Chapter 6 General principles and processes of isolation of elements

One mark Questions

1.Differentiate between a mineral and an ore.

Ans: the naturally occurring chemical substances present in the earth's crust which can be obtained by mining are called minerals while minerals from which metals can be extracted economically are called ores.

2. Why is it that only sulphide ores are concentrated by froth floatation process.

Ans: This is because sulphide ores particles are wetted by oil and gangue particles are wetted by water.

3. Name one acidic flux and one basic flux.

Ans: silica and lime

4. Name the chief ore of silver.

Ans: argentite or silver glance

5. Name a reagent used during leaching of bauxite ore.

Ans : NaOH (sodium hydroxide)

6. Why is silica added to sulphide ore of copper in the reverberatory furnace?

Ans : in order to remove the iron impurity as slag

7. What is the role of flux in metallurgical processes?

Ans : flux is used for making the molten mass more conducting.

8. What is the thermodynamic relation between Gibbs free energy and emf of the cell.

Ans: $\Delta G^0 = -nFE^0$

9. What is the relation between gibbs free energy and equilibrium constant?

Ans: $\Delta G^0 = -RT\ln K$

10. Give the expression for Gibbs Helmholtz equation.

Ans : ΔG= ΔH—TΔS

11. Name one chemical which can be used to concentrate galena selectively by froth floatation process.

Ans: sodium cyanide (NaCN)

12. What type of ores are roasted?

Ans : sulphide ores

13. Out of C and CO which is a better reducing agent for ZnO?

Ans : the free energy of formation of CO from C becomes lower at temp. above 1120K whereas that of CO_2 from C becomes lower above 1323K than free energy of formation of ZnO. The free energy of formation of CO_2 from CO is always higher than that of ZnO. Therefore, C can reduce ZnO to Zn better than CO.

14. What is the chemical principle on which chromatography separation based on?

Ans : Adsorption

15. What are the products obtained during the electrolysis of brine solution? Also write the name of this process.

Ans : chlorine, hydrogen and sodium hydroxide. The process is popularly known as chlor-alkali process.

16. What is roasting?

Ans : The preliminary treatment of the concentrated ore in which the ore is heated in excess of air below its melting point.

17. What is calcination?

Ans: The process of heating the concentrated ore in absence/ limited supply of air below its melting point.

18. What is smelting?

Ans: Reduction of metal oxide into metal in the presence of carbon or carbon monoxide.

19. What is blister copper/ copper matte?

Ans: The copper obtained after extraction has blistered appearance due to the evolution of SO_2. It is called blistered copper/ copper matte.

20.What is meant by beneficiation process?

Ans: The process of removal of unwanted earthy and silicious impurities form the ore is called beneficiation process.

2marks questions

1. Write down the reactions taking place in blast furnace related to the metallurgy of iron.

Ans : $3Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 + CO_2$

$Fe_3O_4 + 4CO \longrightarrow 3Fe + 4CO_2$

$Fe_2O_3 + CO \longrightarrow 2FeO + CO_2$

2. Describe with chemical equation the extraction of silver from its ore.

Ans : argentite ore is treated with dilute solution of NaCN in presence of oxygen to form complex.

$2Ag_2S + 8CN^- + O_2 + 2H_2O \longrightarrow 4\,[Ag(CN)_2]^- + 2S + 4OH^-$

Zn acts as reducing agent and displaces silver from the complex.

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

The crude silver obtained is refined by fusion with borax or by electrolysis.

3. Describe the role of the following.

(a) NaCN in the extraction of silver from a silver ore

(b) Cryolite in the extraction of aluminium from pure alumina.

Ans : (a) $2Ag + 8NaCN + O_2 + 2H_2O \longrightarrow 4\,Na[Ag(CN)_2] + 2S + 4NaOH$

OR

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

(b) i. it lowers the melting point of the mixture

ii. it increase the electrical conductivity of the mixture.

4. Explain the role of carbon monoxide in the purification of nickel and iodine in zirconium.

Ans : When nickel is heated carbon monoxide forms a volatile complex nickel tetracarbonyl which on further heating at higher temperature decomposes to give pure nickel.

$Ni + 4CO \xrightarrow{330\text{-}350K} [Ni(CO)_4] \xrightarrow{450\text{-}470K} Ni + 4\,CO$

Impure zirconium is heated with iodine to form volatile compound ZrI_4 which on further heating over tungsten filament decomposes to give pure zirconium.

