CHAPTER

5 GENERAL PRINCIPLES AND PROCESSES OF ISOLATION OF ELEMENTS

Syllabus

➢ *Principles and methods of extraction – concentration, oxidation, reduction–electrolytic method and refining; occurrence and principles of extraction of aluminium, copper, zinc and iron.*

Chapter Analysis

List of Topics	2016		2017		2018
	D	OD	D	OD	D/OD
Methods and Principles of Isolation of Elements	1Q (3 marks)		1 Q. (3 marks)*	1 Q. (3 marks)	
Refining of Nickel, Extraction of Aluminium and Extraction of Iron		1 Q. (3 marks)			
Extraction of Gold and Role of NaCN and Zn					1 Q. (3 marks)

● **One question of 3 marks on Principles of Vapour Phase Refining, Zone Refining and Chromatography was asked.*

On the basis of above analysis, it can be said that from exam point of view, Methods and Principles of Isolation of Elements are the most important topics of the chapter.

TOPIC-1
Principles and Methods of Extraction

Revision Notes

➢ **Minerals :** The naturally occurring chemical substances in the earth's crust which are obtained by mining.

➢ **Ore :** The mineral from which a particular metal can be extracted conveniently and economically.

➢ **Gangue :** The earthy materials associated with the ores.

➢ **Occurrence of metals :**

In free state : Very few metals exist in the free or native state. Only metals like gold, platinum and mercury are occasionally found in the free state, *i.e.*, in the pure form.

In the combined state : The rest of the metals occur in the combined form of compounds such as oxides, carbonates, sulphides, sulphates, silicates, chlorides, nitrates, phosphates etc.

Note : Copper and silver are two metals which occur in free as well as combined state as sulphides, oxides or halides ores.

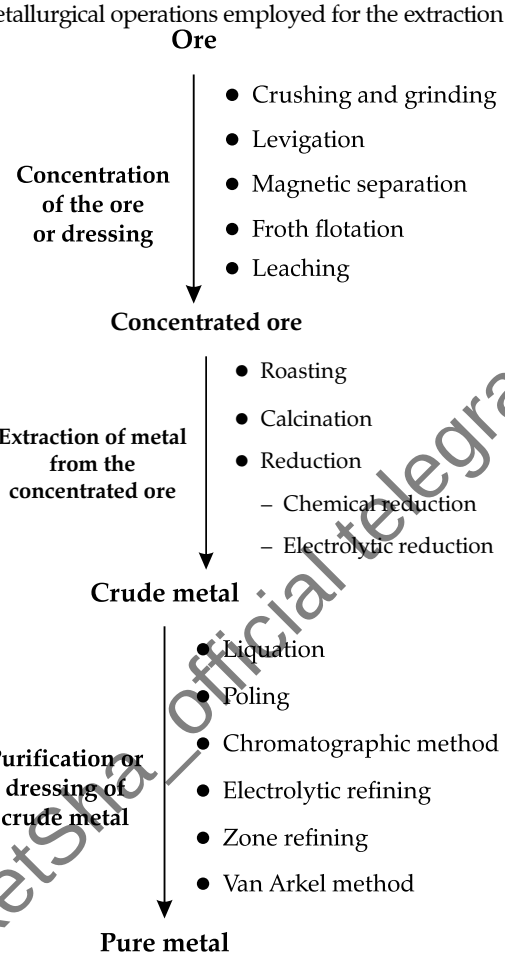
➢ **Metallurgy :** Metallurgy is the entire scientific and technological process used to obtain the pure metal from its ore.

➢ **Flux :** The substance which is added in the ore to convert non-fusible gangue to fusible compound is called flux. There are three types of flux : acidic flux (Silica borax) and basic flux (Limestone) and neutral flux (Graphite).

➢ **Slag :** The fusible compound formed by combination of flux and gangue is called slag.

- **The processes involved in the metallurgy :**
  - **(i)** Concentration of the ore
  - **(ii)** Isolation of metal from its concentrated ore
  - **(iii)** Refining or purification of metals
- **Metallurgy :** The whole process of obtaining a pure metal from one of it's ore is known as metallurgy.

A general scheme of various metallurgical operations employed for the extraction of metals from ores is given below :



- **Concentration of ore :** It is a process used for removing the gangue from the ore and increasing ore's grade on the basis of difference between the physical or chemical properties of the gangue and the ore.

The concentration of the ore is carried out by the following methods :

- **(i) Crushing and Grinding :** The huge lumps are first broken into small pieces in the jaw crushers and then powdered with the help of a ball mill or stamp mill. This process is termed as pulverisation.
- **(ii) Levigation or Gravity separation :** It is based on difference in densities (gravities) of ore and the gangue. In this process, ores is washed with stream of water under pressure, light impurities are washed away whereas heavy ore are left behind. Eg. Generally oxides and carbonates ores are concentrated by this method.
- **(iii) Magnetic separation method :** Ore and gangue are separated, if only one of them is magnetic in nature. Magnetic separation method is used to remove tungsten $FeWO_4$–magnetic ore particles from cassiterite (non magnetic–SnO_2). It is also used to concentrate magnetite (Fe_3O_4), chromite ($FeCr_2O_4$) and pyrolusite (MnO_2) from unwanted gangue.

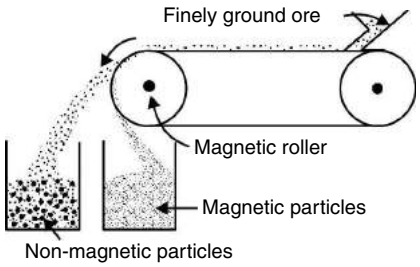


Fig. 1 : Magnetic separation method

- **(iv) Froth flotation process :** This process makes use of the principle of preferential wetting of solid surfaces by various liquids. This process is used for the concentration of sulphide ores *e.g.*, ores of lead, zinc and copper,

because of the fact that metallic sulphides are more wetted by certain oils (pine oil) and less by water. The mixture is then agitated by passing a blast of air through it. The froth is formed which carries the ore particles along with it to the surface leaving the impurities behind. The froth is scummed off and in this way the ore is concentrated by froth flotation process.

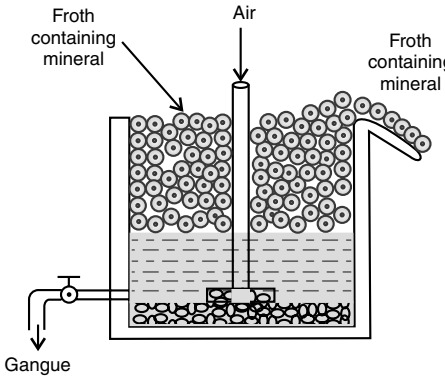


Fig. 2 : Froth flotation process

(v) Hydraulic washing : It is based on the difference in the gravities of the ore and the gangue particles. An upward stream running water is used to wash the powdered ore. The lighter gangue particles are washed away and the heavier ores are left behind.

(vi) Leaching : It is used if the ore is soluble in a suitable reagent which can selectively dissolve the ore but not the impurities.

➢ **Conversion of ore into oxide :** Following two methods are used to convert the ore into :

(i) Calcination : It is a process in which ore is heated in the absence of air so as to convert carbonate ores into oxides. Process temperature is below the melting point of treated ores. In this process, the moisture and volatile impurities are removed. Thereby one becomes porous.

$$FeCO_3 \xrightarrow{\text{Heat}} FeO + CO_2$$

Siderite

$$Fe_2O_3.xH_2O(s) \xrightarrow{\text{Heat}} Fe_2O_3(s) + xH_2O(g)$$

(ii) Roasting : It is a process in which ore is heated in regular supply of air at a temperature below the melting point of the metal so as to convert the given ore into oxide ore. It is also used to remove impurities as volatile oxides. Sulphide ores are converted into oxide by roasting. *e.g.*,

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

This process is done in reverberatory furnace.

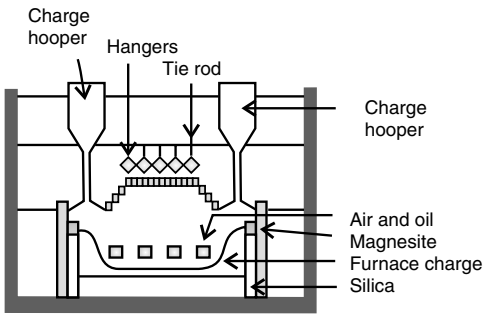


Fig. 3 : A section of a modern reverberatory furnace

➢ **Slag :** The compound formed on reaction of gangue with flux is called **slag**. It is a fusible mass which floats over metal.

$$\underset{\text{Iron (II) oxide (Basic Gangue)}}{FeO} + \underset{\text{Silica (Acidic flux)}}{SiO_2} \rightarrow \underset{\text{Iron (II) silicate}}{FeSiO_3\ (\text{slag})}$$

➢ **Reduction of oxide to metal :** Reduction of the metal oxide involves heating it with some other substance acting as a reducing agent. The common reducing agent used are carbon, carbon monoxide or any other metal like Al, Mg etc. Some common methods used for the reduction are given below :

(i) Auto reduction : In this method inactive metals can be reduced simply by heating the ore in air. Extraction of copper, lead, antimony, mercury etc, have been carried out by this process. *e.g.*,

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2 \uparrow$$
$$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2 \uparrow$$

(ii) Smelting : In this process metal oxide is reduced to metal with C or CO. *e.g.*,

$$Fe_2O_3 + 3C \xrightarrow{> 1123\ K} 2Fe + 3CO \uparrow$$
$$Fe_2O_3 + 3CO \xrightarrow{1123\ K} 2Fe + 3CO_2 \uparrow$$
$$ZnO + C \rightarrow Zn + CO \uparrow$$

(iii) Aluminothermic reduction : The process of reduction of metal oxide by aluminium is known as aluminothermic reduction. Metals like manganese and chromium are extracted by thermite process.

$$3MnO_4 + 8Al \rightarrow 4Al_2O_3 + 3Mn$$
$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$$

(iv) Reduction with hydrogen : It is an efficient reducing agent for metal oxides. For this purpose, the roasted ore is heated in a current of hydrogen and metal oxide is reduced to metal. For example, oxides of W, Mo, etc. are reduced with hydrogen.

$$WO_3 + 3H_2 \rightarrow W + 3H_2O$$

- **Hydrometallurgy :** The process of extraction of a metal by dissolving the ore in a suitable reagent followed by precipitation or displacement of the metal by a more electropositive metal is known as hydrometallurgy.
- **Refining or Purification of Metals :**

(i) Liquation : This method is based on the principle of difference in melting points of metal and impurity. It is the process of refining a low melting metal like tin which can be made to flow on a sloping surface.

