SAMPLE CONTENT

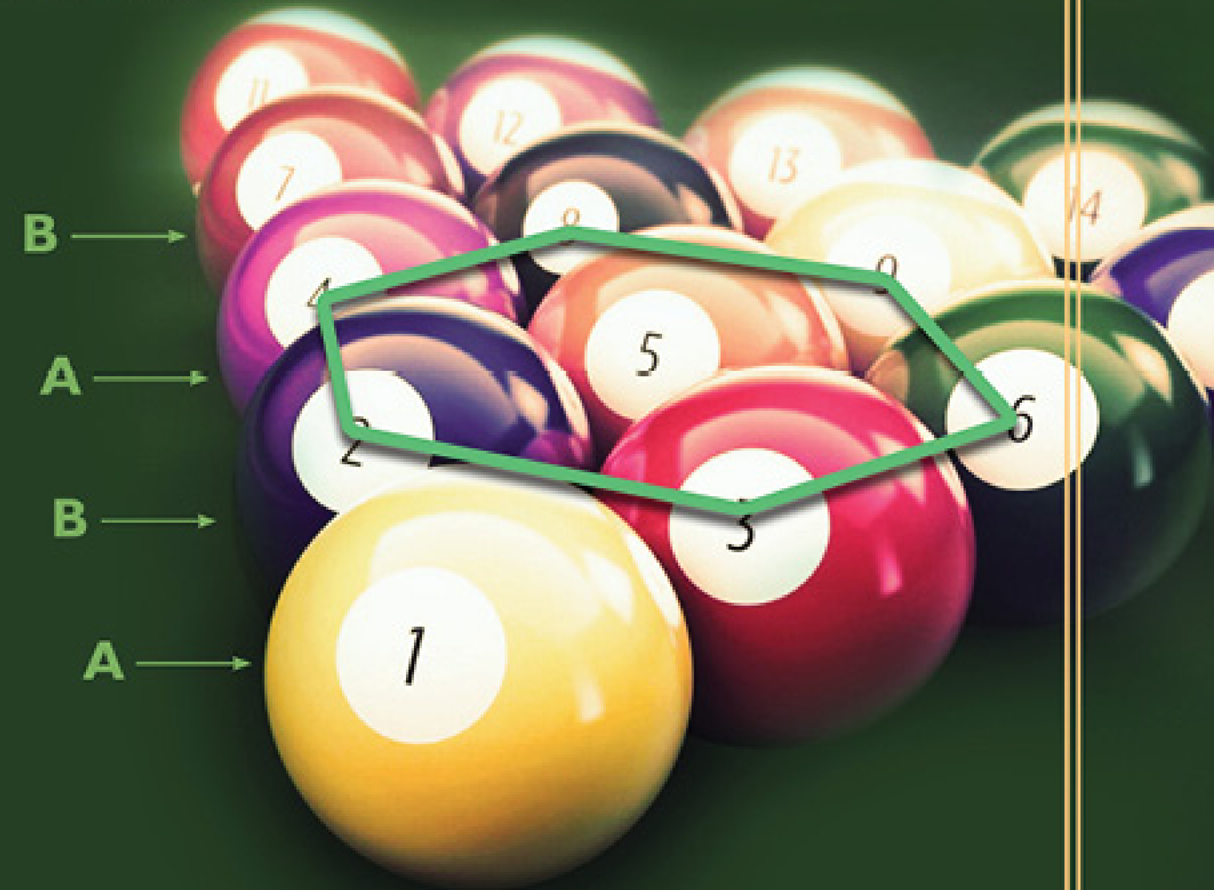
Precise

CHEMISTRY - I

STD. XII Sci.

Packing in solids

The arrangement of pool balls represents two dimensional ABAB type hexagonal close packing in solids.



Target Publications Pvt. Ltd.

Written as per the revised syllabus prescribed by the Maharashtra State Board of Secondary and Higher Secondary Education, Pune.

Precise
Chemistry – I
STD. XII Sci.

Salient Features

- Concise coverage of syllabus in Question Answer Format.
- Covers answers to all Textual Questions, Intext Questions and Numericals.
- Includes solved Board Questions from 2013 to 2018.
- Includes Board Question Papers of 2017 and 2018.
- Quick Review for instant revision and summary of the chapter.
- Exercise, Multiple Choice Questions and Topic Test at the end of each chapter for effective preparation.

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Preface

In the case of good books, the point is not how many of them you can get through, but rather how many can get through to you.

"Std. XII Sci. : PRECISE CHEMISTRY - I" is a compact yet complete guide designed to boost students' confidence and prepare them to face the conspicuous Std. XII final exam.

This book is specifically aimed at Maharashtra Board students. The content of the book is framed in accordance with Maharashtra State board syllabus and collates each and every important concept in question and answer format.

This book has been developed on certain key features as detailed below:

- Sub-topic wise classified **Question and Answer** format of the book provides students with appropriate answers for all textual and intext questions. We've also included few additional questions to ensure complete coverage of every concept.
- **Solved Examples** provide step-wise solution to various numerical problems. This helps students to understand the application of different concepts and formulae. Few selected numericals have also been solved using log-tables to help students with the logarithmic calculations.
- **Solutions to Board Questions** along with marking scheme (wherever relevant) have been included.
- **Notes** cover additional bits of relevant information on each topic.
- **Quick Review** and **Formulae** sections facilitate instant revision at a glance.
- **Exercise** helps the students to gain insight on the various levels of theory and numerical-based questions.
- **Multiple Choice Questions** and **Topic Test** assess the students on their range of preparation and the amount of knowledge of each topic.

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

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A book affects eternity; one can never tell where its influence stops.

Best of luck to all the aspirants!

Yours faithfully,
Publisher

Edition: Second

PAPER PATTERN

- There will be one single paper of 70 Marks in Chemistry.
- Duration of the paper will be 3 hours.

Section A: **(8 Marks)**

This section will contain Multiple Choice Questions and Very Short Answer (VSA) type of questions.

There will be 4 MCQs and 4 VSA type of questions, each carrying one mark.

Students will have to attempt all these questions.

Section B: **(14 Marks)**

This section will contain 7 Short Answer (SA-I) type of questions, each carrying 2 marks.

Internal choice is provided for only one question.

Section C: **(33 Marks)**

This section will contain 11 Short Answer (SA-II) type of questions, each carrying 3 marks.

Internal choice is provided for only one question.

Section D: **(15 Marks)**

This section will contain 3 Long Answer (LA) type of questions, each carrying 5 marks.

Internal choice is provided for each question.

Distribution of Marks According to Type of Questions

Type of Questions		
MCQ	1 Mark each	4 Marks
VSA	1 Mark each	4 Marks
SA I	2 Marks each	14 Marks
SA II	3 Marks each	33 Marks
LA	5 Marks each	15 Marks

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'Chapters 8 to 16 are a part of Std. XII: Precise Chemistry - II'

Note: All the Textual questions are represented by * mark.
All the Intext questions are represented by # mark.

06 General Principles and Processes of Isolation of Elements

Subtopics

6.1 Introduction	6.6 Extraction of iron from haematite
6.2 Concentration	6.7 Extraction of aluminium from bauxite
6.3 Extraction of crude metal from concentrated ore	6.8 Extraction of copper from copper pyrites
6.4 Refining of crude metals	
6.5 Extraction of zinc from zinc blende	

6.1 Introduction

Q.1. Explain the following terms:
i. Mineral ii. Ore *iii. Gangue

Ans: i. Mineral: *A naturally occurring substance obtained by mining which contains the metal in free state or combined state (form) is called* ***mineral.***

eg. Magnesite ($MgCO_3$), Cryolite (Na_3AlF_6), etc.

ii. Ore: *A mineral containing a high percentage of the metal, from which the metal can be profitably extracted is called an* ***ore.***

eg. Haematite (Fe_2O_3), Zinc blende (ZnS), etc.

iii. Gangue: *A sandy, earthy and other unwanted impurities present in the ore are called* ***gangue.***

eg. In the extraction of iron, silica is the gangue present in the haematite ore.

Q.2. Define metallurgy. **[Mar 17]**

Ans: Metallurgy: *The process of extraction of a metal in a pure state from its ore is called* ***metallurgy.***

*[Definition – **1 Mark**]*

Q.3. All the ores are minerals but all the minerals are not ores. Explain with suitable example.

Ans: i. Aluminium occurs in the earth's crust in the form of two minerals, bauxite and China clay.

ii. Out of these two, aluminium can be conveniently and economically extracted from bauxite, while it is not possible to extract aluminium from China clay by some easy and cheap method. Therefore, though both bauxite and China clay are minerals of aluminium, only bauxite is the ore of aluminium.

Thus, it may be concluded that all the ores are minerals but all the minerals are not ores.

Note: Minerals and ores of some metals:

Metal	Minerals		Ore
Iron (Fe)	Haematite Magnetite Limonite Iron pyrites Siderite	(Fe_2O_3) (Fe_3O_4) ($2Fe_2O_3.3H_2O$) (FeS_2) ($FeCO_3$)	Haematite (Fe_2O_3)
Zinc (Zn)	Zinc blende Zincite Calamine Willemite	(ZnS) (ZnO) ($ZnCO_3$) (Zn_2SiO_4)	Zinc blende (ZnS)
Magnesium (Mg)	Dolomite Magnesite Epsom salt	($MgCO_3.CaCO_3$) ($MgCO_3$) ($MgSO_4.7H_2O$)	Dolomite ($MgCO_3.CaCO_3$)

Aluminium (Al)	Bauxite Cryolite China clay Diaspore Corundum	$(Al_2O_3.2H_2O)$ (Na_3AlF_6) $(Al_2O_3.2SiO_2.2H_2O)$ $(Al_2O_3.H_2O)$ (Al_2O_3)	Bauxite $(Al_2O_3.2H_2O)$
Copper (Cu)	Copper pyrites/Chalco pyrites Copper glance Cuprite/Ruby copper Malachite Azurite	$(CuFeS_2)$ (Cu_2S) (Cu_2O) $(Cu(OH)_2.CuCO_3)$ $(Cu(OH)_2.2CuCO_3)$	Copper pyrites $(CuFeS_2)$

Q.4. Write chemical formulae of the following ores: **[Oct 14]**
i. Calamine ii. Haematite iii. Magnetite iv. Corundum

Ans: i. Calamine : $ZnCO_3$ ii. Haematite : Fe_2O_3 iii. Magnetite: Fe_3O_4 iv. Corundum : Al_2O_3

*[Chemical formulae – ½ **Mark each**]*

Q.5. Write the names and chemical formulae of any one ore of iron and zinc each. **[Mar 16]**

Ans: **i. Iron:** Name of the ore: Haematite ***[½ Mark]***
Formula: Fe_2O_3 ***[½ Mark]***
ii. Zinc: Name of the ore: Zinc blende ***[½ Mark]***
Formula: ZnS ***[½ Mark]***

Q.6. Write the names and chemical formulae of any 'two' minerals of aluminium. **[July 17]**

Ans: Minerals of aluminium:

	Name of mineral	Formula
i.	Bauxite	$Al_2O_3.2H_2O$
ii.	Cryolite	Na_3AlF_6

[1 Mark]
[1 Mark]

Q.7. *What is the difference between minerals and ores? **OR**
Differentiate between "minerals" and "ores". **(NCERT)**

Ans:

	Minerals	Ores
i.	*A naturally occurring substance obtained by mining which contains the metal in free state or combined state (form) is called **mineral.***	*A mineral containing a high percentage of the metal, from which the metal can be profitably extracted is called an **ore.***
ii.	All minerals of a metal cannot be its ores.	All ores of a metal are basically its minerals.
eg.	Aluminium occurs in the earth's crust in the form of two chemical substances bauxite $(Al_2O_3.2H_2O)$ and China clay $(Al_2O_3.2SiO_2.2H_2O)$. These are called minerals of aluminium.	Aluminium can be conveniently and economically extracted from bauxite. Therefore, bauxite is an ore of aluminium.

***Q.8. Which are the different methods used in metallurgy?**

Ans: Depending upon the nature of metal and the nature of ore, different methods are used in the extraction process of metals. They are as follows:

i. Pyrometallurgy: *A process in which the ore is reduced to the metal at high temperature using suitable reducing agent like carbon, hydrogen, aluminium, etc., is called **pyrometallurgy.***

ii. Hydrometallurgy: *A process of extracting metals from aqueous solutions of their salts using suitable reducing agents is called **hydrometallurgy.***

iii. Electrometallurgy: *A process of extraction of metals by electrolytic reduction of molten (fused) metallic compounds is called **electrometallurgy.***

***Q.9. Which are the various steps involved in the extraction of pure metals from their ores?** **OR**
Mention the names of various steps involved in the extraction of pure metals from their ores. **[July 17]**

Ans: The various steps involved in the extraction of pure metals from their ores are as follows:

i. Concentration of ores
ii. Conversion of ores into oxides or other desired compounds
iii. Reduction of ores to form crude metals
iv. Refining of metals *[For each step – ½ **Mark**]*

6.2 Concentration

Q.10. What is concentration of an ore? State the factors taken into consideration in concentration process.

Ans: i. *The process of removal of gangue from the ore is called* ***concentration of ore.***

ii. The process of concentration of ore (also known as **dressing or benefaction** of the ore) is mainly carried out to increase the percentage of the desired metal or metal compound in the ore.

iii. Concentration process involves several steps and selection of these steps depends upon the following factors:

a. Differences in physical properties of the compound of the metal present and that of the gangue.

b. The type of metal, the available facilities and the environmental factors.

Q.11. Enlist the different methods used in the benefaction of an ore.

Ans: Benefaction of an ore/ore concentration/ore dressing can be carried out using different methods. These methods include:

i. Gravity separation or hydraulic washing:

a. Gravity separation method is used when the ore particles are heavier than the earthy or rocky gangue particles.

b. When the powdered ore is fed into a stream of running water; due to differences in the specific gravities, heavier ore particles are retained while lighter impurities are washed away.

c. Hydraulic washing can be carried out by the following two methods:

1. Hydraulic washing by using Wilfley table 2. Hydraulic classifier method.

ii. Magnetic separation: The magnetic separation method is based on the differences in magnetic properties of the ore components.

iii. Froth floatation process: This process is based on the principle of difference in the wetting properties of the metallic ore and gangue particles with oil and water respectively.

Q.12. Explain the following:

i. Hydraulic washing by using Wilfley's table. ii. Hydraulic washing by hydraulic classifier method.

Ans: i. Hydraulic washing by using Wilfley's table:

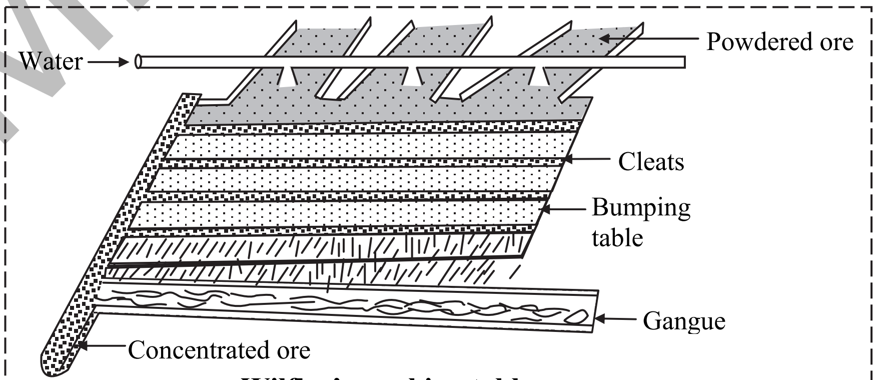
a. Wooden table having a slanting floor and long wooden strips (called **riffles or cleats**) fixed on it is called **Wilfley's table.**

b. The pulverized ore (powdered ore) is fed on the top of Wilfley's table and running stream of water is passed across the table.

c. The table is given a regular rocky motion.

d. The lighter gangue particles are carried away by water and heavy ore particles settle between the wooden cleats or riffles fixed on the table.

e. Heavier ore particles settled behind the riffles move to one side due to rocky motion of table and are collected.



