

**SAMPLE CONTENT**

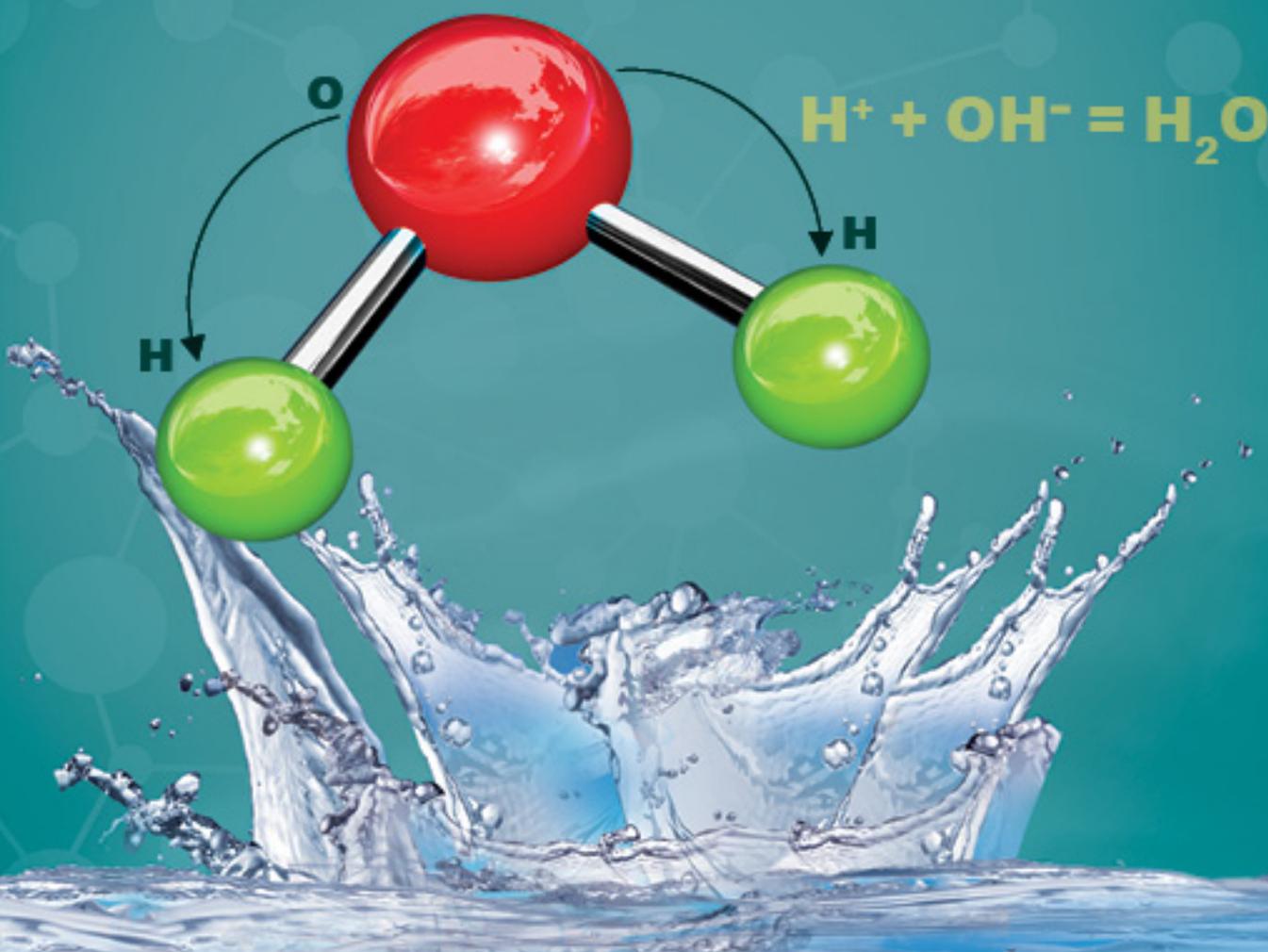


**PERFECT**

# **CHEMISTRY-I**

**Std. XII Sci.**

**Atomic Structure of Water Molecule**



**Target** Publications Pvt. Ltd.

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

# Perfect Chemistry – I STD. XII Sci.

## Salient Features

- Exhaustive coverage of syllabus in Question Answer Format.
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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. : PERFECT CHEMISTRY - I**” is a treasure house of knowledge that'd not only prepare you to face the conspicuous Std. XII final exam but also equip you up on parallel ground to face the prospective NEET and JEE exam.

This book is specifically aimed at Maharashtra Board students. The content of the book is framed in accordance with Maharashtra State board syllabus splattered with additional snippets of information from the NCERT syllabus. This lethal combination of apt material from both the syllabus makes it the ultimate reference material for Std. XII.

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 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.
- **NCERT Corner, Do You Know, Enrich Your Knowledge** and **Notes** cover additional bits of relevant information on each topic.
- **Apply Your Knowledge, Brain Teasers** and **Check Your Grasp** cover brain-storming questions to strengthen the students' conceptual understanding.
- **Quick Review** and **Formulae** sections facilitate instant revision.
- **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.

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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

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## 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: Perfect 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

6.0	Prominent scientists	6.5	Extraction of zinc from zinc blende
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		

#### 6.0 Prominent scientists

Scientists		Contributions
<b>Charles Martin Hall</b> (1863-1914) (American scientist)	i. ii.	Invented best method for preparing aluminium (in 1886) by passing electric current through the solution of alumina dissolved in cryolite. Was the originator of American spelling of aluminium which is aluminum.
<b>Paul Heroult</b> (1863-1914) (French scientist)		Discovered the process of extraction of aluminium, by passing an electric current through alumina dissolved in cryolite.

#### 6.1 Introduction

##### Q.1. How do the metals occur in nature?

**Ans:** Few metals occur in the earth crust in free state or native state while other metals occur in the combined forms.

**i. Free state or native state:** The metals which do not react with air, water, carbon dioxide and non-metals occur in free or native state.

**eg.** a. Metals like gold and platinum are found exclusively in free or native state.

b. Copper, silver and mercury occur partly in the free state.

**Note:** Non-metals like carbon, sulphur, etc. and noble gases usually occur in free or native state.

**ii. Combined form:** Metals which are reactive and have a tendency to combine with oxygen/air, moisture/water, carbon dioxide and other non-metals like C,N,S,P,As and X (halogens), etc., occur in the combined state in the form of sulphides, halides, silicates, carbonates, nitrates and phosphates.

**eg.** a. Iron usually occurs as its oxide  $\text{Fe}_2\text{O}_3$  (ferric oxide) in the earth's crust.

b. Zinc usually occurs as zinc sulphide ( $\text{ZnS}$ ) or zinc oxide ( $\text{ZnO}$ ).

##### Q.2. 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 ( $\text{MgCO}_3$ ), Cryolite ( $\text{Na}_3\text{AlF}_6$ ), 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 ( $\text{Fe}_2\text{O}_3$ ), Zinc blende ( $\text{ZnS}$ ), 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.3. 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.4. 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 (Fe <sub>2</sub> O <sub>3</sub> ) Magnetite (Fe <sub>3</sub> O <sub>4</sub> ) Limonite (2Fe <sub>2</sub> O <sub>3</sub> .3H <sub>2</sub> O) Iron pyrites (FeS <sub>2</sub> ) Siderite (FeCO <sub>3</sub> )	Haematite (Fe <sub>2</sub> O <sub>3</sub> )
Zinc (Zn)	Zinc blende (ZnS) Zincite (ZnO) Calamine (ZnCO <sub>3</sub> ) Willemite (Zn <sub>2</sub> SiO <sub>4</sub> )	Zinc blende (ZnS)
Magnesium (Mg)	Dolomite (MgCO <sub>3</sub> .CaCO <sub>3</sub> ) Magnesite (MgCO <sub>3</sub> ) Epsom salt (MgSO <sub>4</sub> .7H <sub>2</sub> O)	Dolomite (MgCO <sub>3</sub> .CaCO <sub>3</sub> )
Aluminium (Al)	Bauxite (Al <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O) Cryolite (Na <sub>3</sub> AlF <sub>6</sub> ) China clay (Al <sub>2</sub> O <sub>3</sub> .2SiO <sub>2</sub> .2H <sub>2</sub> O) Diaspore (Al <sub>2</sub> O <sub>3</sub> .H <sub>2</sub> O) Corundum (Al <sub>2</sub> O <sub>3</sub> )	Bauxite (Al <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O)
Copper (Cu)	Copper pyrites/Chalco pyrites (CuFeS <sub>2</sub> ) Copper glance (Cu <sub>2</sub> S) Cuprite/Ruby copper (Cu <sub>2</sub> O) Malachite (Cu(OH) <sub>2</sub> .CuCO <sub>3</sub> ) Azurite (Cu(OH) <sub>2</sub> .2CuCO <sub>3</sub> )	Copper pyrites (CuFeS <sub>2</sub> )

**Q.5. Write chemical formulae of the following ores:**

[Oct 14]

- i. Calamine      ii. Haematite      iii. Magnetite      iv. Corundum

**Ans:** i. Calamine : ZnCO<sub>3</sub>      ii. Haematite : Fe<sub>2</sub>O<sub>3</sub>      iii. Magnetite: Fe<sub>3</sub>O<sub>4</sub>      iv. Corundum : Al<sub>2</sub>O<sub>3</sub>

[Chemical formulae – ½ Mark each]

**Q.6. 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<sub>2</sub>O<sub>3</sub>

[½ Mark]

**ii. Zinc:**

Name of the ore: Zinc blende

[½ Mark]

Formula: ZnS

[½ Mark]

**Q.7. 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 <sub>2</sub> O <sub>3</sub> .2H <sub>2</sub> O
ii.	Cryolite	Na <sub>3</sub> AlF <sub>6</sub>

[1 Mark]

[1 Mark]



**Q.8. \*What is the difference between minerals and ores? Differentiate between “minerals” and “ores”.**

OR

(NCERT)

Ans:

	Minerals	Ores
i.	<b>Definition:</b> Refer Q.2.i.	<b>Definition:</b> Refer Q.2.ii.
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 ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) and China clay ( $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ ). These are called minerals of aluminium.	Aluminium can be conveniently and economically extracted from bauxite. Therefore, bauxite is an ore of aluminium.

**\*Q.9. 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:

- 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**.
- Hydrometallurgy:** A process of extracting metals from aqueous solutions of their salts using suitable reducing agents is called **hydrometallurgy**.
- Electrometallurgy:** A process of extraction of metals by electrolytic reduction of molten (fused) metallic compounds is called **electrometallurgy**.

**\*Q.10. 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:

- Concentration of ores
- Conversion of ores into oxides or other desired compounds
- Reduction of ores to form crude metals
- Refining of metals

[For each step – ½ Mark]



### Enrich Your Knowledge

Naturally occurring huge lumps of ore are broken down into small pieces by using crushers or grinders. These pieces are then converted into fine powder (pulverized ore) by using ball mill or stamp mill and the process is called as **pulverization**.

## 6.2 Concentration

**Q.11. What is concentration of an ore? State the factors taken into consideration in concentration process?**

- Ans:**
- The process of removal of gangue from the ore is called **concentration of ore**.
  - 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.
  - Concentration process involves several steps and selection of these steps depends upon the following factors:
    - Differences in physical properties of the compound of the metal present and that of the gangue.
    - The type of metal, the available facilities and the environmental factors.

**Q.12. 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:

- Gravity separation or hydraulic washing:**
  - Gravity separation method is used when the ore particles are heavier than the earthy or rocky gangue particles.
  - 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.
  - Hydraulic washing can be carried out by the following two methods:
    - Hydraulic washing by using Wilfley table
    - Hydraulic classifier method.



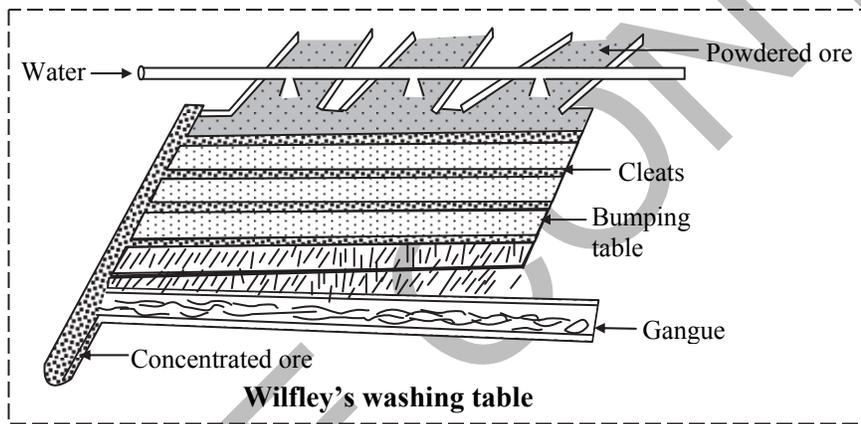
- ii. **Magnetic separation:** The magnetic separation method is based on the differences in magnetic properties of the ore components.
- iii. **Froth floatation process:** This process is based on the principle of difference in the wetting properties of the metallic ore and gangue particles with oil and water respectively.

**Q.13. 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:**

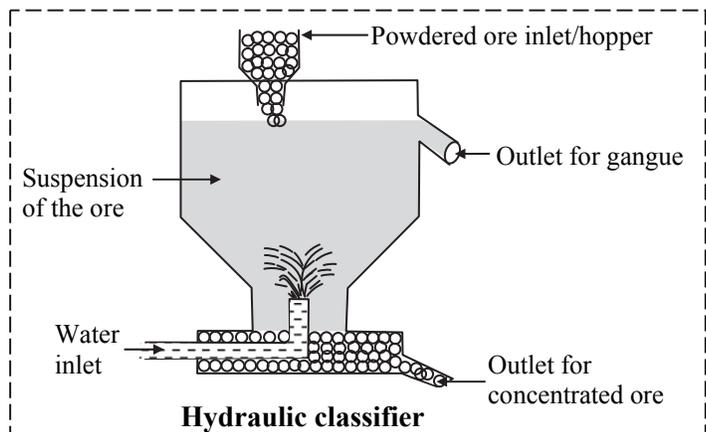
- a. Wooden table having a slanting floor and long wooden strips (called **riffles or cleats**) fixed on it is called **Wilfley's table**.
- b. The pulverized ore (powdered ore) is fed on the top of Wilfley's table and running stream of water is passed across the table.
- c. The table is given a regular 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.