(ii) Zone refining : This method is particularly used when metals are required in high degree of purity. In this method, a metal rod is placed inside a small high frequency induction furnace. A narrow zone of metal is melted (Fig. 4). This furnace is now slowly moved along the rod. The pure metal recrystallizes out of the melt while impurities remain in the melt which moves along with the melted zone of the rod with the movement of the furnace. The process is repeated several times. The end of the rod where the impurities have collected is cut off. This method is employed for the purification of germanium, silicon, gallium, etc., which are used in semiconductors.

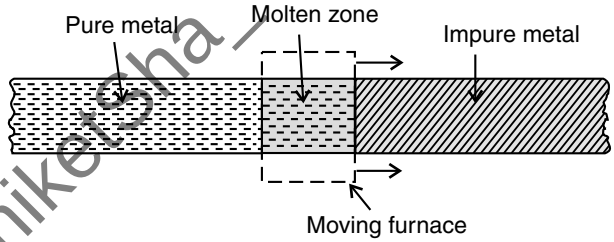


Fig. 4 : Zone refining

(iii) Electrolytic refining : This method is based upon the phenomenon of electrolysis. The crude metal is made anode whereas the thin sheet of pure metal is made cathode. Electrolyte is the solution of same salt of the metal. On passing electricity, the metal from the anode goes into solution as ions due to oxidation, while pure metal gets deposited at the cathode due to reduction of metal ions. The less electropositive impurities settle down below the anode as **anode mud.**

Reaction :

At anode : $M \rightarrow M^{n+} + ne^-$

At cathode : $M^{n+} + ne^- \rightarrow M$

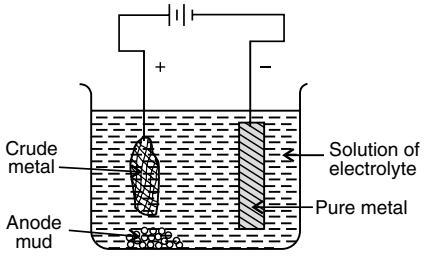


Fig. 5 : Electrolytic refining

(iv) Vapour phase refining : Vapour phase refining is illustrated by the following two methods :

(a) Mond process : This method is applied for purification of nickel. Nickel metal when heated in a stream of carbon monoxide forms volatile nickel carbonyl [$Ni(CO)_4$]. The impurities present in the impure nickel are

left behind as solid. The vapour when heated at higher temperature (450-470K) decomposes giving pure nickel and carbon monoxide.

$$\underset{\text{Impure nickel}}{Ni} + 4CO \xrightarrow{330-350K} Ni(CO)_4 \xrightarrow{450-470K} \underset{\text{Pure nickel}}{Ni} + 4CO$$

(b) Van Arkel method : Small amount of very pure titanium or zirconium metal can be prepared by this method. Impure metal is heated in an evacuated vessel with I_2. TiI_4 is formed which vaporizes leaving behind impurities. The gaseous MI_4 is decomposed on a white hot tungsten filament.

$$\underset{\text{Impure}}{Zr} + 2I_2 \xrightarrow{870K} ZrI_4 \xrightarrow[\text{Tungsten filament}]{1800K} \underset{\text{Pure}}{Zr} + 2I_2$$

$$\underset{\text{Impure}}{Ti} + 2I_2 \xrightarrow{523K} TiI_4 \xrightarrow[\text{Tungsten filament}]{1700K} \underset{\text{Pure}}{Ti} + 2I_2$$

- **Chromatographic method :** It is based on the principle of separation or purification by chromatography which is based on differential adsorption on an adsorbent. In column chromatography, Al_2O_3 is used as adsorbent. The mixture to be separated is taken in suitable solvent and applied on the column. They are then eluted out with suitable solvent (eluent). The weakly adsorbed component is eluted first, then the more strongly adsorbed and so on.
  This method is suitable for those elements which are available only in minute quantity and the impurities are not very much different in their chemical behaviour from the element to be purified.

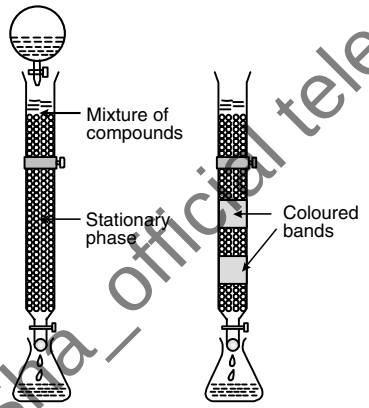


Fig. 6 : Column chromatography (Laboratory Method)

- **Thermodynamic principle of metallurgy :** This principle helps in choosing a suitable reducing agent for the reduction of particular metal oxide to metal. For any process, at any specified temperature, Gibbs free energy change (ΔG) is given by

$$\Delta G = \Delta H - T\Delta S$$

where, ΔH is the enthalpy change and ΔS is the entropy change for any process.
If ΔG is positive for any reaction, then to make such reaction spontaneous, it is coupled with another reaction of large negative ΔG value so that the sum of ΔG becomes negative. This is known as coupling reaction.

- **Ellingham diagram :** This diagram was proposed by Ellingham to select the suitable reductant for the reduction of metal oxide.

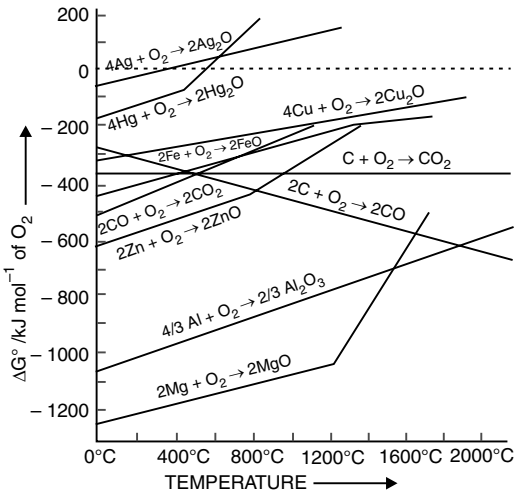


Fig. 7 : Ellingham diagram for some oxides

In this diagram, graph is plotted between change in standard free energy (ΔG°) and absolute temperature (T) for the formation of oxide of elements. This diagram helps in predicting the feasibility of reduction of an ore. The criterion of feasibility of reduction is negative value of change in free energy. This diagram explains the following important facts :

(i) Entropy decreases during formation of metal oxide from metal *i.e.*, ΔS is negative.

$$x\,M(s) + \frac{y}{2}O_2(s) \rightarrow M_xO_y(s)$$

(ii) Change in entropy (ΔS) increases on melting or boiling (change in state) of a substance. Hence, during the change in state, change in free energy takes place suddenly.

(iii) Formation of carbon monoxide is the result of oxidation. It is due to positive change in entropy (ΔS).

$$2C(s) + O_2(g) \rightarrow 2CO(g)$$

➢ **Limitations of Ellingham diagram :**

(i) Ellingham diagram simply indicates the feasibility of a reduction process as it is based only on thermodynamic principles. It is unable to explain the kinetics of a reduction process. On the basis of Ellingham diagram it cannot be predicted that how fast a reduction process will occur.

(ii) Reactions are assumed at equilibrium in this diagram.

Know the Terms

- **Refining :** The process of purifying the impure metals is called refining.
- **Froth stabilisers :** Substances like cresol and aniline which stabilise the froth.
- **Extraction :** The process used to obtain metals in free state from the concentrated ore is called extraction.
- **Ellingham diagram :** The graphical representation of Gibbs energy.

Very Short Answer-Objective Type Questions (1 mark each)

A. Multiple choice Questions:

Q. 1. Number of elements are available in the Earth's crust but most abundant elements are :

(a) Al and Fe. **(b)** Al and Cu.
(c) Fe and Cu. **(d)** Cu and Ag.

R [NCERT Exemp. Q. 4, Page 78]

Ans. Correct option : (a)

Q. 2. Zone refining is based on the principle that

(a) impurities of low boiling metals can be separated by distillation.

(b) impurities are more soluble in molten metal than in solid metal.

(c) different components of a mixture are differently adsorbed on an adsorbent.

(d) vapours of volatile compound can be decomposed in pure metal. R [NCERT Exemp. Q. 5, Page 78]

Ans. Correct option : (b)

Q. 3. Which of the following reactions is an example of auto-reduction?

(a) $Fe_3O_4 + 4CO \rightarrow 3Fe + 4CO_2$
(b) $Cu_2O + C \rightarrow 2Cu + CO$
(c) $Cu^{2+}(aq.) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq.)$
(d) $Cu_2O + \frac{1}{2}Cu_2S \rightarrow 3Cu + \frac{1}{2}SO_2$

R [NCERT Exemp. Q. 3, Page 77]

Ans. Correct option : (d)

Explanation : Reaction includes reduction of copper (I) oxide by copper (I) sulphide and in this process copper is reduced by itself. This process is called as auto-reduction. The solidified copper so obtained is known as blistered copper.