Wilfley's washing table

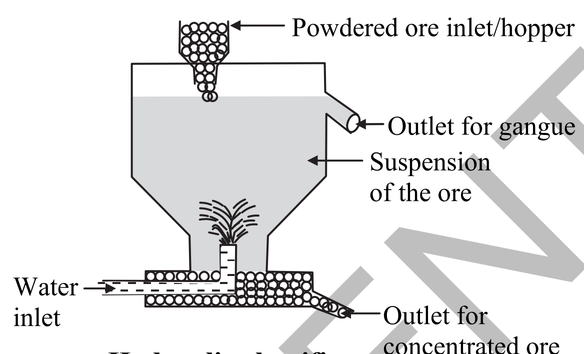
f. Wilfley's table method is used for concentration of native gold ore or ore of tin called **cassiterite (SnO_2).**

ii. Hydraulic washing by hydraulic classifier method:

a. Hydraulic classifier is the large conical reservoir fitted with hopper (ore inlet) at the top and water inlet at the bottom.

b. The reservoir is also provided with one outlet at the top (for the collection of lighter gangue particles) and one outlet at the bottom (for the collection of concentrated ore).

c. The pulverized ore is dropped through hopper and a powerful stream of water is forced through the water inlet at the bottom.



Hydraulic classifier

d. The lighter particles of the gangue are carried up by the current of water and pass out alongwith water flowing out from the outlet near the top. The heavier ore particles get settled at the base of the reservoir.

e. The reservoir is constructed in the conical shape so that the velocity of current of water is reduced, thus preventing ore particles from being carried away along with the stream of water.
eg. Ores of iron, gold, chromium, etc., are concentrated by this method.

Q.13. *Describe the magnetic separation process. OR
Explain magnetic separation process of ores with the help of a neat, labelled diagram. [Mar 17]

Ans: Magnetic separation process:

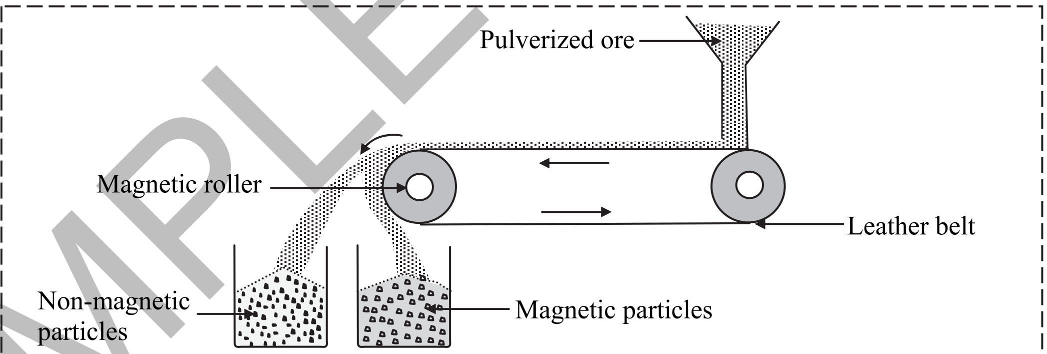
i. The magnetic separation process is based on the differences in magnetic properties of the ore components.

ii. If either ore or the gangue is attracted by a magnet, then the ore can be separated from the impurities with the help of magnetic separation method.

iii. It requires an electromagnetic separator which consists of a brass or leather belt moving over two rollers, one of which is magnetic in nature as shown in the figure.

iv. Powdered ore is dropped over the moving belt at one end.

v. At the other end, the magnetic portion of the ore is attracted by the magnetic roller and falls nearer to the roller, while the non-magnetic impurities fall separately farther off. *[Explanation – **1 Mark**]*



Magnetic separation using electromagnetic separator

*[Diagram + Labelling – **1 Mark**]*

eg. Cassiterite/tin stone (Ore of tin) $\longrightarrow$ SnO_2 (Stannic oxide (Non-magnetic ore particles)) + $FeWO_4$ (Ferrous tungstate (Wolframite)) + $MnWO_4$ (Manganese tungstate)

$\underbrace{FeWO_4 + MnWO_4}_{\text{Magnetic gangue particles}}$

Q.14. Which types of ores can be concentrated by magnetic separation method? Give two examples. (NCERT)

Ans: The ores in which one of the components (either the ore or the impurity) is magnetic in nature can be separated from the non-magnetic components by magnetic separation method.
eg. Haematite (Fe_2O_3), cassiterite (SnO_2).

#Q.15. Identify the ores mentioned below which can be concentrated by magnetic separation method?
Fe_2O_3, $FeCO_3$, ZnS, ZnO, $CuFeS_2$

Ans: The ores which can be concentrated by magnetic separation method are Fe_2O_3, $FeCO_3$, $CuFeS_2$ as they contain Fe as the magnetic component.

***Q.16. Explain the working of froth floatation process.**

Ans: Froth floatation process:

i. The froth floatation process is based on the principle of difference in the wetting properties of the ore and gangue particles with oil and water respectively.

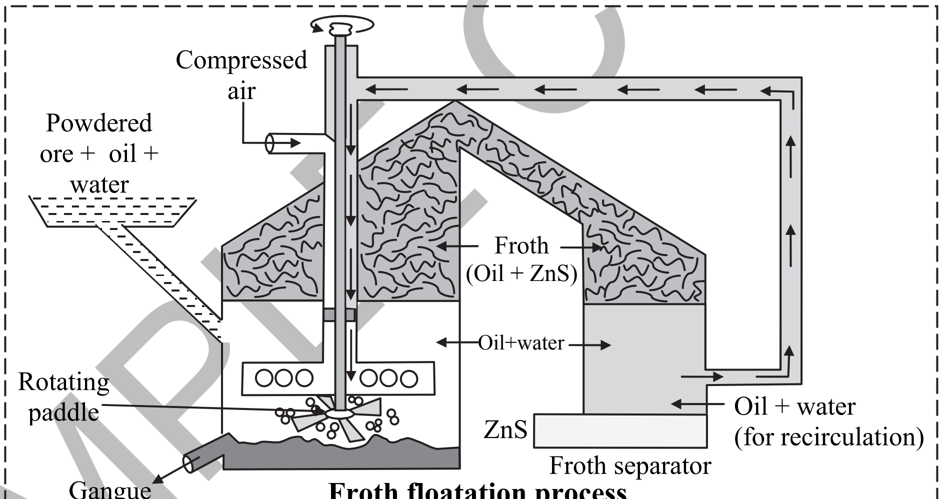
ii. It is used for the extraction of those metals in which the ore particles are preferentially wetted by oil and gangue particles by water.

iii. This method has been used for removing gangue from sulphide ores.
eg. Galena (PbS), zinc blende (ZnS), copper pyrites ($CuFeS_2$), etc.

iv. In this method, a suspension of the powdered ore is made with water. To this suspension small quantities of collectors and froth stabilizers are added. Collectors (**eg.** pine oil, eucalyptus oil, fatty acids, xanthates, etc.) enhance non-wettability of the mineral particles and froth stabilizers (**eg.** cresols, aniline) help in stabilization of the froth.

v. In the floatation tank, a current of compressed air is circulated through the water. A rotating paddle agitates the mixture and draws air into it. As a result, froth is formed which carries the mineral particles. The froth is light and is skimmed off. It is then dried for recovery of the ore particles. The gangue material is wetted by water and settles at the bottom.

vi. Sometimes, it is possible to separate two sulphide ores by adjusting proportion of oil to water or by using **'depressants'**. **eg.** In case of an ore containing ZnS and PbS, the depressant used is NaCN. It selectively prevents ZnS from coming to the froth but allows PbS to come with the froth, which can be further removed off.



Froth floatation process

#Q.17. What is the role of depressant in froth floatation process? **(NCERT)**

Ans: i. The depressants are used to prevent certain types of particles from forming the froth in froth floatation process.

ii. This helps to separate two sulphide ores.
eg. In case of an ore containing zinc sulphide (ZnS) and lead sulphide (PbS), sodium cyanide (NaCN) is used as a depressant.

iii. It forms a layer of zinc complex $Na_2[Zn(CN)_4]$ with ZnS on the surface of ZnS and therefore, prevents it from forming the froth. Therefore, it acts as a depressant.

$$\underset{\text{Zinc sulphide}}{ZnS} + 4NaCN \longrightarrow \underset{\text{Sodium tetracyanozincate (II)}}{Na_2[Zn(CN)_4]} + Na_2S$$

iv. However, NaCN does not prevent PbS from forming the froth and thereby allows it to come along with the froth, which can be further removed off.

#Q.18. Which process is generally preferred for concentration of sulphide ores?

Ans: Froth floatation process is generally preferred for concentration of sulphide ores.

***Q.19. Explain the term leaching.**

Ans: i. ***Leaching*** *is the process of extracting a soluble material from an insoluble solid by dissolving out in a suitable solvent.*

ii. During this process, the powdered ore is treated with certain reagents in which the ore is soluble, but the impurities are not soluble.

iii. The undissolved impurities left behind are removed by filtration.

iv. It is a chemical method of concentration and is mainly useful for concentrating ores of aluminium, silver, gold, etc.

eg. a. Leaching of alumina from bauxite can be done by Baeyer's process or by Hall's process.

b. The ore containing silver and gold is leached with dilute solution of NaCN or KCN in the presence of air.

Q.20. Write a short note on leaching of alumina from bauxite. OR
How can you separate alumina from bauxite ore associated with silica? Give equations if any. (NCERT)

Ans: Leaching of alumina from bauxite:

i. The chief ore of aluminium, bauxite ($Al_2O_3.2H_2O$) contains impurities like silica (SiO_2), iron oxide (Fe_2O_3), titanium oxide (TiO_2), etc.

ii. Converting the ore (Al_2O_3) into soluble $NaAlO_2$ by treating it either with NaOH (Baeyer's Process) or with Na_2CO_3 (Hall's Process), results in the concentration of the ore.

a. Baeyer's process:

1. When ferric oxide is the main impurity present in the bauxite ore, Baeyer's process is used.
2. In this process, the ore is digested in concentrated solution of NaOH to form sodium meta aluminate ($NaAlO_2$) at about 423K in an autoclave.

$$\underset{\substack{\text{Alumina}\\\text{(from pulverized}\\\text{bauxite ore)}}}{Al_2O_3.2H_2O_{(s)}} + 2NaOH_{(aq)} \longrightarrow \underset{\substack{\text{Sodium}\\\text{meta aluminate}\\\text{(soluble)}}}{2NaAlO_{2(aq)}} + 3H_2O_{(l)}$$

3. The solution is filtered to remove insoluble impurities and agitated with freshly prepared $Al(OH)_3$, so that aluminium in $NaAlO_2$ gets precipitated as $Al(OH)_3$.

$$\underset{\substack{\text{Sodium}\\\text{meta aluminate}}}{NaAlO_2} + 2H_2O \longrightarrow NaOH + \underset{\substack{\text{Aluminium}\\\text{hydroxide (ppt)}}}{Al(OH)_3}$$

b. Hall's process:

1. In Hall's process, alumina/aluminium oxide (Al_2O_3) is converted into soluble sodium meta aluminate by fusing it with sodium carbonate. The insoluble part contains the impurities of silica, iron oxide, titanium oxide, etc.

$$\underset{\substack{\text{Alumina}\\\text{(from pulverized}\\\text{bauxite ore)}}}{Al_2O_3.2H_2O_{(s)}} + \underset{\substack{\text{Sodium}\\\text{carbonate}}}{Na_2CO_{3(aq)}} \longrightarrow \underset{\substack{\text{Sodium}\\\text{meta aluminate}\\\text{(soluble)}}}{2NaAlO_{2(aq)}} + \underset{\substack{\text{Carbon}\\\text{dioxide}}}{CO_{2(g)}} + \underset{\text{Water}}{2H_2O_{(l)}}$$

2. The fused mass is treated with water and filtered. The filtrate is warmed (323 K − 333 K) and neutralized by passing carbon dioxide through it, when aluminium hydroxide gets precipitated.

$$\underset{\substack{\text{Sodium}\\\text{meta aluminate}\\\text{(soluble)}}}{2NaAlO_{2(aq)}} + \underset{\text{Water}}{3H_2O_{(l)}} + \underset{\substack{\text{Carbon}\\\text{dioxide}}}{CO_{2(g)}} \xrightarrow{323K-333K} \underset{\substack{\text{Aluminium}\\\text{hydroxide}\\\text{(ppt)}}}{2Al(OH)_{3(s)}} + \underset{\substack{\text{Sodium}\\\text{carbonate}}}{Na_2CO_{3(l)}}$$

iii. The precipitate of aluminium hydroxide obtained in both the processes is washed, dried and ignited (heated) at 1473 K to get pure alumina.

$$\underset{\substack{\text{Aluminium}\\\text{Hydroxide}}}{2Al(OH)_3} \xrightarrow{1473K} \underset{\text{Alumina}}{Al_2O_3} + 3H_2O$$

Q.21. Write the reactions involved in extraction of silver from its ore by leaching process. **[Oct 14]**

Ans: Following are the reactions involved in extraction of silver from its ore by leaching process:

$$\underset{\text{Native silver ore}}{4Ag_{(s)}} + 8CN^-_{(aq)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow \underset{\text{(Soluble complex)}}{4[Ag(CN)_2]^-_{(aq)}} + 4OH^-_{(aq)}$$ ***[1 Mark]***

$$\underset{\text{(Soluble complex)}}{2[Ag(CN)_2]^-_{(aq)}} + Zn_{(s)} \longrightarrow 2Ag_{(s)} + \underset{\text{(Soluble complex)}}{[Zn(CN)_4]^{-2}}$$ ***[1 Mark]***

Q.22. Extraction of Au by leaching with NaCN involves both oxidation and reduction. Justify by giving equations for the reactions involved.

Ans: i. During leaching process, gold (Au) is first oxidised by O_2 of the air to Au^+ which then combines with CN^- ions to form the soluble complex, sodium dicyanoaurate (I).

$$\underset{\text{Native gold ore}}{4Au_{(s)}} + 8NaCN_{(aq)} + O_{2(g)} + 2H_2O_{(l)} \longrightarrow \underset{\substack{\text{Sodium dicyanoaurate (I)}\\ \text{(Soluble complex)}}}{4Na[Au(CN)_2]_{(aq)}} + 4NaOH_{(aq)}$$

ii. Gold is then extracted from this complex by displacement method by using a more electropositive zinc metal. In this reaction, zinc acts as a reducing agent and it reduces Au^+ to Au. Zinc itself gets oxidised to Zn^{2+} ions which combine with CN^- ions to form soluble complex, sodium tetracyanozincate (II).

$$\underset{\substack{\text{Sodium dicyanoaurate (I)}\\ \text{(Soluble complex)}}}{2Na[Au(CN)_2]_{(aq)}} + Zn_{(s)} \longrightarrow 2Au_{(s)} + \underset{\substack{\text{Sodium tetracyanozincate (II)}\\ \text{(Soluble complex)}}}{Na_2[Zn(CN)_4]}$$

iii. The above process of leaching of an ore containing native metal (Au or Ag) is called **Mac Arthur Forest Cyanide process**.

Thus, extraction of gold by leaching with NaCN involves both oxidation and reduction.

