CHAPTER

6 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.*

Trend Analysis

List of Concept names	2018	2019		2020	
	D/OD	D	OD	D	OD
Methods and Principles of Isolation of Elements		1 Q (3 marks)		Chapter was not included in syllabus	
Refining of Nickel, Extraction of Aluminum and Extraction of Iron			1 Q (3 marks)		
Extraction of Gold and Role of NaCN and Zn	1 Q (3 marks)				

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 :** It 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), 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 its ore is known as metallurgy.

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

Ore

Concentration of the ore or dressing
- Crushing and grinding
- Levigation Hydraulic wasl
- Magnetic separation
- Froth flotation
- Leaching

Concentrate dore

Extraction of metal from the concentrate dore
- Roasting
- Calcination
- Reduction
  - Chemical reduction
  - Electrolytic reduction

Crude metal

Purification or dressing of crude metal
- Liquation
- Distillation
- Chromatographic method
- Electrolytic refining
- Zone refining
- Vapour Phase Refining

Pure metal

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, ore is washed with stream of water under pressure, light impurities are washed away whereas heavy ore is left behind. *e.g.* 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.

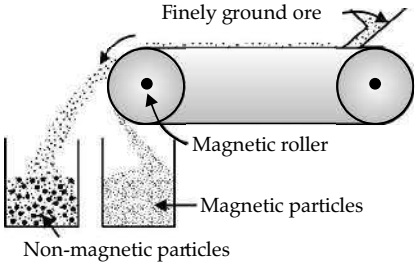


Fig. 1 : Magnetic separation method

(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.

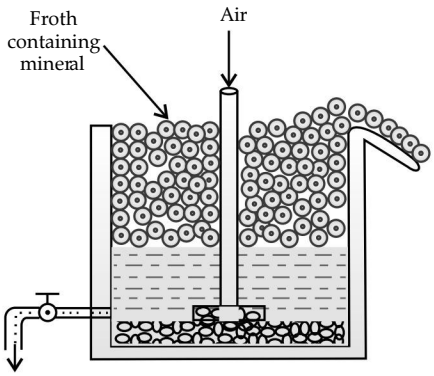


Fig. 2 : Froth flotation process

(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 ore 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.

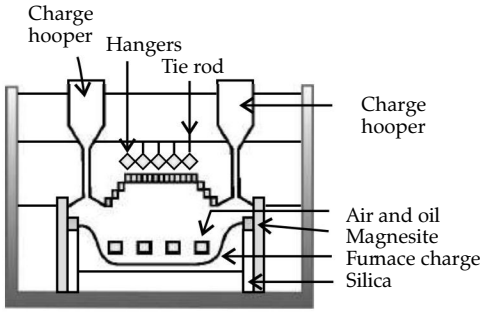


Fig. 3 : A section of a modern reverberatory furnace

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

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

- **Reduction of oxide to metal :** Reduction of the metal oxide involves heating it with some other substances acting as a reducing agent. The common reducing agents 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.

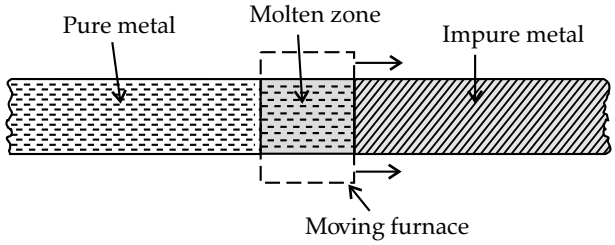


Fig. 4 : Zone refining

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

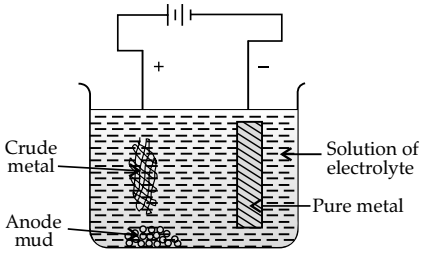


Fig. 5 : Electrolytic refining

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

(a) Mond's 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 (450–470 K) decomposes giving pure nickel and carbon monoxide.

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

(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 a method of separation or purification 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 (eluant). 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.

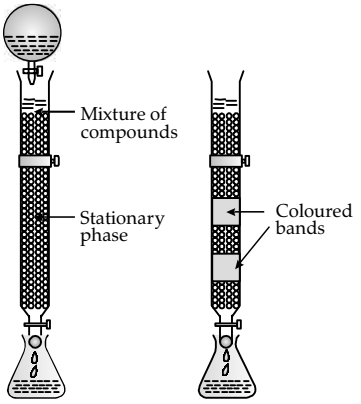


Fig. 6 : Column chromatography (Laboratory Method)

- **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, Gibb's 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.