$Zr + 2\,I_2 \xrightarrow{870K} ZrI_4 \xrightarrow{2075K} Zr + 2\,I_2$

5. (a) Name the method used for refining of (i) nickel (ii) zirconium

(b)The extraction of gold by leaching with NaCN involves both oxidation and reduction. Justify giving equations.

Ans : (a) (i)Mond's process (ii) van arkel method

(b) $4\,Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4\,[Au(CN)_2]^- + 4OH^-$

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

In the first reaction Au changes into Au^+ i.e. oxidation takes place. In the second case Au^+ changes to Au i.e. reduction takes place.

6. What criterion is followed for selection of the stationary phase in chromatography?

Ans : the stationary phase is selected in such a way that the impurities are more strongly adsorbed or are more soluble in the stationary phase than element to be purified. Under these conditions, when the column is extracted the impurities will be retained by the stationary phase and the pure component is easily eluted.

7. Explain electrolytic refining of copper with thermodynamic principle involve in the process.
   Ans : in this method impure metal is made to act as anode. A strip of same metal in pure form is used as cathode. They are put in an electrolytic bath containing soluble salt of the same metal. On passing electric current metal ions from the electrolyte solution are deposited at the cathode while an equivalent amount of metal dissolves from the anode and goes into the solution.
   At Cathode: $Cu^{2+}(aq) + 2e- \longrightarrow Cu\ (s)$
   At anode: $Cu\ (s) \longrightarrow Cu^{2+}(aq) + 2e-$
   The thermodynamic principle involve during the process can be explained by the following expression $\Delta G^0 = -nFE^0$.
8. What are the limitations of Ellingham diagram?
   Ans: (i) Ellingham diagram simply indicates whether a reaction is possible or not. It does not say about the kinetics of the reduction process. (ii) the interpretation of ΔG^0 is based on K , thus it is presumed that the reactant and products are in equilibrium which is not always true.
9. What is the role of depressant in froth floatation process?
   Ans: in froth floatation process the role of the depressant is to prevent certain type of particles from forming the froth with the air bubbles. Example NaCN is used as a depressant to separate PbS from ZnS. NaCN forms a zinc complex $Na_2[Zn\ (CN)_4]$ on the surface of ZnS preventing it from the formation of froth.
10. How are metals used as semiconductors refined? What is the principle of the method used?
    Ans : Semiconductors metals is produced by zone refining method which is based on the principle that the impurities are more soluble in melt than in the solid state of metals.

3marks questions:

1. Describe how the following changes are brought about :
   (i) Pig iron into steel
   (ii) Zinc oxide into metallic zinc
   (iii) Impure titanium into pure titanium

   Ans : (i) pig iron is converted into steel by heating in a converter. A blast of oxygen diluted with carbon dioxide is blown through the converter. Oxygen reacts with impurities and raised the temperature to 2173K. carbon gets oxidized to CO which burns of at the mouth of the converter. Oxides of silicon and magnesium form slag. When the flame is stopped, slag is tapped out and other metals like Mn, Cr, Ni, W may be added in the end.

   (ii) the reduction of zinc oxide is done using coke as a reducing agent. For the purpose of heating, the oxide is made into brickettes with coke and clay.

$$ZnO + C \longrightarrow Zn + CO$$

The metal is distilled off and collected by rapid chilling.

(iii) Impure titanium is heated with iodine to form volatile TiI_4 which decomposes on tungsten filament at higher temperature to give pure titanium.

$$Ti + 2\ I_2 \longrightarrow TiI_4 \longrightarrow Ti + 2\ I_2$$

2. Describe the role of
   (a) NaCN in the extraction of gold from gold ore.
   (b) SiO_2 in the extraction of copper from copper matte.
   (c) Iodine in the refining of zirconium

   Ans : (a) $4\ Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4\ [Au\ (CN)_2]^- + 4OH^-$

   (b) the role of SiO_2 is to convert FeS, FeO present in the matte into slag.

   $$2FeS + 3O_2 \xrightarrow{} 2SO_2$$
   $$FeO + SiO_2 \xrightarrow{} FeSiO_3$$

   (c) Impure zirconium is heated with iodine to form volatile compound ZrI_4 which on further heating over tungsten filament decomposes to give pure zirconium.

