# SAIVEERA ACADEMY'S GUIDE

## VOL -I

(2022-2023 EDITION)

## It includes

- ✓ Complete Book Back Answers
- ✓ Knowledge Based Questions
- ✓ Knowledge Based One Marks
- ✓ Additional Book Inside Questions
- ✓ Evaluate Yourself Answers

# UNIT –1 METALLURGY

## Points To Overlook

- **Ore:** Minerals that contains a high percentage of metal, from which it can be extracted conveniently and economically are called ores.
- **Gangue:** Ores are associated with non-metallic impurities, rocky materials and siliceous matter which are collectively known as gangue.
- **Metallurgical processes consists of**
    1. Concentration of the ore
    2. Extraction of crude metal
    3. Refining of crude metal
- **Gravity separation or Hydraulic wash :** In this method, the ore having high specific gravity is separated from the gangue that has low specific gravity by simply washing with running water. For native ore such as gold and oxide ores such as hematite ($Fe_2O_3$), tin stone ($SnO_2$) etc.
- **Froth flotation :** The metallic ore particles which are preferentially wetted by oil can be separated from gangue. It used to concentrate sulphide ores such as galena (PbS), zinc blende (ZnS) etc...,
- **Leaching :** In this method, the crushed ore is allowed to dissolve in a suitable solvent, the metal present in the ore is converted to its soluble salt or complex while the gangue remains insoluble.
- **Magnetic separation :** This method is applicable to ferromagnetic ores and it is based on the difference in the magnetic properties of the ore and the impurities.
- **Roasting:** Roasting is the method, usually applied for the conversion of sulphide ores into their oxides. In this method, the concentrated ore is oxidized by heating it with excess of oxygen in a suitable furnace below the melting point of the metal.
- **Calcination:** It is the process in which the concentrated ore is strongly heated in the absence of air. Here ore is converted into their oxides.
- **Smelting:** It is the process of reducing the roasting metallic oxide to metal in molten condition.
- **Blistered copper:** The solidified copper obtained after the reduction of copper matte has blistered appearance. This is called blistered copper.
- **Ellingham diagram:** The graphical representation of variation of the standard Gibbs free energy of reaction for the formation of various metal oxides with temperature is called Ellingham diagram.
- **Distillation:** In this method, the impure metal is heated to evaporate and the vapour are condensed to get pure metal
- **Liquation:** This method is employed to remove the impurities with high melting points from metals having relatively low melting points such as tin.

- **Electrolytic refining:** The crude metal is refined by electrolysis. It is carried out in an electrolytic cell containing aqueous solution of the salts of the metal of interest. The rods of impure metal are used as anode and thin strips of pure metal are used as cathode.
- **Zone Refining :**This method is based on the principles of fractional crystallisation. When an impure metal is melted and allowed to solidify, the impurities will prefer to be in the molten region
- **Vapour phase method** : In this method, the metal is treated with a suitable reagent which can form a volatile compound with the metal. Then the volatile compound is decomposed to give the pure metal.

## Notable Reactions

1.**Cyanide leaching:**

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

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

3.**Acid leaching:** $2ZnS(s) + 2H_2SO_4(aq) + O_2(g) \rightarrow 2ZnSO_4(aq) + 2S(s) + H_2O(aq)$

4. $2ZnS + 3O_2 \xrightarrow{\Delta} 2ZnO + 2SO_2 \uparrow$

5. $4As + 3O_2 \rightarrow 2As_2O_3 \uparrow$

6. $S_8 + 8O_2 \rightarrow 8SO_2 \uparrow$

7. $P_4 + 5O_2 \rightarrow P_4O_{10} \uparrow$

8. $ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$

9. $2CuFeS_2(s) + O_2(g) \rightarrow 2FeS(l) + 2Cu_2S(l) + 2SO_2(g)$

10. $FeO(s) + SiO_2(s) \rightarrow FeSiO_3(s)$

11. $Cr_2O_3 + 2Al \xrightarrow{\Delta} 2Cr + Al_2O_3$

12. **Auto-reduction:** $HgS(s) + O_2(g) \rightarrow Hg(l) + SO_2 \uparrow$

13. **Change in Gibbs free energy:** $\Delta G = \Delta H - T\Delta S$

14. **Gibbs free energy change for the electrolysis process:** $\Delta G^\circ = -nFE^\circ$