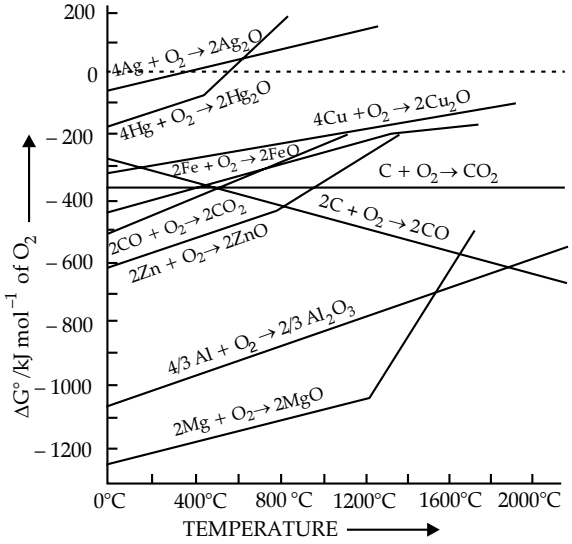


Fig. 7 : Ellingham diagram for some oxides

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).

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

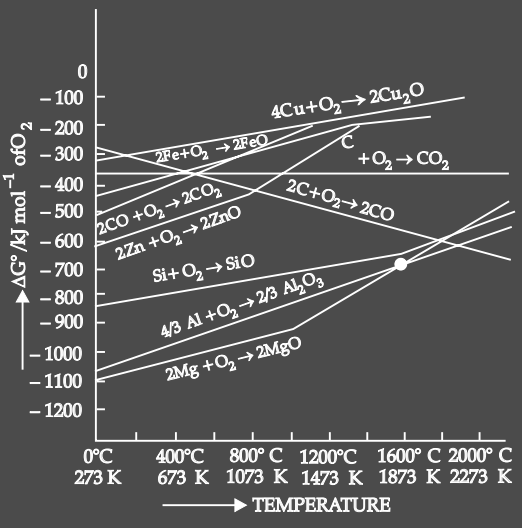
- **Limitations of Ellingham diagram :**
  - **(i)** Ellingham diagram simply indicates the feasibility of a reduction process as it is based only on thermodynamic principles. It is unable to explain the kinetics of a reduction process. On the basis of Ellingham diagram, it cannot be predicted that how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

How is it done on the GREENBOARD?

Q. 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.



Solution:

STEP-I: The feasibility of thermal reduction can be predicted on the basis of Ellingham diagram. Metals for which the standard free energy of formation **(Δ_f G°) is more negative can reduce those metals for which** Δ_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.

STEP-2: Below the temperature approx. 1623 K, corresponding to the point of intersection of Al_2O_3 and MgO curves, Mg can reduce alumina.

STEP-3: 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.

Objective Type Questions (1 marks each)

[A] MULTIPLE CHOICE QUESTIONS :

Q. 1. 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

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. 2. 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

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

Q. 3. In the Mond's process the gas used for the refining of a metal is

(a) H_2

(b) CO_2

(c) CO

(d) N_2 R

Ans. Correct option : (c)

[B] ASSERTION AND REASON TYPE QUESTIONS:

In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation of assertion.

(b) Assertion and reason both are correct statements but reason is not the correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

Q. 1. Assertion : Zone refining method is very useful for producing semiconductors.

Reason : Semiconductors are of high purity. R

Ans. Correct option: (b)

Explanation: The impurities of semiconductors are more soluble in molten zone and the ultrapure semiconductor crystallizes in zone refining method.

Q. 2. Assertion : Zirconium can be purified by Van Arkel method.

Reason : ZrI_4 is volatile and decomposes at 1,800 K. R **[NCERT Exemplar]**

Ans. Correct option: (a)

Explanation: Zirconium is also purified by vapour phase refining method in which it is treated with iodine to form ZrI_4 which on heating decomposes to give pure zirconium.

Q. 3. Assertion : Nickel can be purified by Mond's process.

Reason : $Ni(CO)_4$ is a volatile compound which decomposes at 460 K to give pure Ni. R

Ans. Correct option: (a)

Explanation: When nickel (Ni) is treated with carbon monoxide, it forms nickel tetra carbonyl $Ni(CO)_4$, while impurities are left behind. When the vapour of $Ni(CO)_4$ is heated at 460 K, it is decomposed to give pure nickel, while carbon monoxide is removed as gas.

[C] VERY SHORT ANSWER TYPE QUESTIONS :

Q. 1. Name the substance used as depressant in the separation of two sulphide ores in Froth flotation method. R **[CBSE SQP 2020]**

Ans. Sodium cyanide.