- f. Wilfley's table method is used for concentration of native gold ore or ore of tin called **cassiterite ( $\text{SnO}_2$ )**.

**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.



- d. The lighter particles of the gangue are carried up by the current of water and pass out along with 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.



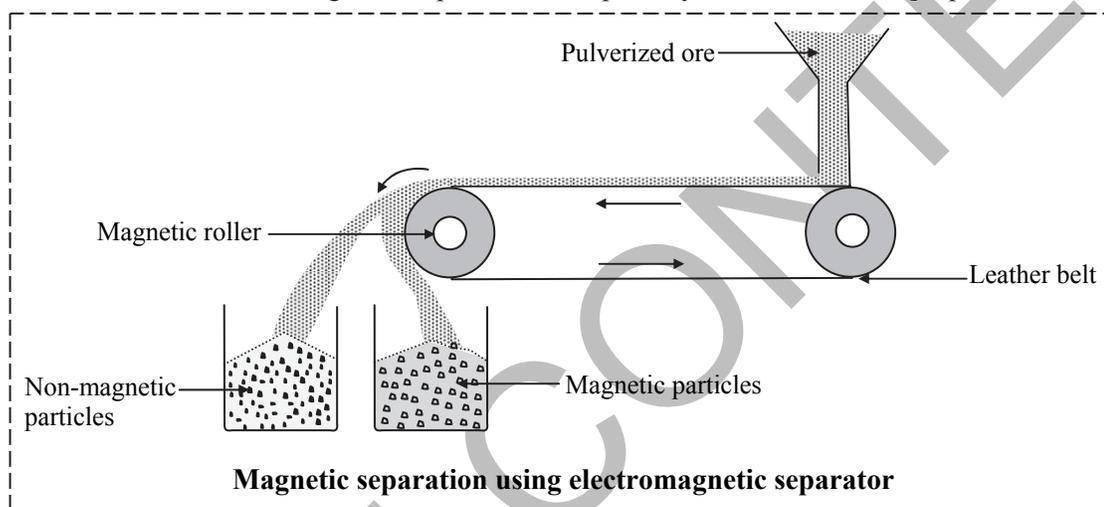
**Q.14. \*Describe the magnetic separation process. OR**

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

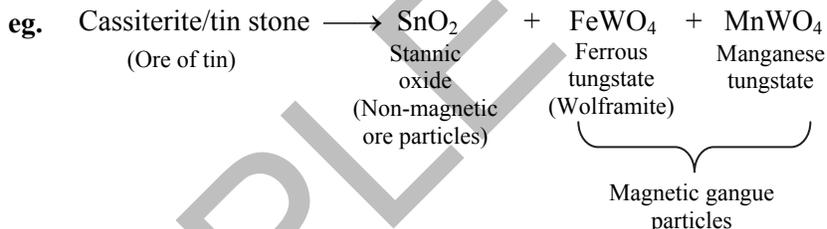
**Ans: Magnetic separation process:**

- The magnetic separation process is based on the differences in magnetic properties of the ore components.
- 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.
- 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.
- Powdered ore is dropped over the moving belt at one end.
- 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]



[Diagram + Labelling – 1 Mark]



**Q.15. 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 ( $\text{Fe}_2\text{O}_3$ ), cassiterite ( $\text{SnO}_2$ ).

**#Q.16. Identify the ores mentioned below which can be concentrated by magnetic separation method?**

$\text{Fe}_2\text{O}_3$ ,  $\text{FeCO}_3$ ,  $\text{ZnS}$ ,  $\text{ZnO}$ ,  $\text{CuFeS}_2$

**Ans:** The ores which can be concentrated by magnetic separation method are  $\text{Fe}_2\text{O}_3$ ,  $\text{FeCO}_3$ ,  $\text{CuFeS}_2$  as they contain Fe as the magnetic component.

**\*Q.17. Explain the working of froth floatation process.**

**Ans: Froth floatation process:**

- 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.
- It is used for the extraction of those metals in which the ore particles are preferentially wetted by oil and gangue particles by water.
- This method has been used for removing gangue from sulphide ores.  
eg. Galena ( $\text{PbS}$ ), zinc blende ( $\text{ZnS}$ ), copper pyrites ( $\text{CuFeS}_2$ ), etc.





- 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.21. 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.**

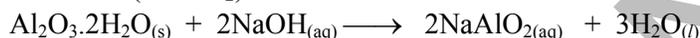
(NCERT)

**Ans: Leaching of alumina from bauxite:**

- i. The chief ore of aluminium, bauxite ( $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ ) contains impurities like silica ( $\text{SiO}_2$ ), iron oxide ( $\text{Fe}_2\text{O}_3$ ), titanium oxide ( $\text{TiO}_2$ ), etc.
- ii. Converting the ore ( $\text{Al}_2\text{O}_3$ ) into soluble  $\text{NaAlO}_2$  by treating it either with NaOH (Baeyer's Process) or with  $\text{Na}_2\text{CO}_3$  (Hall's Process), results in the concentration of the ore.

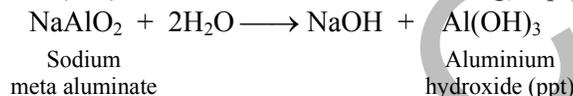
**a. Baeyer's process:**

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 ( $\text{NaAlO}_2$ ) at about 423K in an autoclave.



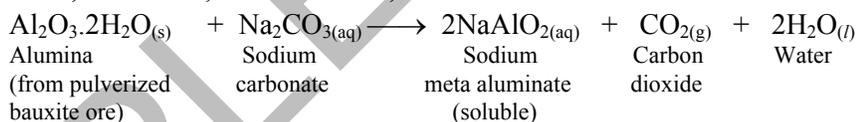
Alumina (from pulverized bauxite ore)                      Sodium meta aluminate (soluble)

3. The solution is filtered to remove insoluble impurities and agitated with freshly prepared  $\text{Al}(\text{OH})_3$ , so that aluminium in  $\text{NaAlO}_2$  gets precipitated as  $\text{Al}(\text{OH})_3$ .

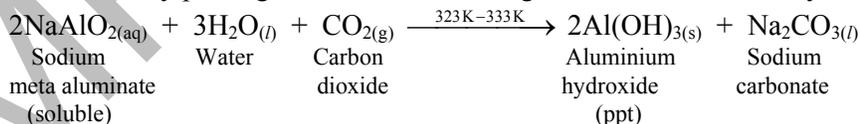


**b. Hall's process:**

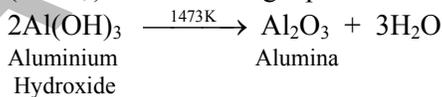
1. In Hall's process, alumina/aluminium oxide ( $\text{Al}_2\text{O}_3$ ) is converted into soluble sodium meta aluminate by fusing it with sodium carbonate. The insoluble part contains the impurities of silica, iron oxide, titanium oxide, etc.



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.



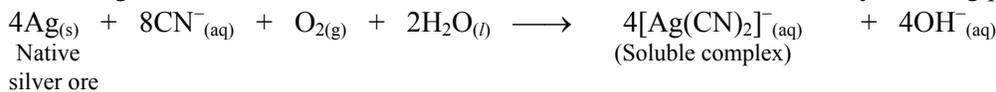
- iii. The precipitate of aluminium hydroxide obtained in both the processes is washed, dried and ignited (heated) at 1473 K to get pure alumina.



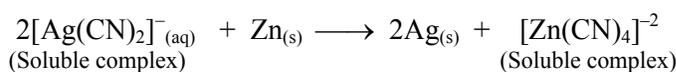
**Q.22. Write the reactions involved in extraction of silver from its ore by leaching process.**

[Oct 14]

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



[1 Mark]

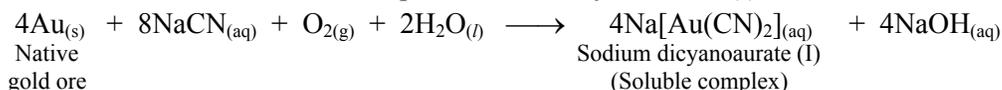


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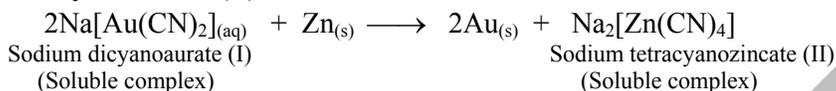


**Q.23. Extraction of Au by leaching with NaCN involves both oxidation and reduction. Justify by giving equations for the reactions involved.**

**Ans:** i. During leaching process, gold (Au) is first oxidised by O<sub>2</sub> of the air to Au<sup>+</sup> which then combines with CN<sup>-</sup> ions to form the soluble complex, sodium dicyanoaurate (I).



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<sup>+</sup> to Au. Zinc itself gets oxidised to Zn<sup>2+</sup> ions which combine with CN<sup>-</sup> ions to form soluble complex, sodium tetracyanozincate (II).



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

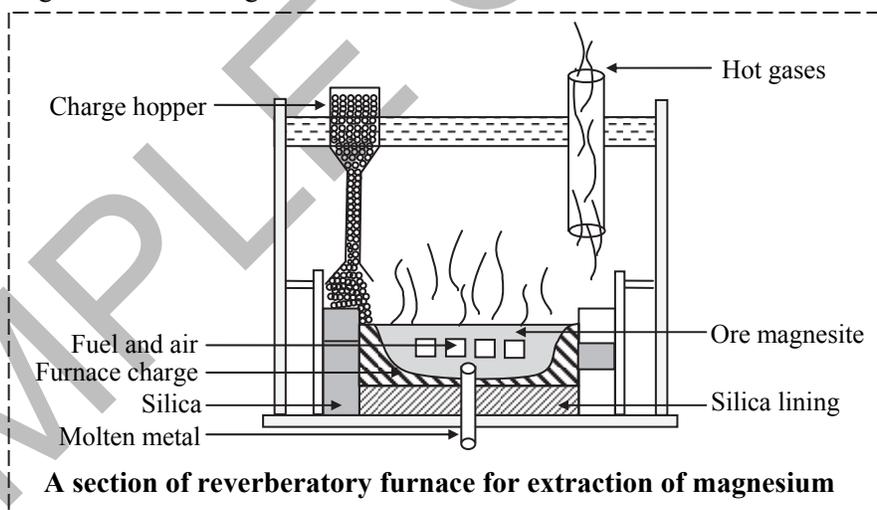
#### Oxidation (conversion of ores into oxides)

**Q.24. \*Explain the term roasting. OR**

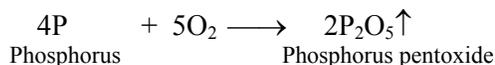
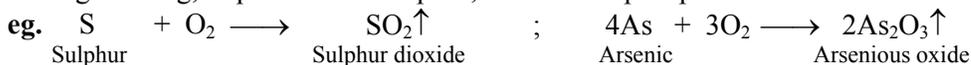
**What is roasting? Write examples with reactions.**

**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.

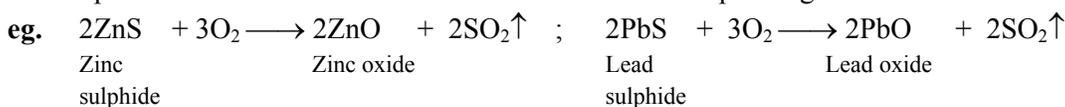


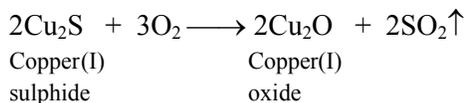
ii. During roasting, impurities like sulphur, arsenic and phosphorus are removed as their volatile oxides.



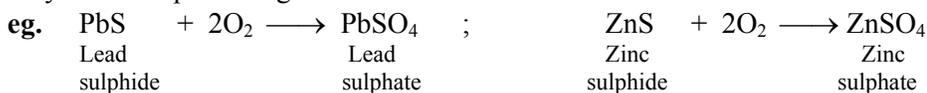
Moisture is also removed and the mass becomes porous.

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



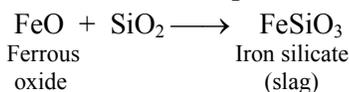


iv. Sometimes, when the roasting is done at moderate temperature, the oxidation of sulphides takes place only to the sulphate stage.



**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  $\text{Cu}_2\text{S}$  and  $\text{FeS}$ .



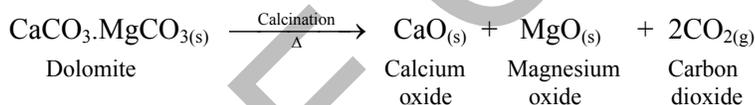
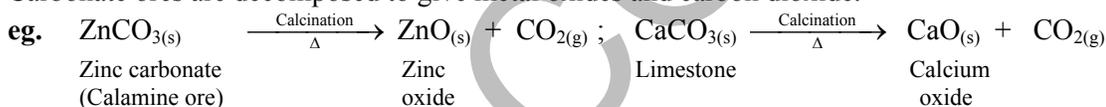
**Q.25. \*What is calcination? Write examples with reactions. OR**

**\*Explain the term calcination.**

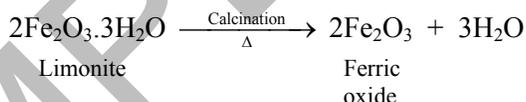
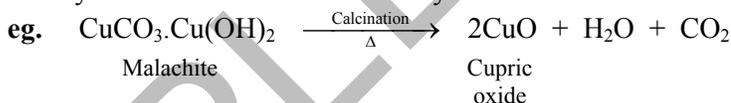
**Ans:** i. *Calcination* is a process in which the ore is heated to a high temperature below its melting point in the absence of air or in a limited supply of air.

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.

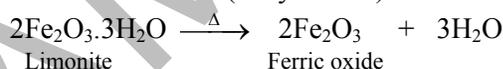


iv. The hydrated ore loses its water of hydration.