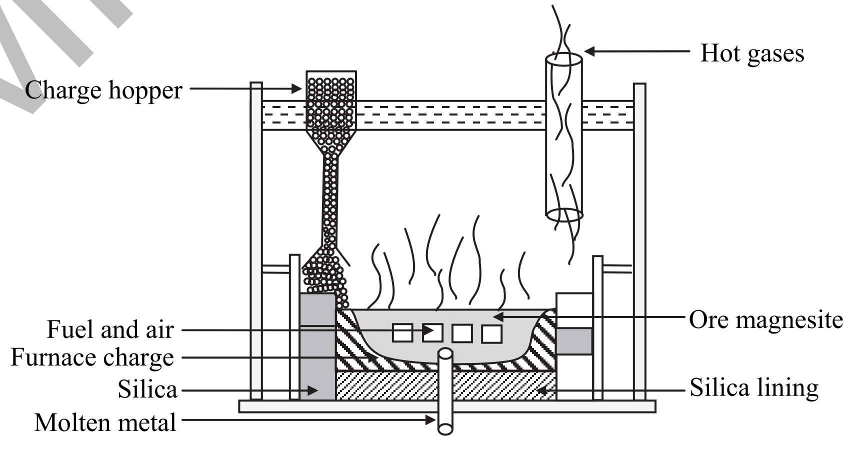
6.3 Extraction of crude metal from concentrated ore

Oxidation (conversion of ores into oxides)

Q.23. *Explain the term roasting. OR
What is roasting? Write examples with reactions.

Ans: i. ***Roasting*** *is a process in which ores are heated to a high temperature below their melting point in the presence of excess of air.*

eg. This process is generally carried out in a reverberatory furnace and is used for the extraction of magnesium from magnesite ore.



A section of reverberatory furnace for extraction of magnesium

ii. During roasting, impurities like sulphur, arsenic and phosphorus are removed as their volatile oxides.

eg. $\underset{\text{Sulphur}}{S} + O_2 \longrightarrow \underset{\text{Sulphur dioxide}}{SO_2\uparrow}$; $\underset{\text{Arsenic}}{4As} + 3O_2 \longrightarrow \underset{\text{Arsenious oxide}}{2As_2O_3\uparrow}$

$\underset{\text{Phosphorus}}{4P} + 5O_2 \longrightarrow \underset{\text{Phosphorus pentoxide}}{2P_2O_5\uparrow}$

Moisture is also removed and the mass becomes porous.

iii. The sulphide ores of the metal are converted into their corresponding metal oxides.

eg. $\underset{\text{Zinc sulphide}}{2ZnS} + 3O_2 \longrightarrow \underset{\text{Zinc oxide}}{2ZnO} + 2SO_2\uparrow$; $\underset{\text{Lead sulphide}}{2PbS} + 3O_2 \longrightarrow \underset{\text{Lead oxide}}{2PbO} + 2SO_2\uparrow$

$\underset{\text{Copper(I) sulphide}}{2Cu_2S} + 3O_2 \longrightarrow \underset{\text{Copper(I) oxide}}{2Cu_2O} + 2SO_2\uparrow$

iv. Sometimes, when the roasting is done at moderate temperature, the oxidation of sulphides takes place only to the sulphate stage.

eg. $\underset{\text{Lead sulphide}}{PbS} + 2O_2 \longrightarrow \underset{\text{Lead sulphate}}{PbSO_4}$; $\underset{\text{Zinc sulphide}}{ZnS} + 2O_2 \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4}$

Note: i. The sulphide ore of copper containing oxide impurities of iron is mixed with silica and then heated in a reverberatory furnace.

ii. Iron oxide forms iron silicate as a slag. Thus, copper is obtained in the form of copper matte which contains Cu_2S and FeS.

$\underset{\text{Ferrous oxide}}{FeO} + SiO_2 \longrightarrow \underset{\text{Iron silicate (slag)}}{FeSiO_3}$

Q.24. *What is calcination? Write examples with reactions. OR
***Explain the term calcination.**

Ans: i. ***Calcination*** *is a process in which the ore is heated to a high temperature below its melting point in the absence of air or in a limited supply of air.*

ii. It is carried out in a reverberatory furnace. During calcination the organic matter, moisture, volatile impurities like carbon dioxide and sulphur dioxide are expelled from the ore which makes the ore porous.

iii. Carbonate ores are decomposed to give metal oxides and carbon dioxide.

eg. $\underset{\text{Zinc carbonate (Calamine ore)}}{ZnCO_{3(s)}} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Zinc oxide}}{ZnO_{(s)}} + CO_{2(g)}$; $\underset{\text{Limestone}}{CaCO_{3(s)}} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Calcium oxide}}{CaO_{(s)}} + CO_{2(g)}$

$\underset{\text{Dolomite}}{CaCO_3.MgCO_{3(s)}} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Calcium oxide}}{CaO_{(s)}} + \underset{\text{Magnesium oxide}}{MgO_{(s)}} + \underset{\text{Carbon dioxide}}{2CO_{2(g)}}$

iv. The hydrated ore loses its water of hydration.

eg. $\underset{\text{Malachite}}{CuCO_3.Cu(OH)_2} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Cupric oxide}}{2CuO} + H_2O + CO_2$

$\underset{\text{Limonite}}{2Fe_2O_3.3H_2O} \xrightarrow[\Delta]{\text{Calcination}} \underset{\text{Ferric oxide}}{2Fe_2O_3} + 3H_2O$

Q.25. Differentiate between roasting and calcination. (NCERT)

Ans:

	Calcination	Roasting
i.	In calcination, the ore is heated to a high temperature below its melting point in the absence of air or in a limited supply of air.	In roasting, the ore is heated to a high temperature below its melting point in the presence of excess of air.
ii.	It is used for carbonates and oxide ores.	It is used for sulphide ores.

iii.	In this, metal carbonates decompose to form their oxides and water of hydration is removed from hydrated oxides.	In this, metal sulphides are oxidised to their oxides or sulphates.
iv.	Generally, CO_2 gas is produced along with metal oxide.	Generally, SO_2 gas is produced along with metal oxide.
eg.	$Fe_2O_3{\cdot}xH_2O_{(s)} \xrightarrow{\text{Heat}} Fe_2O_{3(s)} + xH_2O_{(g)}$ $ZnCO_{3(s)} \xrightarrow{\text{Heat}} ZnO_{(s)} + CO_{2(g)}$ $CaCO_3{\cdot}MgCO_{3(s)} \xrightarrow{\text{Heat}} CaO_{(s)} + MgO_{(s)} + 2CO_{2(g)}$	$2ZnS_{(s)} + 3O_{2(g)} \longrightarrow 2ZnO_{(s)} + 2SO_{2(g)}$ $2Cu_2S_{(s)} + 3O_{2(g)} \longrightarrow 2Cu_2O_{(s)} + 2SO_{2(g)}$ $2PbS_{(s)} + 3O_{2(g)} \longrightarrow 2PbO_{(s)} + 2SO_{2(g)}$

Reduction (reduction of the oxide to the metal)

Q.26. What are the methods used for reduction of ores to form crude metal?

Ans: The methods used for reduction of ores to form crude metal are:
- i. Pyrometallurgy
- ii. Hydrometallurgy
- iii. Electrometallurgy

***Q.27. What is pyrometallurgy?**

Ans: i. ***Pyrometallurgy*** *is a process in which the concentrated ores are reduced to form crude metals at high temperature. (Pyro means high temperature).*

ii. In this process, the ores are reduced to crude metals either by smelting or by heating with reducing agents like carbon, hydrogen, aluminium or other metals.

***Q.28. What is smelting? Explain with an example.**

Ans: i. ***Smelting*** *is the process of extracting the impure molten metal from its ore at a high temperature using suitable flux and a reducing agent like carbon, hydrogen, aluminium, etc.*

ii. Mixture of roasted ore, carbon (in the form of charcoal) or carbon monoxide and flux is heated to a high temperature above the melting point of the metal in a blast furnace. Carbon or carbon monoxide reduce the oxide ore to form free metal.

eg. $\underset{\text{(Cassiterite ore)}}{SnO_2} + 2C \xrightarrow{1473\,K-1573\,K} \underset{\text{Tin}}{Sn} + \underset{\text{Carbon monoxide}}{2CO\uparrow}$ **OR** $\underset{\text{Ferric oxide}}{Fe_2O_3} + 3CO \xrightarrow{823\,K} 2Fe + \underset{\text{Carbon dioxide}}{3CO_2\uparrow}$

iii. The flux combines with the gangue to form easily fusible slag.

eg. In the extraction of iron, limestone is used as a flux. Calcium oxide obtained by the decomposition of limestone combines with silica impurity to give calcium silicate which is a slag.

$$\underset{\text{Calcium oxide}}{CaO} + \underset{\text{Silica}}{SiO_2} \longrightarrow \underset{\text{Calcium silicate (Slag)}}{CaSiO_3}$$

Q.29. What is a flux? Discuss its types and uses in metallurgical operations.

Ans: i. *A* ***flux*** *is a chemical substance added to the concentrated ore during smelting in order to remove the gangue to form easily fusible slag.*

eg. In the extraction of copper from copper pyrites, sand is added as a flux because sand combines with ferrous oxide impurity to form ferrous silicate which is a slag.

$$\underset{\text{Silica (Flux)}}{SiO_2} + \underset{\text{Ferrous oxide (Gangue)}}{FeO} \longrightarrow \underset{\text{Ferrous silicate (Slag)}}{FeSiO_3}$$

ii. The selection of a flux depends on the nature of gangue present in the ore.
A **basic flux** is used to form slag with acidic gangue.
Similarly, an **acidic flux** is used to form slag with basic gangue.

eg. $$\underset{\text{Calcium oxide (Basic flux)}}{CaO} + \underset{\text{Silica (Acidic gangue)}}{SiO_2} \longrightarrow \underset{\text{Calcium silicate (Slag)}}{CaSiO_3}$$

$$\underset{\text{Silica (Acidic flux)}}{SiO_2} + \underset{\text{Ferrous oxide (Basic gangue)}}{FeO} \longrightarrow \underset{\text{Ferrous silicate (Slag)}}{FeSiO_3}$$

***Q.30. Explain the term slag.**

Ans: i. *A **slag** is a waste product formed by combination of a flux and gangue during the extraction of metals by smelting process.*

ii. Slag is a light material and insoluble in molten metal.

iii. It prevents the oxidation of metal by air.

iv. It forms separate layer above the molten metal.

Q.31. Explain hydrometallurgy. OR *What is the meaning of hydrometallurgy?

Ans: i. *A process of extracting metals by converting their ores into aqueous solutions of metal compounds and reduction of these solutions using suitable reducing agents is called **hydrometallurgy.***

ii. This process is used in the extraction of less reactive metals like gold and silver.

iii. In this process, the metal present in the ore is converted to its solution with suitable reagents like water, dilute acids or sodium cyanide solution and it is separated from the solution by adding more reactive metals.

eg. Silver and gold present in their ores are dissolved in 0.5% solution of sodium cyanide in the presence of air. Metals form their cyano complexes which are soluble.

$$4M_{(s)} + 8CN^-_{(aq)} + \underset{\text{Water}}{2H_2O_{(l)}} + \underset{\text{Air}}{O_{2(g)}} \longrightarrow \underset{\text{Soluble complex}}{4[M(CN)_2]^-_{(aq)}} + 4OH^-_{(aq)}$$

(where M = Au or Ag)

The cyanide compound is treated with zinc or magnesium (which are active than Ag or Au) to obtain metal by replacement **(displacement reaction).**

$$\underset{\text{Soluble complex of the metal}}{2[M(CN)_2]^-_{(aq)}} + \underset{\text{Zinc}}{Zn_{(s)}} \longrightarrow \underset{\text{Zinc complex}}{[Zn(CN)_4]^{2-}_{(aq)}} + 2M_{(s)}$$

Q.32. Copper can be extracted by hydrometallurgy but not zinc. Explain. (NCERT)

Ans: i. Basic requirement for the hydrometallurgical extraction of any metal is that it should be easily displaced in the solution by any other metal.

ii. Zinc is more electropositive metal (E° = –0.76 V) as compared to copper (which is less electropositive, E° = + 0.34 V).

iii. Hence, zinc is highly reactive metal and cannot be easily displaced from its solution (like $ZnSO_4$ solution).

iv. On the other hand, copper is readily displaced from its solution (like $CuSO_4$ solution) by some more active metal (like zinc).

$$Zn_{(s)} + Cu^{+2}_{(aq)} \longrightarrow Zn^{+2}_{(aq)} + Cu_{(s)}$$

Thus, copper can be easily extracted by hydrometallurgy but not zinc.

***Q.33. Explain electrometallurgy.**

Ans: i. *A process of extraction of metals by electrolytic reduction of molten (fused) metallic compounds is called **electrometallurgy.***

ii. Ores of highly electropositive metals (like sodium, potassium, magnesium, calcium, aluminium, etc.) cannot be reduced by conventional reducing agents such as carbon, carbon monoxide, hydrogen, etc. Electrometallurgy is employed for the extraction of these metals from their respective ores.

iii. In this method, the metallic compounds such as oxides, hydroxides, halides are electrolyzed in their fused state.

iv. The metal ions are discharged at the cathode.

eg. When molten sodium chloride is electrolyzed in Down's cell, sodium is formed at the cathode and chlorine is liberated at the anode. It involves reduction and oxidation.

$$\underset{\text{(Fused)}}{2NaCl_{(l)}} \xrightarrow{\text{Electrolysis}} 2Na_{(s)} + Cl_{2(g)}$$

Q.34. Explain electrolytic method of extraction of sodium and magnesium.

Ans: Electrolytic method of extraction:

i. Certain highly electropositive metals such as alkali metals of group 1, alkaline earth metals of group 2 and aluminium, etc., are commonly extracted by the electrolysis of their fused salts.

ii. Sodium is extracted from fused sodium chloride by electrolysis as:

$$\underset{\text{(Molten)}}{NaCl} \xrightarrow{\text{ionisation}} Na^+ + Cl^-$$

At cathode: $Na^+ + e^- \longrightarrow Na_{(s)}$

At anode: $Cl^- \longrightarrow Cl + e^-$

$Cl + Cl \longrightarrow Cl_{2(g)}$

The sodium metal is liberated at cathode and collected.

iii. Similarly, magnesium is prepared by the electrolysis of $MgCl_2$.

$$MgCl_2 \xrightarrow{\text{ionisation}} Mg^{2+} + 2Cl^-$$

At cathode: $Mg^{2+} + 2e^- \longrightarrow Mg_{(s)}$

At anode: $2Cl^- \longrightarrow Cl_{2(g)} + 2e^-$

Reduction of metal oxides – Ellingham diagram (Thermodynamic principles of metallurgy)

Q.35. Explain Ellingham diagram.

Ans: i. Ellingham diagram:

The graphical representation showing the variation of Gibbs energy with increase of temperature for the formation of oxide (oxidation) is known as ***Ellingham diagram.*** **OR**

The ***Ellingham diagram*** *is the plot of free energy change ΔG° against temperature for the reaction of a metal and other elements with one mole of gaseous oxygen at 1 atmosphere.*

It was first used by H.J.T. Ellingham.

ii. Features of Ellingham diagram:

The Ellingham diagram for oxides shows the following important features:

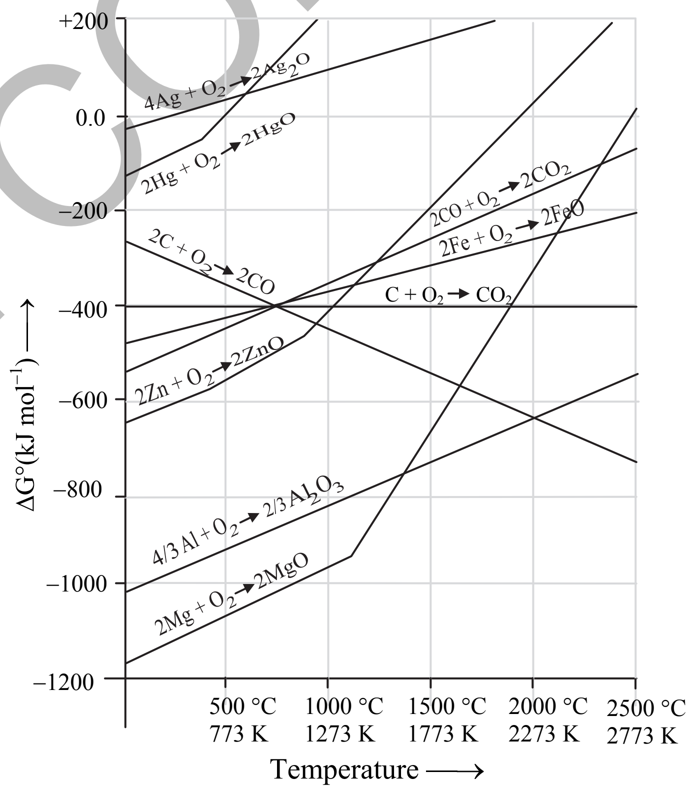
a. The graph for the formation of a metal oxide is a straight line with an upward slope.

b. There is sudden change in the slopes for some metal oxides, like MgO, ZnO and HgO.

c. For a few metal oxides of mercury and silver, the graph is at the upper part in Ellingham diagram (Ag_2O and HgO).

d. The graph for the formation of CO is straight line with the negative slope. This line intersects the lines of many metal oxides.

e. The graph for the formation of CO_2 is straight line almost parallel to the temperature axis.