   $$Zr + 2\ I_2 \xrightarrow{870K} ZrI_4 \xrightarrow{2075K} Zr + 2\ I_2$$

3. Describe how the following changes are brought about :
   (i) Pig iron into steel
   (ii) Bauxite into pure alumina
   (iii) Impure copper into pure copper

Ans (i) pig iron is converted into steel by heating in a converter. A blast of oxygen diluted with carbon dioxide is blown through the converter. Oxygen reacts with impurities and raised the temperature to 2173K. carbon gets oxidized to CO which burns of at the mouth of the converter. Oxides of silicon and magnesium form slag. When the flame is stopped, slag is tapped out and other metals like Mn, Cr, Ni, W may be added in the end.

(ii) Finely powdered bauxite is digested with an aqueous solution of sodium hydroxide . Al_2O_3 is leached out as sodium aluminate leaving impurities behind .

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

The aluminate is neutralised by passing CO_2 and hydrated Al_2O_3 is precipitated. The solution is seeded with freshly prepared hydrated Al_2O_3 which induced the precipitation.

$$2Na[Al(OH)_4] + CO_2 \longrightarrow Al_2O_3 \cdot x\ H_2O + 2NaHCO_3$$

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

$Al_2O_3 \cdot x\ H_2O \longrightarrow Al_2O_3 + x\ H_2O$

(iii)In this method impure metal is made to act as anode. A strip of same metal in pure form is used as cathode. They are put in an electrolytic bath containing soluble salt of the same metal. On passing electric current metal ions from the electrolyte solution are deposited at the cathode while an equivalent amount of metal dissolves from the anode and goes into the solution.

At Cathode: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu\ (s)$

At anode: $Cu\ (s) \longrightarrow Cu^{2+}(aq) + 2e^-$

4. Describe the principle behind each of the following process.
   (i) Vapour phase refining of a metal
   (ii) Electrolytic refining of a metal
   (iii) Recovery of silver after silver ore was leached with NaCN

Ans : (i) in this method the metal is converted into its volatile compound and collected. It is then decomposed to give the pure metal .

(ii) in this method impure metal is made to act as anode. A strip of same metal in pure form is used as cathode. They are put in an electrolytic bath containing soluble salt of the same metal. On passing electric current metal ions from the electrolyte solution are deposited at the cathode while an equivalent amount of metal dissolves from the anode and goes into the solution.

At Cathode: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu\ (s)$

At anode: $Cu\ (s) \longrightarrow Cu^{2+}(aq) + 2e^-$

(iii) During leaching Ag is oxidized to Ag^+ which then combines with CN^- to form soluble complex. Silver is then recovered from the complex by displacement method using more electro positive metal. Zn acts as reducing agent and displaces silver from the complex.

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

5. Write the reaction involved in the following process
   (i) Leaching of bauxite ore to prepare pure alumina
   (ii) Refining of zirconium by Van Arkel method
   (iii) Recovery of gold after gold ore has been leached with NaCN

Ans (i) $Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na[Al(OH)_4]$

$2Na\ [Al(OH)_4] + CO_2 \longrightarrow Al_2O_3 \cdot x\ H_2O + 2NaHCO_3$

$Al_2O_3 \cdot x\ H_2O \longrightarrow Al_2O_3 + x\ H_2O$

(ii) 870K2075K

$Zr + 2\ I_2 \longrightarrow ZrI_4 \longrightarrow Zr + 2\ I_2$

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

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

6. Write the reactions involved in the following process:
   (i) Mond's process

(ii) Mac Arthur forest cyanide process

(iii) Hall heroult's process

Ans (i) $330\text{-}350K$ $450\text{-}470K$

$Ni + 4CO \longrightarrow [Ni(CO)_4]$ $Ni + 4CO \longrightarrow$

(ii) $4M + 8CN^- + O_2 + 2H_2O \longrightarrow 4[M(CN)_2]^- + 4OH^-$

$2[M(CN)_2]^- + Zn \longrightarrow [Zn(CN)_4]^{2-} + 2M$ where M=Ag or Au

(iii) $Al_2O_3 \longrightarrow 2Al^{3+} + 3O^{2-}$

Cathode: $Al^{3+} + 3e^- \longrightarrow Al$

Anode: $C + O^{2-} \longrightarrow CO + 2e^-$

$C + 2O^{2-} \longrightarrow CO_2 + 4e^-$

Overall reaction

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

7. Account for the following facts :

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

(b) The reduction of Cr_2O_3 with aluminium is thermodynamically feasible, yet it does not occur at room temperature

(c) Pine oil is used in froth floatation method

Ans : (a) in liquid state entropy is higher than the solid form. This makes ΔG more negative.