Q. 2. Name the depressant which is used to separate PbS and ZnS containing ore in froth flotation process. R **[CBSE OD Set 2, 2020]**

Ans. NaCN: It selectively allows PbS form froth but prevents ZnS from coming to froth.

Q. 3. Name the method used for the refining of Zinc. R **[CBSE OD Set 3, 2020]**

Ans. Electrolytic refining.

Short Answer Type Questions-I (2 marks each)

Q. 1. What factors should be considered while extraction of metals by electrochemical method? R

Ans. The following factors should be considered while using electrochemical method for metal extraction.

(a) Reactivity of the metal

(b) Suitability of the electrode

Q.2. How can two sulphide ores be separated by froth floatation method? Explain by giving an example. U

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.

Q. 3. Give two requirements for vapour phase refining. C

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.

Short Answer Type Questions-II (3 marks each)

Q. 1. Write the principle of the following :
(i) Zone refining
(ii) Froth flotation 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) Froth Floatation : Mineral particles are wetted by oils forming froth while gangue particles are wetted by water and settle down. **[1]**

(iii) Chromatography : Different components of a mixture are differently adsorbed on an adsorbent.
[1] [CBSE Marking Scheme 2017]

Commonly Made Error

- Students often write lengthy answers to direct questions thus losing time.

Answering Tip

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

Q. 2. (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. 3. (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 SAT- II Q.1 (i) **[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. 4. (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. 5. (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.

Q. 6. (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) Refer Q.8 (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. 7. (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 2017]**

Ans. (i) See SAT-(II) Q.1 (i) **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]

AI **Q. 8. (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) Metal is converted into its volatile compound and collected else where. It is then decomposed at high temperature to give pure metal. **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 used 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 $Na[Ag(CN)]$, 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. 9. (i) Name the method of refining which is based on the principle of adsorption .

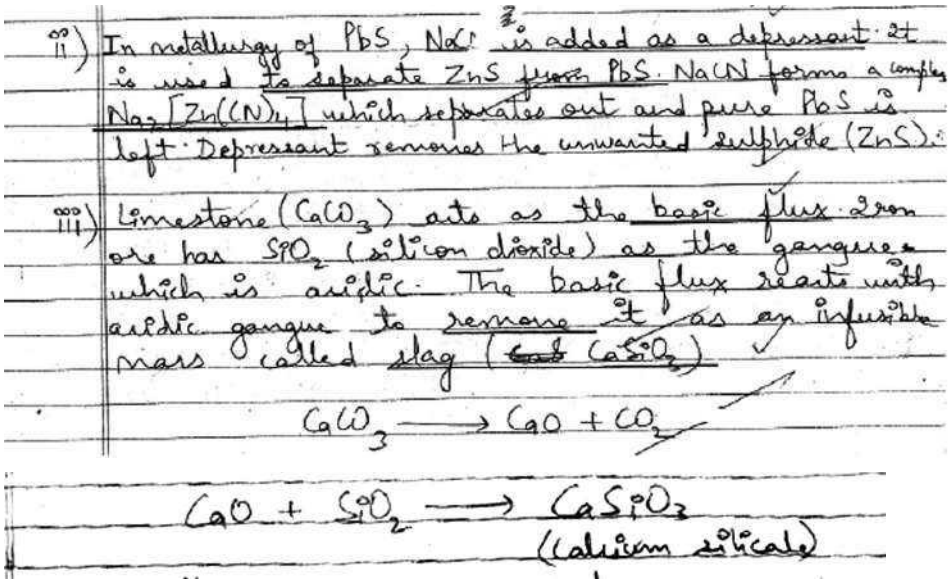
(ii) What is the role of depressant in froth flotation process?

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

Ans.

in the adsorbant and are separated.

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



3

[Topper's Answer 2016]

AI Q. 10. (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 Set-1 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. 11. 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]**

OR

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

R **[CBSE D/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]**

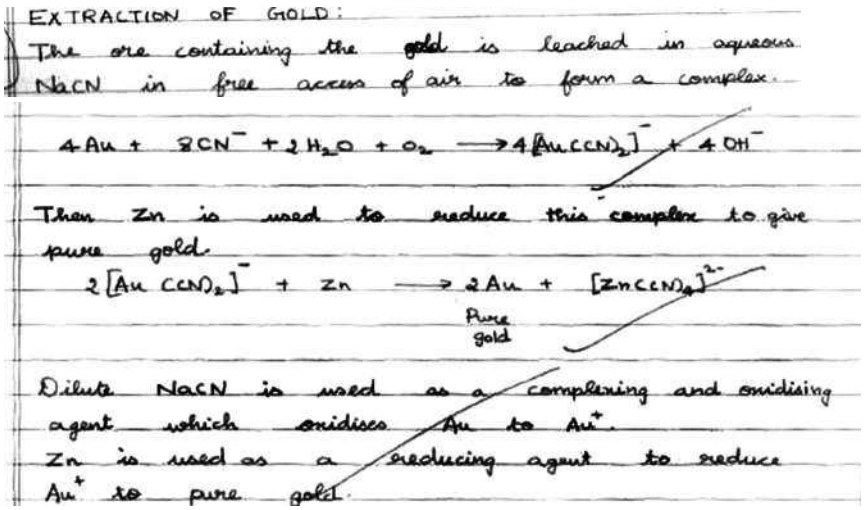
(No marks will be deducted for not balancing)