**Q.26. What is the process involved in removal of water from limonite? Give its reaction.**

**Ans:** Removal of water (dehydration) from limonite is the process of calcination.



**Q.27. 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 <sub>2</sub> gas is produced along with metal oxide.	Generally, SO <sub>2</sub> gas is produced along with metal oxide.
eg.	$\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}_{(s)} \xrightarrow{\text{Heat}} \text{Fe}_2\text{O}_{3(s)} + x\text{H}_2\text{O}_{(g)}$ $\text{ZnCO}_{3(s)} \xrightarrow{\text{Heat}} \text{ZnO}_{(s)} + \text{CO}_{2(g)}$ $\text{CaCO}_3 \cdot \text{MgCO}_{3(s)} \xrightarrow{\text{Heat}} \text{CaO}_{(s)} + \text{MgO}_{(s)} + 2\text{CO}_{2(g)}$	$2\text{ZnS}_{(s)} + 3\text{O}_{2(g)} \longrightarrow 2\text{ZnO}_{(s)} + 2\text{SO}_{2(g)}$ $2\text{Cu}_2\text{S}_{(s)} + 3\text{O}_{2(g)} \longrightarrow 2\text{Cu}_2\text{O}_{(s)} + 2\text{SO}_{2(g)}$ $2\text{PbS}_{(s)} + 3\text{O}_{2(g)} \longrightarrow 2\text{PbO}_{(s)} + 2\text{SO}_{2(g)}$

**Reduction (reduction of the oxide to the metal)**

**Q.28. 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:

- Pyrometallurgy
- Hydrometallurgy
- Electrometallurgy

**\*Q.29. 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.

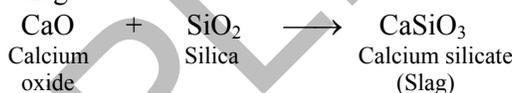
**\*Q.30. What is smelting? Explain with an example.**

- 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 reduces the oxide ore to form free metal.



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

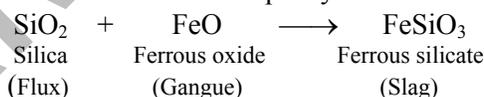
eg. In the extraction of iron, limestone is used as a flux. Calcium oxide obtained by the decomposition of limestone combines with silica impurity to give calcium silicate which is a slag.



**Q.31. 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.

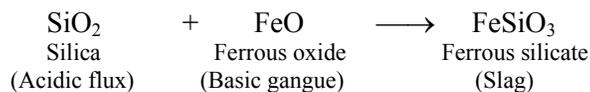
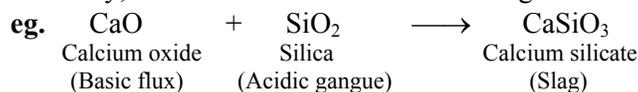
eg. In the extraction of copper from copper pyrites, sand is added as a flux because sand combines with ferrous oxide impurity to form ferrous silicate which is a slag.



- 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.



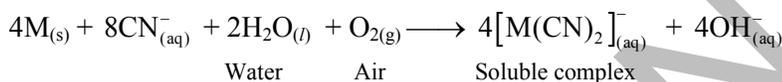
**\*Q.32. Explain the term slag.**

- 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.33. Explain hydrometallurgy. OR****\*What is the meaning of hydrometallurgy?**

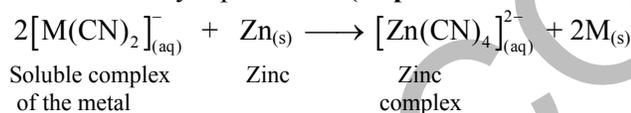
- Ans:** i. A process of extracting metals by converting their ores into aqueous solutions of metal compounds and reduction of these solutions using suitable reducing agents is called **hydrometallurgy**.
- ii. This process is used in the extraction of less reactive metals like gold and silver.
- iii. 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.



(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**).

**Q.34. 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 ( $E^\circ = -0.76$  V) as compared to copper (which is less electropositive,  $E^\circ = +0.34$  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).

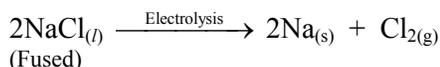


Thus, copper can be easily extracted by hydrometallurgy but not zinc.

**\*Q.35. 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.

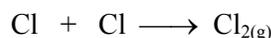
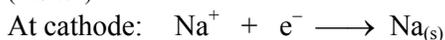
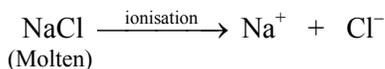
**eg.** When molten sodium chloride is electrolyzed in Down's cell, sodium is formed at the cathode and chlorine is liberated at the anode. It involves reduction and oxidation.

**Q.36. 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.

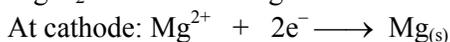
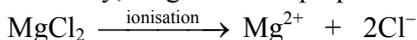


- ii. Sodium is extracted from fused sodium chloride by electrolysis as:



The sodium metal is liberated at cathode and collected.

- iii. Similarly, magnesium is prepared by the electrolysis of  $\text{MgCl}_2$ .



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

#### Thermodynamic principles of metallurgy:

- Thermodynamic considerations are very important in metallurgical transformations. These help in deciding the temperature and the choice of reducing agents in the reduction processes.
- The extraction of metals from their oxides by using a particular reducing agent can be predicted by some basic concepts of thermodynamics.
- In thermodynamics, the feasibility of a process can be predicted in terms of Gibbs free energy change,  $G_{\text{products}} - G_{\text{reactants}}$  ( $\Delta G$ ) at any specified temperature. This is related to enthalpy change ( $\Delta H$ ) and entropy change  $S_{\text{products}} - S_{\text{reactants}}$  ( $\Delta S$ ) as  $\Delta G = \Delta H - T\Delta S$  .....(1)  
where, T is the absolute temperature (in Kelvin) at which process is carried out.
- For any reaction, the Gibbs energy change is also related to equilibrium constant (K) of the reactant-product system at the temperature T as  $\Delta G^\circ = -RT \ln K$
- For a spontaneous process or reaction, the energy change ( $\Delta G$ ) must be negative. This also implies positive value of K and can happen only when reaction proceeds towards products. Consider the following examples:
  - Consider the formation of metal oxide from a metal,  
 $2\text{M}_{(\text{s})} + \text{O}_{2(\text{g})} \longrightarrow 2\text{MO}_{(\text{s})}$   
For this reaction,  $\Delta H$  is negative (as it is a combustion process and all combustion reactions are exothermic) and  $\Delta S$  is also negative ( $\text{O}_{2(\text{g})}$  is converted to  $\text{MO}_{(\text{s})}$ ). At low temperature,  $\Delta G$  may be negative, it increases with increase of temperature (i.e., it becomes positive).
  - Consider the formation of carbon monoxide from carbon,  
 $2\text{C}_{(\text{s})} + \text{O}_{2(\text{g})} \longrightarrow 2\text{CO}_{(\text{g})}$   
For this reaction,  $\Delta H$  is negative and  $\Delta S$  is positive (volume of gaseous product > volume of gaseous reactants),  $T\Delta S$  in equation (1) becomes negative.  $\Delta G$  decreases with increase in temperature.
  - Consider the formation of  $\text{CO}_2$  from C,  
 $\text{C}_{(\text{s})} + \text{O}_{2(\text{g})} \longrightarrow \text{CO}_{2(\text{g})}$   
For this reaction,  $\Delta H$  is negative and  $\Delta S$  is almost zero. Since  $T\Delta S$  in equation (1) is zero,  $\Delta G$  does not vary much with temperature.  
From the above examples, following conclusions can be drawn based on the thermodynamic principles of metallurgy.
    - For the formation of metal oxide,  $\Delta G^\circ$  increases with increase in temperature.
    - For the formation of carbon monoxide,  $\Delta G^\circ$  decreases with increase in temperature.
    - For the formation of  $\text{CO}_2$ ,  $\Delta G^\circ$  does not change significantly with temperature.In terms of thermodynamics, the reduction of metal oxide with given reducing agent should be carried out at low temperature if the free energy change ( $\Delta G^\circ$ ) for the reaction is negative.



**Q.37. Why is the reduction of a metal oxide easier if the metal formed is in liquid state at the temperature of reduction? (NCERT)**

**Ans:** The entropy is higher if the metal is in liquid state than when it is in solid state. The value of entropy change ( $\Delta S$ ) of the reduction process is more on +ve side when the metal formed is in liquid state and the metal oxide being reduced is in solid state. Thus, the value of  $\Delta G^\circ$  becomes more on negative side and the reduction becomes easier.

**Q.38. 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  $\Delta G^\circ$  against temperature for the reaction of metal and other elements with one mole of gaseous oxygen at 1 atmosphere.

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

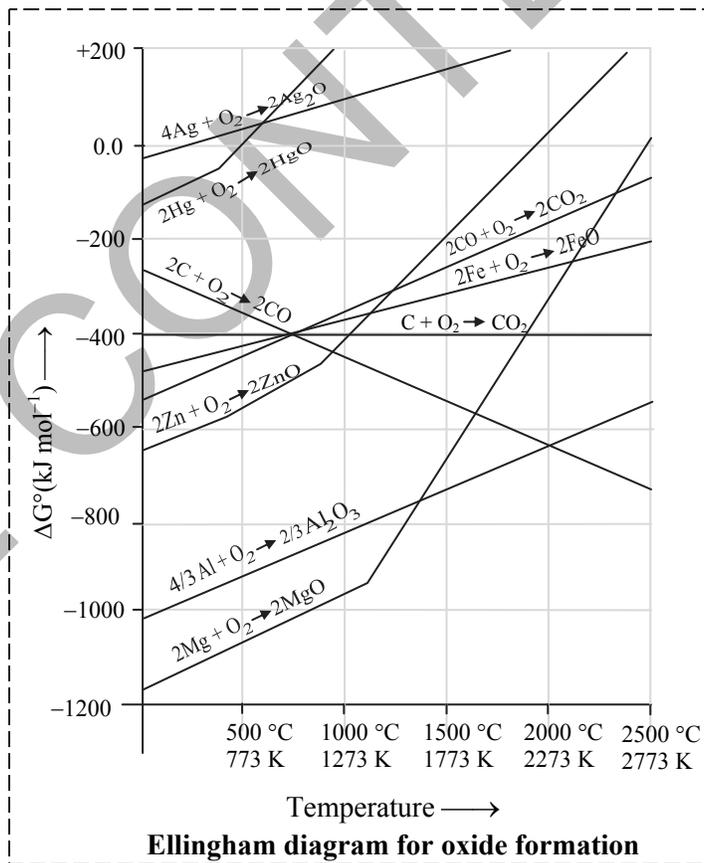
**ii. Features of Ellingham diagram:**

The Ellingham diagram for oxides shows the following important features:

- The graph for the formation of a metal oxide is a straight line with an upward slope.
- There is sudden change in the slopes for some metal oxides, like MgO, ZnO and HgO.
- For a few metal oxides of mercury and silver, the graph is at the upper part in Ellingham diagram ( $\text{Ag}_2\text{O}$  and HgO).
- The graph for the formation of CO is straight line with the negative slope. This line intersects the lines of many metal oxides.
- The graph for the formation of  $\text{CO}_2$  is straight line almost parallel to the temperature axis.

**iii. Significance of Ellingham diagram:**

- 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  $\Delta G^\circ$  value.
- The sudden change in the graph shows a phase change that is, change from solid to liquid or from liquid to vapour.
- 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).
- The relative tendency of the metals to undergo oxidation is in the order, as shown below:  
 $\text{Mg} > \text{Al} > \text{Cr} > \text{Fe} > \text{Hg} > \text{Ag}$ .  
 This is due to the increase in the negative free energy change of the formation of oxide in the order given below:  
 $\text{MgO} > \text{Al}_2\text{O}_3 > \text{Cr}_2\text{O}_3 > \text{FeO} > \text{Ag}_2\text{O}$ .



**Note:**  $\Delta G^\circ$  values of HgO and  $\text{Ag}_2\text{O}$  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  $\text{Ag}_2\text{O}$  and HgO are unstable and can be decomposed at moderate temperatures (by heating at 600 K and 700 K respectively).



- \*Q.39. i. What are the features of Ellingham diagram?  
ii. What is its significance?

Ans: i. Refer Q.38.ii.  
ii. Refer Q.38.iii.

### NCERT Corner

#### • Limitations of Ellingham diagram:

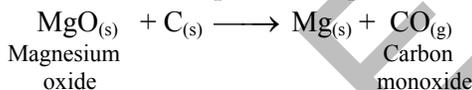
- Ellingham diagram is based on the thermodynamic concepts. It simply indicates whether the reaction is possible or not, however it cannot predict the kinetics of the reaction (i.e., rate or time taken for reduction to occur or how fast it could be).
- The interpretation of  $\Delta G^\circ$  is based on the equilibrium constant (K) [ $\Delta G^\circ = -RT \ln K$ ]. Hence, it is assumed that the reactants and products are in equilibrium. However, this is not always true as the reactant or product may be solid.

- \*Q.40. Explain how  $\Delta G^\circ$  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  $\Delta G^\circ$  becomes more negative on increasing the temperature. Therefore, it becomes more stable with increase in temperature.

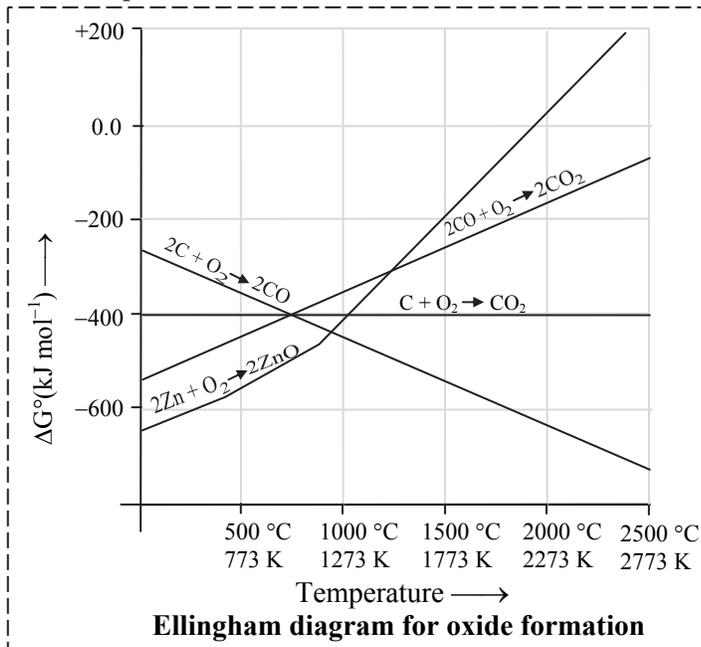
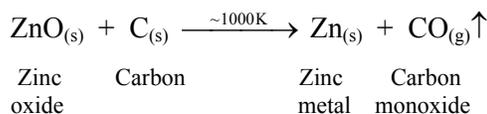
- #Q.41. What is the minimum temperature for reduction of MgO by carbon?