Ellingham diagram for oxide formation

iii. Significance of Ellingham diagram:

a. The positive slope of metal oxides shows that their stabilities decrease with increase in temperature. The decrease in their stabilities is due to an increase in ΔG° value.

b. The sudden change in the graph shows a phase change that is, change from solid to liquid or from liquid to vapour.

c. The negative slope of CO shows that it becomes more stable with increase in temperature (this is the opposite of that taking place in metal oxides).

d. The relative tendency of the metals to undergo oxidation is in the order, as shown below:
$Mg > Al > Cr > Fe > Hg > Ag$.
This is due to the increase in the negative free energy change of the formation of oxide in the order given below:
$MgO > Al_2O_3 > Cr_2O_3 > FeO > Ag_2O$.

Note: ΔG° values of HgO and Ag_2O are positive even at low temperature. The graph of formation of oxides of silver and mercury is at the upper part of the Ellingham diagram. This indicates that Ag_2O and HgO are unstable and can be decomposed at moderate temperatures (by heating at 600 K and 700 K respectively).

***Q.36. i. What are the features of Ellingham diagram?**
ii. What is its significance?

Ans: i. *Refer Q.35.ii.*
ii. *Refer Q.35.iii.*

***Q.37. Explain how ΔG° varies with temperature in the reaction $2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$.**

Ans: The graph for the formation of CO is straight line with negative slope. The negative slope of CO indicates that the value of ΔG° becomes more negative on increasing the temperature. Therefore, it becomes more stable with increase in temperature.

#Q.38. What is the minimum temperature for reduction of MgO by carbon?

Ans: i. Below 1800 °C, in the Ellingham diagram, standard free energy change ΔG° is more negative for the formation of MgO than ΔG° for oxidation of carbon (C) to CO.
ii. Above 1800 °C, in the Ellingham diagram, the line of graph of ΔG° against absolute temperature for C to CO crosses the graph of the formation of MgO.
iii. Since, above 1800 °C, ΔG° for the formation of CO is more negative than for the formation of MgO, the minimum temperature required for the reduction of MgO by carbon is 1800 °C.

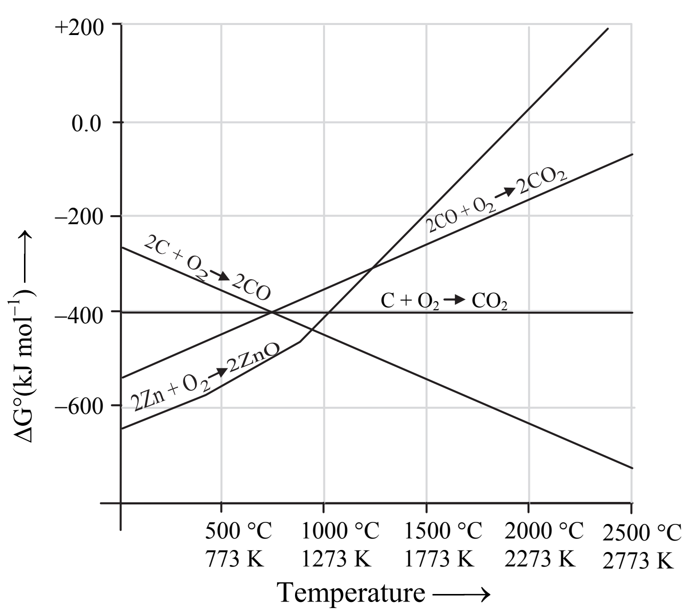
$$\underset{\text{Magnesium oxide}}{MgO_{(s)}} + C_{(s)} \longrightarrow Mg_{(s)} + \underset{\text{Carbon monoxide}}{CO_{(g)}}$$

***Q.39. Using an Ellingham diagram, indicate the lowest temperature at which ZnO can be reduced to zinc metal by carbon. Write the overall reaction at this temperature.**

Ans: i. From the Ellingham diagram, the standard free energy change ΔG° for the formation of CO (by combustion of carbon) is lesser than the ΔG° for the formation of ZnO at about 1000 K. Hence, the lowest temperature at which ZnO can be reduced to zinc metal by carbon is at about 1000 K.

ii. The overall reaction at this temperature is as follows:

$$\underset{\text{Zinc oxide}}{ZnO_{(s)}} + \underset{\text{Carbon}}{C_{(s)}} \xrightarrow{\sim 1000\,K} \underset{\text{Zinc metal}}{Zn_{(s)}} + \underset{\text{Carbon monoxide}}{CO_{(g)}}\uparrow$$



Ellingham diagram for oxide formation

Q.40. Predict conditions under which Al might be expected to reduce MgO. OR
Is it true that under certain conditions, Mg can reduce Al_2O_3 and Al can reduce MgO? What are those conditions? (NCERT)

Ans: i. In the Ellingham diagram, ΔG° versus T plot for $2Mg + O_2 \longrightarrow 2MgO$ and $4/3Al + O_2 \longrightarrow 2/3Al_2O_3$ intersects at around temperature corresponding to 1623 K.

ii. Thus below 1623 K, magnesium reduces aluminium oxide whereas above 1623 K, aluminium reduces magnesium oxide. However, the latter is difficult as there are practical difficulties to attain higher temperatures.

Q.41. The value of $\Delta_fG°$ for formation of Cr_2O_3 is – 540 kJ mol^{-1} and that of Al_2O_3 is – 827 kJ mol^{-1}. Is reduction of Cr_2O_3 possible with Al? (NCERT)

Ans: The two equations are:

i. $\frac{4}{3}Al_{(s)} + O_{2(g)} \longrightarrow \frac{2}{3}Al_2O_{3(s)}$, $\Delta_f G^o_{(Al,Al_2O_3)} = -827 \text{ kJ mol}^{-1}$ ….(1)

ii. $\frac{4}{3}Cr_{(s)} + O_{2(g)} \longrightarrow \frac{2}{3}Cr_2O_{3(s)}$, $\Delta_f G^o_{(Cr,Cr_2O_3)} = -540 \text{ kJ mol}^{-1}$ ….(2)

Subtracting equation (2) from equation (1), we get

$$\frac{4}{3}Al_{(s)} + \frac{2}{3}Cr_2O_{3(s)} \longrightarrow \frac{2}{3}Al_2O_{3(s)} + \frac{4}{3}Cr_{(s)}, \quad \Delta_fG° = -287 \text{ kJ mol}^{-1}$$

Since, $\Delta_fG°$ for the combined reaction is –ve, therefore, the above reaction, i.e., reduction of Cr_2O_3 by Al is possible.

Q.42. *At 673 K, which is the better reducing agent carbon or carbon monoxide? OR
Out of C and CO, which is a better reducing agent at 673 K? (NCERT)

Ans: i. In the Ellingham diagram, ΔG° versus T line for $2CO + O_2 \longrightarrow 2CO_2$ at 673 K is lower than that of $2C + O_2 \longrightarrow 2CO$ line.

ii. Therefore, between C and CO, CO can be used as a better reducing agent at 673 K.

6.4 Refining of crude metals

Q.43. Define refining.

Ans: *The purification of crude metals by removing metallic and non-metallic impurities is known as* ***refining of metals****.*

Q.44. Why refining of crude metals is important? Enlist different methods of refining.

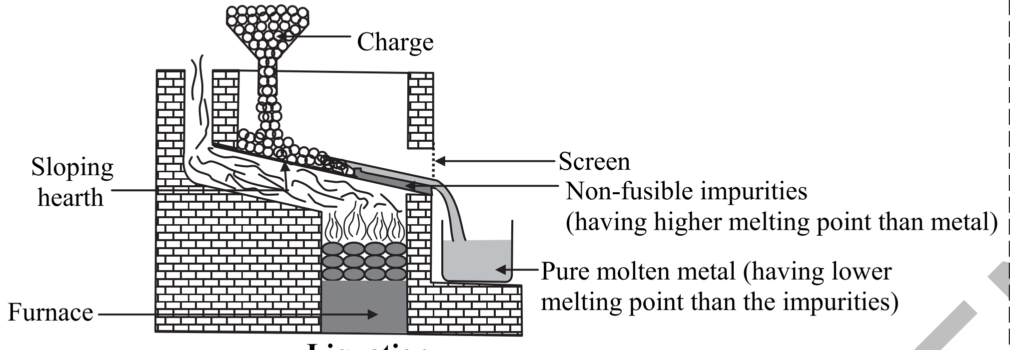
Ans: i. Refining of crude metals is an important step in the metallurgy and it is carried out in order to remove impurities like unreacted (unreduced) metal oxides, other metals, non-metals and gases from crude metals (which are obtained after smelting or any other method).

ii. Refining can be carried out by using different methods which are as follows:
   a. Liquation process
   b. Polling
   c. Electrolytic refining
   d. Zone refining
   e. Vapour phase refining
   f. Van Arkel method (for refining Zr or Ti)
   g. Chromatography.

Q.45. Explain liquation process for refining of crude metals.

Ans: Liquation process for refining of crude metals:

i. In the liquation process, the low melting metal forms fusible liquid on heating and flows down.
ii. This method is employed when the impurity has higher melting point than the required metal.
iii. The impure metal is placed on the sloping hearth of the reverberatory furnace and is heated in the absence of air slightly above the melting point of the metal.
iv. The metal melts and flows down leaving the non-fusible impurities (called dross) on the hearth.
v. The pure metal is collected at the bottom of the sloping hearth in a receiver.

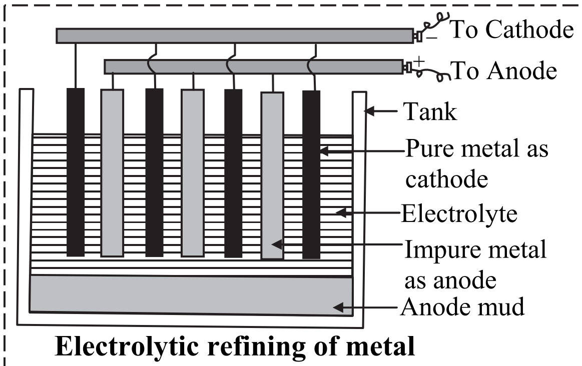


Liquation

eg. a. Metals like bismuth (m.p. of Bi: 544.3 K), lead (m.p. of Pb: 600.4 K), mercury (m.p. of Hg: 234.6 K), etc., are separated from their crude form by liquation.
b. The pure tin metal (m.p. of Sn: 504.8 K) obtained by this method is called pig tin.

***Q.46. What is polling?**
Ans: Polling:
i. Polling is a method of refining crude metals. In this method, the impure metal is melted and stirred with green logs of wood.
ii. The hydrocarbon gases liberated (due to the heat of molten metal) from freshly cut green logs/poles of wood reduce the metal oxide into metal.
iii. This method is generally employed in the purification of copper or tin which contain oxide impurities.
eg. Molten impure copper is 98% pure. When it is stirred with green poles of wood, the hydrocarbon gases thus released, reduce cuprous oxide to copper which is about 99.5% pure. Its further purification is done by electrolytic refining.

Q.47. Describe the process of electrolytic refining of metals.
Ans: Electrolytic refining:
i. This is the most general method for the refining of metals and is based upon the phenomenon of electrolysis. In this method, the impure metal is made to act as an anode while a strip/thin sheet of the same metal in pure form is used as cathode.
ii. Both anode and cathode are placed in a suitable electrolytic bath containing soluble salt of the same metal.
iii. On passing current, metal ions from the electrolyte are deposited at the cathode in the form of pure metal while equivalent amount of metal dissolves from the anode into the electrolyte in the form of metal ions.
iv. The impurities like more reactive metals dissolve in the solution. Less reactive metals are insoluble and form anode mud at the bottom.
v. The reaction occurring at the electrodes are:
At cathode: $M^{n+} + ne^- \longrightarrow M$
At anode: $M \longrightarrow M^{n+} + ne^-$
vi. Metals like Cu, Ag, Ni, Al and Zn are refined by this method and 99.9% pure metal is obtained.

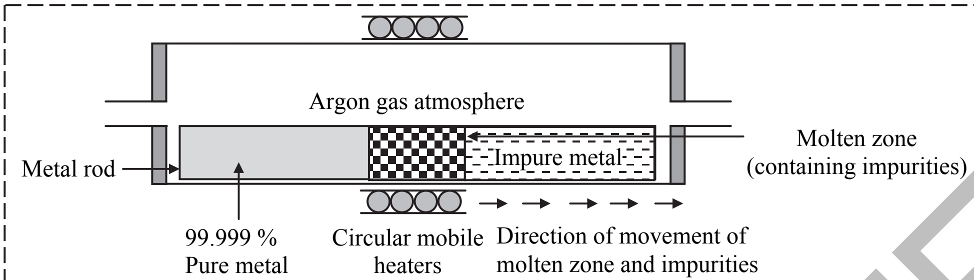


Electrolytic refining of metal

Q.48. *How is zone refining process used to obtain ultra pure metals? OR
Explain zone refining. (NCERT)
Ans: Zone refining/Fractional crystallization:
i. **Principle:** Impurities are more soluble in the molten state than in the solid state of the metal.
ii. In this method, the impure metal is cast into a thin bar and circular mobile heater or high frequency induction furnace is fixed at one of its end. The molten zone moves along with the heater which is moved forward. The heating is done in an inert atmosphere like argon, to prevent oxidation of the metal.
iii. As the heater moves forward, the pure metal crystallizes out of the melt and the impurities pass on into the adjacent molten zone.

iv. The process is repeated in the same direction until purity of 99.999% is achieved. The end of the metal bar, where the impurities get concentrated is cut off, thus obtaining completely pure metal.

v. This method is especially useful for producing semi-conductors of very high purity. Thus, ultra pure metals and non-metals are obtained by zone refining.



Zone refining of metals

eg. Elements like germanium, silicon, gallium and indium which are used as semi-conductors are refined by this process.

Q.49. Explain the basic principle in vapour phase refining.