Q. 4. Electrolytic refining is used to purify which of the following metals?

(a) Cu and Zn **(b)** Ge and Si
(c) Zr and Ti **(d)** Zn and Hg

R [NCERT Exemp. Q. 9, Page 78]

Ans. Correct option : (a)

Explanation : Copper (Cu) and zinc (Zn) are two metals which are purified by electrolytic refining. In this process, impure metal is used as anode and pure metal is used as cathode. Impurities from the blistered copper or impure zinc deposit as anode mud.

Q. 5. Brine electrolysed by using inert electrodes. The reaction at anode is :

(a) $Cl^-(aq.) \rightarrow \frac{1}{2}Cl_2(g) + e^-;\ E^\ominus_{Cell} = 1.36\ V.$

(b) $2H_2O(l) \rightarrow O_2(g) + 4H^+ + 4e^-;\ E^\ominus_{Cell} = 1.23\ V.$

(c) $Na^+(aq.) + e^- \rightarrow Na(s);\ E^\ominus_{Cell} = 2.71\ V.$

(d) $H^+(aq.) + e^- \rightarrow \frac{1}{2}H_2(g);\ E^\ominus_{Cell} = 0.00\ V.$

A [NCERT Exemp. Q. 7, Page 78]

Ans. Correct option : (a)

Explanation : Electrolysis of brine solution:

At anode: $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

At cathode: $2H_2O(l) + 2e^- \rightarrow 2OH^-(aq) + H_2(g)$

Reaction: $2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH$

B. Match the following :

Q. 1. Match the items of Column I with the items of Column II and assign the correct code :

Column I	Column II
(A) Coloured bands	(1) Zone refining
(B) Impure metal to volatile complex	(2) Fractional distillation
(C) Purification of Ge and Si	(3) Mond Process
(D) Purification of mercury	(4) Chromatography
	(5) Liquation

Code :

(a) A (1) B (2) C (4) D (5)
(b) A (4) B (3) C (1) D (2)
(c) A (3) B (4) C (2) D (1)
(d) A (5) B (4) C (3) D (2)

[NCERT Exemp. Q. 46, Page 84]

Ans. Correct Code : (b)

Column I	Column II	Explanation
(A)	(4)	Coloured bands are observed in chromatography.
(B)	(3)	Impure metal is converted to volatile complex by using Mond's process.
(C)	(1)	Ge and Si are purified by zone refining method.
(D)	(2)	Purification of mercury is done by fractional distillation.

C. Answer the following:

Q. 1. Name the method that is used for refining of nickel. R **[CBSE OD 2014]**

Ans. Mond process. **[CBSE Marking Scheme 2014] 1**

Q. 2. Name the method used for refining of copper metal. R **[CBSE OD 2014]**

Ans. Electrolytic refining. **1**
[CBSE Marking Scheme 2014]

Q. 3. Name the method used for the vapour phase refining of impure titanium and nickel metals.
R **[CBSE Comptt. Delhi 2013]**

Ans. Van Arkel method for refining impure titanium. Mond's process for refining impure nickel. **1**

Q. 4. State the principle of the method of zone refining of metals. R **[CBSE Comptt. Delhi 2013]**

Ans. Zone refining is based on the principle that the impurities are more soluble in (the melt) than in the solid state of the metal. **1**

Q. 5. Write the chemical reaction which takes place in Mond's process for refining of nickel.
R **[CBSE Comptt. Delhi 2013]**

Ans. $\underset{\text{Impure nickel}}{Ni} + 4CO \xrightarrow{330-350K} Ni(CO)_4 \xrightarrow{450-470K} \underset{\text{Pure metal}}{Ni} + 4CO$ **1**

AI **Q. 6. What is the role of graphite in the electrometallurgy of aluminium ?**
R **[CBSE Delhi 2012; KVS]**

Ans. Graphite acts as an anode in the electrometallurgy of Aluminium. **1**
[CBSE Marking Scheme 2012]

Q. 7. What is the role of collectors in froth floatation process ? R **[CBSE OD 2012]**

Ans. Collectors such as pine oils, fatty acids, xanthates etc, enhance non-wettability of ore particles. They stick to the surface of mineral particles and allow them to float. **1**

Short Answer Type Questions (2 marks each)

Q. 1. Outline the principles behind the refining of metals by the following methods :
(i) Zone refining method
(ii) Chromatographic method R **[CBSE Delhi 2014]**

Ans. (i) Impurities are more soluble in molten state than in solid state of the metal. **1**

(ii) Different components of a mixture are differently adsorbed on an adsorbent. **1**
[CBSE Marking Scheme 2014]

Answering Tip

- Write the main principle and not the process/steps involved in the process.

Q. 2. Write the principle behind the following methods of refining :
(i) Hydraulic washing
(ii) Vapour phase refining R **[CBSE Delhi 2014]**

Ans. (i) Hydraulic washing : This is based on the differences in gravities of the ore and the gangue particles. **1**

(ii) Vapour phase refining : In this method, the metal forms a volatile compound which on further heating at higher temperature decomposes to pure metal. **[CBSE Marking Scheme 2014] 1**

Answering Tip

- Outline the main principle only.

Q. 3. Write the principles of the following methods :
(i) Froth flotation method
(ii) Electrolytic refining R **[CBSE Delhi 2014]**

Ans. (i) Froth flotation method : This is based upon the preferential wetting of mineral/ore particles by oil while the gangue particles by water. **1**

(ii) Electrolytic refining : Electrolytic refining is based on the principle of deposition of pure metal on cathode. **[CBSE Marking Scheme 2014] 1**

Answering Tip

- Remember the main keywords of the underlying principle of each concept.

Q. 4. Explain the principle of the method of electrolytic refining of metals. Give one example.
R **[CBSE OD 2014]**

Ans. In this method, the impure metal is made to act as anode. A strip of the same metal in pure form is used as cathode. They are put in a suitable electrolytic bath containing soluble salt of the same metal. Pure metal gets deposited at the cathode and impurities remain in the solution. **1**

For Example : Electrorefining of Cu, Ag, Au. **1**

(Any one) [CBSE Marking Scheme 2014]

AI **Q. 5. Write the principle behind the froth flotation process. What is the role of collectors in this process ?** R **[CBSE OD 2014]**

Ans. This method is based upon the preferential wetting of mineral / ore particles by oil and gangue by water. **1**

Collectors enhance non-wettability of the mineral / ore particles to float. **1**

[CBSE Marking Scheme 2014]

Detailed Answer:

Froth flotation is a process for selectively separating hydrophobic materials from hydrophilic by preferential wetting of mineral or ore particles by oil and gangue (impurities) by water.

Collectors enhance the non-wettability of the mineral particles in the froth flotation process. **2**

Q. 6. Give reasons for the following :
(i) Alumina is dissolved in cryolite for electrolysis instead of being electrolysed directly.
(ii) Zinc oxide can be reduced to metal by heating with carbon but Cr_2O_3 cannot be reduced by heating with carbon. A&E **[CBSE Comptt. Delhi 2013]**

Ans. (i) Cryolite performs two functions in the electrolysis of alumina.

(a) It lowers the melting point of the mixture to about 1250 K.

(b) It improves the electrical conductivity of the metal. **1**

(ii) The choice of a reducing agent in a particular case depends on thermodynamic factor. For a reaction to be feasible, the reaction of metal oxide with the reducing agent should have negative ΔG°. Therefore, that reducing agent is suitable for which ΔG° for the reduction is negative. Thus,

$ZnO + C \rightarrow Zn + CO$

$\Delta_r G^\circ$ = – ve (Feasible)

$Cr_2O_3 + 3C \rightarrow 2Cr + 3CO$

$\Delta_r G^\circ$ = +ve (Not feasible) **1**

Q. 7. Describe the role of the following :
(i) SiO_2 in the extraction of copper from copper matte.
(ii) NaCN in froth flotation process.
R **[CBSE OD 2014]**

Ans. (i) It acts as flux to remove iron oxide as silicate (slag). $FeO + SiO_2 \rightarrow FeSiO_3$ (Slag). **1**

(ii) NaCN acts as the depressant. It selectively depress the flotation property of ZnS particles and hence PbS particles go into froth when air is blown in. **1**

[CBSE Marking Scheme 2014]

Q. 8. Explain the role of the following :
(i) Iodine in the refining of titanium.
(ii) NaCN in the extraction of silver from silver ore.
R **[CBSE Comptt. Delhi 2013]**

Ans. (i) Iodine in the refining of titanium :

$$Ti + 2I_2 \xrightarrow{525K} TiI_4 \xrightarrow[\text{Tungsten filament}]{1675K} Ti + 2I_2$$

1

(ii) NaCN is used to convert silver into cyanide complex.

$Ag_2S + 4NaCN \rightarrow 2Na[Ag(CN)_2] + Na_2S$

Sodium dicyanoargentate **1**

Q. 9. Giving examples, differentiate between calcination and roasting.
U **[CBSE Comptt. OD 2013]**

Ans. Calcination : Calcination involves heating of the concentrated ore in absence of air to remove water or CO_2 from hydrated oxides or carbonates respectively below its melting point. Whereas roasting is carried out by heating the ore strongly in the presence of excess of air. It oxidises the impurities of P, As, S, etc, and converts sulphide ores into metal oxides. **1**

Example for calcination :

$CaCO_3 \rightarrow CaO + CO_2$
Limestone

$MgCO_3 \rightarrow MgO + CO_2$
Magnesite ½

$CuCO_3.Cu(OH)_2 \rightarrow 2CuO + H_2O + CO_2$
Malachite

Examples for roasting :

$S + O_2 \rightarrow SO_2 \uparrow$

$4As + 3O_2 \rightarrow 2As_2O_3 \uparrow$ ½

$P_4 + 5O_2 \rightarrow 2P_2O_5 \uparrow$

Q. 10. What criterion is followed for the selection of the stationary phase in chromatography?
C **[NCERT]**

Ans. The stationary phase is selected in such a way that the components of the sample have different solubility in the phase. Hence, different components have different rates of movement through the stationary phase and as a result, can be separated from each other. **2**

Q. 11. What should be the considerations during the extraction of metals by electrochemical method?

R **[NCERT Exemp. Q. 39, Page 83]**

Ans. The following factors should be kept in mind to ensure proper precautions :

(i) Reactivity of the metal.