- Ans: i. Below 1800 °C, in the Ellingham diagram, standard free energy change  $\Delta G^\circ$  is more negative for the formation of MgO than  $\Delta G^\circ$  for oxidation of carbon (C) to CO.  
ii. Above 1800 °C, in the Ellingham diagram, the line of graph of  $\Delta G^\circ$  against absolute temperature for C to CO crosses the graph of the formation of MgO.  
iii. Since, above 1800 °C,  $\Delta G^\circ$  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.



- \*Q.42. 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  $\Delta G^\circ$  for the formation of CO (by combustion of carbon) is lesser than the  $\Delta G^\circ$  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:





**Q.43. Predict conditions under which Al might be expected to reduce MgO. OR**

**Is it true that under certain conditions, Mg can reduce  $\text{Al}_2\text{O}_3$  and Al can reduce MgO? What are those conditions? (NCERT)**

- Ans:** i. In the Ellingham diagram,  $\Delta G^\circ$  versus T plot for  $2\text{Mg} + \text{O}_2 \longrightarrow 2\text{MgO}$  and  $4/3\text{Al} + \text{O}_2 \longrightarrow 2/3\text{Al}_2\text{O}_3$  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.

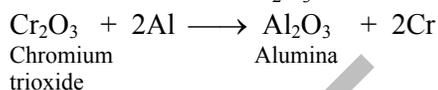


### Check Your Grasp

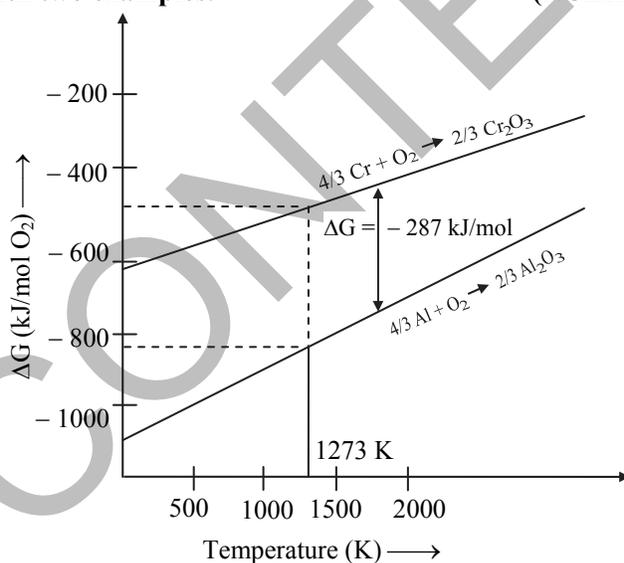
**The choice of a reducing agent in a particular case depends on thermodynamic factor. How far do you agree with this statement? Support your opinion with two examples. (NCERT)**

- i. The thermodynamic factor helps us in choosing a suitable reducing agent for the reduction of a particular metal oxide to metal.
- ii. From Ellingham diagram, it can be deduced that any metal can reduce the oxide of other metal which appears above it in the diagram.

**eg.** a. From the adjacent Ellingham diagram, it is clear that at any given temperature  $\Delta G^\circ$  value for the formation of  $\text{Al}_2\text{O}_3$  is more negative than that of  $\text{Cr}_2\text{O}_3$  i.e.,  $\text{Al}_2\text{O}_3$  is more stable than  $\text{Cr}_2\text{O}_3$ . Thus, aluminium is used as reducing agent for the reduction of  $\text{Cr}_2\text{O}_3$ .



- b. Similarly, zinc is used as a reducing agent for the reduction of  $\text{FeO}$  to  $\text{Fe}$ .



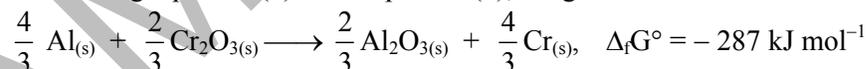
**Ellingham diagram for Cr and Al**

**Q.44. The value of  $\Delta_f G^\circ$  for formation of  $\text{Cr}_2\text{O}_3$  is  $-540 \text{ kJ mol}^{-1}$  and that of  $\text{Al}_2\text{O}_3$  is  $-827 \text{ kJ mol}^{-1}$ . Is reduction of  $\text{Cr}_2\text{O}_3$  possible with Al? (NCERT)**

**Ans:** The two equations are:



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



Since,  $\Delta_r G^\circ$  for the combined reaction is  $-ve$ , therefore, the above reaction, i.e., reduction of  $\text{Cr}_2\text{O}_3$  by Al is possible.



### Brain Teaser

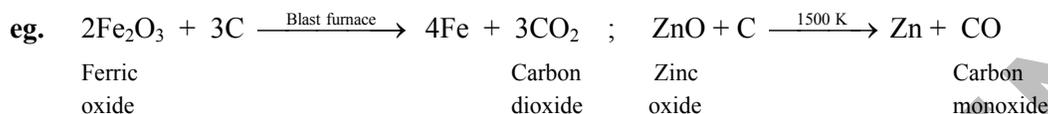
**The reaction,  $\text{Cr}_2\text{O}_3 + 2\text{Al} \longrightarrow \text{Al}_2\text{O}_3 + 2\text{Cr}$ ,  $\Delta G^\circ = -421 \text{ kJ}$  is thermodynamically feasible as is apparent from the Gibbs energy value. Why does it not take place at room temperature? (NCERT)**

- i. Since, the given redox reaction is thermodynamically favourable; ideally it should occur at all temperatures.
- ii. However, all the reactants and products of the given reaction are solids at room temperature and therefore, it does not occur at room temperature.
- iii. At high temperature, the chromium melts and the reaction proceeds rapidly indicating that heating is required for initiation of this reaction.



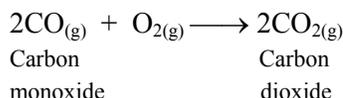
**Importance of carbon and carbon monoxide as reducing agents:**

- i. Carbon is used as a reducing agent for several metal oxides. For temperature at which  $C \rightarrow CO$  line lie below the metal oxide line, carbon can be used to reduce metal oxide and it itself gets oxidised to CO. Larger the difference, easier is the reduction.



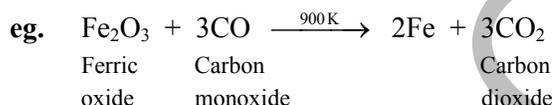
- ii. For the reduction of oxides of chromium, aluminium and magnesium, carbon is not used as reducing agent. Theoretically, carbon could be used for reduction, but in practice this is not so because reduction occurs only at high temperatures and these metals form corresponding carbides under these conditions.

- iii. Carbon monoxide combines with oxygen to give carbon dioxide.



Here,  $\Delta S = -ve$  (volume of gaseous products < volume of gaseous reactants).

and  $\Delta G^\circ$  increases with the increase in temperature. Hence, CO proves to be a better reducing agent at low temperatures.



- iv. It is observed that sometimes carbon is oxidized to  $\text{CO}_2$  and sometimes to CO. The plausible explanation for this is as follows:

a. In the Ellingham diagram, graph for the formation of  $\text{CO}_2$  is almost parallel to the horizontal axis and that of CO is a straight line with negative slope.

b. These two graphs intersect at about 1000 K. Below 1000 K, carbon reduces metal oxides to metal and itself gets oxidised to  $\text{CO}_2$  i.e., formation of  $\text{CO}_2$  is favoured while above 1000 K, formation of CO is favoured.

- v. Thus, C and CO both can act as reducing agents but since CO can be easily oxidised to  $\text{CO}_2$  than C to  $\text{CO}_2$ , therefore CO is more effective reducing agent than C below 1000 K.

**eg.** In the Ellingham diagram, at temperatures below 1000 K, the  $C \rightarrow CO$  line lies above the  $\text{Fe} \rightarrow \text{FeO}$  line [ $\Delta G_{(C, CO)} > \Delta G_{(Fe, FeO)}$ ]. So, in this temperature range, CO will be reducing FeO.

- vi. However, CO is more stable above 1000 K hence its oxidation to  $\text{CO}_2$  is less rapid than that of C to  $\text{CO}_2$ . Therefore, carbon is better reducing agent than that of CO, above 1000 K.

**eg.** In the Ellingham diagram, at temperatures above 1000 K, the  $C \rightarrow CO$  line comes below the  $\text{Fe} \rightarrow \text{FeO}$  line [ $\Delta G_{(C, CO)} < \Delta G_{(Fe, FeO)}$ ]. So, in this temperature range, C will be reducing FeO.

**Q.45. \*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,  $\Delta G^\circ$  versus T line for  $2\text{CO} + \text{O}_2 \longrightarrow 2\text{CO}_2$  at 673 K is lower than that of  $2\text{C} + \text{O}_2 \longrightarrow 2\text{CO}$  line.

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



### NCERT Corner

#### Extraction of non-metals based on oxidation:

- Chlorine gas is obtained by electrolysis of brine or sea water [as chlorine is abundant in it in the form of common salt (NaCl)]. This extraction is based on oxidation of chloride ( $\text{Cl}^-$ ) ions to give chlorine gas.
- Overall reaction is:  $2\text{Cl}^-_{(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})} \longrightarrow 2\text{OH}^-_{(\text{aq})} + \text{H}_{2(\text{g})} + \text{Cl}_{2(\text{g})}$  ;  $\Delta G^\circ = +422 \text{ kJ}$
- Since,  $\Delta G^\circ = -nFE^\circ$   
 $E^\circ = -2.2 \text{ V}$   
 Therefore, an external e.m.f. greater than 2.2 V has to be applied. Further, an excess potential is also required in order to overcome some hindering reactions.
- Hydrogen gas and aqueous sodium hydroxide are obtained as byproducts.
- Chlorine gas can also be obtained by electrolysis of molten sodium chloride wherein sodium metal is produced and not sodium hydroxide.
- Extraction of gold and silver by leaching method is also an oxidation reaction.

### 6.4 Refining of crude metals

#### Q.46. Define refining.

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

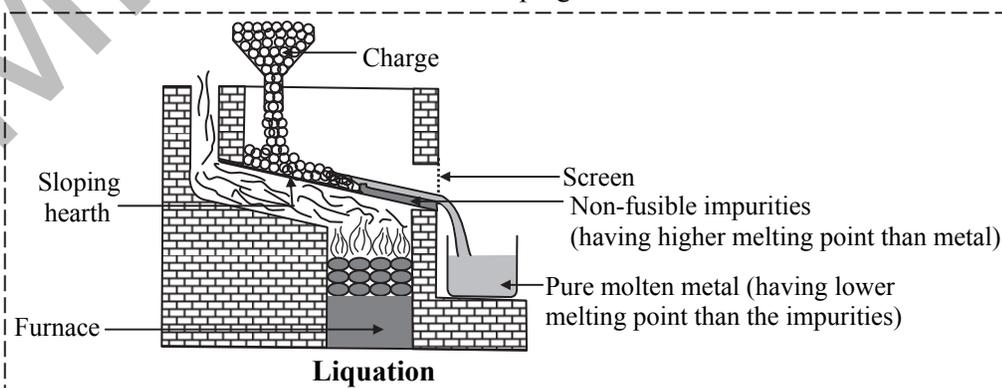
#### Q.47. Why refining of crude metals is important? Enlist different methods of refining.

- Ans:**
- 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).
  - Refining can be carried out by using different methods which are as follows:
    - Liquation process
    - Polling
    - Electrolytic refining
    - Zone refining
    - Vapour phase refining
    - Van Arkel method (for refining zirconium or titanium)
    - Chromatography.

#### Q.48. Explain liquation process for refining of crude metals.

**Ans:** Liquation process for refining of crude metals:

- In the liquation process, the low melting metal forms fusible liquid on heating and flows down.
- This method is employed when the impurity has higher melting point than the required metal.
- 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.
- The metal melts and flows down leaving the non-fusible impurities (called dross) on the hearth.
- The pure metal is collected at the bottom of the sloping hearth in a receiver.



- eg.**
- 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.
  - The pure tin metal (m.p. of Sn: 504.8 K) obtained by this method is called pig tin.



NCERT Corner

● Refining of crude metals by distillation:

In this method of refining, impure metal is evaporated to obtain pure metal as distillate. This method is useful for low boiling metals like Zn and Hg.

\*Q.49. What is polling?

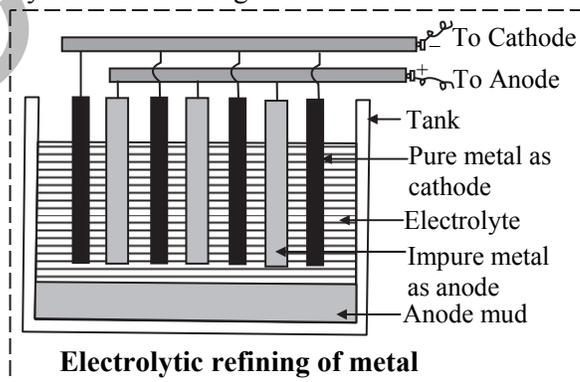
Ans: Polling:

- Polling is a method of refining crude metals. In this method, the impure metal is melted and stirred with green logs of wood.
- 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.
- 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.50. Describe the process of electrolytic refining of metals.

Ans: Electrolytic refining:

- 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.
- Both anode and cathode are placed in a suitable electrolytic bath containing soluble salt of the same metal.
- 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.
- The impurities like more reactive metals dissolve in the solution. Less reactive metals are insoluble and form anode mud at the bottom.
- The reaction occurring at the electrodes are:  
At cathode:  $M^{n+} + ne^{-} \longrightarrow M$   
At anode:  $M \longrightarrow M^{n+} + ne^{-}$
- Metals like Cu, Ag, Ni, Al and Zn are refined by this method and 99.9% pure metal is obtained.



Q.51. \*How is zone refining process used to obtain ultra pure metals?