15.**Hall-Herold process:**

Ionisation of alumina : $Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$

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

Reaction at anode : $2O^{2-}(melt) \rightarrow O_2 + 3e^-$

16. **Mond process:**

Step 1: $Ni(s) + 4CO(g) \xrightarrow{350K} Ni(CO)_4(g)$

Step 2: $Ni(CO)_4 \xrightarrow{460K} Ni(s) + 4CO(g)$

17. **Van-Arkel method:**

Step 1: $Ti(s) + 2I_2(s) \xrightarrow{550K} TiI_4(vapour)$

Step 2: $TiI_4(vapour) \xrightarrow{1800K} Ti(s) + 2I_2(s)$

## Textual Questions

1. Bauxite has the composition

a) $Al_2O_3$ b) $Al_2O_3.nH_2O$ c) $Fe_2O_3.2H_2O$ d)None of these

**Ans.** b) $Al_2O_3.nH_2O$

2. Roasting of sulphide ore gives the gas (A).(A) is a colourless gas. Aqueous solution of (A) is acidic. The gas (A) is

a)$CO_2$ b)$SO_3$ c)$SO_2$ d)$H_2S$

**Ans.** c)$SO_2$

3. Which one of the following reaction represents calcinations?

a) $2Zn + O_2 \rightarrow 2ZnO$ b) $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$

c) $MgCO_3 \rightarrow MgO + CO_2$ d) Both (a) and (c)

**Ans.** c) $MgCO_3 \rightarrow MgO + CO_2$

4. The metal oxide which cannot be reduced to metal by carbon is

a) PbO b) $Al_2O_3$ c) ZnO d) FeO

**Ans.** b) $Al_2O_3$

5. Which of the metal is extracted by Hall-Herold process?

a) Al b) Ni c) Cu d) Zn

**Ans.** a) Al

6. Which of the following statements, about the advantage of roasting of sulphide ore before reduction is not true?

a) $\Delta G_f^o$ of sulphide is greater than those for $CS_2$ and $H_2S$ .

b) $\Delta G_r^o$ is negative for roasting of sulphide ore to oxide

c) Roasting of the sulphide to its oxide is thermodynamically feasible.

d) Carbon and hydrogen are suitable reducing agents for metal sulphides

**Ans.** d) Carbon and hydrogen are suitable reducing agents for metal sulphides

7.Match items in column - I with the items of column – II and assign the correct code

| Column – I | | Column - 2 | |
|---|---|---|---|
| A | Cyanide process | (i) | Ultrapure Ge |
| B | Froth flotation process | (ii) | Dressing of ZnS |
| C | Electrolytic refining | (iii) | Extraction of Al |
| D | Zone refining | (iv) | Extraction of Au |
| | | (v) | Purification of Ni |

| | A | B | C | D |
|---|---|---|---|---|
| a) | (i) | (ii) | (iii) | (iv) |
| b) | (iii) | (iv) | (v) | (i) |
| c) | (iv) | (ii) | (iii) | (i) |
| d) | (ii) | (iii) | (i) | (v) |