(ii Suitability of the electrode. **2**

Q. 12. How do we separate two sulphide ores by froth flotation method? Explain with an example.

A **[NCERT Exemp. Q. 33, Page 83]**

Ans. The separation of two sulphide ores can be done by adjusting the proportions of oil to water or can be also done by using depressants. In the case of an ore containing ZnS and PbS, the depressant used is NaCN. It forms complex with ZnS and prevents it from coming with froth but PbS remains with froth. **2**

Q. 13. Give two requirements for vapour phase refining.

C **[NCERT Exemp. Q. 43, Page 83]**

Ans. The two requirements for vapour phase refining are given below :

(a) The metal should form a volatile compound with available reagent.

(b) The volatile compound should be unstable and easily decomposable so that the recovery is easy. **2**

Long Answer Type Questions-I (3 marks each)

Q. 1. Write the principle of the following methods:

(i) Vapour Phase refining

(ii) Zone refining

(iii) Chromatography

R **[CBSE Delhi Set-2 2017]**

Ans. (i) Metal is converted into its volatile compound and collected elsewhere. It is then decomposed at high temperature to give pure metal. **1**

(ii) The impurities are more soluble in the molten state than in the solid state of metal. **1**

(iii) Different components of a mixture are differently adsorbed on an adsorbent. **1**

[CBSE Marking Scheme 2017]

Q. 2. Write the principle of the following :

(i) Zone refining

(ii) Froth floatation process

(iii) Chromatography R **[CBSE OD Set-1 2017]**

Ans.(i) Zone refining –Impurities are more soluble in the molten state than in the solid state of metal. **1**

(ii) Mineral particles are wetted by oils forming froth while gangue particles are wetted by water and settle down. **1**

(iii) Different components of a mixture are differently adsorbed on an adsorbent. **1**

[CBSE Marking Scheme 2017]

Answering Tip

- Write only the principle and not the process/steps involved in the process.

Q. 3. Outline the principles of refining of metals by the following methods :

(i) Zone refining.

(ii) Electrolytic refining.

(iii) Vapour phase refining.

R **[CBSE Comptt. OD 2016; DDE]**

Ans. (i) See LAT-I Q.1 (ii) **1**

(ii) Electrolytic refining : Tendency of pure metal to deposit on the cathode by passing electricity. **1**

(iii) See LAT-I Q.1 (i) **1**

[CBSE Marking Scheme 2016]

Answering Tip

- Write only the principle and not the process/steps involved in the process.

Q. 4. (i) Write the name of the method used for the refining of the following metals:

(a) Titanium

(b) Germanium

(c) Copper

AI **(ii) Write the name of the method of concentration applied for the following ores:**

(a) Zinc blende

(b) Haematite

(c) Bauxite R **[CBSE Foreign Set-3 2017]**

Ans.(i) (a) Vapour phase refining /van Arkel method ½

(b) Zone refining ½

(c) Electrolytic refining ½

(ii) (a) Froth floatation process ½

(b) Magnetic separation ½

(c) Leaching ½

[CBSE Marking Scheme 2017]

Q. 5. (i) Write the principle involved in the following:

(a) Zone refining of metals

(b) Electrolytic refining

(ii) Name the metal refining by each of the following processes:

(a) Mond Process

(b) van Arkel Method

R **[CBSE Comptt. OD Set-1, 3 2017]**

Ans.(i) (a) See LAT-I Q.1 (ii) **1**
(b) The more basic/reactive ones go the anode mud. **1**
(ii) (a) Ni **(b)** Ti/Zr ½+½
[CBSE Marking Scheme 2017]

Q. 6. Write the principles involved in the following methods of refining of metals:
(i) Zone refining
(ii) Chromatographic method
(iii) Electrolytic refining
R **[CBSE Comptt. OD Set-2 2017]**

Ans. (i) See LAT-I Q.1 (ii) **1**
(ii) See LAT-I Q.1 (iii) **1**
(iii) The more basic / reactive metal gets deposited at the cathode and the less basic /reactive ones go to the anode mud. **1**
[CBSE Marking Scheme 2017]

Answering Tip
- Write only the principle and not the process/steps involved in the process.

Q. 7. (i) What is the principle behind 'Zone refining' of metal ? Name an element which is refined by this method.
(ii) Write the name of the metal refined by each of the following processes:
(a) Distillation
(b) Liquation
R **[CBSE Comptt. Delhi Set-3 2017]**

Ans. (i) Impurities are more soluble in the molten state than in the solid state of the metal. ½
Example: Ge/Si/ B **(any other)** ½
(ii) (a) Zn/Hg **1**
(b) Sn **[CBSE Marking Scheme 2017] 1**

Q. 8. (i) Write the principle of electrolytic refining.
(ii) Why does copper obtained in the extraction from copper pyrites have a blistered appearance?
(iii) What is the role of depressants in the froth flotation process?
R + A&E + U **[CBSE OD Set-3 2017]**

Ans. (i) On passing current through the electrolytic cell, the pure metal gets deposited on the cathode. **1**
(ii) Evolution of SO_2 gas **1**
(iii) It selectively prevents one of the sulphide ores from coming to the froth. **1**
[CBSE Marking Scheme 2017]

Detailed Answer:
(ii) Copper pyrites is concentrated by froth flotation process. The molten copper is poured and cooled. The sulphur dioxide evaluating from the melt gets trapped in the cooler parts of the surface giving a blistery appearance. **1**

Q. 9. (i) Write the principle of vapour phase refining.
(ii) What is the role of depressant in froth flotation process?
(iii) Write the name of reducing agent to obtain iron from Fe_2O_3 at high temperature.
R + U **[CBSE Foreign Set-1 2017]**

Ans. (i) See LAT-I Q.1. (i) **1**
(ii) It selectively prevents one of the sulphide ores from coming to the froth. **1**
(iii) Coke. **[CBSE Marking Scheme 2017] 1**

Q. 10. (i) Write the principle of Zone refining .
(ii) What is the role of collectors in froth flotation process? Give an example of a collector.
(iii) Write the name of a reducing agent to obtain Fe from Fe_2O_3 at low temperature.
R + U **[CBSE Foreign Set-2 2107]**

Ans. (i) See SAT Q.1 (ii) **1**
(ii) Collectors enhance non-wettability of the mineral particles Ex. Pine oil /fatty acids. **1**
(iii) Carbon monoxide (CO). **1**
[CBSE Marking Scheme 2017]

Answering Tip
- Comprehend what is being asked before answering by reading the question carefully. Do not miss any sub-part of the question.

Q. 11. (i) Write the principle involved in the 'vapour phase refining' of metals.
(ii) Write the name of the metal refined by each of the following processes:
(a) Mond process
(b) van Arkel method
(iii) What is the role of depressant in froth flotation process?
R + U **[CBSE Comptt. Delhi Set-1, 2 2017]**

Ans. (i) See LAT-I Q.1 (i) **1**
(ii) (a) Ni (b) Ti/Zr ½+½
(iii) It is used to separate two sulphide ores by preventing one to form froth. **1**
[CBSE Marking Scheme 2017]

Answering Tip
- Comprehend what is being asked before answering by reading the question carefully. Do not miss any sub-part of the question.

Q. 12. (i) Write the principle of vapour phase refining .
(ii) Write the role of dilute NaCN in the extraction of silver.
(iii) What is the role of collectors in the froth flotation process? Give an example of a collector.
R + U **[CBSE OD Set-2 2017]**