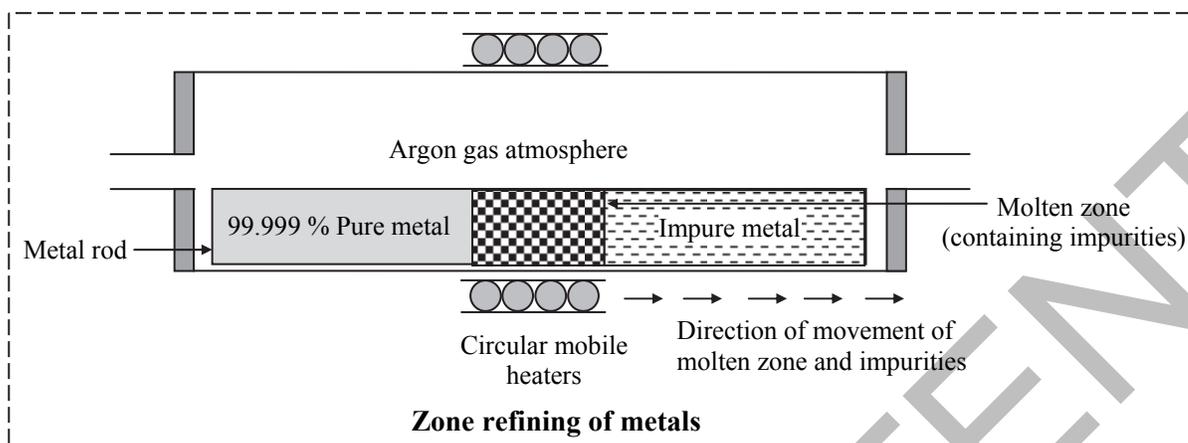
OR

Explain zone refining.

(NCERT)

Ans: Zone refining/Fractional crystallization:

- Principle:** Impurities are more soluble in the molten state than in the solid state of the metal.
- 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.
- As the heater moves forward, the pure metal crystallizes out of the melt and the impurities pass on into the adjacent molten zone.
- 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.
- 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.



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

**Q.52. 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.



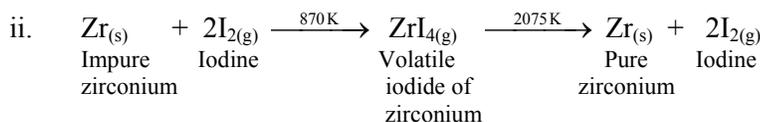
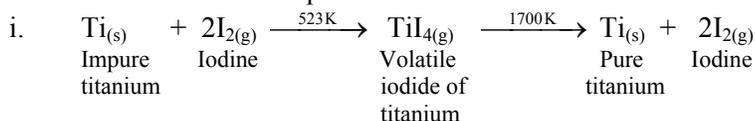
2. The nickel carbonyl complex is subjected to higher temperature so that it is decomposed giving the pure metal.



**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 volatilizes.
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.





**Q.53. What is meant by the term chromatography?**

(NCERT)

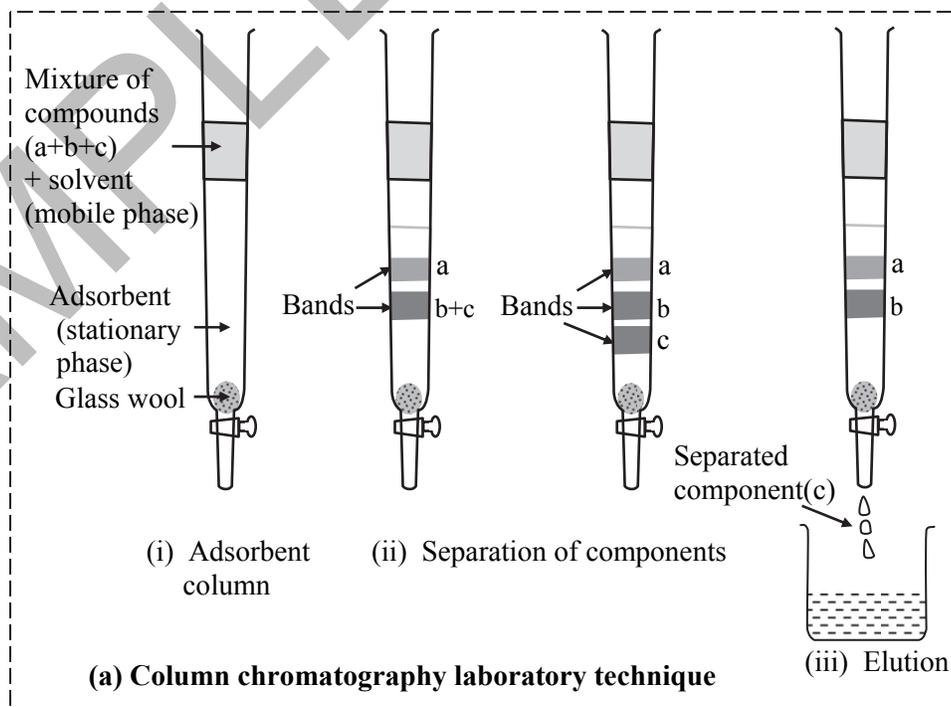
**Ans:** i. Chromatography is a modern, versatile and wide spread technique, which is based on the principle of selective adsorption of the components of a mixture between the two phases, moving phase and stationary phase.

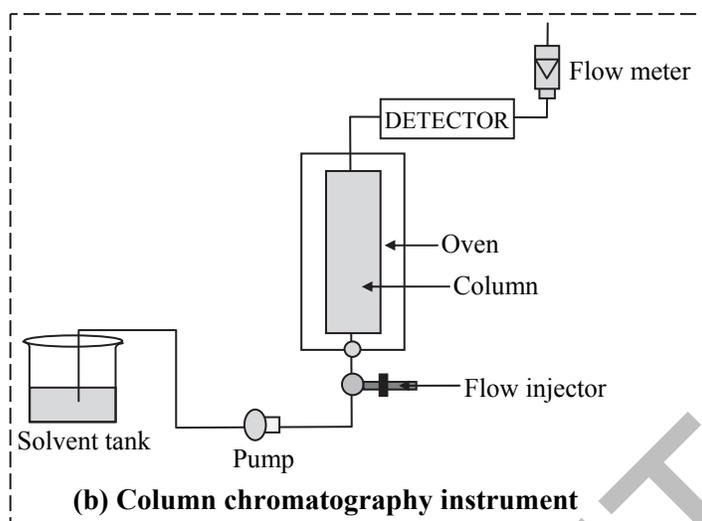
ii. In column chromatography, normally liquid is used as a moving phase and solid as a stationary phase.

**Note:** This method was discovered by a botanist **Tswett** in 1906.

**Chromatographic methods:**

- i. **Principle:** Different components of a mixture get adsorbed on an adsorbent at different levels, depending upon their different rates of adsorption.
- ii. Chromatography is a useful method for purification of the elements which are found in traces. 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.
- iii. Column chromatography is used when impurities and the element to be purified differ only slightly in their chemical properties.
- iv. In a column chromatography, porous medium (either solid or liquid) like  $\text{Al}_2\text{O}_3$  or  $\text{SiO}_2$  (with large surface area) is packed in a column. This acts as an adsorbent and is called as **stationary phase**.
- v. The mixture whose different components are to be separated is dissolved in a suitable liquid or gaseous solvent (**moving/mobile phase**) and it is then moved through the stationary phase.
- vi. 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 order of adsorbability are held up at different zones down the column.
- vii. 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**. The elution is repeated a number of times to ensure complete separation of the different components.
- viii. 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.
- ix. Procedures followed in column chromatography is as depicted in the following figure.





### 6.5 Extraction of zinc from zinc blende

**Q.54. 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 up to 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 $ZnO \cdot Fe_2O_3$	
- 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.55. 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.56. 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).







- c. Limonite,  $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$  (hydrated oxide of iron)
- d. Iron pyrites,  $\text{FeS}_2$
- e. Siderite,  $\text{FeCO}_3$ .
- 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.61. 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.62. How is iron extracted from haematite?**

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

i. **Blast furnace:**

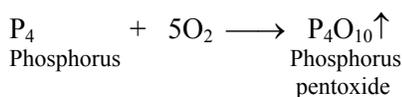
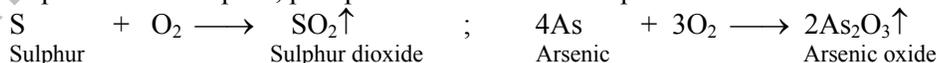
- a. A blast furnace is made of steel and is about 25 m in height.
- b. Its diameter varies between 5 m to 10 m and its inner lining is made of refractory bricks/fire bricks which can withstand high temperature.
- c. The three parts in the blast furnace are:
  - 1. the hearth
  - 2. the bosh and
  - 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 pass 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  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and phosphates (gangue) to form molten slag.

ii. **Extraction of iron involves the following steps:**

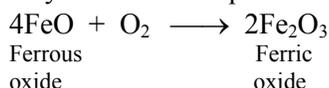
a. **Concentration:** The haematite ore is crushed to small pieces of about 1 inch in size with the help of jaw crushers. It is then concentrated by gravity separation process in which it is washed with water to remove lighter gangue particles.

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 escape as their volatile oxides.



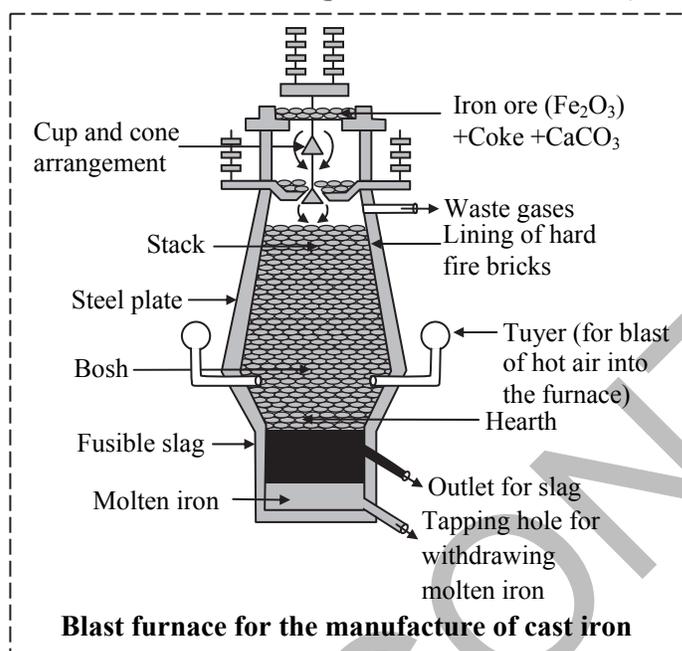
2. Any ferrous oxide present in the ore is converted to ferric oxide.



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):**

- 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.
- At the same time, a blast of hot air (pre-heated at about 1000 K) is blown upwards from the tuyers.



- 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.

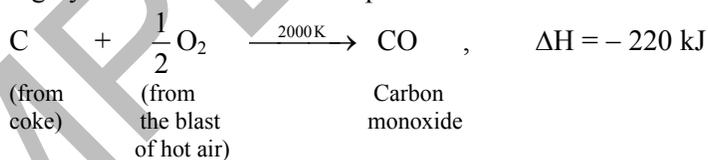
**Q.63. \*Write reactions involved at different temperatures in the blast furnace. OR**

**Write down the reactions taking place in different zones in the blast furnace during the extraction of iron. (NCERT)**

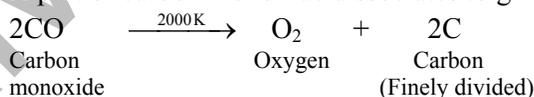
**Ans:** Three main chemical reactions take place at different zones in the blast furnace.

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

- 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.



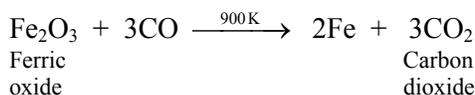
- A part of carbon monoxide dissociates to give finely divided carbon.



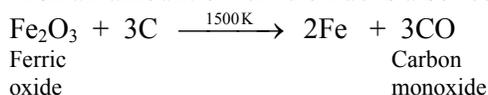
- Carbon monoxide rises up the furnace and heats up the descending charge and also reacts with it.

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

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



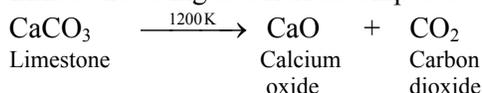
- A small amount of ferric oxide is also reduced to iron by carbon.



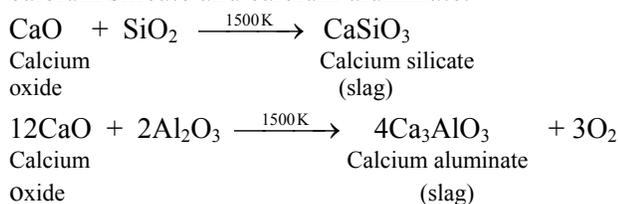


**iii. Zone of slag formation (20 m height from the bottom):**

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

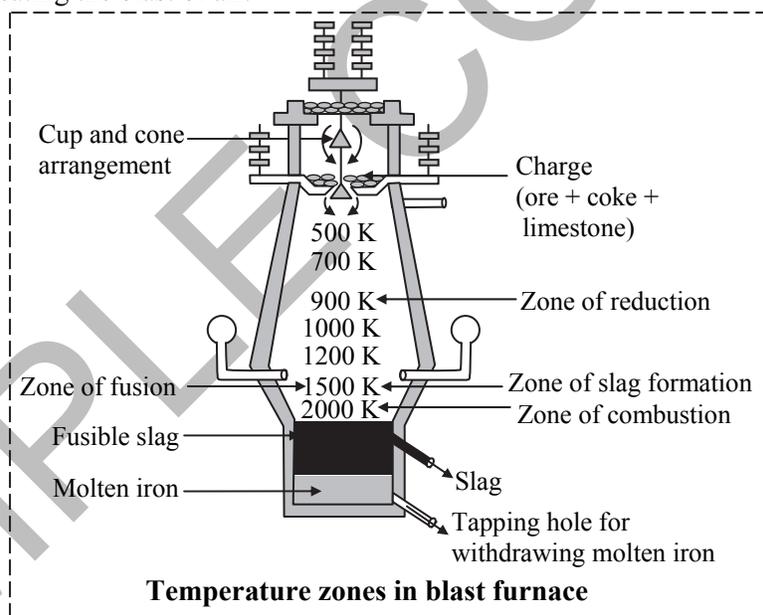


- b. Calcium oxide combines with silica and alumina at about 1500 K to form molten slag of calcium silicate and calcium aluminate.



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

- Mn, P and Si are formed as a result of reduction of  $\text{MnO}_2$ ,  $\text{Ca}_3(\text{PO}_4)_2$  and part of  $\text{SiO}_2$  respectively.
- 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.
- Molten iron and molten slag (floating on the surface of molten iron) are removed through separate outlets.
- 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.
- Hot waste gases ( $\text{N}_2$ ,  $\text{CO}$ ,  $\text{CO}_2$ ) escaping through the outlet at the top of the furnace are used for pre-heating the blast of air.