(b) by increasing temperature fraction of activated molecule increases which help in crossing over the energy barriers.

(c) pine oil enhances non wetting property of the ore particles and acts as a collector.

8. State briefly the principles which serve as basis for the following operation in metallurgy .

(a) Froth floatation process

(b) Zone refining

(c) Refining by liquation

Ans : (a) sulphide ore particle are preferentially wetted by pine oil whereas the gangue particles are wetted by water.

(b)the impurities are more soluble in the melt than in the solid state of the metal .

(c)the impurities whose melting points are higher than the metal are left behind on melting the impure metal. Hence pure metal separates out.

9. Explain the basic principles of the following metallurgical operations

(a) Zone refining

(b) Vapour phase refining

(c) Electrolytic refining

Ans: (a) the impurities are more soluble in the melt than in the solid state of the metal.

(b)in this method the metal is converted into its volatile compound and collected. It is then decomposed to give the pure metal .

(c)In this method impure metal is made to act as anode. A strip of same metal in pure form is used as cathode. They are put in an electrolytic bath containing soluble salt of the same metal. On passing electric current metal ions from the electrolyte solution are deposited at the cathode while an equivalent amount of metal dissolves from the anode and goes into the solution.

10. Complete the following reactions:

(i) $Al_2O_3 + NaOH + H_2O \longrightarrow$

(ii) $Au + CN^- + O_2 + H_2O \longrightarrow$

450-470K

(iii) $[Ni(CO)_4] \longrightarrow$

Ans : (i) $Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na[Al(OH)_4]$

(ii) $4\,Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4\,[Au(CN)_2]^- + 4OH^-$

(iii) $[Ni(CO)_4] \longrightarrow Ni + 4\,CO$

5 marks questions

1. Describe the principle behind each of the following process.
   (i) Vapour phase refining
   (ii) Electrolytic refining of the metal
   (iii) Recovery of silver after silver ore was leached with NaCN
   (iv) Preparation of cast iron from pig iron
   (v) Preparation of pure alumina from bauxite

Ans (i) in this method the metal is converted into its volatile compound and collected. It is then decomposed to give the pure metal . for example mond's process. When nickel is heated carbon monoxide forms a volatile complex nickel tetracarbonyl which on further heating at higher temperature decomposes to give pure nickel.

330-350K 450-470K

$Ni + 4CO \longrightarrow [Ni(CO)_4] \longrightarrow Ni + 4\,CO$

(ii) in this method impure metal is made to act as anode. A strip of same metal in pure form is used as cathode. They are put in an electrolytic bath containing soluble salt of the same metal. On passing electric current metal ions from the electrolyte solution are deposited at the cathode while an equivalent amount of metal dissolves from the anode and goes into the solution.

(iii)During leaching Ag is oxidized to Ag^+ which then combines with CN^- to form soluble complex. Silver is then recovered from the complex by displacement method using more electro positive metal. Zn acts as reducing agent and displaces silver from the complex.

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

(iv)pig iron is melted with scrap iron and coke using hot air blast. Due to this impurities such as carbon, sulphur and phosphorus present in the pig iron are removed as CO_2, SO_2 and P_2O_5 and carbon content is reduced to about 3%.

(v) bauxite is soluble in concentrated NaOH solution whereas impurities are not.

2. Explain the role of each of the following in the extraction of metals from their ores :
   (i) CO in the extraction of nickel
   (ii) Zinc in the extraction of silver
   (iii) Silica in the extraction of copper
   (iv) Iodine in the extraction of titanium
   (v) Cryolite in the extraction of aluminium

Ans (i) in this method the metal is converted into its volatile compound and collected. It is then decomposed to give the pure metal . for example mond's process. When nickel is heated carbon monoxide forms a volatile complex nickel tetracarbonyl which on further heating at higher temperature decomposes to give pure nickel.

$$Ni + 4CO \xrightarrow{330\text{-}350K} [Ni(CO)_4] \xrightarrow{450\text{-}470K} Ni + 4\,CO$$

(ii) Zn acts as reducing agent and displaces silver from the complex.