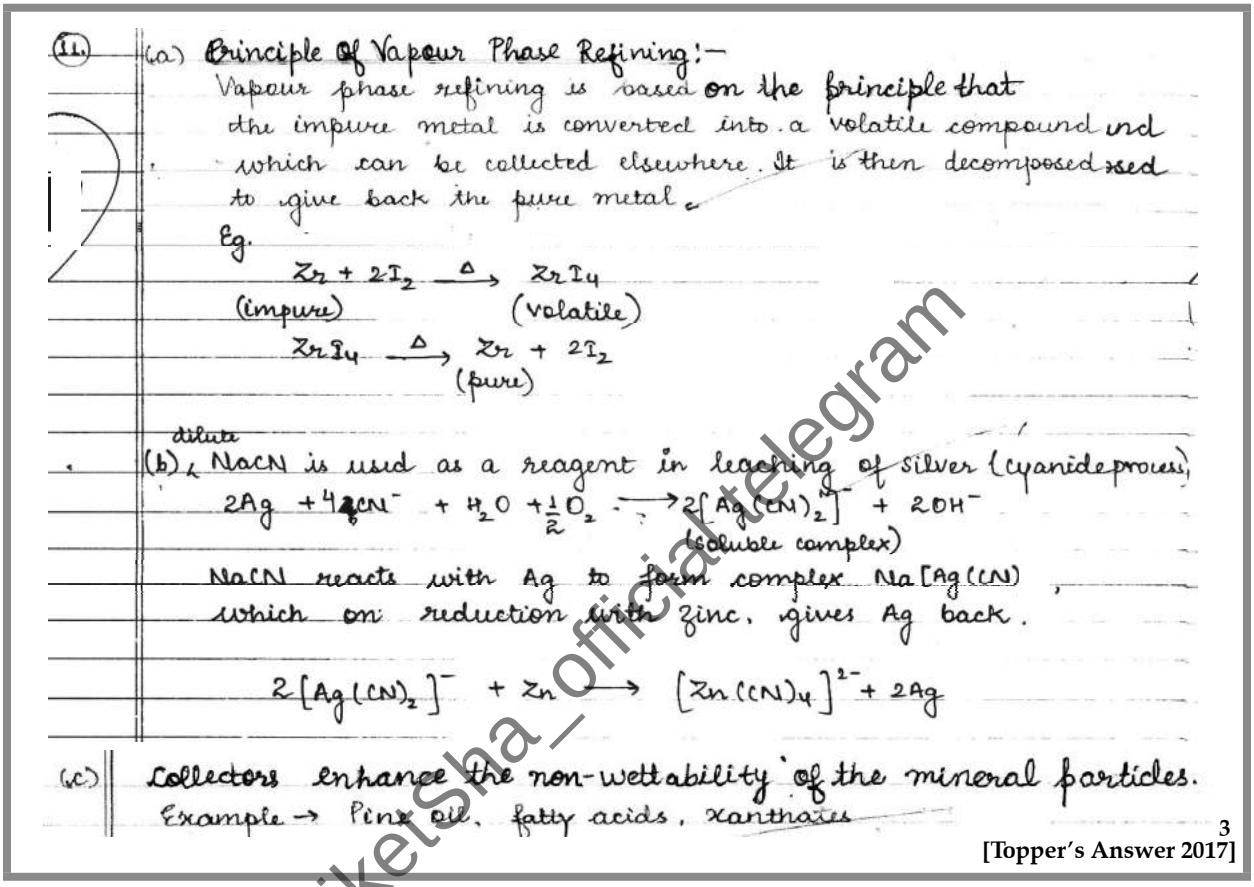
Ans. (i) See LAT-I Q.1 (i) **1**

(ii) It acts as a leaching agent/forms soluble complex with Ag. **1**

(iii) Enhance non-wettability of mineral particles. For e.g. Pine oil, Fatty acids, xanthates (Any one). **1**

[CBSE Marking Scheme 2017]

OR



(ii) (a) Principle of Vapour Phase Refining:–
Vapour phase refining is based on the principle that the impure metal is converted into a volatile compound and which can be collected elsewhere. It is then decomposed to give back the pure metal.
Eg.
$Zr + 2I_2 \xrightarrow{\Delta} ZrI_4$
(impure) (volatile)
$ZrI_4 \xrightarrow{\Delta} Zr + 2I_2$
(pure)

(b) dilute NaCN is used as a reagent in leaching of silver (cyanide process)
$2Ag + 4CN^- + H_2O + \frac{1}{2}O_2 \longrightarrow 2[Ag(CN)_2]^- + 2OH^-$
(soluble complex)
NaCN reacts with Ag to form complex $Na[Ag(CN)_2]$, which on reduction with zinc, gives Ag back.
$2[Ag(CN)_2]^- + Zn \longrightarrow [Zn(CN)_4]^{2-} + 2Ag$

(c) Collectors enhance the non-wettability of the mineral particles.
Example → Pine oil, fatty acids, xanthates

3

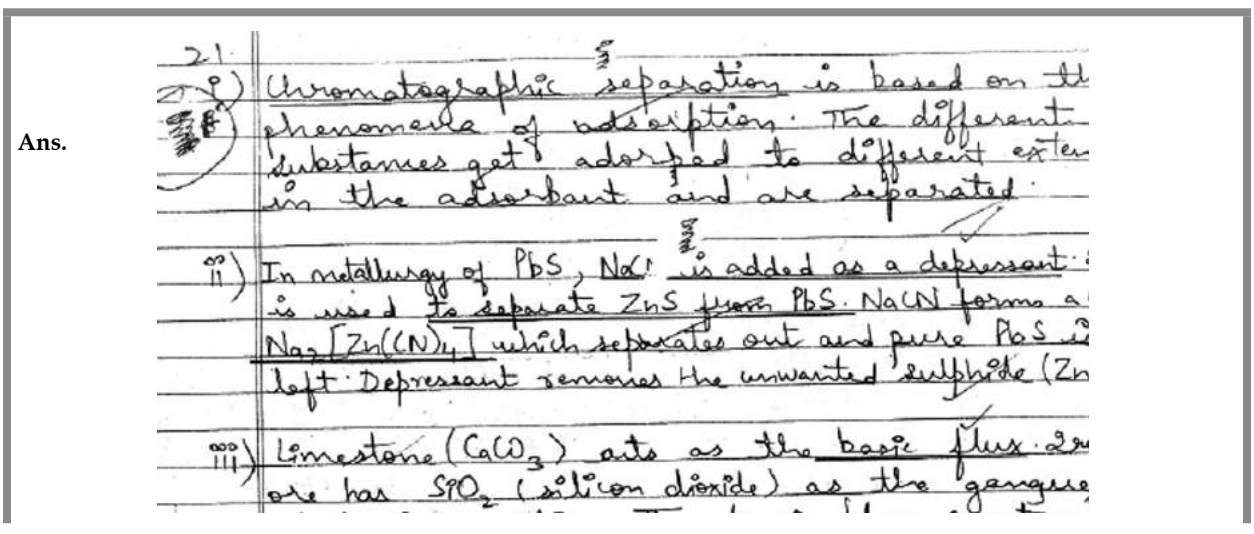
[Topper's Answer 2017]

Q. 13. (i) Name the method of refining which is based on the principle of adsorption .

(ii) What is the role of depressant in froth flotation process?

(iii) What is the role of limestone in the extraction of iron from its oxides? R **[CBSE OD Set-2 2016]**

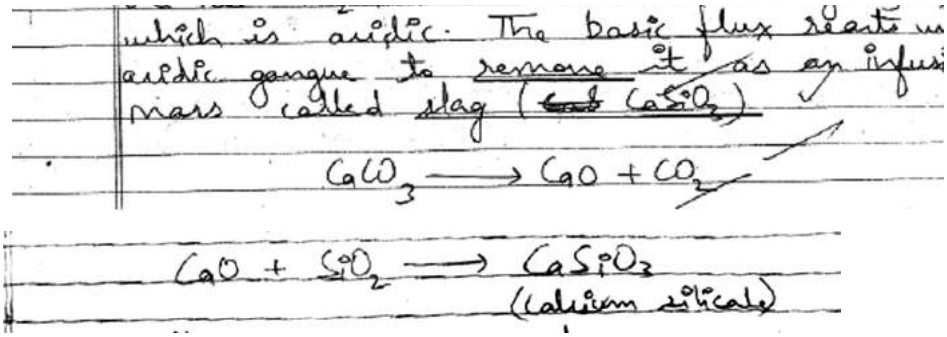
Ans.



21
(i) Chromatographic separation is based on th phenomena of adsorption. The different substances get adsorbed to different exten in the adsorbant and are separated.

(ii) In metallurgy of PbS, NaCN is added as a depressant: is used to separate ZnS from PbS. NaCN forms a $Na_2[Zn(CN)_4]$ which separates out and pure PbS is left. Depressant removes the unwanted sulphide (Zn

(iii) Limestone ($CaCO_3$) acts as the basic flux. Iron ore has SiO_2 (silicon dioxide) as the gangue



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[Topper's Answer 2016]

Detailed Answer:

(i) Chromatography. **1**

(ii) It selectively prevents one of the sulphide ores from coming to the froth. **1**

(iii) Limestone is decomposed to CaO, which removes the silica impurity of the ore as slag. **1**

Q. 14. (i) Name the method of refining of metals such as Germanium.

(ii) In the extraction of Al, impure Al_2O_3 is dissolved in conc. NaOH to form sodium aluminate and leaving impurities behind. What is the name of this process?

(iii) What is the role of coke in the extraction of iron from its oxides? R + U **[CBSE Delhi 2016]**

Ans. (i) Zone refining. **1**

(ii) Leaching / Bayer's process. **1**

(iii) Coke act as a reducing agent resulting in formation of CO. **1**

[CBSE Marking Scheme 2016]

Q. 15. (i) Name the method of refining of nickel.

(ii) What is the role of cryolite in the extraction of aluminium ?

(iii) What is the role of limestone in the extraction of iron from its oxides ? R **[CBSE OD 2016]**

Ans. (i) Mond's process. **1**

(ii) Cryolite acts as a solvent. The melting point of alumina is very high. It is dissolved in cryolite which lowers the melting point and brings conductivity. **1**

(iii) Limestone is decomposed to CaO, which removes the silica impurity of the ore as slag. **1**

[CBSE Marking Scheme 2016]

Q. 16. (i) Indicate the principle behind the method used for the refining of zinc.

(ii) What is the role of silica in the extraction of copper ?

(iii) Which form of the iron is the purest form of commercial iron ? R **[CBSE Delhi 2015]**

Ans. (i) Zinc is refined by electrolytic refining.

(a) This method is based upon the phenomenon of electrolysis.

(b) The crude metal is made anode whereas a thin sheet of pure metal is made cathode.

(c) Electrolyte is the solution of some salt of metal. **1**

(ii) In the extraction of copper, silica (SiO_2) acts as 'flux'. It reacts with FeO and removes it as slag ($FeSiO_3$).

$FeO + SiO_2 \rightarrow FeSiO_3$

(Flux) Slag **1**

(iii) Wrought iron is the purest form of iron. **1**

Q. 17. Write the chemical reactions involved in the process of extraction of Gold. Explain the role of dilute NaCN and Zn in the process.

