with grooves and a jet of water is allowed to flow over it. The denser ore settles in the grooves while the lighter gangue particles are washed away. This method is used for concentration of heavy oxide ores of lead, tin, iron etc. The hydraulic washing method is shown in the following figure.

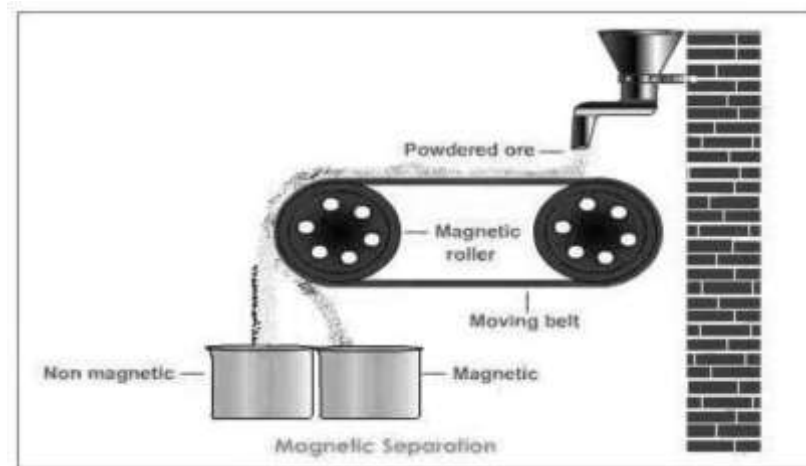


(2) **Froth floatation** - This method is especially used for sulphide ores. The method employs a mixture of water and pine oil which is made to agitate with the ore. A mixture of water, pine oil, detergent and powdered ore is first taken in a tank. A blast of compressed air is blown through the pipe of a rotating agitator to produce froth. The sulphide ore particles are wetted and coated by pine oil and rise up along with the froth (froth being lighter). The gangue particles wetted by water sink to the bottom of the tank (water being heavier). Sulphide being more electronegative attracts the covalent oil molecules. The gangue being less electronegative is attracted by the water. The froth containing the sulphide ore is transferred to another container, washed and dried. Thus sulphide ore is separated from the gangue. The froth floatation process is shown in the following figure.



(3) **Magnetic separation** - Magnetic ores like pyrolusite (MnO_2) and chromite ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$) are enriched by this method by making use of the difference in the magnetic properties of the ore and gangue particles. The powdered ore is dropped on to leather or brass conveyer belt, which moves over two rollers one of which is magnetic. When the ore passes over the magnetic roller, it sticks to the belt due to the force of attraction and falls nearer to magnetic roller. The gangue falls in a normal way under the influence of gravity. The magnetic ore and gangue thus form

two separate heaps. Following figure shows the magnetic separation method.



4-

a) Explain steps which used in the removal of impurities from iron ores.

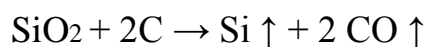
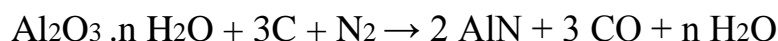
The presence of impurities in the iron ore not only reduce the iron content in the ore but also increase production costs especially with regard to consumption of flux and fuel. If limonite is used, it is first dried before use. When the ore contains large amounts of impurities, appropriate ore dressing operations are carried out on it. When the ore is obtained in small particles, it is sintered into lumps. The main impurities in iron ore are silica and alumina. Silica and alumina in the presence of limestone makes the ore self-fusing with less production costs. At high temperatures of the blast furnace, the flux reacts with alumina and silica to form a complex of calcium-magnesium aluminium silicate known as slag. Sulphur and phosphorus are also found in iron ores as impurities in the form of sulphides (FeS), sulphates (CaSO_4) and phosphates ($\text{Ca}_3(\text{PO}_4)_2$ or $\text{Fe}_3(\text{PO}_4)_2$). Both sulphur and phosphorus, which can also come from the fuel used, are not desired in iron and steel manufacture. Normally steel should not contain more than 0.05% sulphur and

0.05% phosphorus. Sulphur can be removed in the blast furnace slag. Phosphorus cannot be removed in the slag but passes through to the pig iron where it is combined with steel in the convertor. As a result, the ores are sometimes classified as acid or basic ores according to the amount of phosphorus present. Acid ores contain less than 0.05% phosphorus while basic ores has more than 0.05%. A small amount of manganese is generally present in iron ores. Manganese is advantageous for steel production because it reduces the effect of sulphur by forming manganese sulphide (MnS). Sometimes, if manganese is absent from the ores, it is added.