**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	$\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
	1200 K	Limestone decomposes	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$
	1500 K	Reduction of ore by C	$\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 2\text{Fe} + 3\text{CO}$
	1500 K	Fusion of iron and slag formation	$\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$
	2000 K	Combustion of coke	$2\text{C} + \text{O}_2 \rightarrow 2\text{CO}$

- 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.





### 6.7 Extraction of aluminium from bauxite

**Q.70. 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,  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$
  - b. Cryolite,  $\text{Na}_3\text{AlF}_6$
  - c. Diaspore,  $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$
  - d. Corundum,  $\text{Al}_2\text{O}_3$
- iv. Aluminium oxides with other oxides as impurities are occasionally found as corundum, ruby, sapphire, topaz, turquoise, etc., which are valuable precious stones.

**\*Q.71. 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.72. 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.

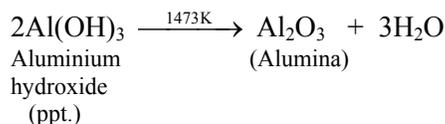
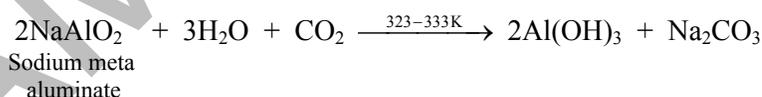
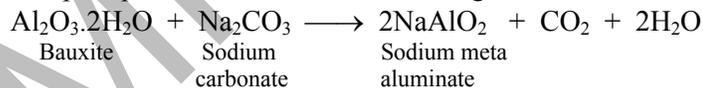
**Q.73. What is the significance of leaching in the extraction of aluminium?**

(NCERT)

- Ans:**
- i. The principal ore of aluminium is bauxite ( $\text{Al}_2\text{O}_3$ ) 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.74. 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  $\text{CO}_2$  is passed when  $\text{Al}(\text{OH})_3$  gets precipitated.
  - iv. The precipitate is filtered, washed and ignited at 1473 K to get pure alumina.



**Q.75. 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,  $\text{Na}_3\text{AlF}_6$  (80–85%),  $\text{AlF}_3$  (5–7%) and fluorspar,  $\text{CaF}_2$  (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.





**Q.78. \*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 ( $\text{Al}_2\text{O}_3$ ) in cryolite and  $\text{CaF}_2$  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,  $\text{O}_2$  is liberated by the reaction of  $\text{F}_2$  formed at anode with alumina,  $\text{Al}_2\text{O}_3$ . This oxygen combines with carbon forming CO and further  $\text{CO}_2$ .

**\*Q.79. Explain the refining of aluminium.**

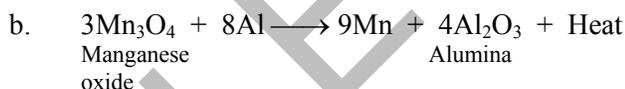
**Ans: Refining of aluminium:**

- 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.80. Explain aluminothermy process.**

**Ans: Aluminothermy or thermite process or Goldschmidt aluminothermite process:**

- i. Aluminium is strongly electropositive metal and can reduce oxides like  $\text{Cr}_2\text{O}_3$ ,  $\text{Mn}_3\text{O}_4$ , 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/aluminothermite process/thermite process.*



- 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.81. 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,  $\text{Cu}_2\text{S}$   
b. Copper pyrites or chalcocite,  $\text{CuFeS}_2$   
c. Malachite,  $\text{Cu}(\text{OH})_2 \cdot \text{CuCO}_3$   
d. Cuprite or Ruby copper,  $\text{Cu}_2\text{O}$   
e. Azurite,  $\text{Cu}(\text{OH})_2 \cdot 2\text{CuCO}_3$

**Q.82. What are the steps involved in extraction of copper?**

**Ans: Extraction of copper involves the following steps:**

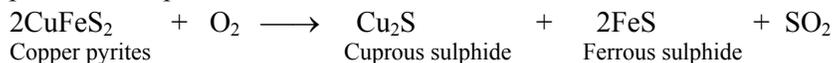
- i. Concentration  
ii. Roasting  
iii. Smelting  
iv. Bessemerization  
v. Electrolytic refining of copper.



**\*Q.83. 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<sub>2</sub>S) while As and Sb present as impurities are removed as volatile oxides.

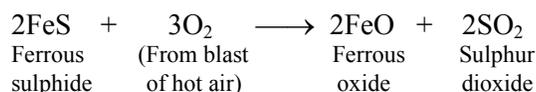


**iii. Smelting:**

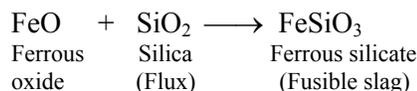
a. The roasted ore is mixed with some powdered coke and sand and it is heated strongly in blast furnace

b. During smelting,

1. FeS is oxidized to FeO.



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



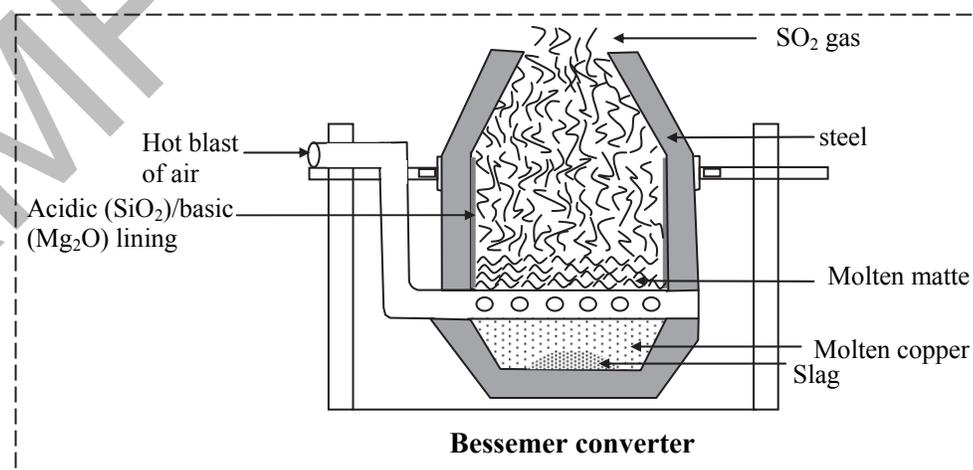
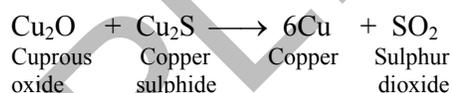
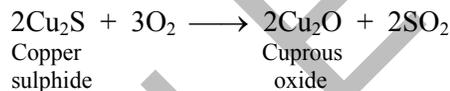
c. Two separate layers are formed at the bottom of the furnace as a result of smelting, out of which the upper layer consists of slag and is removed as a waste.

d. The lower layer consists of sulphides of Cu<sup>+</sup>, Fe<sup>+2</sup>, 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.

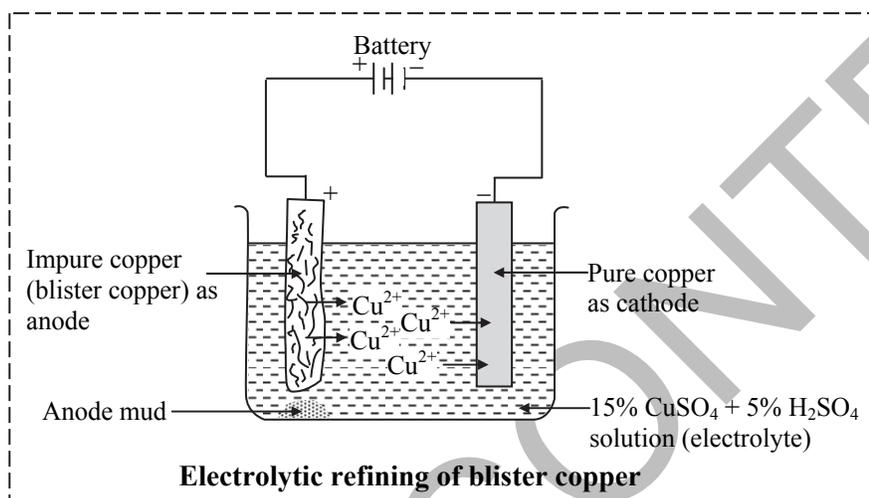


c. This is **self reduction/auto reduction**. After the reduction is complete, the molten copper is poured into sand moulds. **Blisters** are formed on the surface of copper, as sulphur dioxide (SO<sub>2</sub>) escapes from it during solidification. Blister copper thus obtained is about 99% pure.



v. **Refining:**

- 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.
- 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  $\text{CuSO}_4$  as the electrolyte.
- During electrolysis, 99.99% pure copper gets deposited at the cathode while impurities of Fe, Ni, Zn, etc., pass into the electrolytic solution.
- Noble metals like silver and gold do not react with dilute sulphuric acid present in the electrolyte and thus settle down as anode mud.



**Q.84. Name the common elements present in the anode mud in electrolytic refining of copper. Why are they so present? (NCERT)**

- Ans:**
- Blister copper mainly contains the impurities of silver and gold.
  - 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.85. Why copper matte is put in silica lined converter? (NCERT)**

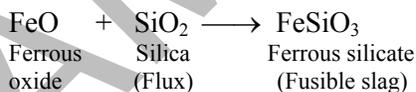
**OR**

**State the role of silica in the metallurgy of copper. (NCERT)**

**Ans:** The copper matte containing  $\text{Cu}_2\text{S}$  and  $\text{FeS}$  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  $\text{FeS}$  to  $\text{FeO}$ , which is removed as slag with silica.

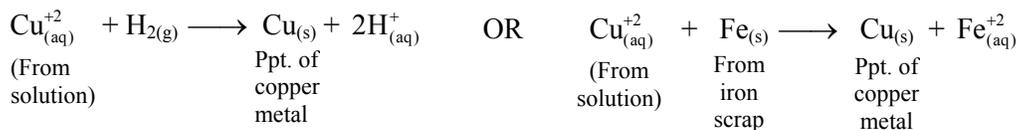


Ferrous oxide combines with silica (flux) to form fusible slag.



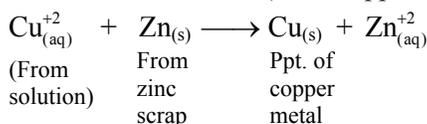
**Q.86. How is leaching carried out in case of low grade copper ores? (NCERT)**

- Ans:**
- In case of low grade copper ores, hydrometallurgical extraction of copper is carried out by leaching with acid or bacteria.
  - During leaching, the solution containing  $\text{Cu}^{+2}$  ions is treated with iron scrap or hydrogen gas and following reactions take place.





- 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.



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

**Note:**  $\text{Cu}^{+2}$  ion is more stable than  $\text{Cu}^{+}$  ion due to extensive hydration and it has higher charge and smaller size as compared to  $\text{Cu}^{+}$  ( $d^{10}$  configuration) ion.

### Electrochemical principle of metallurgy in the reduction of metal ions from their solution:

- i. In electrometallurgy, reduction of metal ions in solution or molten state occurs by electrolysis or by adding some reducing element. The method of reduction of a molten metal salt by electrolysis is based on the electrochemical principle.
- ii. This electrochemical principle could be understood by the following equation which gives the relationship between the change in Gibbs free energy and electrode potential of the redox couple formed in the system.

$$\Delta G^{\circ} = -nFE^{\circ} \quad \dots (1)$$

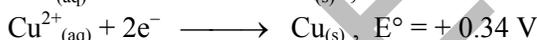
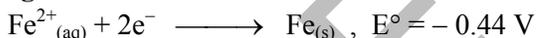
where,

$\Delta G^{\circ}$  = change in Gibbs free energy,  $n$  = number of electrons taking part in the redox reaction

$F$  = Faraday of electricity,  $E^{\circ}$  = electrode potential of the redox couple formed in the system.

- iii. Highly reactive metals having lower values of reduction potentials are reduced with difficulty whereas less reactive metals having higher values of reduction potentials are reduced easily.
- iv. More reactive metal will go into the solution and dissolve as ions whereas less reactive metals will come out of the solution and get deposited as pure metal.

**eg.**



In the above case, the difference of two  $E^{\circ}$  values of a redox system corresponds to a positive  $E^{\circ}$  value and consequently negative  $\Delta G^{\circ}$  in the equation (1). Thus, the more reactive metal (Fe) will go into the solution and less reactive metal (Cu) will come out of the solution as:



- v. Considering the reactivity of the metal produced, suitable materials are used as electrodes. In simple electrolysis, the  $M^{n+}$  ions are discharged at the negative electrode and deposited there.
- vi. Sometimes, a flux is also added for making the molten mass more conducting.

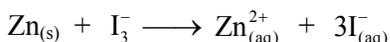
**\*Q.87. Using standard potentials, write equation for the net reaction that you would predict in the following experiments:**

- i. Zinc metal is added to aqueous sodium triiodide.
- ii. Iodine is added to excess aqueous  $\text{HClO}_3$ .

**Ans:** i. The  $E^{\circ}$  value for the  $\text{Zn}^{2+}/\text{Zn}$  and  $\text{I}_3^-/\text{I}^-$  couples are  $-0.76 \text{ V}$  and  $0.54 \text{ V}$ , respectively. Therefore,  $E^{\circ}$  for the net reaction is  $0.54 \text{ V} + 0.76 \text{ V} = 1.30 \text{ V}$ .

$\text{I}_3^-$  will undergo reduction while Zn will undergo oxidation.

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



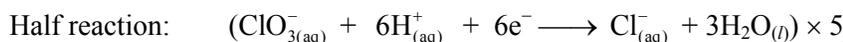


- ii. a.  $E^\circ$  value for  $I_2/I^-$  and  $ClO_3^-/ClO_4^-$  couples are 0.54 V and  $-1.20$  V respectively. The net reaction involving the reduction of  $I_2$  to  $I^-$  and the oxidation of  $ClO_3^-$  to  $ClO_4^-$  will have a negative potential.

$$E^\circ = 0.54 \text{ V} + (-1.20 \text{ V}) = -0.66 \text{ V}$$

Therefore, this net reaction will not occur.

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



### NCERT Corner

#### • Uses of aluminium:

Aluminium is used,

- for wrapping chocolates in the form of aluminium foils.
- in anti-rust paints and lacquers in the form of finely divided powder.
- in the extraction of chromium and manganese from their oxides.
- for making wires as it is a good conductor of electricity.
- in making certain alloys. These alloys are lightweight and are extensively used for various purposes.