R + U **[CBSE Delhi/OD 2018]**

Ans. $4Au(s) + 8CN^-(aq) 2H_2O(aq) + O_2(g) \rightarrow 4[Au(CN)_2]^-(aq) + 4OH^-(aq)$ **1**

$2[Au(CN)_2]^-(aq) + Zn(s) \rightarrow 2Au(s) + [Zn(CN)_4]^{2-}(aq)$ **1**

(No marks will be deducted for not balancing)

NaCN leaches gold/NaCN acts as a leaching agent / complexing agent ½

Zn acts as reducing agent / Zn displaces gold. ½

[CBSE Marking Scheme 2018]

Q. 18. Describe how the following steps can be carried out?

(a) Recovery of Gold from leached gold metal complex.

(b) Conversion of Zirconium iodide to pure Zirconium.

(c) Formation of slag in the extraction of copper.

(Write the chemical equations also for the reactions involved) C

OR

Explain the use of the following:

(a) NaCN in Froth Floatation Method.

(b) Carbon monoxide in Mond process.

(c) Coke in the extraction of Zinc from Zinc Oxide

U **[CBSE SQP 2018-2019]**

Ans. (a) Leached gold complex is treated with Zinc and gold is recovered by displacement method ½

$2Au[(CN)_2]^-(aq) + Zn(s) \rightarrow 2Au(s) + [Zn(CN)_4]^{2-}(aq)$ ½

(b) Zirconium iodide is decomposed on a tungsten filament; electrically heated to 1800 K. Pure Zr metal is deposited on the filament. ½

$ZrI_4 \rightarrow Zr + I_2$ ½

(c) Silica is added to the ore and heated. It helps to slag off iron oxide as iron silicate ½

$FeO + SiO_2 \rightarrow FeSiO_3$ (slag) ½

OR

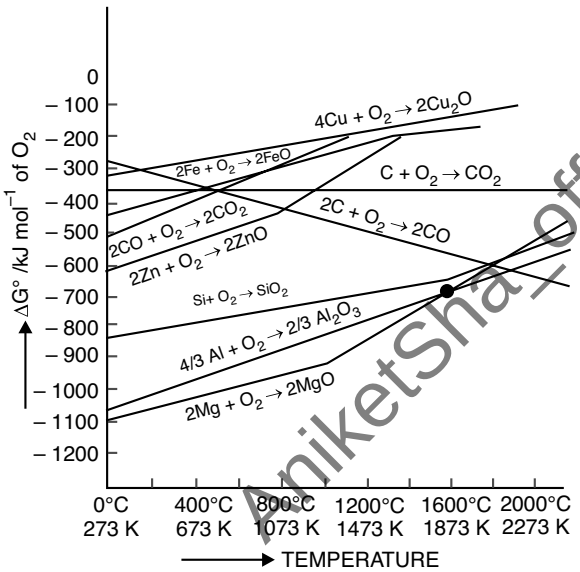
(a) NaCN is used as depressant to separate two sulphide ores (ZnS and PbS) in Froth Floatation Method. **1**

(b) Carbon monoxide forms a volatile complex of nickel, nickel tetracarbonyl. **1**

(c) Coke is used as a reducing agent to reduce zinc oxide to zinc. **1**

[CBSE Marking Scheme 2018]

Q. 19. What chemical principle is involved in choosing a reducing agent for getting the metal from its oxide ore ? Consider the metal oxides, Al_2O_3 and FeO and justify the choice of reducing agent in each case.



OR

Account for the following facts :

(i) The reduction of a metal oxide is easier if the metal formed is in the liquid state at the temperature of reduction.

(ii) Limestone is used in the manufacture of pig iron from haematite.

(iii) Pine oil is used in the froth flotation process used to concentrate sulphide ores. A&E **[CBSE SQP 2016]**

Ans. The feasibility of thermal reduction can be predicted on the basis of Ellingham diagram. Metals for which the standard free energy of formation ($\Delta_f G°$) is more negative can reduce those metals for which $\Delta_f G°$ is less negative. At a given temperature, any metal will reduce the oxide of other metals which lie above it in the Ellingham diagram. **1**

(i) Below the temperature approx. 1623 K, corresponding to the point of intersection of Al_2O_3 and MgO curves, Mg can reduce alumina. **1**

(ii) At temperatures below 1073 K, the CO, CO_2 line lies below Fe, FeO line, thus CO is a better reducing agent.

At temperatures above 1073 K, coke will reduce FeO and itself get oxidised to CO. **1**

OR

(i) Entropy is higher when a metal is in the liquid state than when it is in the solid state. Thus $T\Delta S$ increases, thus $\Delta G°$ becomes more negative and the reduction becomes easier. ($\Delta G = \Delta H - T\Delta S$) **1**

(ii) Limestone provides the flux (CaO) which combines with the impurities (SiO_2) to form slag ($CaSiO_3$). Thus it helps in the removal of impurities. **1**

(iii) Pine oil (collector) enhances the non-wettability of the ore particles, which becomes lighter and hence rise to the surface along with the froth. **1**

Long Answer Type Questions-II (5 marks)

Q. 1. Explain the following :

(a) CO_2 is a better reducing agent below 710 K whereas CO is a better reducing agent above 710 K.

(b) Generally, sulphide ores are converted into oxides before reduction.

(c) Silica is added to the sulphide ore of copper in the reverberatory furnace.

(d) Carbon and hydrogen are not used as reducing agents at high temperatures.

(e) Vapour phase refining method is used for the purification of Ti.

A&E **[NCERT Exemp. Q. 55, Page 86]**

Ans. (a) Ellingham diagram which relates Gibbs free energy and temperature at below 710K.

$\Delta G_{(C, CO_2)} < \Delta G_{(C, CO)}$. Thus, CO_2 is a better reducing agent than CO while above 710K, CO becomes a very good reducing agent. **1**

(b) Sulphide ores cannot be reduced easily but oxide ores can be easily reduced. So, sulphide ores are generally converted into oxides before reduction. **1**

(c) Copper pyrites contain iron sulphide in addition to copper sulphide. In the reverberatory furnace, copper ore is roasted to give oxides. FeO is removed by adding silica from the matte containing Cu_2S and FeS. **1**

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

$FeO + SiO_2 \rightarrow FeSiO_3$
(Slag)

(d) At the high temperature carbon and hydrogen react with metals to form carbides and hydrides respectively. Hence, they are not used as reducing agents. **1**

(e) Ti reacts with iodine to form TiI_4 which is volatile and decomposes to give Ti at high temperature to give extra pure titanium.

$Ti\ (Impure) + 2I_2 \xrightarrow{530K} TiI_4 \xrightarrow{1,800\ K} Ti\ (Pure) + 2I_2$
1

TOPIC-2
Principles of Extraction of Aluminium, Copper, Zinc and Iron

Revision Notes

➢ **Chief Ores and Methods of Extraction of Some Common Metals :**

Metal	Occurrence	Extraction Method	Remark
Copper	Copper pyrites, $CuFeS_2$ Cuprite, Cu_2O Malachite, $CuCO_3.Cu(OH)_2$ Copper glance, Cu_2S Azurite, $2CuCO_3.Cu(OH)_2$	Roasting of sulphide partially and reduction. $2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$	It is self reduction in a specially designed converter. Sulphuric acid leaching is also employed.
Aluminium	Bauxite, $Al_2O_3.xH_2O$ Cryolite, Na_3AlF_6 Kaolinite, $[Al_2(OH)_4Si_2O_5]$ Aluminosilicates	Electrolysis of Al_2O_3 dissolved in molten cryolite or in Na_3AlF_6.	A good source of electricity is needed in the extraction of Al.
Zinc	Zinc blende or Sphalerite, ZnS Zincite, ZnO Calamine, $ZnCO_3$	Roasting and then reduction with C.	The metal may be purified by fractional distillation.
Iron	Haematite, Fe_2O_3 Magnetite, Fe_3O_4 Siderite, $FeCO_3$ Iron pyrites, FeS_2 Limonite, $Fe_2O_3.3H_2O$	Reduction with the help of CO and coke in blast furnace. Chemical reduction with CO. Calcination followed by reduction with CO. Roasting followed by reduction. Chemical reduction with CO.	Limestone is added as flux which removes SiO_2 as calcium silicate (slag) floats over molten iron and prevents its oxidation. Temperature approaching 2170 K is required.

➢ **Flowchart for Extraction of Iron :**

Iron ore :
Haematite (Fe_2O_3) and Magnetite (Fe_3O_4)
↓
Concentration of ore :
Electromagnetic separation
↓
↓
Calcination and roasting :
Concentrated Ore + Air $\xrightarrow{heat}$ Moisture, CO_2, SO_2 and As_2O_3 are removed
FeO is oxidised to Fe_2O_3
↓

Smelting : (Blast furnace)

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

$FeO + SiO_2 \rightarrow FeSiO_3$

(Slag)

$FeS + Cu_2S \rightarrow$ Matte

↓

Bessemerisation in Bessemer's converter lined with lime and magnesia

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

$FeO + SiO_2 \rightarrow FeSiO_3$

(Slag)

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

$2Cu_2O + Cu_2S \xrightarrow[\text{reduction}]{\text{self}} 6Cu + SO_2$

➢ **Flowchart for the Extraction of Zinc :**

Zinc ore :

Zinc blende (ZnS), Calamine ($ZnCO_3$) and Zincite (ZnO)

↓

Concentration by Froth Flotation Process :

Powdered ore + Water + Pine oil + Foam (containing sulphide)

↓

Roasting in Reverberatory Furnace in the presence of air :

$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

$ZnS + 2O_2 \rightarrow ZnSO_4$

$2ZnSO_4 \rightarrow 2ZnO + 2SO_2 + O_2$

↓

Reduction :

$ZnO + C \rightarrow Zn + CO$

↓

Purification by Electrolytic Method

Anode : Plates of impure Zn

Cathode : Plates of pure Zn

Electrolyte : Solution of $ZnSO_4$

Deposition of pure zinc on cathode

➢ **Flowchart for Extraction of Aluminium :**

Aluminium ore :