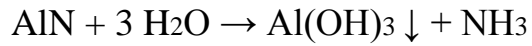
b) Mention the methods which used for purification of bauxite with explain ONLY ONE method.

Bauxite contains iron oxide or silica as major impurity. The bauxite containing iron oxide as major impurity is called **red bauxite** and the bauxite containing silica as major impurity is called **white bauxite**. Iron and silicon both make aluminium metal brittle and liable for corrosion hence they must be eliminated. If bauxite contains iron oxide, Fe₂O₃ as the major impurity, it is purified by Baeyer's process or Hall's process. . If it contains silica , SiO₂ as the major impurity, it is purified by Serpek's process.

(i) **Serpek's process** – This process is used when bauxite ore contains appreciable amount of silica (above 7 %) and low amount of Fe₂O₃ (less than 1 %) .Powdered bauxite is mixed with carbon and heated up to 1800oC in a current of nitrogen. Aluminium from bauxite is converted to aluminium nitride while silica is reduced to silicon.



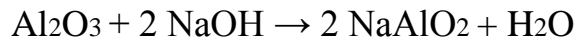
Silicon volatilizes at this temperature. Aluminium nitride is hydrolyzed with hot water. It precipitates aluminium hydroxide.



The precipitate of $\text{Al}(\text{OH})_3$ is washed, dried and ignited at about 1500°C to get pure alumina.

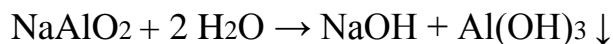


b) **Baeyer's process** – This process is used when bauxite ore contains appreciable amount of Fe_2O_3 (7 to 10 %) and low amount of silica (less than 1 %). The ore is first calcined and then finely ground. It is then digested with a hot and strong solution of caustic soda (45 %) in an autoclave under 80 lb. pressure at 150°C for 2 to 8 hours. At this stage, aluminium oxide dissolves in NaOH to form sodium meta aluminate (NaAlO_2) while ferric oxide and titanium dioxide remain undissolved.. They are then removed by filtration.



Sodium meta aluminate (soluble)

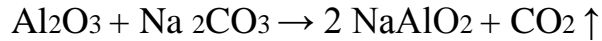
Silica dissolves in the form of silicate. After filtration, sodium meta aluminate solution is diluted with water, slowly cooled and then mixed with a little freshly precipitated aluminium hydroxide which acts as a nucleus for precipitation of aluminium hydroxide.(Alternatively CO_2 can be passed till the solution becomes acidic) It is then digested. Sodium meta aluminate, NaAlO_2 hydrolyses to give precipitate of aluminium hydroxide.



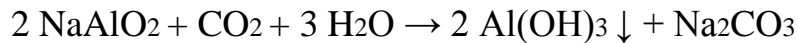
Aluminium hydroxide precipitate is then washed, dried and ignited to get pure alumina (Al_2O_3) .The filtrate containing caustic soda is concentrated and used again.



c) **Hall's process** - This process is used for low grade bauxite ores. In this process, bauxite ore is fused with sodium carbonate, Na_2CO_3 to give water soluble sodium meta aluminate, NaAlO_2 leaving behind Fe_2O_3 and SiO_2 .



The fused mass of sodium meta silicate is extracted with water and filtered. The impurities Fe_2O_3 and SiO_2 remain on the filter paper. The filtrate containing NaAlO_2 is warmed and CO_2 is passed through it, when $\text{Al}(\text{OH})_3$ is precipitated.



The precipitate is filtered, washed and ignited to obtain pure alumina.



5-

a) **Mention the names, compositions of three ores of iron.**

1. Magnetite

Magnetite has a chemical composition of Fe_3O_4 , corresponding to 72.36% iron and 27.64% oxygen; has a color of dark gray to black, and a specific gravity, 5.16 to 5.18. It is strongly magnetic, sometimes possessing polarity so it will act as a natural magnet. The magnetic property of magnetite is important, for it permits exploration by magnetic methods and makes possible the magnetic separation of magnetite from gangue materials to produce a high quality concentrate. Magnetite occurs in igneous, metamorphic, and sedimentary rocks. It has become increasingly important as a source of iron as a consequence of the continued improvements in magnetic concentration techniques and in the expanded use of the high grade products. At times, magnetite contains titanium in small amounts as inclusions of ilmenite. When the titanium content reaches 2–15% or more, the magnetite is termed titaniferous magnetite.