#### • Uses of copper:

Copper is used,

- for making electric wires used in electrical industry and for water and steam pipes.
- in several alloys which are tougher than the metal itself. **eg.** Brass (with zinc), bronze (with tin) and coinage alloy (with nickel).

#### • Uses of zinc:

Zinc is used,

- for galvanising iron and is also used in batteries.
- in the manufacture of many alloys such as brass (Cu 60%, Zn 40%), German silver (Cu 25-30%, Zn 25-30%, Ni 40-50%), etc.
- as a reducing agent in the manufacture of dye-stuffs, paints, etc.

#### • Uses of iron:

- Cast iron, the most important form of iron, is used for casting stoves, railway sleepers, gutter pipes, toys, etc.
- Cast iron is the raw material used in the manufacture of wrought iron and steel.
- Wrought iron is used in making wires, bolts, anchors, chains and agricultural implements.
- Nickel steel is used for making cables, automobiles and aeroplane parts, pendulum, measuring tapes.
- Chrome steel is used for cutting tools and crushing machines.
- Stainless steel is used for cycles, automobiles, utensils, pens, etc.



### Apply Your Knowledge

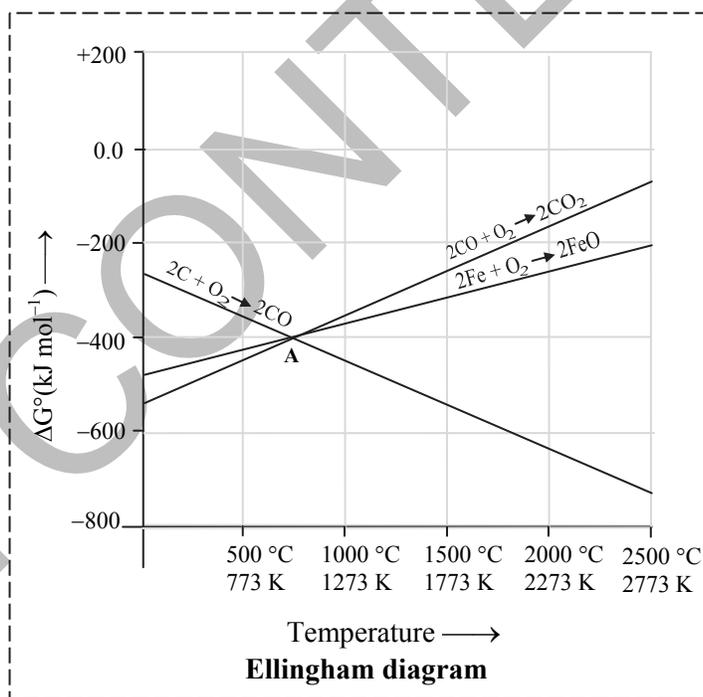
**Q.88.** While travelling in the train, Priya and Tina observed that some workers were repairing the broken railway tracks. Next day they asked their teacher about the process involved in the repairing of railway tracks. The teacher explained them the process.

- Name the process involved in the repairing of railway tracks.
- Write the reaction involved in it.

**Ans:** i. Aluminothermy or thermite process or Goldschmidt aluminothermite process.  
ii. Refer Q.80.ii.c.

**Q.89.** The feasibility of thermal reduction of an ore can be predicted with the help of Ellingham diagram. For this the basic criteria is that,  $\Delta G^\circ$  must be negative at a given temperature. By referring adjacent Ellingham diagram, answer the following questions:

- Between CO and CO<sub>2</sub>, which of the oxide of carbon will be more stable above 1000 K and why?
- Can FeO be reduced by carbon and carbon monoxide? If yes, then select the approximate temperature at which these reductions can be possible?



**Ans:** i. From the Ellingham diagram, it can be seen that above  $\Delta G^\circ$  of CO is more negative compared to  $\Delta G^\circ$  of CO<sub>2</sub>. The more negative value of  $\Delta G^\circ$  means greater the tendency of element to combine with oxygen. Hence, above approximately 1000 K, the formation of CO will be more favorable. Hence, CO will be more stable than CO<sub>2</sub> above 1000 K.

- ii. Yes, FeO can be reduced by carbon and carbon monoxide.

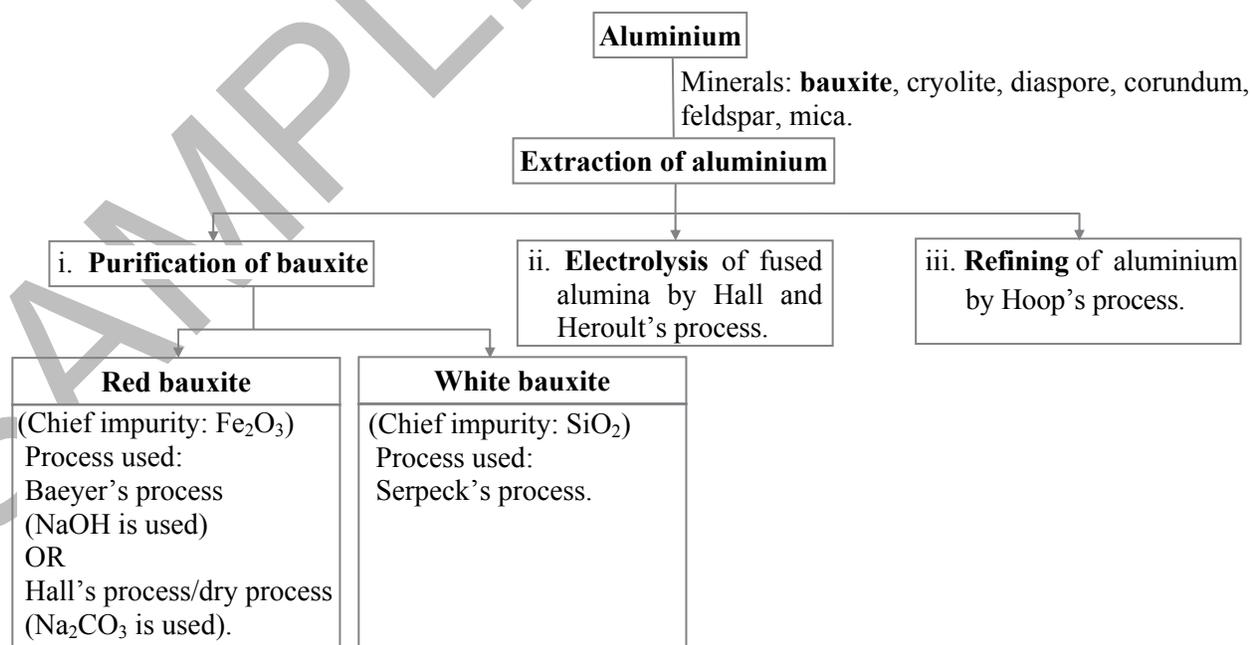
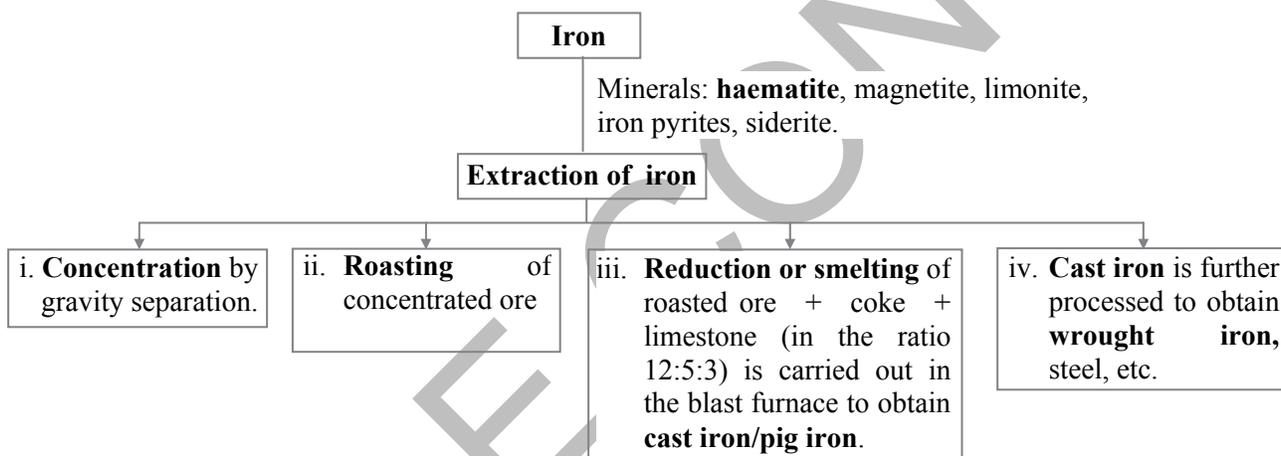
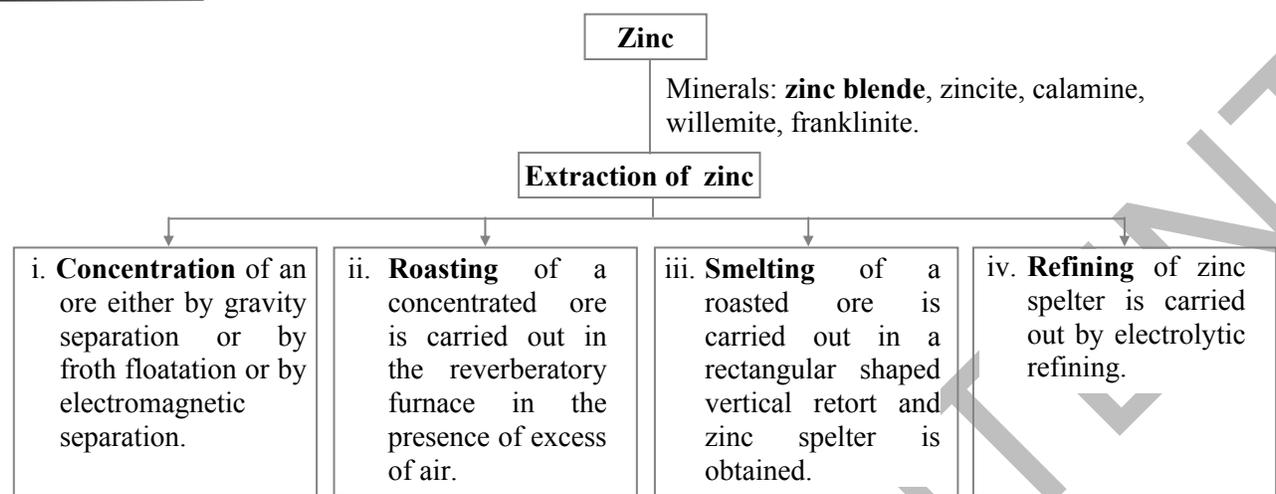
The reduction of FeO by carbon is possible above point A (i.e., above approximately 1000 K) because above 1000 K, the  $\Delta G^\circ_{(C, CO)}$  is less (i.e., more negative) compared to  $\Delta G^\circ_{(Fe, FeO)}$ . Hence, above 1000 K, carbon reduces FeO to Fe and itself get oxidised to CO.

The reduction of FeO by CO can be possible only below point A (i.e., approximately below 1000 K) because below this temperature  $\Delta G^\circ_{(CO, CO_2)}$  is more negative compared to  $\Delta G^\circ_{(Fe, FeO)}$ .

Hence, it will reduce FeO to Fe and itself get oxidised to CO<sub>2</sub>.



Quick Review





## Copper

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

### Extraction of copper

- |   |  |   |  |  |
|---|--|---|--|--|
| i. <b>Crushing</b> and concentration by froth floatation process. | ii. <b>Roasting</b> of concentrated ore in a reverberatory furnace in the presence of excess of air. | iii. <b>Smelting</b> of roasted ore + coke + sand in the blast furnace. Slag and matte are obtained through separate outlets. | iv. <b>Bessemerization</b><br>Molten matte transferred to Bessemer converter and blister copper is obtained. | v. <b>Refining</b> of blister copper by polling and/or electrolytic refining to obtain 99.95% to 99.99% pure copper. |
|---|--|---|--|--|

### Exercise

#### One Mark Questions

1. Define leaching. [Mar 17]  
**Ans:** Refer Q.20.i. [Definition – 1 Mark]
2. Explain the term ‘Smelting’. [Mar 13]  
**Ans:** Refer Q.30.i. [Definition – 1 Mark]
3. Write the chemical formulae of the following ores:  
i. Calamine                      ii. Corundrum  
**Ans:** i. Refer Q.5.i.  
ii. Refer Q.5.iv.
4. Define pyrometallurgy.  
**Ans:** Refer Q.9.i.
5. Explain the term ‘Flux’. [Mar 13]  
**Ans:** Refer Q.31.i. [Definition – 1 Mark]
6. Name any two ores which can be separated by magnetic separation method.  
**Ans:** Refer Q.15.example.
7. Give the principle behind chromatographic technique.  
**Ans:** Refer Chromatographic methods.i.
8. What is wrought iron?  
**Ans:** Refer Q.61.ii.
9. Write the name of any two ores of aluminium.  
**Ans:** Refer Q.70.iii.
10. Distinguish between minerals and ores.  
**Ans:** Refer Q.8.

#### Two Marks Questions

1. Define the following: [Oct 15]  
i. Hydrometallurgy.  
ii. Electrometallurgy.  
**Ans:** i. Refer Q.9.ii.  
ii. Refer Q.9.iii. [Definitions – 1 Mark each]
2. Describe ‘froth floatation process’ for concentration of sulphide ore. [Oct 13]  
**Ans:** Refer Q.17. i, iv, v and Diagram.  
[Explanation – 1 Mark,  
Diagram + Labelling – 1 Mark]
3. Define the following terms:  
i. Roasting                      ii. Calcination  
**Ans:** i. Refer Q.24.i. (only definition)  
ii. Refer Q.25.i.
4. What is calcination? Explain it with reactions. [Mar 15]  
**Ans:** Refer Q.25.i, iii. and iv. [Definition – 1 Mark,  
Any two reactions – ½ Mark each]
5. What is ‘calcination’? How does it differ from ‘roasting’? [Mar 14]  
**Ans:** Refer Q.25.i. and Q.24.i.  
[Definitions – 1 Mark each]
6. What are Ellingham diagrams? Write any two features of it. [Mar 16]  
**Ans:** Refer Q.38.i and ii. [Definition – 1 Mark,  
Any two features – ½ Mark each]
7. Explain refining of nickel by Mond process. [Oct 15]  
**Ans:** Refer Q.52.iii.a.  
[Explanation + Chemical reactions – 2 Marks]



8. Write chemical reactions involved in Van Arkel method for refining titanium. [July 16]

**Ans:** Refer Q.52.iii.b.eg.i.  
[Chemical reaction with names of reactants, products and reagents/reaction conditions – 2 Marks]

9. What is the action of carbon on the following metal oxides: [Mar 18]

- i.  $\text{Fe}_2\text{O}_3$  in blast furnace
- ii.  $\text{ZnO}$  in vertical retort furnace

**Ans:** i. Refer Q.63.ii.b.  
ii. Refer Q.56.iii.c.

10. Why  $\text{CaF}_2$  is added to bauxite ore before electrolysis in the metallurgy of aluminium?

**Ans:** Refer Q.77.

11. Write the reactions involved in the zone of reduction in blast furnace during extraction of iron. [Mar 15]

**Ans:** Refer Q.63.ii.  
[Chemical reactions with names of reactants, products and reagents/reaction conditions – 1 Mark each]

12. What is the role of the following compounds: [July 18]

- i.  $\text{CaF}_2$  in metallurgy of aluminium?
- ii.  $\text{SiO}_2$  in the extraction of copper from copper pyrites?