Bauxite $Al_2O_3.xH_2O$

↓

Concentration of ore : Leaching

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq)$

$2Na[Al(OH)_4](aq) + CO_2(g) \rightarrow Al_2O_3.\,xH_2O(s) + 2NaHCO_3(aq)$

$Al_2O_3\,xH_2O(s) \xrightarrow{1470K} Al_2O_3(s) + xH_2O(g)$

↓

Electrolytic reduction : (Hall and Heroult process)

At cathode : $Al^{3+}(melt) + 3e^- \rightarrow Al(l)$

At anode : $C(s) + O^{2-}(melt) \rightarrow CO(g) + 2e^-$

$C(s) + 2O^{2-}(melt) \rightarrow CO_2(g) + 4e^-$

$2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

➢ **Flowchart for the Extraction of Copper :**

Ores :

Copper pyrite ($CuFeS_2$)

↓

Concentration of ore by Froth flotation method

↓

Roasting :

$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$

↓

Smelting :

$FeO + SiO_2 \rightarrow FeSiO_3$ (Slag)

↓

Bessemerisation :

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$

↓

Purification : By electrolytic refining by taking impure Cu as anode, pure Cu as cathode and acidified $CuSO_4$ solution as electrolyte :

At anode : $Cu \rightarrow Cu^{2+} + 2e^-$

At cathode : $Cu^{2+} + 2e^- \rightarrow Cu$

➢ **Varieties of iron and their comparison :**

S. No.	Properties	Cast Iron	Wrought Iron	Steel
1.	Iron content	94 – 96%	98·5 – 98·8%	98·5 – 99·5%
2.	Carbon content	2·5 – 4·5%	0·12 – 0·25%	0·5– 1·5%
3.	Content of Si, P, S and Mn	1·5%	0·95 – 1·4%	—
4.	Hardness	Very hard	Soft	Hard
5.	Melting point	1200°C	1500°C	1300 °C
6.	Malleability	Brittle	Malleable	Malleable
7.	Welding	Not possible.	May be done.	Can be done but with difficulty.
8.	Rust	Does not rust.	Rusts.	Does not rust.

➢ **Properties and uses of some Alloys :**

S. No.	Steel Alloy	Percentage of the component mixed	Properties of the Alloy	Uses of Alloy
1.	Manganese steel	Mn = 7 – 17%	Extremely hard, low effect of abrasives.	In manufacture of railway tracks, machines for road smashing, safe, etc.
2.	Nickel steel	Ni = 2.5 – 5%	Hard, high tensile strength, malleable, does not rust easily.	Electric wires, plates, shafts, aircraft and motor parts.
3.	Invar	Ni = 35%	Coefficient of thermal expansion is equivalent to that of glass.	In pendulum rods, meter and other articles of measurement.
4.	Chromium steel	Cr = 1.5 – 2%	Very hard	In machines for road smashing, cutting tools etc.
5.	Chromium steel or stainless steel	Cr = 12%	No rusting, no action of acids, hard.	In utensils, knives, motor and cycle parts.

6.	Chrome vanadium steel	Cr = 1 – 10% V = 15%	Very hard and strong, high tensile strength.	In ball bearings and gears, spring, car bodies, etc.
7.	Tungsten steel	W = 10 – 20% Cr = 4 – 6%	Extremely hard and tenacious.	In cutting tools, magnet, spring, etc.

➢ **Some important types of Ores :**

S. No.	Ore type	Example
1.	Native	Cu, Ag, Au, Hg, As, Bi, Sn, Pd, Pt
2.	Oxides	Al_2O_3, Fe_2O_3, Fe_3O_4, SnO_2, MnO_2, TiO_2, $FeCr_2O_4$, WO_3, Cu_2O, ZnO
3.	Carbonates	$CaCO_3$, $MgCO_3$, $FeCO_3$, $PbCO_3$, $BaCO_3$, $SrCO_3$, $ZnCO_3$, $MnCO_3$, $CuCO_3$
4.	Sulphides	Ag_2S, Cu_2S, PbS, ZnS, HgS, FeS, Bi_2S_3, NiS,CaS, MoS_2
5.	Halides	NaCl, KCl, AgCl, $MgCl_2.6H_2O$, NaCl and $MgCl_2$ (in sea water)
6.	Sulphates	$BaSO_4$, $SrSO_4$, $PbSO_4$, $CuSO_4$, $CaSO_4$. H_2O
7.	Silicates	$Be_3Al_2Si_6O_{18}$, $ZnSiO_4$, $Sc_2Si_2O_7$, $NiSiO_3$, $MgSiO_3$
8.	Phosphates	$CrPO_4$, $LaPO_4$, $Th_3(PO_4)_4$, LiF.$AlPO_4$

Know the Terms

➢ **Complex ores :** These are the mixtures of several minerals. For example : Lepidolite [$K(Li, Al, Rb)_2$. $(Al, Si)_4O_{10}(F, OH)_2$], Triphylite [$LiFePO_4$].

➢ **Native ores :** These ores contain metals in their elemental form associated with alluvial impurities like clay, sand, etc.

Very Short Answer-Objective Type Questions (1 mark each)

A. Multiple choice Questions:

Q. 1. When copper ore is mixed with silica, in a reverberatory furnace copper matte is produced. The copper matte contains _____.

(a) sulphides of copper (II) and iron (II).
(b) sulphides of copper (II) and iron (III).
(c) sulphides of copper (I) and iron (II).
(d) sulphides of copper (I) and iron (III).

R [NCERT Exemp. Q. 2, Page 77]

Ans. Correct option : (c)

Explanation : Copper ore when mixed with silica, iron oxide slags off as iron silicate and copper is produced in the form of copper matte which contains Cu_2S (I) and FeS (II).

Q. 2. In the extraction of copper from its sulphide ore, the metal is formed by the reduction of Cu_2O with :

(a) FeS. **(b) CO.**
(c) Cu_2S. **(d) SO_2.**

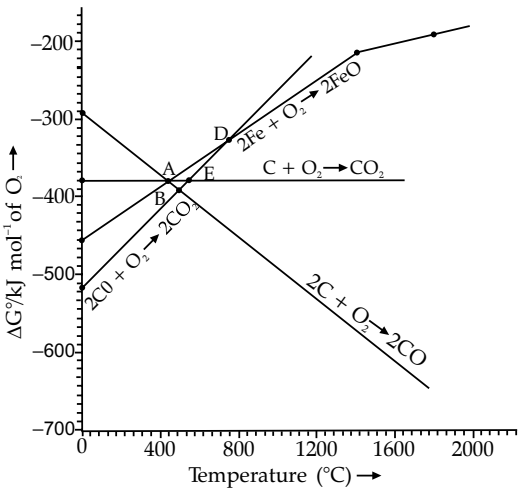
R [NCERT Exemp. Q. 6, Page 78]

Ans. Correct option : (c)

Explanation : In the extraction of copper from its sulphide ore, the metal is formed by the reduction of Cu_2O with Cu_2S. The process of the reaction is finished by the process of auto-reduction. In this reaction, copper appears as blistered copper. Chemical reaction occurring in this reaction is given below :

$$Cu_2O + \frac{1}{2}Cu_2S \rightarrow 3Cu + \frac{1}{2}SO_2$$

Note : Answer the questions 3–6 on the basis of figure following :



Q. 3. Choose the correct option of temperature at which carbon reduces FeO to iron and produces CO.
(a) Below temperature at point A.
(b) Approximately at the temperature corresponding to point A.
(c) Above temperature at point A but below temperature at point D.
(d) Above temperature at point A.
A&E **[NCERT Exemp. Q. 11, Page 79]**

Ans. Correct option : (d)
Explanation : $FeO + C \rightarrow Fe + CO$
It can be seen as a couple of two simpler reactions :

$$FeO \rightarrow Fe + \frac{1}{2}O_2 \ (\Delta G^0_{FeO,\ Fe})$$

$$C + \frac{1}{2}O_2 \rightarrow CO \ (\Delta G^0 C,\ CO)$$

Total Gibb's energy change becomes
$\Delta G^{\Theta}_{(C,\ CO)} < \Delta_{(Fe,FeO)} \Delta_r G^0$

In ΔG^{Θ} versus T plotting Fe to FeO goes upwards and the plot for C to CO goes downwards.
At temperature above point A, the C to CO lines comes below Fe to FeO and $\Delta G^{\Theta}_{(C,\ CO)} < \Delta G^{\Theta}_{(Fe,\ FeO)}$
So, in this range, C will reduce FeO to Fe and itself be oxidised to CO.

Q. 4. Below point 'A' FeO can _____.
(a) be reduced by carbon monoxide only.
(b) be reduced by both carbon monoxide and carbon.
(c) be reduced by carbon only.
(d) not be reduced by both carbon and carbon monoxide. A&E **[NCERT Exemp. Q. 12, Page 80]**

Ans. Correct option : (a)
Explanation : Below point 'A' Gibbs free energy changes for the formation of CO_2 (carbon dioxide) from CO (carbon monoxide) has lower value that means, it has more negative value than Gibbs free energy change for the formation of FeO (ferrous oxide). Hence, FeO will be reduced by CO only below point 'A'.