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

(iii)the role of SiO_2 is to convert FeS, FeO present in the matte into slag.

$$2FeS + 3O_2 \xrightarrow{2FeO} 2SO_2$$
$$FeO + SiO_2 \xrightarrow{FeSiO_3}$$

(iv)impure titanium is heated with iodine to form volatile TiI_4 which decomposes on tungsten filament at higher temperature to give pure titanium.

$$Ti + 2\,I_2 \longrightarrow TiI_4 \xrightarrow{Ti} + 2\,I_2$$

(v)i. it lowers the melting point of the mixture

ii. it increase the electrical conductivity of the mixture

3. Explain the following
   (a) Generally sulphide ores are converted into oxides before reduction
   (b) Carbon and hydrogen are not used as reducing agent at high temperature
   (c) Silica is added to sulphide ore of copper in the reverberatory furnace
   (d) NaCN acts as a depressant in preventing ZnS from forming the froth
   (e) Role of cryolite in the metallurgy of aluminium

Ans : (a) because sulphide ores are not reduced easily but oxide ores are easily reduced.

(b) because at high temp. carbon and hydrogen react with metals to form carbides and hydrides respectively.

(c)the role of SiO_2 is to convert FeS, FeO present in the matte into slag.

$$2FeS + 3O_2 \xrightarrow{2FeO} 2SO_2$$

$$FeO + SiO_2 \xrightarrow{} FeSiO_3$$

(d) in froth floatation process the role of the depressant is to prevent certain type of particles from forming the froth with the air bubbles. Example NaCN is used as a depressant to separate PbS from ZnS. NaCN forms a zinc complex $Na_2[Zn(CN)_4]$ on the surface of ZnS preventing it from the formation of froth.

(e) i. it lowers the melting point of the mixture

ii. It increase the electrical conductivity of the mixture

4. (a) Describe the principle of froth floatation process. What is the role of depressant? Give an example.
(b) Define leaching. How is this process used in the benefaction of silver and gold ores?

(f) Ans : (a) sulphide ore particle are preferentially wetted by pine oil whereas the gangue particles are wetted by water.In froth floatation process the role of the depressant is to prevent certain type of particles from forming the froth with the air bubbles. Example NaCN is used as a depressant to separate PbS from ZnS. NaCN forms a zinc complex $Na_2[Zn(CN)_4]$ on the surface of ZnS preventing it from the formation of froth.

(b)Leaching consist of treating the powdered ore with a suitable reagent which can selectively dissolved ore but not the impurity . for leaching silver and gold, the powdered ore is treated with sodium cyanide. As a result a dissolved complex is obtained which is further treated with zinc metal which displaces the less active metals from the complex. This can be represented by following reaction.

$$4\,M + 8CN^- + O_2 + 2H_2O \longrightarrow 4\,[M(CN)_2]^- + 4OH^-$$

$$2[M(CN)_2]^- + Zn \xrightarrow{[Zn(CN)_4]^{2-}} 2M \text{ where M=Ag or Au}$$

5. Write the chemical reaction which takes place in the following operations:
(a) Electrolytic reduction of Alumina
(b) Mond's process
(c) Van Arkel method
(d) Mac Arthur forest cynide process
(e) Electrolysis of brine

Ans (a) $Al_2O_3 \qquad 2Al^{3+} + 3\,O^{2-}$

Cathode: $Al^{3+} + 3e^- \longrightarrow Al$

Anode: $C + O^{2-} \longrightarrow CO + 2\,e^-$

$C + 2O^{2-} \longrightarrow CO_2 + 4\,e^-$

Overall reaction

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

(b) $Ni + 4CO \xrightarrow{330\text{-}350K,\ 450\text{-}470K} [Ni(CO)_4] \xrightarrow{} Ni + 4CO$

(c) $Ti + 2\ I_2 \xrightarrow{} TiI_4 \xrightarrow{} Ti + 2\ I_2$

(d) $4\ M + 8CN^- + O_2 + 2H_2O \xrightarrow{} 4\ [M(CN)_2]^- + 4OH^-$

$2[M(CN)_2]^- + Zn \xrightarrow{} [Zn(CN)_4]^{2-} + 2M$ where M=Ag or Au

(e) $2NaCl + 2H_2O \xrightarrow{} 2NaOH + H_2 + Cl_2$