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]

OR



[Topper's Answer 2018]

Detailed Answer :

During extraction of gold, aqueous NaCN leaches gold from its ore in presence of air to form a complex $[Au(CN)_2]^-$. The reaction takes place is given as below :

$4Au + 8CN^- + 2H_2O + O_2 \rightarrow 4[Au(Cn)_2]^- 4OH^-$

Zinc reduces the complex formed to give pure gold as follows :

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

Pure gold

Role of Dil. NaCN : Dil. NaCN is used as complexing agent oxidising agent which oxidises Au to Au^+.

Role of Zn : Zinc is used as reducing agent which reduces Au^+ to pure gold.

Q. 12. 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

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

Q. 13. Explain the use of the following:

(a) NaCN in Froth Floatation Method.

(b) Carbon monoxide in Mond's process.

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

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

Q. 14. Give reasons :

(a) Name the method of refining which is :

(i) Used to obtain semiconductor of high purity,

(ii) Used to obtain low boiling metal.

(b) Write chemical reactions taking place in the extraction of copper from Cu_2S.

R **[CBSE Delhi Set-1 2019]**

Ans.(a) (i) Zone refining **(ii)** Distillation **[½ + ½]**

(b) $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$ **[1]**

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

[CBSE Marking Scheme, 2019] [1]

Detailed Answer :

(a) (i) Zone refining

(ii) distillation

(b) (i) Roasting of the sulphide are:

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

(If iron sulphide is present) :

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

(ii) Removal of iron oxide as slag :

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

(iii) Reduction of coper(I) oxide :

$Cu_2O + C \rightarrow Cu + CO$

$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$ **[3]**

AI **Q. 15. Write the principle of the following :**

(a) Hydraulic washing

(b) Chromatography

(c) Froth-floatation process

R **[CBSE OD, Set-3 2019]**

Ans. (a) This is based on difference in gravities of the ore and gangue particles. **1**

(b) Different compounds of a mixture are differently adsorbed on an adsorbent. **1**

(c) The mineral particles become wet by oil while the gangue particles by water. **1**

[CBSE Marking Scheme 2019]

Detailed Answer :

(a) Hydraulic washing : It is based on the differences in gravities of the ore and the gangue particles.

(b) Chromatography : Different components of a mixture are differently adsorbed on an adsorbent.

(c) Froth-floatation process : This is based upon the preferential wetting of mineral/ore particles by oil while the gangue particles by water.

Long Answer Type Question

(5 marks each)

Q. 1. Explain the following:

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

(b) Sulphide ores are generally converted into oxides before reduction.

(c) In the reverberatory furnace, silica is added to the sulphide ore of copper.

(d) At high temperatures, carbon and hydrogen are not used as reducing agents.

(e) For purification of Ti, vapour phase refining method is used. A&E

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

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

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

$$FeO + SiO_2 \rightarrow \underset{\text{(Slag)}}{FeSiO_3}$$

(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]

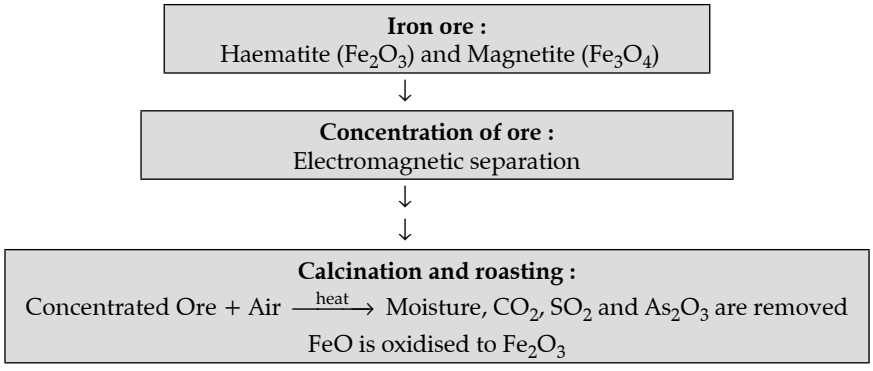
TOPIC-2
Principles of Extraction of Aluminium, Copper, Zinc and Iron

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 :**



↓

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

➢ **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.