Ans: Vapour phase refining:

i. In this method, the metal is converted into its volatile compound and collected elsewhere. It is then decomposed to give pure metal.

ii. So, the two requirements are:
   a. the metal should form a volatile compound with an available reagent.
   b. the volatile compound should be easily decomposable, so that the recovery of metal is easy.

iii. Following are some of the methods of vapour phase refining:

a. Mond process for refining nickel:

1. In this process, nickel is heated in a stream of carbon monoxide forming a volatile complex, nickel tetracarbonyl.

$$\underset{\text{(Impure)}}{Ni} + 4CO \xrightarrow{330-350\,K} \underset{\substack{\text{Nickel tetracarbonyl}\\ \text{(Volatile)}}}{Ni(CO)_4}$$

2. The nickel carbonyl complex is subjected to higher temperature so that it is decomposed giving the pure metal.

$$Ni(CO)_4 \xrightarrow{450-470\,K} \underset{\text{(Pure)}}{Ni} + 4CO$$

b. Van Arkel method for refining zirconium or titanium:

1. In this method, oxygen and nitrogen present in the impure form of metals like Zr or Ti are completely removed.
2. The impure metal is heated in a vessel with little iodine to form iodide of metal, which is covalent and thus volatizes.
3. This method is used for the purification of metals like titanium and zirconium, but it is quite expensive method.

eg. The volatile iodide of the corresponding metal (formed after treatment of impure metal with iodine) is electrically heated using tungsten filament above 1700 K. The pure metal gets deposited on the filament and as the deposition goes on, the current is steadily raised to maintain the temperature.

i. $$\underset{\substack{\text{Impure}\\ \text{titanium}}}{Ti_{(s)}} + \underset{\text{Iodine}}{2I_{2(g)}} \xrightarrow{523\,K} \underset{\substack{\text{Volatile}\\ \text{iodide of}\\ \text{titanium}}}{TiI_{4(g)}} \xrightarrow{1700\,K} \underset{\substack{\text{Pure}\\ \text{titanium}}}{Ti_{(s)}} + \underset{\text{Iodine}}{2I_{2(g)}}$$

ii. $$\underset{\substack{\text{Impure}\\ \text{zirconium}}}{Zr_{(s)}} + \underset{\text{Iodine}}{2I_{2(g)}} \xrightarrow{870\,K} \underset{\substack{\text{Volatile}\\ \text{iodide of}\\ \text{zirconium}}}{ZrI_{4(g)}} \xrightarrow{2075\,K} \underset{\substack{\text{Pure}\\ \text{zirconium}}}{Zr_{(s)}} + \underset{\text{Iodine}}{2I_{2(g)}}$$

Q.50. Write a short note on chromatography.

Ans: i. Chromatography is a modern, versatile and wide spread technique, which is based on the principle of selective adsorption of the components of a mixture between the two phases, moving phase and stationary phase.

ii. **Principle:** Different components of a mixture gets adsorbed on an adsorbent at different levels, depending upon their different rates of adsorption.

iii. Depending upon the physical states of stationary and mobile phase and also on the process of passage of mobile phase, the chromatographic techniques are named such as gas chromatography, thin layer chromatography (TLC), paper chromatography, etc. In column chromatography, normally liquid is used as a moving phase and solid as a stationary phase.

iv. Due to different rates of adsorption of mixture components, separate bands are formed in the column. The component which is adsorbed strongly forms the band at the top of the column while the components with decreasing orders of adsorbabilities are held up at different zones down the column.

v. After the separation, the different adsorbed components are extracted/recovered from the adsorbent by the passage of a series of eluants (solvents) and the process is called as **elution.**

vi. The weakly adsorbed component will be eluted more rapidly than a more strongly adsorbed component and they are collected in the form of different fractions in separate containers.

6.5 Extraction of zinc from zinc blende

Q.51. How does zinc occur in nature? OR
Write a short note on occurrence of zinc.

Ans: Occurrence of zinc:

i. Being a reactive metal, zinc does not occur in native form, but always occurs in the combined state.

ii. Zinc occurs in the earth's crust upto the extent of 132 ppm by weight.

iii. The important minerals of zinc are:

a.	Zinc blende	ZnS	b.	Zincite	ZnO
c.	Calamine	$ZnCO_3$	d.	Willemite	Zn_2SiO_4
e.	Franklinite	$ZnO.Fe_2O_3$			

iv. In India, zinc is found at Zawar mines in Udaipur (Rajasthan) and in Kashmir in the form of zinc blende. Zinc blende (the most abundant ore of zinc) is also found in other countries like Mexico, USA, Australia, Germany, England, Canada, Burma, Belgium, etc.

Q.52. What are the steps involved in the extraction of zinc from zinc blende?

Ans: Extraction of zinc from zinc blende involves following steps:

i. Concentration
ii. Roasting
iii. Reduction of zinc oxide (smelting)
iv. Electrolytic refining of zinc (purification).

***Q.53. How is zinc extracted from zinc blende?**

Ans: Extraction of zinc metal from zinc blende involves the following steps:

i. Concentration: Zinc blende ore (after being freed from superficial rocky material and other minerals) is crushed to fine particles. The ore is concentrated either by gravity separation or by froth floatation process or by electromagnetic separation.

a. Concentration by gravity separation: The powdered ore is washed with powerful stream of water. The lighter gangue impurity particles are washed away and the heavier ore particles remain behind.

b. Concentration by electromagnetic separation: The impurities of iron oxide which is magnetic in nature are separated from zinc blende by magnetic separation.

c. Froth floatation:

1. In concentrating zinc blende, the important step which is carried out is froth floatation process.
2. In this process, pulverized zinc blende ore is treated with pine oil in a large tank.
3. A current of compressed air is passed through the oily mixture and it is simultaneously stirred by using a stirrer. This process leads to the formation of froth.
4. Sulphide particles wetted by pine oil rise to the surface of tank (in the form of foam) and thus, getting separated from other earthy impurities (which on the other hand are wetted by water and settle down at the bottom of the tank).

ii. Roasting:

a. The concentrated zinc sulphide ore is then roasted at about 1200 K, in the presence of excess of air in a reverberatory furnace.

$$\underset{\text{Zinc sulphide}}{2ZnS} + 3O_2 \xrightarrow[\Delta]{1200\text{ K}} \underset{\text{Zinc oxide}}{2ZnO} + 2SO_{2(g)}\uparrow$$

b. In the roasting process, $ZnSO_4$ may get formed as follows:

$$\underset{\text{Zinc sulphide}}{ZnS} + 2O_2 \xrightarrow[1200\text{ K}]{\Delta} \underset{\text{Zinc sulphate}}{ZnSO_4}$$

c. In order to decompose this $ZnSO_4$, care is taken to complete the roasting at 1200 K.

$$\underset{\text{Zinc sulphate}}{2ZnSO_4} \xrightarrow[\Delta]{1200\text{ K}} \underset{\text{Zinc oxide}}{2ZnO} + 2SO_2 + O_2\uparrow$$

iii. Smelting (reduction by modern vertical retort process):

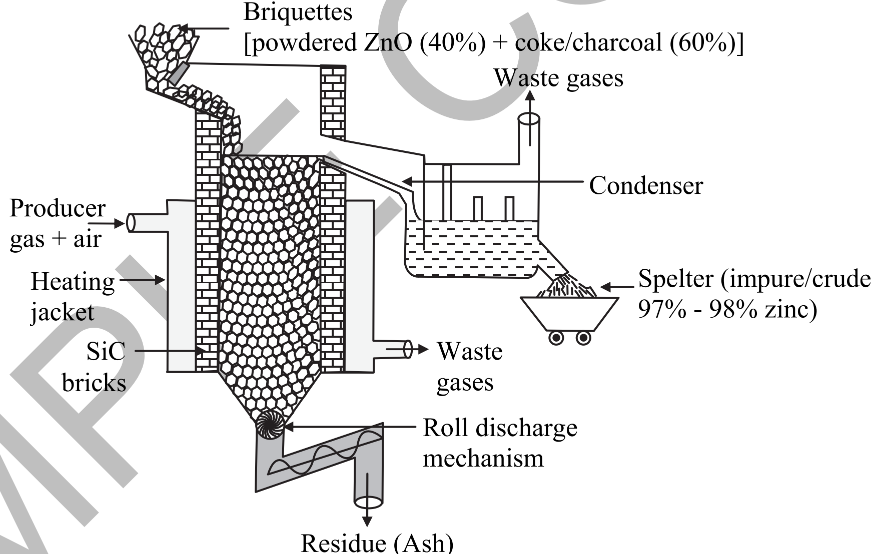
a. In this process, rectangular shaped vertical retort made up of refractory silicon carbide (SiC) bricks which withstand high temperature is used.

b. Small briquettes made up of powdered ZnO (40%) and charcoal/coke (60%) are fed into vertical retort and it is then placed in a heating jacket.

c. The heating jacket is heated to about 1673 K by burning a mixture of carbon monoxide (CO) and nitrogen (N_2) (producer gas) as a fuel. At this temperature, carbon reduces zinc oxide to zinc.

$$\underset{\text{Zinc oxide}}{ZnO} + C \xrightarrow[1673\text{ K}]{\Delta} Zn + \underset{\text{Carbon monoxide}}{CO}$$

d. Fresh charge may be added from the top of the retort and waste residue is continuously removed from the bottom with the help of automatic discharge mechanism (roll discharge mechanism).



Vertical retort process for the reduction of ZnO to Zn metal

e. Zinc formed after reduction reaches the top of the retort, vaporizes and condenses in condenser to form molten zinc. Molten zinc on cooling solidifies into the zinc spelter (crude zinc or impure zinc) which contains 97% to 98% of zinc alongwith impurities like cadmium, lead, iron, etc. Spelter is then further purified by electrolysis method.

f. The modern process is commercial, economical and gives continuous yield of 95% to 99%.

iv. Purification by electrolytic refining:

a. Electrolysis is carried out using an electrolytic cell consisting of aluminium cathode and lead anode at a voltage of 3.5 V.

b. The electrolyte used in this cell is a $ZnSO_4$ solution (obtained by dissolving spelter in dil. H_2SO_4) containing about 3% free H_2SO_4.

c. On passing electric current, pure zinc is deposited on aluminium cathode.

Q.54. Write chemical reactions taking place in the extraction of zinc from zinc blende. **(NCERT)**

Ans: i. **Roasting in air (oxidation):** The concentrated zinc blende ore (ZnS) is roasted in the presence of excess air at about 1200 K to convert it to zinc oxide.

$$\underset{\text{Zinc blende}}{2ZnS} + 3O_2 \xrightarrow[1200\,K]{\Delta} \underset{\text{Zinc oxide}}{2ZnO} + 2SO_{2(g)}\uparrow$$

ii. **Reduction:** Zinc oxide is reduced to zinc by heating with crushed coke at 1673 K.

$$\underset{\text{Zinc oxide}}{ZnO} + C \xrightarrow[1673\,K]{\Delta} Zn + \underset{\text{Carbon monoxide}}{CO_{(g)}}$$

iii. **Purification by electrolytic refining:** The impure zinc is refined by electrolytic refining method. In this method, aluminium cathode and lead anode are taken in an electrolytic bath containing zinc sulphate and a small amount of dilute H_2SO_4. Electrolysis is carried out at a voltage of 3.5 V and pure zinc is deposited on the aluminium cathode.

At anode: $Zn \longrightarrow Zn^{2+} + 2e^-$ (Oxidation)

At cathode: $Zn^{2+} + 2e^- \longrightarrow Zn$ (Reduction)

6.6 Extraction of iron from haematite

Q.55. Write a short note on occurrence of iron. OR How does iron occur in nature?

Ans: i. Iron is the fourth abundant element (6.2% by mass) in the earth's crust. Iron and nickel are the main two constituents of earth's inner core.

ii. Being a reactive metal, iron does not occur in the free state but occurs in the combined state as oxides, carbonates and sulphides.

iii. The common ores of iron are:

a. Haematite, Fe_2O_3 (red oxide of iron)
b. Magnetite, Fe_3O_4 (magnetic oxide of iron)
c. Limonite, $2Fe_2O_3.3H_2O$ (hydrated oxide of iron)
d. Iron pyrites, FeS_2
e. Siderite, $FeCO_3$.

iv. Large deposits of iron ore are found in Karnataka near Kuduremukha in Chikkamangalur district and near Hospet in Bellary district.

v. Iron is also present in living matter, as an essential constituent of haemoglobin (in blood).

Q.56. Mention the commercial forms of iron.

Ans: There are three commercial forms of iron namely:

i. **Cast iron or pig iron:** Cast iron/pig iron is a hard and brittle form of iron containing 4% C.

ii. **Wrought iron:** Wrought iron is a soft form of iron containing very little carbon (less than 0.2%). It is the purest form of iron.

iii. **Steel:** Steel is a form of iron containing 0.2 to 2% carbon. It is neither too brittle nor too soft. The mechanical properties of steel can be altered to obtain alloy steels, by the addition of alloying elements such as Mn, Cr and Ni.

***Q.57. How is iron extracted from haematite?**

Ans: Extraction of iron (mostly from haematite ore) is carried out in blast furnace.

i. **Blast furnace:**

a. A blast furnace is made of steel and is about 25 m in height.

b. Its diameter varies between 5 m to 10 m and its inner lining is made of refractory bricks/fire bricks which can withstand high temperature.

c. The three parts in the blast furnace are:

1. the hearth 2. the bosh and 3. the stack.

d. The blast furnace is narrow at the top and has cup and cone arrangement for the introduction of the charge and outlet for waste gases. The cone enables the uniform distribution of charge and the cup prevents the loss of gases during the charging process.

e. The base of the furnace is provided with:
   1. tuyers through which blast of hot air is introduced in the furnace.
   2. a tapping hole for withdrawing molten iron.
   3. outlet for the slag.

f. Blast furnace works on a counter current principle; that is the charge comes down and the hot gases passes up the tower.

g. **Principle:** In blast furnace, iron oxide (from haematite) is reduced to iron metal by C (from coke) and CO (formed by oxidation of coke). Limestone acts as a flux and combines with the SiO_2, Al_2O_3 and phosphates (gangue) to form molten slag.

ii. Extraction of iron involves the following steps:

a. Concentration: The haematite ore is crushed to small pieces of about 1 inch in size with the help of jaw crushers. It is then concentrated by gravity separation process in which it is washed with water to remove lighter gangue particles.

b. Roasting: The concentrated ore is heated in a current of air during which following reactions take place:

1. Impurities like sulphur, phosphorus and arsenic escapes as their volatile oxides.

$$\underset{\text{Sulphur}}{S} + O_2 \longrightarrow \underset{\text{Sulphur dioxide}}{SO_2\uparrow} \quad ; \quad \underset{\text{Arsenic}}{4As} + 3O_2 \longrightarrow \underset{\text{Arsenic oxide}}{2As_2O_3\uparrow}$$

$$\underset{\text{Phosphorus}}{P_4} + 5O_2 \longrightarrow \underset{\text{Phosphorus pentoxide}}{P_4O_{10}\uparrow}$$

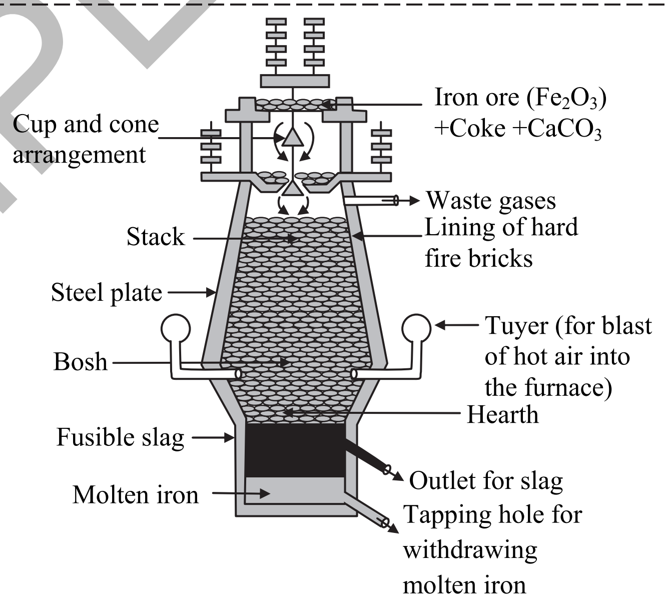
2. Any ferrous oxide present in the ore is converted to ferric oxide.

$$\underset{\text{Ferrous oxide}}{4FeO} + O_2 \longrightarrow \underset{\text{Ferric oxide}}{2Fe_2O_3}$$

3. The roasted ore is then converted into small lumps by sintering. The entire mass becomes porous which helps in the reduction process at a later stage.

c. Smelting (Reduction):

1. The charge consisting of roasted ore, coke and limestone in the approximate ratio of 12 : 5 : 3 is introduced in the blast furnace from the top through cup and cone arrangement.
2. At the same time, a blast of hot air (pre-heated at about 1000 K) is blown upwards from the tuyers.