Q. 5. For the reduction of FeO at the temperature corresponding to point D, which of the following statements is correct?
(a) ΔG value for the overall reduction reaction with carbon monoxide is zero.
(b) ΔG value for the overall reduction reaction with a mixture of 1 mol carbon and 1 mol oxygen is positive.
(c) ΔG value for the overall reduction reaction with a mixture of 2 mol carbon and 1 mol oxygen will be positive.
(d) ΔG value for the overall reduction reaction with carbon monoxide is negative.
A&E **[NCERT Exemp. Q. 13, Page 81]**

Ans. Correct option : (a)
Explanation : At point D both the curves of oxidation of iron (Fe) and oxidation of carbon monoxide (CO) meet each other.
Thus, ΔG^{Θ} for the reaction $FeO + CO \rightarrow Fe + CO_2$ is zero.

$$2Fe + O_2 \rightarrow 2FeO;\ \Delta G = -280$$
$$2CO + O_2 \rightarrow 2CO_2;\ \Delta G = -280$$
$$2FeO + 2CO \rightarrow 2Fe + 2CO_2$$
$$\Delta G^{\Theta} = (-280 + 280) = 0$$

B. Match the following :

Q. 1. Match the items of Column I with the items of Column II and assign the correct code :

Column I	Column II
(A) Sapphire	(1) Al_2O_3
(B) Sphalerite	(2) NaCN
(C) Depressant	(3) Co
(D) Corundum	(4) ZnS
	(5) Fe_2O_3

Code :
(a) **A (3) B (4) C (2) D (1)**
(b) **A (5) B (4) C (3) D (2)**
(c) **A (2) B (3) C (4) D (5)**
(d) **A (1) B (2) C (3) D (4)**
[NCERT Exemp. Q. 48, Page 84]

Ans. Correct Code : (a)

Column I	Column II	Explanation
(A)	(3)	Sapphire is a gemstone which contains Co.
(B)	(4)	Molecular formula of sphalerite is ZnS.
(C)	(2)	NaCN is used as a depressant in froth flotation method.
(D)	(1)	Molecular formula of corundum is Al_2O_3.

C. Answer the following:

Q. 1. Which reducing agent is employed to get copper from the leached low grade copper ore ?
R **[CBSE Delhi 2014]**

Ans. Hydrogen/Iron. **[CBSE Marking Scheme 2014] 1**

AI **Q. 2. What is the role of zinc metal in the extraction of silver ?** R **[CBSE OD 2014]**

Ans. Zn acts as reducing agent. **1**
[CBSE Marking Scheme 2014]

Short Answer Type Question **(2 marks each)**

Q. 1. Name the principle ore of aluminium. Explain the significance of leaching in the extraction of aluminium. R + U **[CBSE OD 2013]**

Ans. Bauxite is the main ore of aluminium. It is concentrated by leaching. **1**
Preparation of bauxite by leaching : Bayer's process—

Bauxite ore is treated with caustic soda at 473-523 K and 35-36 bar pressure. Al_2O_3 dissolves in concentrated solution leaving behind impurities.

$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na[Al(OH)_4](aq)$

The aluminate in solution is neutralised by passing CO_2 gas and hydrated Al_2O_3 is precipitated.

$2Na[Al(OH)_4](aq) + CO_2(g) \rightarrow Al_2O_3.xH_2O(s) + 2NaHCO_3(aq)$

The sodium silicate remains in the solution and hydrated alumina is filtered, dried and heated to get back pure Al_2O_3.

$Al_2O_3.xH_2O(s) \xrightarrow{1470K} Al_2O_3(s) + xH_2O(g)$ **1**

Q. 2. The mixture of compounds A and B is passed through a column of Al_2O_3 by using alcohol as eluant. Compound A is eluted in preference to compound B. Which of the compounds A or B, is more readily adsorbed on the column?

A&E **[NCERT Exemp. Q. 35, Page 83]**

Ans. The mixture of compounds A and B is passed through a column of Al_2O_3 by using alcohol as eluant. Compound A is eluted in preference to compound B since compound A is eluted in preference to compound B. Compound B is more readily adsorbed on the column. **2**

Q. 3. Wrought iron is the purest form of iron. Write a reaction used for the preparation of wrought iron from cast iron. How can the impurities of sulphur, silicon and phosphorus be removed from cast iron? C **[NCERT Exemp. Q. 29, Page 82]**

Ans. The required reaction is given below:

$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$

Limestone is added as flux and the impurities of sulphur, silicon and phosphorus change to their oxides and pass into slag. **2**

Long Answer Type Questions-I (3 marks each)

Q. 1. Outline the principles of refining of metals by the following methods :
(i) Distillation
(ii) Zone refining
(iii) Electrolysis R

OR

Write down the reactions taking place in different zones in the blast furnace during the extraction of iron. How is pig iron different from cast iron ?

U **[CBSE Comptt. Delhi 2015]**

Ans. (i) The impurities are evaporated from volatile metals to obtain the pure metal as distillate. **1**

(ii) This method is based on the principle that the impurities are more soluble in the molten state than in the solid state of the metal. **1**

(iii) The impure metal is made to act as anode. A strip of the same metal in pure form is used as cathode. They are put in a suitable electrolytic bath containing soluble salt of the same metal.

The more basic metal remains in the solution and the less basic ones go to the anode mud. **1**

OR

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$ (Iron ore)

$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$

$CaCO_3 \rightarrow CaO + CO_2$ (Limestone)

$CaO + SiO_2 \rightarrow CaSiO_3$ (Slag)

$FeO + CO \rightarrow Fe + CO_2$

$C + CO_2 \rightarrow 2CO$ Coke

$C + O_2 \rightarrow CO_2$

$FeO + C \rightarrow Fe + CO$ **½ × 4 = 2**

(Any four correct equations)

Cast iron has lower carbon content (about 3%) than pig iron / cast iron is hard & brittle whereas pig iron is soft. **1**

[CBSE Marking Scheme 2015]

Answering Tip

- The extraction of metals should be studied in detail. All the steps must be shown in proper order with balanced chemical equation.

Q. 2. (i) Write the principle of method used for the refining of germanium.
(ii) Out of PbS and $PbCO_3$ (ores of lead), which one is concentrated by froth flotation process preferably?
(iii) What is the significance of leaching in the extraction of aluminium ?

R + U **[CBSE Delhi Set-1, 3 2017]**

Ans. (i) Zone refining : The impurities are more soluble in the molten state (melt) than in the solid state of the metal. **1**

(ii) PbS **1**

(iii) Impurities like SiO_2 etc, are removed by using NaOH solution and pure alumina is obtained. **1**

[CBSE Marking Scheme 2017]

Commonly Made Error

- Students often write the process involved instead of mentioning the principle behind the process.

AI **Q. 3. Write the role of**
(i) NaCN in the extraction of gold from its ore.
(ii) Cryolite in the extraction of aluminium from pure alumina.
(iii) CO in the purification of Nickel.

R **[CBSE Comptt. Delhi/OD 2018]**

OR

Describe the role of
(i) NaCN in the extraction of gold from its ore.
(ii) Cryolite in the extraction of aluminium from pure alumina.
(iii) CO in the purification of Nickel.

R **[CBSE SQP 2017]**

Ans. (a) Gold is leached out in the form of a complex with dil. solution of NaCN in the presence of air/ NaCN acts as leaching agent. **1**

(b) It lowers the melting point of alumina and makes it a good conductor of electricity. **1**

(c) CO forms a volatile complex with nickel which is further decomposed to give pure Ni metal. **1**

[CBSE Marking Scheme 2018]

AI **Q. 4. (i) Indicate the principle behind the method used for the refining of zinc.**

(ii) What is the role of silica in the extraction of copper ?

(iii) Which form of the iron is the purest form of commercial iron ? R **[CBSE Delhi 2015]**

Ans. (i) Zinc is refined by electrolytic refining.
In the method, the impure metal acts as anode. A strip of the same metal in pure form is used as cathode. These are put in suitable electrolytic bath containing soluble salt of the same metal. The more basic metal remains in the solution and the less basic ones go to the anode mud. **1**

(ii) Roasting of copper pyrite ($CuFeS_2$) gives FeO, Cu_2O and SO_2.

$4CuFeS_2(s) + 11O_2(g) \rightarrow 4FeO(s) + 2Cu_2O(s) + 8SO_2(g)$

To remove FeO, SiO_2 acts as flux and is added to form slag.

$FeO(s) + SiO_2(s) \rightarrow \underset{\text{(slag)}}{FeSiO_3(l)}$ **1**

(iii) Wrought iron. **1**

Q. 5. Answer the following :

(i) What is the role of cryolite in the metallurgy of aluminium ?

(ii) Differentiate between roasting and calcination.

(iii) What is meant by the term 'chromatography' ?

OR

Write the reactions taking place in different zones of the blast furnace to obtain Iron.

R + U **[CBSE Comptt. 2015]**

Ans. (i) It lowers the melting point of alumina / acts as a solvent. **1**

(ii)

S. No.	Roasting	Calcination
(a)	Process of heating the ore below its melting point with excess of air	Process of heating the ore below its melting point in absence or limited supply of air.
(b)	Volatile impurities are removed as oxides.	Water and inorganic impurities are removed.

1

(iii) It is a process of separation of different components of a mixture which are differently adsorbed on a suitable adsorbent. **1**

OR

$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
(Iron ore)

$Fe_3O_4 + CO \rightarrow 3FeO + CO_2$

$CaCO_3 \rightarrow CaO + CO_2$
(Limestone)

$CaO + SiO_2 \rightarrow \underset{\text{(Slag)}}{CaSiO_3}$

$FeO + CO \rightarrow Fe + CO_2$

$C + CO_2 \rightarrow 2CO$
Coke

$C + O_2 \rightarrow CO_2$

$FeO + C \rightarrow Fe + CO$ **½ × 4 = 2**

(Any four correct equations)

Cast iron has lower carbon content (about 3%) than pig iron / cast iron is hard & brittle whereas pig iron is soft. **[CBSE Marking Scheme 2015] 1**

Commonly Made Error

- Confusion with reactions at different temperatures.

Answering Tip

- Understand and learn the reactions in blast furnace at different temperatures by making a model or diagram to avoid errors.

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