How is it done on the GREENBOARD?

Q. 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' ?

Solution:

STEP-1: It lowers the melting point of alumina / acts as a solvent.

STEP-2:

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.

STEP-3: It is a process of separation of different components of a mixture which are differently adsorbed on a suitable adsorbent.

Objective Type Questions

(1 mark each)

[A] MULTIPLE CHOICE QUESTIONS :

Q. 1. 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

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. 2. 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

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

Q. 3. 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

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).

[B] ASSERTION & REASON TYPE QUESTIONS :

In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) **Both assertion and reason are correct statements, and reason is the correct explanation of the assertion.**

(b) **Both assertion and reason are correct statements, but reason is not the correct explanation of the assertion.**

(c) **Assertion is correct, but reason is wrong statement.**

(d) **Assertion is wrong, but reason is correct statement.**

Q. 1. **Assertion : Zone refining method is very useful for producing semiconductors.**
Reason : Semiconductors are of high purity.

Ans. **Correct option: (b)**
Explanation: The impurities of semiconductors are more soluble in molten zone and the ultrapure semiconductor crystallizes in zone refining method.

Q. 2. **Assertion : Zirconium can be purified by van Arkel method.**
Reason : ZrI_4 is volatile and decomposes at 1,800 K.

Ans. **Correct option: (a)**
Explanation: Zirconium is also purified by vapour phase refining method in which it is treated with iodine to form ZrI_4 which on heating decomposes to give pure zirconium.

Q. 3. **Assertion : Nickel can be purified by Mond's process.**
Reason : $Ni(CO)_4$ is a volatile compound which decomposes at 460 K to give pure Ni.

Ans. **Correct option: (a)**
Explanation: When nickel (Ni) is treated with carbon monoxide, it forms nickel tetracarbonyl $Ni(CO)_4$, while impurities are left behind. When the vapour of $Ni(CO)_4$ is heated at 460 K, it is decomposed to give pure nickel, while carbon monoxide is removed as gas.

[C] VERY SHORT ANSWER TYPE QUESTIONS :

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

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

AI **Q. 2. What is the role of zinc metal in the extraction of silver ?** R

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

Q. 3. **Name the substance used as depressant in the separation of two sulphide ores in Froth flotation method.** R

Ans. Sodium cyanide.

Short Answer Type Question-I (2 marks each)

Q. 1. A mixture containing two compounds A and B is passed through a column of Al_2O_3 using alcohol as eluent. Compound A is eluted in preference to compound B, which compound is more readily adsorbed on the column? A&E

Ans. As the mixture of compounds A and B is passed through a column of Al_2O_3 by using alcohol as eluent and compound A is eluted in preference to compound B, it indicates that compound B is more readily adsorbed on the column. **[2]**

Q.2. How can the impurities like sulphur, silicon and phosphorus be removed from cast iron? Write a reaction used for the preparation of wrought iron (purest form of iron) from cast iron.

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 are converted to their oxides and pass into slag. **[2]**

AI **Q. 3. What is meant by Vapour phase refining? Write any one example of the process which illustrates this technique, giving the chemical equations involved.**

OR

Write and explain the reactions involved in the extraction of gold. R

Ans. **Vapour phase refining :** It is a refining method in which the metal is converted into its volatile compound and collected elsewhere. It is then decomposed to give pure metal.
Example : Mond's process for refining of Nickel / van Arkel method for refining of Zirconium. **[1]**
Equations involved :

$$Ni + 4CO \xrightarrow{330-350\,K} Ni(CO)_4$$ **[½]**

$$Ni(CO)_4 \xrightarrow{450-470\,K} Ni + 4CO$$ **[½]**

OR

Extraction of gold involves leaching the metal with CN^-. **[½]**
Oxidation reaction :

$$4Au(s) + 8CN^-(aq) + 2H_2O(aq) + O_2(g) \rightarrow 4[Au(CN)_2]^-(aq) + 4OH^-(aq)$$ **[½]**

The metal is recovered by displacement method :

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

Zinc acts as a reducing agent. **[½]**

Short Answer Type Questions-II (3 marks each)

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

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]**

Q. 2. 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.
$3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
(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]

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

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

AI **Q. 3. (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]

AI **Q. 4. 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]**

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. 5. (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 this 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.
$FeO(s) + SiO_2(s) \rightarrow FeSiO_3(l)$ **[1]**
(slag)
(iii) Wrought iron. **[1]**

AI **Q. 6. (i) Write the role of 'CO' in the purification of nickel.**
(ii) What is the role of silica in the extraction of copper?
(iii) What type of metals are generally extracted by electrolytic method?
R **[CBSE Delhi Set-2 2019] 3**

Ans. (i) To produce a volatile complex, which decomposes on further heating to give pure nickel. **1**
(ii) To remove impurities (FeO) by forming a slag. / acts as a flux. **1**

(iii) More reactive metals having large negative electrode potential.