Blast furnace for the manufacture of cast iron

3. The added coke serves as both fuel as well as reducing agent while limestone serves as a flux. It may be noted that at the bottom of the furnace, the reducing agent is carbon itself, but at the top part of the furnace, the reducing agent is carbon monoxide.

Q.58. *Write reactions involved at different temperatures in the blast furnace. OR
Write down the reactions taking place in different zones in the blast furnace during the extraction of iron. (NCERT)

Ans: Three main chemical reactions take place at different zones in the blast furnace.

i. Zone of combustion (5 m – 10 m height from the bottom):

a. Coke reacts with the hot air blown through tuyers and forms carbon monoxide. The reaction is highly exothermic and the temperature raises to around 2000 K.

$$\underset{\text{(from coke)}}{C} + \underset{\text{(from the blast of hot air)}}{\frac{1}{2}O_2} \xrightarrow{2000\,K} \underset{\text{Carbon monoxide}}{CO}, \quad \Delta H = -220 \text{ kJ}$$

b. A part of carbon monoxide dissociates to give finely divided carbon.

$$\underset{\text{Carbon monoxide}}{2CO} \xrightarrow{2000\,K} \underset{\text{Oxygen}}{O_2} + \underset{\text{Carbon (Finely divided)}}{2C}$$

c. Carbon monoxide rises up the furnace and heats up the descending charge and also reacts with it.

ii. Zone of reduction (22 m – 25 m height from the bottom):

a. Carbon monoxide reduces ferric oxide to spongy iron (porous solid) at about 900 K.

$$\underset{\text{Ferric oxide}}{Fe_2O_3} + 3CO \xrightarrow{900\,K} 2Fe + \underset{\text{Carbon dioxide}}{3CO_2}$$

b. A small amount of ferric oxide is also reduced to iron by carbon.

$$\underset{\text{Ferric oxide}}{Fe_2O_3} + 3C \xrightarrow{1500\,K} 2Fe + \underset{\text{Carbon monoxide}}{3CO}$$

iii. Zone of slag formation (20 m height from the bottom):

a. Limestone acting as a flux, decomposes to give calcium oxide (quick lime) at about 1200 K.

$$\underset{\text{Limestone}}{CaCO_3} \xrightarrow{1200\,K} \underset{\text{Calcium oxide}}{CaO} + \underset{\text{Carbon dioxide}}{CO_2}$$

b. Calcium oxide combines with silica and alumina at about 1500 K to form molten slag of calcium silicate and calcium aluminate.

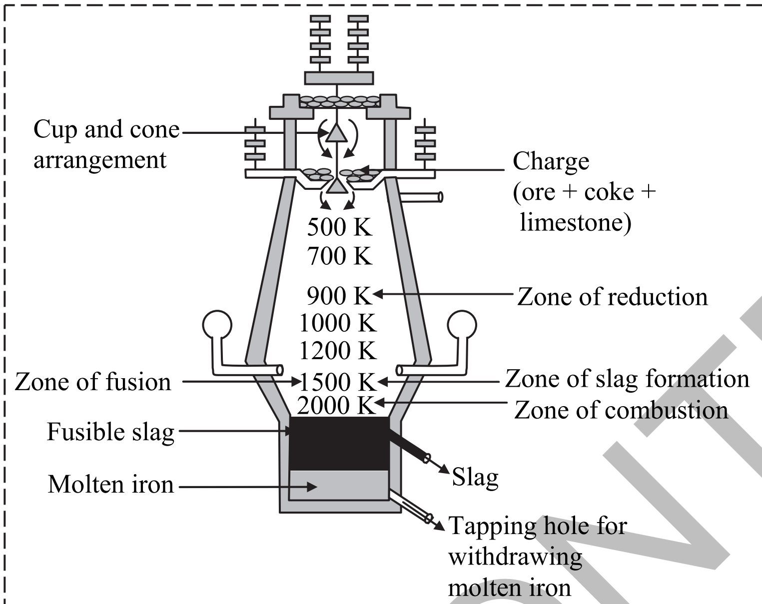
$$\underset{\text{Calcium oxide}}{CaO} + SiO_2 \xrightarrow{1500\,K} \underset{\text{Calcium silicate (slag)}}{CaSiO_3}$$

$$\underset{\text{Calcium oxide}}{12CaO} + 2Al_2O_3 \xrightarrow{1500\,K} \underset{\text{Calcium aluminate (slag)}}{4Ca_3AlO_3} + 3O_2$$

iv. Zone of fusion (15 m height from the bottom):

a. Mn, P and Si are formed as a result of reduction of MnO_2, $Ca_3(PO_4)_2$ and part of SiO_2 respectively.
b. The spongy iron descending from the top of the furnace melts and absorbs the impurities like C, Si, Mn, P and S. It then gets collected at the bottom of the furnace.
c. Molten iron and molten slag (floating on the surface of molten iron) are removed through separate outlets.
d. Pig iron/cast iron containing 4% carbon is obtained in the form of solid blocks of iron (referred as pigs) which are nothing but molten iron cooled in moulds.

e. Hot waste gases (N_2, CO, CO_2) escaping through the outlet at the top of the furnace are used for pre-heating the blast of air.



Temperature zones in blast furnace

Note: i. The various changes taking place in the blast furnace as the temperature gradually increases (temperature gradient) are summarized as follows:

	Temperature	Change taking place	Equation
Hot gases	500 K	Ore loses moisture	
	900 K	Reduction of ore by CO	$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
	1200 K	Limestone decomposes	$CaCO_3 \rightarrow CaO + CO_2$
	1500 K	Reduction of ore by C	$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$
	1500 K	Fusion of iron and slag formation	$CaO + SiO_2 \rightarrow CaSiO_3$
	2000 K	Combustion of coke	$2C + O_2 \rightarrow 2CO$

ii. Cast iron/pig iron is hard and brittle and cannot be welded or tempered. It is used in the manufacture of casted material and certain automobile parts.

#Q.59. Name the principal gangue associated with haematite.

Ans: Principal gangue associated with haematite are silica (SiO_2), alumina (Al_2O_3) and phosphates.

#Q.60. Which is the effective reducing agent in the extraction of iron from haematite?

Ans: Carbon monoxide is the effective reducing agent in the extraction of iron from haematite.

#Q.61. Why is carbon monoxide a better reducing agent than carbon for the reduction of haematite at lower temperature?

Ans: i. Both carbon and carbon monoxide acts as a good reducing agents because both can undergo oxidation as follows:

a. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ (ΔS becomes zero and ΔG° remain constant with increase in temperature)

b. $2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$ (ΔS increases and ΔG° decreases with increase in temperature)

c. $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$ (ΔS decreases and ΔG° increases with increase in temperature)

ii. From the Ellingham diagram, it can be inferred that carbon can reduce metal oxide at high temperature and itself get oxidised to CO. But practically some metals react with carbon at high temperature and form carbides.

iii. At low temperature, the oxidation of carbon monoxide is more favourable due to decrease in free energy (i.e., ΔG° for oxidation of CO becomes more negative than ΔG° for formation of Fe_2O_3.) Hence, for the reduction of haematite (Fe_2O_3) at low temperature, carbon monoxide acts as a better reducing agent.

#Q.62. Suggest a flux for the removal of silica gangue.

Ans: i. Since silica, SiO_2 is an acidic gangue, basic flux can be used to remove it as slag.

ii. Limestone is used as a flux for the removal of silica gangue.

iii. Limestone decomposes to give calcium oxide (quick lime) at about 1200 K.

$$\underset{\substack{\text{Limestone}\\\text{(Basic flux)}}}{CaCO_3} \longrightarrow \underset{\substack{\text{Calcium oxide}\\\text{(quick lime)}}}{CaO} + CO_2$$

iv. Calcium oxide combines with silica at about 1500 K to form molten slag of calcium silicate.

$$\underset{\substack{\text{Calcium}\\\text{oxide}}}{CaO} + \underset{\substack{\text{Silica}\\\text{(Acidic}\\\text{gangue)}}}{SiO_2} \longrightarrow \underset{\substack{\text{Calcium silicate}\\\text{(slag)}}}{CaSiO_3}$$

***Q.63. Why is permanganate not a suitable oxidizing agent for quantitative estimation of Fe^{2+} in the presence of HCl?**

Ans: i. Fe^{2+} can be estimated quantitatively by titrating against a standard solution of $KMnO_4$ in acidic medium. For acidic medium, aqueous H_2SO_4 solution is used. The redox reaction occurring is:

$$5Fe^{2+}_{(aq)} + MnO^{-}_{4(aq)} + 8H^{+}_{(aq)} \longrightarrow 5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}$$

ii. If HCl solution is used instead of H_2SO_4 solution, then it is necessary to consider the standard reduction potentials of the following two half reduction reactions:

a. $MnO^{-}_{4(aq)} + 8H^{+}_{(aq)} + 5e^{-} \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$, $E^{o}_{red} = 1.51$ V

b. $\frac{1}{2}Cl_{2(g)} + e^{-} \longrightarrow Cl^{-}_{(aq)}$, $E^{o}_{red} = 1.40$ V

iii. The reduction potential of Fe^{3+} is

$Fe^{3+}_{(aq)} + e^{-} \longrightarrow Fe^{2+}_{(aq)}$, $E^{o}_{red} = 0.77$ V

iv. The standard reduction potentials of Cl_2 / Cl^{-} and Fe^{2+}/Fe^{3+} couples are less than that for MnO^{-}_{4}. Hence, both HCl and Fe^{2+} will be oxidised by permanganate solution.

v. The redox reaction in the presence of HCl is,

$$10Fe^{2+}_{(aq)} + 4MnO^{-}_{4(aq)} + 10HCl_{(aq)} + 22H^{+}_{(aq)} \longrightarrow 10Fe^{3+}_{(aq)} + 4Mn^{2+}_{(aq)} + 5Cl_{2(g)} + 16H_2O_{(l)}$$

Therefore, Fe^{2+} cannot be estimated quantitatively by permanganate in the presence of HCl.

***Q.64. What are the different furnaces used for extraction of metals?**

Ans: The different types of furnaces used for extraction of metals are:

i. Reverberatory furnace
ii. Blast furnace

6.7 Extraction of aluminium from bauxite

Q.65. Explain the occurrence of aluminium.

Ans: Occurrence of aluminium:

i. Aluminium is third most abundant element after oxygen and silicon and the most abundant metal found in earth's crust.

ii. It does not occur in the free state in nature.

iii. Its main ores are:

a. Bauxite, $Al_2O_3.2H_2O$
b. Cryolite, Na_3AlF_6
c. Diaspore, $Al_2O_3.H_2O$
d. Corundum, Al_2O_3

iv. Aluminium oxides with other oxides as impurities are occasionally found as corundum, ruby, sapphire, topaz, turquoise, etc., which are valuable precious stones.

***Q.66. What are the steps involved in the extraction of aluminium from bauxite?**

Ans: Extraction of aluminium involves the following steps:

i. Purification of bauxite
ii. Electrolysis of fused alumina (Hall and Heroult's process)
iii. Refining of aluminium.

Q.67. How is bauxite purified depending upon the nature of impurities in it?

Ans: Depending upon the nature of impurities, bauxite can be purified by any of the following three processes:

- **i. Baeyer's process:** This process is used for red variety of bauxite containing iron oxide as the chief impurity.
- **ii. Hall's process:** This process is also used for red bauxite.
- **iii. Serpeck's process:** This process is used for purification of white bauxite which contains silica as the chief impurity.

Q.68. What is the significance of leaching in the extraction of aluminium? (NCERT)

Ans:
- i. The principal ore of aluminium is bauxite (Al_2O_3) and it contains the impurities such as silica, iron oxides and titanium oxide.
- ii. In the extraction of aluminium from bauxite, the significance of leaching (which is a chemical concentration method) is to remove the impurities from the ore.

Q.69. Explain Hall's process or dry process for purifying bauxite.

Ans:
- i. In this process, bauxite is fused with sodium carbonate in the presence of little lime when alumina dissolves as sodium-meta-aluminate.
- ii. The fused mass is extracted with water and filtered to remove impurities.
- iii. The clear filtrate is heated to 323–333 K and a stream of CO_2 is passed when $Al(OH)_3$ gets precipitated.
- iv. The precipitate is filtered, washed and ignited at 1473 K to get pure alumina.

$$\underset{\text{Bauxite}}{Al_2O_3.2H_2O} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + CO_2 + 2H_2O$$

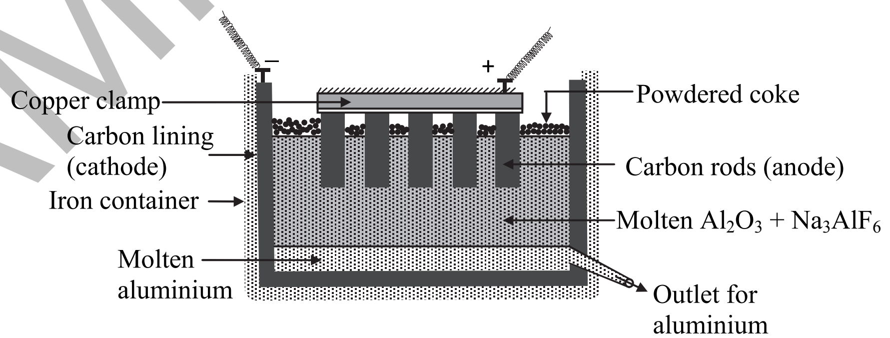
$$\underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2O + CO_2 \xrightarrow{323-333\text{K}} 2Al(OH)_3 + Na_2CO_3$$

$$\underset{\text{Aluminium hydroxide (ppt.)}}{2Al(OH)_3} \xrightarrow{1473\text{K}} \underset{\text{(Alumina)}}{Al_2O_3} + 3H_2O$$

Q.70. Explain the electrolytic method for the extraction of aluminium.

Ans: The electrolytic method for the extraction of aluminium (Hall and Heroult's process):

- i. Fused mixture of alumina 2–8%, synthetic cryolite, Na_3AlF_6 (80–85%), AlF_3(5–7%) and fluorspar, CaF_2 (5–7%) is subjected to electrolysis in an iron tank having a lining of carbon (which acts as cathode) and the temperature is maintained between 1150 K–1225 K.
- ii. The anode comprises of a number of carbon rods which are dipped in the fused electrolyte. The molten electrolyte is covered with the layer of powdered coke to prevent oxidation and loss of heat due to radiation.
- iii. The synthetic cryolite and fluorspar added in the mixture lowers the fusion temperature of alumina to around 1140 K and also increases its electrical conductivity.



Electrolytic cell for the extraction of aluminium

- iv. The overall reaction is as follows:

$$\underset{\text{Alumina}}{2Al_2O_3} + 3C \longrightarrow \underset{\text{Aluminium (Purified)}}{4Al} + 3CO_2$$

Following reduction and oxidation reactions take place at cathode and anode respectively:

$\underset{\text{Cryolite}}{Na_3AlF_6} \rightleftharpoons \underset{\text{Sodium fluoride}}{3NaF} + AlF_3$

$AlF_3 \rightleftharpoons Al^{3+} + 3F^-$

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

At anode: $F^- \longrightarrow F + e^-$ (Oxidation)

$\underset{\text{Alumina}}{2Al_2O_3} + 6F_2 \longrightarrow \underset{\text{Aluminium trifluoride}}{4AlF_3} + 3O_2$

$2C + O_2 \longrightarrow \underset{\text{Carbon monoxide}}{2CO}$

$\underset{\text{Carbon monoxide}}{2CO} + O_2 \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2}$

v. Thus, aluminium is liberated at cathode and gets collected at the bottom of the tank from where it is removed periodically. The oxygen evolved at the anode, combines with the carbon of the anode to produce carbon monoxide which either burns to CO_2 or escapes out.

vi. In this way, for each kg of aluminium produced, about 0.5 kg of carbon anode is burnt away and carbon rods need to be replaced periodically.