2. Hematite

Hematite has a chemical composition of Fe_2O_3 corresponding to 69.94% iron and 30.06% oxygen, has a color from steel gray to dull red or bright red, can be either earthy, compact or crystalline, and has a specific gravity of 5.26. Common varieties are termed crystalline, specular, martite (pseudomorphic after magnetite), maghemite (magnetic ferric oxide), earthy, ocherous, and compact.

Hematite is one of the most important iron minerals. It has a wide occurrence in many types of rocks and is of varying origins. It occurs associated with vein deposits, igneous, metamorphic, and sedimentary rocks, and as a product of the weathering of magnetite. Some low-grade deposits of disseminated crystalline hematite have been successfully treated by both gravity and flotation techniques to produce high quality concentrates.

3. Hydrous Oxides

Limonite is the name commonly given to hydrous iron oxides that mineralogically are composed of various mixtures of the minerals goethite or lepidocrocite. The chemical formula for goethite is HFeO_2 and that for lepidocrocite is $\text{FeO}(\text{OH})$. Goethite contains 62.85% iron, 27.01% oxygen, and 10.14% water; has a specific gravity in the range of 3.6–4.0, is commonly yellow or brown to nearly black in color, and is compact to earthy and ocherous. In non-technical parlance, the term limonite is used to denote unidentified oxides with a variable moisture content due to absorbed or capillary water. It is a secondary mineral, formed commonly by weathering, and occurs in association with other iron oxides and in sedimentary rocks.

4. Ilmenite

Ilmenite has a chemical composition of FeTiO_3 , corresponding to 36.80% iron, 31.57% titanium, and 31.63% oxygen. This is commonly considered an iron

titanate. Ilmenite is often associated in small amounts with magnetite. Although generally mined as a source of titanium rather than as an ore of iron, iron may be recovered as a byproduct.

5. Siderite

Siderite has a chemical composition of FeCO_3 corresponding to 48.20% iron, 37.99% CO_2 and 13.81% oxygen, a specific gravity of 3.83–3.88, and a color from white to greenish gray and brown. Siderite commonly contains variable amounts of calcium, magnesium or manganese. Siderite varies from dense, fine grained and compact to crystalline. The siderite ores are sometimes termed spathic iron ore or black-band ore. Carbonate ores are commonly calcined before they are charged into the blast furnace. They frequently contain enough lime and magnesite to be self-fluxing.

Table 8.1 Chief Iron Bearing Minerals

Class and Mineralogical Name	Chemical Composition of Pure Mineral	Common Designation
Oxide		
Magnetite	Fe_3O_4	Ferrous-ferric oxide
Hematite	Fe_2O_3	Ferric oxide
Ilmenite	FeTiO_3	Iron-titanium oxide
Limonite	HFeO_2 ^(a) FeO(OH) ^(b)	Hydrous iron oxides
Carbonate		
Siderite	FeCO_3	Iron carbonate

^(a) Goethite
^(b) Lepidocrocite

- c. Leaching - It means washing. In this process, the ore is washed with some suitable reagent (solvent) so that the main metal passes into its salt solution. This solution is separated and subjected to further treatment like precipitation. It is then treated further to recover the metal. This is a chemical method of concentration.

d. Explain the types of ores which used in extraction of metals.

(i) Native ores - These ores contain metals in the Free State. e.g. Ag, Au, Pt, Hg, Cu etc. These are usually found associated with rock or alluvial materials like clay, sand etc. Sometimes, lumps of pure metals are also found in them. These are termed nuggets. Iron is found in Free State as meteorites which also have 20 to 30 nickel.

(ii) Sulphurised and arsenical ores - These ores consist of sulphides and arsenides in simple and complex forms of metals. Some examples of this group are PbS, ZnS, Ag₂S, NiAs, CuFeS₂, 3Ag₂S. Sb₂S₃ etc. (iii) Oxide ores - In these ores, metals are present as their oxides or oxysalts such as carbonates, nitrates, sulphates, phosphates, silicates etc. The examples include Fe₂O₃, Al₂O₃, BeO.Al₂O₃, MnO₂, CaCO₃, FeO.TiO₂, NaNO₃, BaSO₄, Zn₂SiO₄, Ca₃(PO₄)₂ etc. (iv) Halide ores - Metallic halides are very few in nature. Chlorides are more common. The examples include common salt, NaCl, Carnallite, KCl, MgCl₂.6H₂O, Fluospar, CaF₂, Horn silver, AgCl etc.