[CBSE Marking Scheme, 2019] 1

Detailed Answer :

(i) In Mond's process for refining nickel, nickel is heated with CO to form $Ni(CO)_4$ which is decomposed at a higher temperature to obtain the pure metal. So CO acts like a catalyst in this process.

$$Ni(\text{impure}) + 4CO \xrightarrow{\text{Heat}} Ni(CO)_4$$

$$Ni(CO)_4 \xrightarrow{\text{Heat}} Ni(\text{pure}) + 4CO$$

(ii) The ore is heated in a furnace after mixing with silica. In the furnace, iron oxide reacts with silica to form a slag of iron silicate. The copper is produced in the form of copper matte. This contains Cu_2S and FeS. The copper matte then charged into silica line convertor and it converts any remaining FeS, FeO into slag and Cu_2S/CuO into metallic copper.

The role of silica in copper extraction is to remove the iron oxide obtained during the process of roasting.

$$FeO + SiO_2 \rightarrow FeSiO_3(\text{slag})$$

The silica act as a flux.

(iii) The metals which are highly reactive in nature are generally extracted through electrolytic process. For example, Sodium, Aluminium, Calcium, etc.

Q. 7. How will you convert the following?

(i) Impure Nickel to pure Nickel.

(ii) Zinc blende to Zinc metal.

(iii) $[Ag(CN)_2]^-$ to Ag. R **[CBSE Delhi Set-3 2019]**

Ans. (i) Nickel is heated in a stream of carbon monoxide forming a volatile complex named as nickel tetracarbonyl. This complex is decomposed at higher temperature to obtain pure metal. **1**

(ii) ZnS is roasted to give ZnO which is heated with reducing agent coke to give Zn. **1**

(iii) Complex is treated with zinc , displacement reaction occurs to give pure Ag. **1**

[CBSE Marking Scheme, 2019]

Detailed Answer :

(i) The conversion of impure Nickel to pure Nickel is done by the Mond's process.

(ii) The conversion of Zinc blende to Zinc metal is done by fractional distillation.

(iii) The conversion of $[Ag(CN)_2]^-$ to Ag is done by Leaching.

AI **Q. 8. Write the name and principle of the method used for refining of (a) Zinc, (b) Germanium, (c) Titanium.** R **[CBSE OD Set-1 2019] 3**

Ans. (a) Distillation/ Electrolytic refining : The impure metal is evaporated to obtain the pure metal as distillate / The more basic metal remains in the solution and the less basic ones go to the anode mud. **[½ + ½]**

(b) Zone refining : Impurities are more soluble in the melt than in the solid state of the metal. **[½ + ½]**

(c) van Arkel method : The metal should form a volatile compound which decomposes at higher temperature to pure metal.

[CBSE Marking Scheme, 2019] [½ + ½]

AI **Q. 9. Write the name and principle of the method used for refining of (a) Tin, (b) Copper, (c) Nickel.** R **[CBSE OD Set-2 2019]**

Ans. (a) Liquation : Metals having low melting points than impurities. **[½ + ½]**

(b) Electrolytic refining : The more basic metal remains in the solution and the less basic ones go to the anode mud. **[½ + ½]**

(c) Mond's process : Ni should form a volatile compound with a suitable reagent which decomposes at higher temperature to pure Ni.

[CBSE Marking Scheme, 2019] [½ + ½]

Detailed Answer :

(a) Liquation.

Principle : This method is based on the lower melting point than the impurities and tendency of the molten metal to flow on the sloping surfaces.

(b) Electrolytic refining.

Principle : This method is based on the phenomenon of electrolysis where pure metal gets deposited on cathode when electricity is passed through the electrolyte.

(c) Vapour phase refining (Mond's process).

Principle : The metal is converted into its volatile compound and collected else where which gives pure metal when decomposed at high temperature.

Visual Case-Based Questions

(4 marks each)

Q. 1. Read the passage given below and answer the following questions: (1×4=4)

Chromatography is based on the principle where molecules in mixture applied onto the surface or into the solid, and fluid stationary phase (stable phase) is separating from each other while moving with the aid of a mobile phase. The factors effective on this separation process include molecular characteristics related to adsorption (liquid-solid), partition (liquid-solid), and affinity or differences among their molecular weights. Because of these differences, some components of the mixture stay longer in

the stationary phase, and they move slowly in the chromatography system, while others pass rapidly into mobile phase, and leave the system faster.

Source: Separation techniques: Chromatography (nih.gov)

In these questions a statement of Assertion followed by a statement of Reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

(i) Assertion: Different components of the mixture are adsorbed at different levels on the chromatographic column.