Q.71. What is the role of cryolite in the metallurgy of aluminium? (NCERT)

Ans: Cryolite is added to bauxite ore before electrolysis because of the following reasons:

i. Addition of cryolite to alumina increases the electrical conductivity.

ii. It lowers the melting point of alumina to about 1140 K.

***Q.72. What is the role of CaF_2 in metallurgy of aluminium? [July 18]**

Ans: CaF_2 is added to bauxite ore before electrolysis because of the following reasons:

i. CaF_2 makes alumina a good conductor of electricity.

ii. It lowers the fusion temperature to around 1140 K.

Q.73. *In electrometallurgy of aluminium, why is the graphite rod used? OR
What is the role of graphite rod in the electrometallurgy of aluminium? (NCERT)

Ans: i. In the electrometallurgy, aluminium is obtained by the electrolysis of fused electrolyte of alumina (Al_2O_3) in cryolite and CaF_2 at a temperature of 1150 K – 1225 K.

ii. At such high temperature, the carbon (graphite) rods, which are used as anode, give high efficiency of electrolytic process.

iii. During electrolysis, O_2 is liberated by the reaction of F_2 formed at anode with alumina, Al_2O_3. This oxygen combines with carbon forming CO and further CO_2.

***Q.74. Explain the refining of aluminium.**

Ans: Refining of aluminium:

i. The aluminium metal obtained by the electrolysis of alumina is 99 % pure. It can be further refined by **Hoop's electrolytic method**. It has three layers of molten liquids having different densities.

   a. The top layer consists of pure molten aluminium which serves as cathode.
   b. The middle layer consists of a mixture of cryolite and barium fluoride.
   c. The bottom layer consists of impure aluminium and forms an anode.

ii. On passing electric current, aluminium ions from the middle layer are discharged at the cathode as pure aluminium.

iii. The pure aluminium is removed from the tapping hole.

iv. An equivalent amount of aluminium from the bottom layer moves into the middle layer leaving behind the impurities. Thus, this method gives completely pure aluminium.

Q.75. Explain aluminothermy process.

Ans: Aluminothermy or thermite process or Goldschmidt alumino thermite process:

i. Aluminium is strongly electropositive metal and can reduce oxides like Cr_2O_3, Mn_3O_4, etc., which are not easily reduced by carbon or carbon monoxide.

ii. *The process of reduction of a metal oxide to the metal with the help of aluminium powder is called* ***aluminothermy/Goldschmidt thermite process/alumino thermite process/thermite process***.

eg. a. $$\underset{\text{Chromium trioxide}}{Cr_2O_3} + 2Al \longrightarrow 2Cr + \underset{\text{Alumina}}{Al_2O_3} + \text{Heat}$$

b. $$\underset{\text{Manganese oxide}}{3Mn_3O_4} + 8Al \longrightarrow 9Mn + \underset{\text{Alumina}}{4Al_2O_3} + \text{Heat}$$

c. $$\underset{\text{Ferric oxide}}{Fe_2O_3} + 2Al \longrightarrow 2Fe + \underset{\text{Alumina}}{Al_2O_3} + \text{Heat}$$

iii. The heat liberated in these reactions is so large that metal is produced in molten state which can be used for welding purposes.

6.8 Extraction of copper from copper pyrites

Q.76. How does copper occur in nature? OR Write a short note on occurrence of copper.

Ans: Occurrence of copper:

i. Copper occurs in native form as well as in combined state.

ii. The main ores of copper are:

a. Copper glance, Cu_2S

b. Copper pyrites or chalco pyrites, $CuFeS_2$

c. Malachite, $Cu(OH)_2.\ CuCO_3$

d. Cuprite or Ruby copper, Cu_2O

e. Azurite, $Cu(OH)_2.2CuCO_3$

Q.77. What are the steps involved in extraction of copper?

Ans: Extraction of copper involves the following steps:

i. Concentration

ii. Roasting

iii. Smelting

iv. Bessemerization

v. Electrolytic refining of copper .

***Q.78. Describe the process of extraction of copper.**

Ans: i. Concentration: Copper is extracted mainly from copper pyrites. The powdered ore is concentrated by froth floatation process.

ii. Roasting: The concentrated ore is roasted in a limited supply of air in a reverberatory furnace. Copper pyrites is converted to ferrous sulphide (FeS) and cuprous sulphide (Cu_2S) while As and Sb present as impurities are removed as volatile oxides.

$$\underset{\text{Copper pyrites}}{2CuFeS_2} + O_2 \longrightarrow \underset{\text{Cuprous sulphide}}{Cu_2S} + \underset{\text{Ferrous sulphide}}{2FeS} + SO_2$$

iii. Smelting:

a. The roasted ore is mixed with some powdered coke and sand and it is heated strongly in blast furnace

b. During smelting,

1. FeS is oxidized to FeO.

$$\underset{\text{Ferrous sulphide}}{2FeS} + \underset{\text{(From blast of hot air)}}{3O_2} \longrightarrow \underset{\text{Ferrous oxide}}{2FeO} + \underset{\text{Sulphur dioxide}}{2SO_2}$$

2. Ferrous oxide combines with silica (flux) to form fusible slag.

$$\underset{\text{Ferrous oxide}}{FeO} + \underset{\text{Silica (Flux)}}{SiO_2} \longrightarrow \underset{\text{Ferrous silicate (Fusible slag)}}{FeSiO_3}$$

c. Two separate layers are formed at the bottom of the furnace as a result of smelting, out of which the upper layer consists of slag and is removed as a waste.

d. The lower layer consists of sulphides of Cu^+, Fe^{+2}, coke and sand. It is called **matte** and is taken out from the tapping hole.

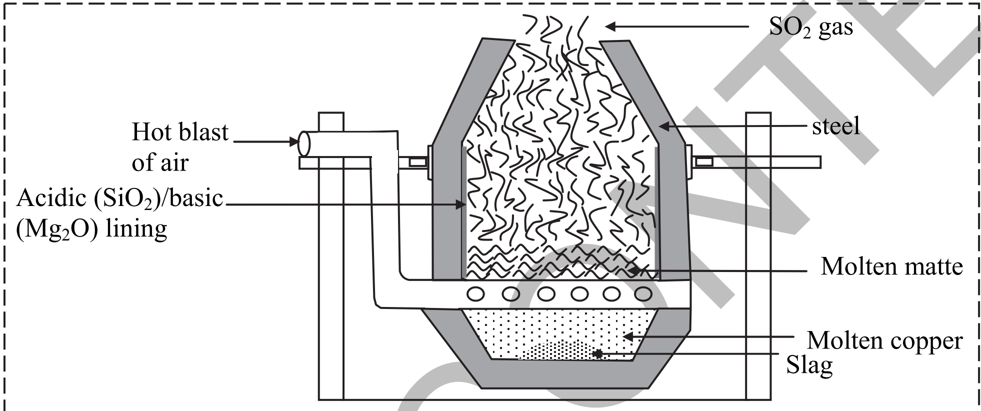
iv. Bessemerization:

a. The molten matte obtained from blast furnace is transferred into a Bessemer converter.

b. On blowing blast of hot air into the molten matte, copper sulphide is partially oxidised to cuprous oxide which further reacts with remaining copper sulphide to form copper and sulphur dioxide.

$$\underset{\text{Copper sulphide}}{2Cu_2S} + 3O_2 \longrightarrow \underset{\text{Cuprous oxide}}{2Cu_2O} + 2SO_2$$

$$\underset{\text{Cuprous oxide}}{Cu_2O} + \underset{\text{Copper sulphide}}{Cu_2S} \longrightarrow \underset{\text{Copper}}{6Cu} + \underset{\text{Sulphur dioxide}}{SO_2}$$



Bessemer converter

c. This is **self reduction/auto reduction**. After the reduction is complete, the molten copper is poured into sand moulds. **Blisters** are formed on the surface of copper, as sulphur dioxide (SO_2) escapes from it during solidification. Blister copper thus obtained is about 99% pure.

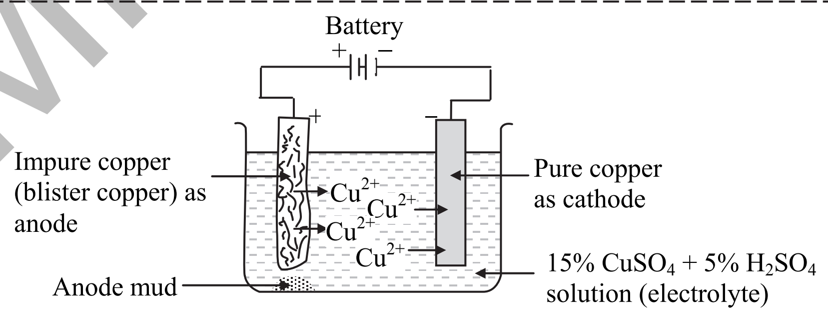
v. Refining:

a. Blister copper mainly contains the impurities of Ag and Au. Electrolytic refining of impure copper is done to obtain 99.95% to 99.99% pure copper.

b. In the electrolytic refining of blister copper, impure copper is used as anode, a rod of pure copper as cathode and the acidified solution of $CuSO_4$ as the electrolyte.

c. During electrolysis, 99.99% pure copper gets deposited at the cathode while impurities of Fe, Ni, Zn, etc., pass into the electrolytic solution.

d. Noble metals like silver and gold do not react with dilute sulphuric acid present in the electrolyte and thus settle down as anode mud.



Electrolytic refining of blister copper

Q.79. Name the common elements present in the anode mud in electrolytic refining of copper. Why are they so present? (NCERT)

Ans: i. Blister copper mainly contains the impurities of silver and gold.

ii. When blister copper is subjected to the electrolytic refining, these noble metals settle down as anode mud. This is mainly because they do not react with dilute sulphuric acid present in the electrolyte.

Q.80. Why copper matte is put in silica lined converter? (NCERT) OR
State the role of silica in the metallurgy of copper. (NCERT) OR
What is the role of SiO_2 in the extraction of copper from copper pyrites? [July 18]

Ans: The copper matte containing Cu_2S and FeS is put in silica lined converter in order to remove impurities as fusible slag. Some silica is also added and hot air blast is blown to convert remaining FeS to FeO, which is removed as slag with silica.

$$\underset{\text{Ferrous sulphide}}{2FeS} + \underset{\text{(From blast of hot air)}}{3O_2} \longrightarrow \underset{\text{Ferrous oxide}}{2FeO} + \underset{\text{Sulphur dioxide}}{2SO_2}$$

Ferrous oxide combines with silica (flux) to form fusible slag.

$$\underset{\text{Ferrous oxide}}{FeO} + \underset{\text{Silica (Flux)}}{SiO_2} \longrightarrow \underset{\text{Ferrous silicate (Fusible slag)}}{FeSiO_3}$$

Q.81. How is leaching carried out in case of low grade copper ores? (NCERT)

Ans: i. In case of low grade copper ores, hydrometallurgical extraction of copper is carried out by leaching with acid or bacteria.

ii. During leaching, the solution containing Cu^{+2} ions is treated with iron scrap or hydrogen gas and following reactions take place.

$$\underset{\text{(From solution)}}{Cu^{+2}_{(aq)}} + H_{2(g)} \longrightarrow \underset{\text{Ppt. of copper metal}}{Cu_{(s)}} + 2H^{+}_{(aq)} \quad \text{OR} \quad \underset{\text{(From solution)}}{Cu^{+2}_{(aq)}} + \underset{\text{From iron scrap}}{Fe_{(s)}} \longrightarrow \underset{\text{Ppt. of copper metal}}{Cu_{(s)}} + Fe^{+2}_{(aq)}$$

iii. Instead of iron scrap if the zinc scrap is used, the reduction will be at faster rate. This is because zinc is more reactive metal (which appears above the electrochemical series) than iron.

$$\underset{\text{(From solution)}}{Cu^{+2}_{(aq)}} + \underset{\text{From zinc scrap}}{Zn_{(s)}} \longrightarrow \underset{\text{Ppt. of copper metal}}{Cu_{(s)}} + Zn^{+2}_{(aq)}$$

iv. However, use of iron scrap is advisable and economically advantageous in metallurgy as iron is cheaper than zinc.

***Q.82. Using standard potentials, write equation for the net reaction that you would predict in the following experiments:**
i. Zinc metal is added to aqueous sodium triiodide.
ii. Iodine is added to excess aqueous $HClO_3$.

Ans: i. The E° value for the Zn^{2+}/Zn and I_3^-/I^- couples are –0.76 V and 0.54 V, respectively. Therefore, E° for the net reaction is 0.54 V + 0.76 V = 1.30 V.

I_3^- will undergo reduction while Zn will undergo oxidation.

Thus, when zinc metal is added to aqueous sodium triiodide, the overall reaction is

$$Zn_{(s)} + I_3^- \longrightarrow Zn^{2+}_{(aq)} + 3I^-_{(aq)}$$

ii. a. E° value for I_2/I^- and ClO_3^-/ClO_4^- couples are 0.54 V and –1.20 V respectively. The net reaction involving the reduction of I_2 to I^- and the oxidation of ClO_3^- to ClO_4^- will have a negative potential.

E° = 0.54 V + (–1.20 V) = –0.66 V

Therefore, this net reaction will not occur.

b. However, E° values for IO_3^- / I_2 and ClO_3^-/Cl^- couples are 1.19 V and 1.47 V, respectively. Therefore, the following net reaction will occur, with a net E° = 0.28 V.

Half reaction: $(ClO^-_{3(aq)} + 6H^+_{(aq)} + 6e^- \longrightarrow Cl^-_{(aq)} + 3H_2O_{(l)}) \times 5$

Half reaction: $(I_{2(s)} + 6H_2O_{(l)} \longrightarrow 2IO^-_{3(aq)} + 12H^+_{(aq)} + 10e^-) \times 3$

Net reaction: $3I_{2(s)} + 5ClO^-_{3(aq)} + 3H_2O_{(l)} \longrightarrow 6IO^-_{3(aq)} + 5Cl^-_{(aq)} + 6H^+_{(aq)}$

Quick Review

Zinc

Minerals: **zinc blende**, zincite, calamine, willemite, franklinite.

Extraction of zinc

i. **Concentration** of an ore either by gravity separation or by froth floatation or by electromagnetic separation.

ii. **Roasting** of a concentrated ore is carried out in the reverberatory furnace in the presence of excess of air.

iii. **Smelting** of a roasted ore is carried out in a rectangular shaped vertical retort and zinc spelter is obtained.

iv. **Refining** of zinc spelter is carried out by electrolytic refining.

Iron

Minerals: **haematite**, magnetite, limonite, iron pyrites, siderite.

Extraction of iron

i. **Concentration** by gravity separation.

ii. **Roasting** of concentrated ore

iii. **Reduction or smelting** of roasted ore + coke + limestone (in the ratio 12:5:3) is carried out in the blast furnace to obtain **cast iron/pig iron**.

iv. **Cast iron** is further processed to obtain **wrought iron,** steel, etc.

Aluminium

Minerals: **bauxite**, cryolite, diaspore, corundum, feldspar, mica.

Extraction of aluminium

i. **Purification of bauxite**

Red bauxite
(Chief impurity: Fe_2O_3)
Process used:
Baeyer's process
(NaOH is used)
OR
Hall's process/dry process
(Na_2CO_3 is used).

White bauxite
(Chief impurity: SiO_2)
Process used:
Serpeck's process.

ii. **Electrolysis** of fused alumina by Hall and Heroult's process.

iii. **Refining** of aluminium by Hoop's process.

Copper

Minerals: copper glance, **copper pyrites/ chalco pyrites**, malachite, cuprite or ruby copper, azurite.