**Ans:** i. Refer Q.77. ii. Refer Q.85.

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

**Ans:** Refer Q.70.iii. [Names – ½ Mark each, Formulae – ½ Mark each]

14. Draw a neat, well labelled diagram of electrolytic cell for extraction of aluminium. [Oct 13]

**Ans:** Refer Q.75.  
[Diagram – 1 Mark, Labelling – 1 Mark]

15. Draw neat labelled diagram of electrolytic refining of blister copper. [July 16]

**Ans:** Refer Q.83.v.  
[Diagram – 1 Mark, Labelling – 1 Mark]

16. Write the chemical equations involved in van Arkel method for refining zirconium metal. [Mar 18]

**Ans:** Refer Q.52.iii. b.eg.ii.

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

**Ans:** Refer Q.38. i. and iii.

### Three Marks Questions

1. Explain the vertical retort process for the reduction of zinc oxide to zinc metal.

[Mar 13 old course]

**Ans:** Refer Q.56.iii. [Explanation – 1 Mark, Chemical reaction – 1 Mark, Diagram + Labelling – 1 Mark]

2. Explain magnetic separation process along with a neat labelled diagram and a suitable example.

**Ans:** Refer Q.14.

\*3. Explain the term smelting:

**Ans:** Refer Q.30.

4. 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.50.iii. ii. Refer Q.51.i.  
iii. Refer Q.52.i.

5. Describe Van Arkel method used for purification of metals.

**Ans:** Refer Q.52.iii.b.

6. Describe the blast furnace used in the extraction of iron from haematite.

**Ans:** Refer Q.62.i.a. to f.

7. Explain Hall's process involved in the purification of bauxite.

**Ans:** Refer Q.74.

8. Describe Bessemerization process involved in the extraction of copper.

**Ans:** Refer Q.83.iv.

9. Explain the process of leaching in case of low grade copper ores.

**Ans:** Refer Q.86.

### 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.46.

ii. Refer Q.48. and Q.49.



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.83.iv.  
 [Diagram – 1 Mark, Labelling – 1 Mark]  
 ii. Refer Q.62.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. Metallurgy is the process of \_\_\_\_\_.  
 (A) concentrating the ore  
 (B) roasting the ore  
 (C) extracting the metal from the ore  
 (D) adding carbon to the ore in blast furnace
3. Which among the following minerals does NOT contain aluminium? **[July 16]**  
 (A) Cryolite (B) Siderite  
 (C) China clay (D) Corundum
4. Which of the following is NOT an ore?  
 (A) Bauxite (B) Malachite  
 (C) Zinc blende (D) Pig iron
5. Which of the following statement is CORRECT?  
 (A) Bauxite is an ore of aluminium.  
 (B) Magnetite is an ore of manganese.  
 (C) Haematite is an ore of mercury.  
 (D) Pyrites is an ore of phosphorus.
6. Which ore is used for the manufacture of iron?  
 (A) Cryolite (B) Bauxite  
 (C) Haematite (D) Chalcopyrites
7. Formula of magnetite is \_\_\_\_\_.  
 (A)  $\text{Fe}_2\text{O}_3$  (B)  $\text{FeS}_2$   
 (C)  $\text{FeCO}_3$  (D)  $\text{Fe}_3\text{O}_4$
8. The formula of haematite is \_\_\_\_\_.  
 (A)  $\text{Fe}_3\text{O}_4$  (B)  $\text{Fe}_2\text{O}_3$   
 (C)  $\text{FeCO}_3$  (D)  $\text{FeS}_2$
9. Calamine is \_\_\_\_\_.  
 (A)  $\text{ZnSO}_3$  (B)  $\text{ZnO}$   
 (C)  $\text{Zn}(\text{NO}_3)_4$  (D)  $\text{ZnCO}_3$
10. Of the following substances, the one which does NOT contain oxygen is \_\_\_\_\_.  
 (A) bauxite (B) haematite  
 (C) cryolite (D) dolomite
11. 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
12. Magnetic separation is used for increasing concentration of \_\_\_\_\_ ore.  
 (A) bauxite (B) calcite  
 (C) haematite (D) magnesite
13. Sulphide ores are generally concentrated by \_\_\_\_\_.  
 (A) froth floatation process  
 (B) magnetic separation  
 (C) gravity separation  
 (D) leaching
14. 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
15. Roasting is generally done in case of \_\_\_\_\_.  
 (A) oxide ores (B) silicate ores  
 (C) sulphide ores (D) carbonate ores
16. Bauxite ore is concentrated by \_\_\_\_\_.  
 (A) froth flotation  
 (B) electromagnetic separation  
 (C) chemical separation  
 (D) hydraulic separation
17. When limestone is heated strongly, it gives off  $\text{CO}_2$ . In metallurgy, this process is known as \_\_\_\_\_.  
 (A) calcination (B) roasting  
 (C) smelting (D) ore dressing
18. The important step in the extraction of metal from carbonate ore is \_\_\_\_\_.  
 (A) calcination  
 (B) roasting  
 (C) leaching  
 (D) auto reduction



19. Which of the following processes involves smelting?  
(A)  $\text{ZnCO}_3 \longrightarrow \text{ZnO} + \text{CO}_2$   
(B)  $\text{Fe}_2\text{O}_3 + 3\text{C} \longrightarrow 2\text{Fe} + 3\text{CO}$   
(C)  $2\text{PbS} + 3\text{O}_2 \longrightarrow 2\text{PbO} + 2\text{SO}_2$   
(D)  $\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O} \longrightarrow \text{Al}_2\text{O}_3 + 2\text{H}_2\text{O}$
20. Which of the following is used as a reducing agent in smelting?  
(A) C (B) Cr (C) Zn (D) Fe
21. A substance which reacts with gangue to form fusible material is called \_\_\_\_\_.  
(A) flux (B) catalyst  
(C) ore (D) slag
22. The slag obtained during the extraction of copper from copper pyrites is composed mainly of \_\_\_\_\_.  
(A)  $\text{CaSiO}_3$  (B)  $\text{FeSiO}_3$   
(C)  $\text{CuSiO}_3$  (D)  $\text{SiO}_2$
23. Flux added in the extraction of iron is \_\_\_\_\_.  
(A) silica (B) feldspar  
(C) limestone (D) flint
24. The impurities associated with minerals used in metallurgy are collectively called \_\_\_\_\_.  
(A) slag (B) flux  
(C) gangue (D) ore
25. Liquefaction process is carried out using \_\_\_\_\_.  
(A) blast furnace  
(B) hydraulic classifier  
(C) reverberatory furnace  
(D) Wilfley's washing table
26. 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
27. 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
28. In electrolytic refining, the impure metal is used as \_\_\_\_\_.  
(A) cathode (B) anode  
(C) electrolyte (D) none of these
29. Zone refining is a method to obtain \_\_\_\_\_.  
(A) very high temperature  
(B) ultra pure sulphides  
(C) ultra pure metals  
(D) ultra pure oxides
30. 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
31. Four metals and their methods of refinement 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
32. The chemical formula of willemite is \_\_\_\_\_.  
[Mar 18]  
(A)  $\text{ZnS}$  (B)  $\text{ZnCO}_3$   
(C)  $\text{Zn}$  (D)  $\text{Zn}_2\text{SiO}_4$
33. In the metallurgical extraction of zinc from  $\text{ZnO}$  the reducing agent used is \_\_\_\_\_.  
(A) carbon  
(B) sulphur dioxide  
(C) carbon monoxide  
(D) nitric oxide
34. Iron is obtained on a large scale from  $\text{Fe}_2\text{O}_3$  by \_\_\_\_\_.  
(A) reduction with Al  
(B) reduction with CO  
(C) reduction with  $\text{H}_2$   
(D) reduction with sodium
35. In blast furnace, the highest temperature is in \_\_\_\_\_.  
(A) reduction zone  
(B) slag zone  
(C) fusion zone  
(D) combustion zone



36. 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
37. Calcium carbonate used in the extraction of iron acts as \_\_\_\_\_. [July 17]  
 (A) oxidising agent (B) reducing agent  
 (C) gangue (D) flux
38. 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
39.  $MnO_2$  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
40.  $Fe_2O_3$  is reduced to spongy iron near the top of blast furnace by \_\_\_\_\_. [Mar 13]  
 (A)  $H_2$  (B)  $CaO$   
 (C)  $SiO_2$  (D)  $CO$
41. The most abundant metal in the earth crust is \_\_\_\_\_.  
 (A) Na (B) Mg  
 (C) Al (D) Fe
42. 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
43. Which metal is extracted by electrolytic reduction method?  
 (A) Au (B) Al  
 (C) Fe (D) Ag
44. Purification of aluminium by electrolytic refining is carried out by \_\_\_\_\_. [Mar 14]  
 (A) Hoope process  
 (B) Hall process  
 (C) Baeyer process  
 (D) Serperck process
45. A metal which is refined by Hoope's electrolytic method is \_\_\_\_\_.  
 (A) sodium  
 (B) aluminium  
 (C) zinc  
 (D) silver
46. The substance used in the thermite process of reducing metal ores is \_\_\_\_\_.  
 (A) aluminium  
 (B) carbon monoxide  
 (C) heated platinum gauge  
 (D) carbon
47. Copper can be extracted from \_\_\_\_\_.  
 (A) epsom salt  
 (B) dolomite  
 (C) galena  
 (D) malachite
48. 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)  $Cu_2O.Cu(OH)_2$
49. 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

### Answers to Multiple Choice Questions

1. (B) 2. (C) 3. (B) 4. (D)  
 5. (A) 6. (C) 7. (D) 8. (B)  
 9. (D) 10. (C) 11. (B) 12. (C)  
 13. (A) 14. (C) 15. (C) 16. (C)  
 17. (A) 18. (A) 19. (B) 20. (A)  
 21. (A) 22. (B) 23. (C) 24. (C)  
 25. (C) 26. (D) 27. (D) 28. (B)  
 29. (C) 30. (D) 31. (B) 32. (D)  
 33. (A) 34. (B) 35. (D) 36. (C)  
 37. (D) 38. (C) 39. (C) 40. (D)  
 41. (C) 42. (D) 43. (B) 44. (A)  
 45. (B) 46. (A) 47. (D) 48. (B)  
 49. (B)



TOPIC TEST

Total : 25 Marks

Section A (1 × 5 = 5 Marks)

Choose the correct alternative:

- In the extraction of zinc, \_\_\_\_\_ process is carried out in a vertical retort.  
(A) leaching (B) roasting (C) smelting (D) froth floatation
- \_\_\_\_\_ metal is refined by Mond process.  
(A) Cu (B) Zn (C) Ti (D) Ni
- The chemical formula of magnetite is \_\_\_\_\_.  
(A)  $\text{FeCO}_3$  (B)  $\text{Fe}_3\text{O}_4$  (C)  $\text{FeS}_2$  (D)  $\text{Fe}_2\text{O}_3$

Answer the following:

- Define the term 'hydrometallurgy'.
- What is the role of fluorspar in the metallurgy of aluminium?

Section B (2 × 3 = 6 Marks)

- Name the various steps involved in the extraction of pure metal from their ores.
- What are the reactions involved in the extraction of silver from its ore by leaching process?
- 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)

- What is gangue?
  - Explain the froth floatation process.
- Define the following term:
  - Roasting
  - Smelting
  - Calcination
- Give two examples of ores which can be concentrated by magnetic separation method.
  - With a neat labelled diagram, explain magnetic separation process of an ore.

OR

- What are Ellingham diagrams?
- Write any four features of Ellingham diagrams.

Section D (5 × 1 = 5 Marks)

- Define the terms: Mineral and Metallurgy.
    - Explain Van Arkel method for refining of titanium.
- OR
- Write the chemical formulae of two ores of aluminium.
  - Explain polling method refining of crude metals.
  - Draw neat labelled diagram of Bessemer converter used in the extraction of copper.

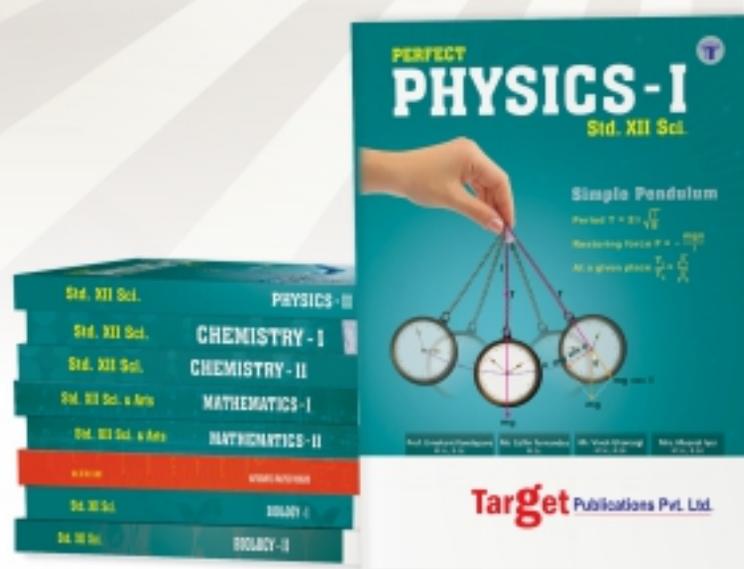


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