Reason: The adsorbed components are eluted by using suitable solvents.

(ii) Assertion : Column chromatography is used for purification of substances in large quantities.

Reason : It produces coloured bands on the column.

(iii) Assertion : Chromatography is used in analysis, isolation and purification of substances.

Reason: It requires a mobile and a stationary phase.

(iv) Assertion : Some components of the mixture stay longer in the stationary phase, and they move slowly in the chromatography system.

Reason: Stationary phase is always composed of phase is always composed of "liquid" or a "gaseous component.

Ans. (i) Correct option : (b)

Explanation : Different components of the mixture are adsorbed at different levels on the chromatographic column depending on mobile medium, the adsorbent material etc. The adsorbed components are later eluted using suitable solvents.

(ii) Correct option : (d)

Explanation: Column chromatography is used for purification of substances available in minute quantities.

(iii) Correct option : (b)

Explanation: Chromatography is used in analysis, isolation and purification of substances where components are separated based on their distribution in two phases- a mobile and a stationery phase.

(iv) Correct option : (c)

Explanation: Stationary phase is always composed of a "solid" phase or "a layer of a liquid adsorbed on the surface a solid support".

Q. 2. Read the passage given below and answer the following questions: (1×4=4)

In general, all blast furnace feed materials require some form of processing before being deemed suitable for blast furnace needs.

Fine and ultra-fine ferrous ores must first be agglomerated to produce sinter or pellets respectively. Lump ore may be charged directly to a blast furnace but only after it has been suitably sized and screened to remove over and undersize material. Lump ore, however, usually comprises a minor portion of the total ferrous feed. Coal cannot be directly charged via the furnace top, it must first be transformed to coke.

Raw materials are charged to the furnace in alternating layers of coke and ore. This alternating layer structure inside the furnace has a profound impact on the operation of the furnace and on the required quality of coke.

Source: Blast Furnace Operation - an overview | ScienceDirect Topics

(i) The main reactions occurring in blast furnace during extraction of iron from haematite are _____.

(a) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

(b) $FeO + SiO_2 \rightarrow FeSiO_3$

(c) $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$

(d) All of the above

(ii) Choose the correct statement from the following:

(a) In extraction of silver, silver is extracted as cationic complex.

(b) Nickel is purified by zone refining.

(c) Cast iron is obtained by remelting pig iron with scrap iron and coke using hot air blast.

(d) None of the above

(iii) For the metallurgical process of which of the ores, calcined ore cannot be reduced by carbon?

(a) haematite

(b) calamine

(c) iron pyrites

(d) All of the above

(iv) Iron obtained from blast furnace with about 4% carbon and impurities like S,P,Mn,Si in smaller amounts is known as

(a) Wrought iron

(b) Pig iron

(c) Cast iron

(d) Commercial iron

Ans. (i) Correct option : (a)

Explanation : The main reactions occurring in blast furnace during extraction of iron from haematite is _____.

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

(ii) Correct option : (c)

Explanation: Cast iron is obtained by remelting pig iron with scrap iron and coke using hot air blast.

(iii) Correct option : (c)

Explanation: Haematite (Fe_2O_3) and Calamine ($ZnCO_3$) can be reduced by carbon during the metallurgical process as these are the oxides of iron and zinc (Calamine ore on calcination dissociates to give oxide $ZnCO_3 \rightarrow ZnO + CO_2$) respectively.

Iron pyrites (FeS_2) is sulphide ore of iron.

(iv) Correct option : (b)

Explanation: Pig iron is obtained from the blast furnace which has 4% carbon and impurities like S,P,Mn,Si in smaller amounts.

Q. 3. Read the passage given below and answer the following questions: (1×4=4)

Pfann's technique of zone-refining has been applied to the purification of many metals, particularly silicon and germanium. The high purity silicon required for transistors for the electronic industry is produced by the concept of purification based on zone-refining. The concept is based on the non-equilibrium behaviour during solidification of the solid solution alloys. Purification of a metal by zone-melting (i.e., melting in zones, certain thickness at a time) technique is called zone-refining.

The solidifying phase, in a solid solution type of liquid alloy (in diagrams having separate liquid and solids), is purer than the liquid.

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) 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 different absorbed on an adsorbent.

(d) Vapour of volatile compound can be decomposed in pure metal.

(ii) Zone refining is useful for producing metals used in

(a) Pendulum **(b) Coinage alloy**

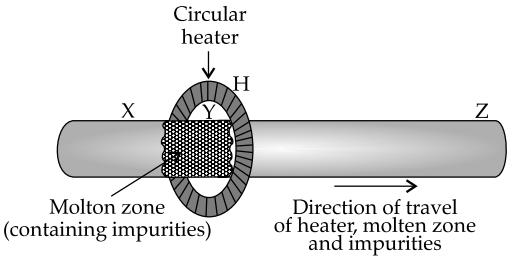
(c) Wires **(d) Semiconductors**

(iii) Zone refining is used in the purification of which of the following metals?