Extraction of copper

i. **Crushing** and concentration by froth floatation process.

ii. **Roasting** of concentrated ore in a reverberatory furnace in the presence of excess of air.

iii. **Smelting** of roasted ore + coke + sand in the blast furnace. Slag and matte are obtained through separate outlets.

iv. **Bessemerization** Molten matte transferred to Bessemer converter and blister copper is obtained.

v. **Refining** of blister copper by polling and/or electrolytic refining to obtain 99.95% to 99.99% pure copper.

Exercise

One Mark Questions

1. What is wrought iron?

Ans: *Refer Q.56.ii.*

2. Write the name of any two ores of aluminium.

Ans: *Refer Q.65.iii.*

3. Define pyrometallurgy.

Ans: *Refer Q.8.i.*

4. Name any two ores which can be separated by magnetic separation method.

Ans: *Refer Q.14. Example.*

5. Distinguish between minerals and ores.

Ans: *Refer Q.7.*

6. Define leaching. **[Mar 17]**

Ans: *Refer Q.19.i.* *[Definition – **1 Mark**]*

7. Explain the term 'Smelting'. **[Mar 13]**

Ans: *Refer Q.28.i.* *[Definition – **1 Mark**]*

8. Explain the term 'Flux'. **[Mar 13]**

Ans: *Refer Q.29.i.* *[Definition – **1 Mark**]*

9. Write the chemical formulae of the following ores:
   i. Calamine ii. Corundrum

Ans: i. *Refer Q.4.i.* ii. *Refer Q.4.iv.*

10. Give the principle behind chromatographic technique.

Ans: *Refer Q.50.ii.*

Two Marks Questions

1. Define the following: **[Oct 15]**
   i. Hydrometallurgy.
   ii. Electrometallurgy.

Ans: i. *Refer Q.8.ii.* ii. *Refer Q.8.iii.*
*[Definitions – **1 Mark each**]*

2. Explain refining of nickel by Mond process. **[Oct 15]**

Ans: *Refer Q.49.iii.a.*
*[Explanation + Chemical reactions – **2 Marks**]*

3. Mention names and formulae of two ores of aluminium. **[Mar 13]**

Ans: *Refer Q.65.iii.* *[Names – **½ Mark each**, Formulae – **½ Mark each**]*

4. Describe 'froth floatation process' for concentration of sulphide ore. **[Oct 13]**

Ans: *Refer Q.16. i, iv, v and Diagram.*
*[Explanation – **1 Mark**, Diagram + Labelling – **1 Mark**]*

5. Define the following terms:
   i. Roasting ii. Calcination

Ans: i. *Refer Q.23.i. (only definition)*
ii. *Refer Q.24.i.*

6. What is 'calcination'? How does it differ from 'roasting'? **[Mar 14]**

Ans: *Refer Q.24.i. and Q.23.i.*
*[Definitions – **1 Mark each**]*

7. What is calcination? Explain it with reactions. **[Mar 15]**

Ans: *Refer Q.24.i, iii. and iv.* *[Definition – **1 Mark**, Any two reactions – **½ Mark each**]*

8. What are Ellingham diagrams? Write any two features of it. **[Mar 16]**

Ans: *Refer Q.35.i and ii.* *[Definition – **1 Mark**, Any two features – **½ Mark each**]*

9. What is 'Ellingham diagram'? Write any 'two points' of its significance. **[July 18]**

Ans: *Refer Q.35.i. and iii. (any two points)*

10. What is the role of silica in the metallurgy of copper?
Ans: *Refer Q.80.*

11. Write chemical reactions involved in van Arkel method for refining titanium. **[July 16]**
Ans: *Refer Q.49.iii.b.eg.i.*
*[Chemical reaction with names of reactants, products and reagents/reaction conditions – **2 Marks**]*

12. Draw a neat, well labelled diagram of electrolytic cell for extraction of aluminium. **[Oct 13]**
Ans: *Refer Q.70.*
*[Diagram – **1 Mark,** Labelling – **1 Mark**]*

13. Write the chemical equations involved in van Arkel method for refining zirconium metal. **[Mar 18]**
Ans: *Refer Q.49.iii.b. eg. ii.*

14. Write the reactions involved in the zone of reduction in blast furnace during extraction of iron. **[Mar 15]**
Ans: *Refer Q.58.ii.*
*[Chemical reactions with names of reactants, products and reagents/reaction conditions – **1 Mark each**]*

15. Draw neat labelled diagram of electrolytic refining of blister copper. **[July 16]**
Ans: *Refer Q.78.v.*
*[Diagram – **1 Mark,** Labelling – **1 Mark**]*

16. What is the action of carbon on the following metal oxides? **[Mar 18]**
    i. Fe_2O_3 in blast furnace
    ii. ZnO in vertical retort furnace
Ans: i. *Refer Q.58.ii.b.* ii. *Refer Q.53.iii.c.*

17. Why CaF_2 is added to bauxite ore before electrolysis in the metallurgy of aluminium?
Ans: *Refer Q.72.*

Three Marks Questions

*1. Explain the term smelting:
Ans: *Refer Q.28.*

2. Describe Bessemerization process involved in the extraction of copper.
Ans: *Refer Q.78.iv.*

3. State the principles of refining of metals by the following methods:
    i. Electrolytic refining
    ii. Zone refining
    iii. Vapour phase refining
Ans: i. *Refer Q.47.iii.* ii. *Refer Q.48.i.*
iii. *Refer Q.49.i.*

4. Describe Van Arkel method used for purification of metals.
Ans: *Refer Q.49.iii.b.*

5. Explain the vertical retort process for the reduction of zinc oxide to zinc metal. **[Mar 13 old course]**
Ans: *Refer Q.53.iii.* *[Explanation – **1 Mark**, Chemical reaction – **1 Mark**, Diagram + Labelling – **1 Mark**]*

6. Explain magnetic separation process along with a neat labelled diagram and a suitable example.
Ans: *Refer Q.13.*

7. Describe the blast furnace used in the extraction of iron from haematite.
Ans: *Refer Q.57.i.a. to f.*

8. Explain Hall's process involved in the purification of bauxite.
Ans: *Refer Q.69.*

Five Marks Questions

1. i. Define the term refining.
   ii. Describe the liquation and polling process for refining of crude metals.
Ans: i. *Refer Q.43.*
ii. *Refer Q.45. and Q.46.*

2. i. Draw neat and labelled diagram of Bessemer converter used in the extraction of copper. **[Mar 14]**
   ii. Explain the following processes of extraction of iron from haematite.
      a. Concentration
      b. Roasting
      c. Smelting
Ans: i. *Refer Q.78.iv.*
*[Diagram – **1 Mark,** Labelling – **1 Mark**]*
ii. *Refer Q.57.ii.*

Multiple Choice Questions

1. Naturally occurring substances from which a metal can be profitably (or economically) extracted are called _______.
   (A) minerals (B) ores
   (C) gangue (D) salts

2. Which among the following minerals does NOT contain aluminium? **[July 16]**
   (A) Cryolite (B) Siderite
   (C) China clay (D) Corundum

3. Which of the following is NOT an ore?
(A) Bauxite (B) Malachite
(C) Zinc blende (D) Pig iron

4. Formula of magnetite is _______.
(A) Fe_2O_3 (B) FeS_2
(C) $FeCO_3$ (D) Fe_3O_4

5. What is the chemical composition of malachite? **[Mar 15]**
(A) $CuO.CuCO_3$ (B) $Cu(OH)_2.CuCO_3$
(C) $CuO.Cu(OH)_2$ (D) $Cu_2O.Cu(OH)_2$

6. The chemical formula of willemite is _______. **[Mar 18]**
(A) ZnS (B) $ZnCO_3$
(C) ZnO (D) Zn_2SiO_4

7. Calamine is _______.
(A) $ZnSO_3$ (B) ZnO
(C) $Zn(NO_3)_4$ (D) $ZnCO_3$

8. Of the following substances, the one which does NOT contain oxygen is ________.
(A) bauxite (B) haematite
(C) cryolite (D) dolomite

9. Magnetic separation is used for increasing concentration of _______ ore.
(A) bauxite (B) calcite
(C) haematite (D) magnesite

10. Sulphide ores are generally concentrated by _______.
(A) froth floatation process
(B) magnetic separation
(C) gravity separation
(D) leaching

11. The process of extracting a soluble material from an insoluble solid by dissolving out in a suitable solvent is known as _________. **[July 18]**
(A) calcination (B) roasting
(C) leaching (D) smelting

12. Roasting is generally done in case of _______.
(A) oxide ores (B) silicate ores
(C) sulphide ores (D) carbonate ores

13. When limestone is heated strongly, it gives off CO_2. In metallurgy, this process is known as _______.
(A) calcination (B) roasting
(C) smelting (D) ore dressing

14. Purpose of smelting of an ore is to _______.
(A) to oxidise it
(B) to reduce it
(C) to remove volatile impurities
(D) to obtain an alloy

15. Which of the following is used as a reducing agent in smelting?
(A) C (B) Cr (C) Zn (D) Fe

16. Which of the following processes involves smelting?
(A) $ZnCO_3 \longrightarrow ZnO + CO_2$
(B) $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$
(C) $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$
(D) $Al_2O_3.2H_2O \longrightarrow Al_2O_3 + 2H_2O$

17. Flux added in the extraction of iron is _______.
(A) silica (B) feldspar
(C) limestone (D) flint

18. The slag obtained during the extraction of copper from copper pyrites is composed mainly of _______.
(A) $CaSiO_3$ (B) $FeSiO_3$
(C) $CuSiO_3$ (D) SiO_2

19. The impurities associated with minerals used in metallurgy are collectively called _______.
(A) slag (B) flux
(C) gangue (D) ore

20. A substance which reacts with gangue to form fusible material is called _______.
(A) flux (B) catalyst
(C) ore (D) slag

21. Silica is added to roasted copper ore during smelting process to remove _______. **[Oct 15]**
(A) ferrous sulphide (B) ferrous oxide
(C) cuprous sulphide (D) cuprous oxide

22. What is the process in which concentrated ore is reduced to the corresponding metal by heating at high temperature with a reducing agent? **[Oct 14]**
(A) Polling (B) Pyrometallurgy
(C) Hydrometallurgy (D) Calcination

23. Liquation process is carried out using ______.
(A) blast furnace
(B) hydraulic classifier
(C) reverberatory furnace
(D) Wilfley's washing table

24. During polling, heat of molten metal makes the green logs of wood to liberate ________.
(A) sulphur dioxide
(B) carbon dioxide
(C) carbon monoxide
(D) hydrocarbon gases

25. During the process of polling, ________.
(A) metals are oxidised to their corresponding carbonates
(B) metals are oxidised to their corresponding oxides
(C) metals are oxidised to their corresponding nitrates
(D) metal oxides are reduced to metals

26. Which metal is extracted by electrolytic reduction method?
(A) Au (B) Al
(C) Fe (D) Ag

27. In Van Arkel method of refining metal, impure zirconium is converted to unstable volatile compound by heating it with _______. **[Oct 13]**
(A) oxygen (B) chlorine
(C) bromine (D) iodine

28. Four metals and their methods of refining are given:
(i) Ni, Cu, Zr, Ga
(ii) Electrolysis, Van Arkel process, Zone refining, Mond's process
Choose the CORRECT method for each.
(A) Ni : Electrolysis, Cu : Van Arkel process, Zr : Zone refining, Ga : Mond's process
(B) Ni : Mond's process, Cu: Electrolysis, Zr: Van Arkel process, Ga : Zone refining
(C) Ni : Mond's process, Cu : Van Arkel process, Zr: Zone refining, Ga : Electrolysis
(D) Ni : Electrolysis, Cu : Zone refining, Zr: Van Arkel process, Ga : Mond's process

29. In the metallurgical extraction of zinc from ZnO the reducing agent used is _______.
(A) carbon (B) sulphur dioxide
(C) carbon monoxide (D) nitric oxide

30. In the cup and cone arrangement of blast furnace, the cone enables ________.
(A) introduction of pre-heated air into the furnace
(B) prevention of loss of gases
(C) uniform distribution of charge
(D) all of these

31. In metallurgy of iron, charge introduced in the blast furnace consists of ________.
(A) roasted ore, silica and calcium aluminate
(B) roasted ore, coke and calcium hydroxide
(C) roasted ore, coke and calcium carbonate
(D) roasted ore, coke and calcium silicate

32. In blast furnace, the highest temperature is in _______.
(A) reduction zone
(B) slag formation zone
(C) fusion zone
(D) combustion zone

33. Calcium carbonate used in the extraction of iron acts as _______. **[July 17]**
(A) oxidising agent (B) reducing agent
(C) gangue (D) flux

34. MnO_2 and $Ca_3(PO_4)_2$ present in iron ore get reduced to Mn and P in the zone of _______. **[Mar 17]**
(A) combustion (B) reduction
(C) fusion (D) slag formation

35. Fe_2O_3 is reduced to spongy iron near the top of blast furnace by _______. **[Mar 13]**
(A) H_2 (B) CaO
(C) SiO_2 (D) CO

36. Iron is obtained on a large scale from Fe_2O_3 by _______.
(A) reduction with Al
(B) reduction with CO
(C) reduction with H_2
(D) reduction with sodium

37. Bauxite ore is concentrated by _______.
(A) froth flotation
(B) electromagnetic separation
(C) chemical separation
(D) hydraulic separation

38. The process of leaching alumina, using sodium carbonate is called _______. **[Mar 16]**
(A) Baeyer's process (B) decomposition
(C) cyanide process (D) Hall's process

39. Purification of aluminium by electrolytic refining is carried out by _______. **[Mar 14]**
(A) Hoope process (B) Hall process
(C) Baeyer process (D) Serperck process

Answers to Multiple Choice Questions

1. (B)	2. (B)	3. (D)	4. (D)
5. (B)	6. (D)	7. (D)	8. (C)
9. (C)	10. (A)	11. (C)	12. (C)
13. (A)	14. (B)	15. (A)	16. (B)
17. (C)	18. (B)	19. (C)	20. (A)
21. (B)	22. (B)	23. (C)	24. (D)
25. (D)	26. (B)	27. (D)	28. (B)
29. (A)	30. (C)	31. (C)	32. (D)
33. (D)	34. (C)	35. (D)	36. (B)
37. (C)	38. (D)	39. (A)	

TOPIC TEST

Total : 25 Marks

Section A (1 × 5 = 5 Marks)

Choose the correct alternative:

1. In the extraction of zinc, _______ process is carried out in a vertical retort.
   (A) leaching (B) roasting (C) smelting (D) froth floatation

2. _______ metal is refined by Mond process.
   (A) Cu (B) Zn (C) Ti (D) Ni

3. The chemical formula of magnetite is _______.
   (A) $FeCO_3$ (B) Fe_3O_4 (C) FeS_2 (D) Fe_2O_3

Answer the following:

4. Define the term 'hydrometallurgy'.

5. What is the role of fluorspar in the metallurgy of aluminium?

Section B (2 × 3 = 6 Marks)

6. Name the various steps involved in the extraction of pure metal from their ores.
7. What are the reactions involved in the extraction of silver from its ore by leaching process?
8. Name any four methods of refining of crude metals.

   OR

   Write the names and chemical formulae of two ores of copper.

Section C (3 × 3 = 9 Marks)

9. i. What is gangue?
   ii. Explain the froth floatation process.

10. Define the following term:
    i. Roasting
    ii. Smelting
    iii. Calcination

11. i. Give two examples of ores which can be concentrated by magnetic separation method.
    ii. With a neat labelled diagram, explain magnetic separation process of an ore.

    OR

    i. What are Ellingham diagrams?
    ii. Write any four features of Ellingham diagrams.

Section D (5 × 1= 5 Marks)

12. i. Define the terms: Mineral and Metallurgy.
    ii. Explain Van Arkel method for refining of titanium.

    OR

    i. Write the chemical formulae of two ores of aluminium.
    ii. Explain polling method refining of crude metals.
    iii. Draw neat labelled diagram of electrolytic cell for refining of blister copper.