(a) Zn **(b) Tl**

(c) In **(d) Se**

(iv)



Zone refining of germanium metal

In the given image, identify the zones X and Z.

(a) X-Impure Germanium, Z- Pure Germanium

(b) X- Recrystallised pure Germanium, Z- Impure Germanium

(c) X- Molten Germanium, Z- Solid Germanium

(d) X- Solid Germanium, Z- Molten Germanium

Ans. (i) Correct option : (b)

Explanation: Zone refining is based on the principle that impurities are more soluble in molten metal than in solid metal.

(ii) Correct option : (d)

Explanation: Zone refining is useful for producing metals used in semiconductors and other metals of very high purity e.g Ge, Si.

(iii) Correct option : (c)

Explanation: Zone refining is used for the purification of Indium(In) metal.

(iv) Correct option : (b)

Explanation: X- Recrystallised pure Germanium, Z- Impure Germanium

As the heater moves along an impure solid rod of Germanium, the impurities move along the length in the adjacent molten zone.

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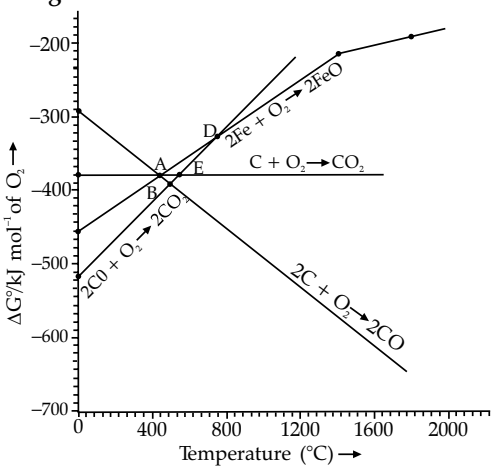
Self Assessment Test - 6

Time : 1 Hour **Max. Marks : 25**

Q. 1. Read the passage given below and answer the following questions : (1 × 4 = 4)

Note : Answer the questions on the basis of following figure :



(i) 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

(ii) 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

(iii) 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

(iv) At the temperature corresponding to which of the points in Fig. FeO will be reduced to Fe by coupling the reaction $2FeO \rightarrow 2Fe + O_2$ with all of the following reactions?

(A) $C + O_2 \rightarrow CO_2$ **(B)** $2C + O_2 \rightarrow 2CO$ **and (C)** $2CO + O_2 \rightarrow 2CO$

(a) Point A and D
(b) Point B and D
(c) Point A and E
(d) Point B and E

Q. 2. Read the passage given below and answer the following questions : (1 × 4 = 4)

Froth flotation is a process for selectively separating hydrophobic materials from hydrophilic. This is used in mineral processing, paper recycling and waste-water treatment industries. Historically this was first used in the mining industry, where it was one of the great enabling technologies of the 20th century. It has been described as "the single most important operation used for the recovery and upgrading of sulfide ores". The development of froth flotation has improved the recovery of valuable minerals, such as copper- and lead-bearing minerals. Along with mechanized mining, it has allowed the economic recovery of valuable metals from much lower grade ore than previously.

Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

(i) Assertion : Sulphide ores are concentrated by froth flotation method
Reason : Cresols stabilize the froth in froth flotation method.

(ii) Assertion : Pine oil is used to concentrate sulphide ores.
Reason : It helps in the rise of impurities to the surface.

(iii) Assertion : NaCN acts as a depressant in case of an ore containing ZnS and PbS.
Reason : The role of the depressants is to separate two sulphide ores by selectively preventing one ore from forming froth.

(iv) Assertion : Collectors enhance the non-wettability of the mineral particles.
Reason : A suspension of the powdered ore is made with oil.

Q.3. In the metallurgy of aluminium _____.

(i) Al^{3+} is oxidised to Al(s).

(ii) graphide anode is oxidised to carbon monoxide and carbon dioxide.

(iii) oxidation state of oxugen changes in the reaction at anode.

(iv) oxidation state of oxygen changes in the overall reaction involved in the process.

Q.4. In the following question a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

Assertion : Hydrometallurgy involves dissolving the ore in a suitable reagent followed by precipitation by a more electropositive metal.

Reason : Copper is extracted by hydrometallurgy.

Q.5. Name the method that is used in the refining of nickel and copper. R

Q.6. Write the 2 reactions involved to obtain metallic copper from its sulphide ore by roasting/smelting.

Q. 7. (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?

Q. 8. (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

Q. 9. 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

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