**Ans.** c) A – (iv) , B – (ii) , C – (iii) , D – (i)

8. Wolframite ore is separated from tinstone by the process of

a) Smelting b) Calcination

c) Roasting d) Electromagnetic separation

**Ans.** d) Electromagnetic separation

9. Which one of the following is not feasible

a) $Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$

b) $Cu(s) + Zn^{2+}(aq) \rightarrow Zn(s) + Cu^{2+}(aq)$

c) $Cu(s) + 2Ag^{+}(aq) \rightarrow Ag(s) + Cu^{2+}(aq)$

d) $Fe(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Fe^{2+}(aq)$

**Ans.** b) $Cu(s) + Zn^{2+}(aq) \rightarrow Zn(s) + Cu^{2+}(aq)$

10. Electrochemical process is used to extract

a) Iron b) Lead c) Sodium d) silver

**Ans.** c) Sodium

11. Flux is a substance which is used to convert

a) Mineral into silicate

b) Infusible impurities to soluble impurities

c) Soluble impurities to infusible impurities

d) All of these

**Ans.** b) Infusible impurities to soluble impurities

12. Which one of the following ores is best concentrated by froth – floatation method?

a) Magnetite b) Hematite c) Galena d) Cassiterite

**Ans.** c) Galena

13. In the extraction of aluminium from alumina by electrolysis, cryolite is added to

a) Lower the melting point of alumina b) Remove impurities from alumina

c) Decrease the electrical conductivity d) Increase the rate of reduction

**Ans.** a) Lower the melting point of alumina

14. Zinc is obtained from ZnO by

a) Carbon reduction b) Reduction using silver

c) Electrochemical process d) Acid leaching

**Ans.** a) Carbon reduction

15. Cupellation is a process used for the refining of

a) Silver b) Lead c) Copper d) iron

**Ans.** a) Silver

16. Extraction of gold and silver involves leaching with cyanide ion. silver is later recovered by

a) Distillation b) Zone refining c) Displacement with zinc d) liquation

**Ans.** c) Displacement with zinc

17. Considering Ellingham diagram, which of the following metals can be used to reduce alumina?

a) Fe b) Cu c) Mg d) Zn

**Ans.** c) Mg

18.The following set of reactions are used in refining Zirconium

$Zr(\text{Impure}) + 2I_2 \xrightarrow{523K} ZrI_4$

$ZrI_4 \xrightarrow{1800K} Zr(\text{ Pure}) + 2I_2$

This method is known as

a) Liquation b) van Arkel process c) Zone refining d) Mond's process

**Ans.** b) van Arkel process

19. Which of the following is used for concentrating ore in metallurgy?

a) Leaching b) Roasting c) Froth floatation d) Both (a) and (c)

**Ans.** d) Both (a) and (c)

20. The incorrect statement among the following is

a) Nickel is refined by Mond's process

b) Titanium is refined by Van Arkel's process

c) Zinc blende is concentrated by froth floatation

d) In the metallurgy of gold, the metal is leached with dilute sodium chloride solution

**Ans.** d) In the metallurgy of gold, the metal is leached with dilute sodium chloride solution

21. In the electrolytic refining of copper, which one of the following is used as anode?

a) Pure copper b) Impure copper c) Carbon rod d) Platinum electrode

**Ans.** b) Impure copper

22. In the Ellingham diagram, for the formation of carbon monoxide

a) $\Delta S^o/\Delta T$ is negative b) $\Delta G^o/\Delta T$ is positive

c) $\Delta G^o/\Delta T$ is negative d) initially $\Delta T/\ \Delta G^o$ is positive, after 700°C , $\Delta G^o/\Delta T$ is negative

**Ans.** c) $\Delta G^o/\Delta T$ is negative

23.Which of the following plot gives Ellingham diagram

a) $\Delta S$ Vs T b) $\Delta G^o$ Vs T

c) $\Delta G^o$ Vs $\frac{1}{T}$ is negative d) $\Delta G^o$ Vs $T^2$ is negative

**Ans.** b) $\Delta G^o$ Vs T

24.Which of the following reduction is not thermodynamically feasible?

a) $Cr_2O_3$+ 2Al → $Al_2O_3$ + 2Cr b) $Al_2O_3$ + 2Cr → $Cr_2O_3$ + 2Al

c) $3TiO_2$ + 4Al → 2 $Al_2O_3$ + 3Ti d) none of these

**Ans.** b) $Al_2O_3$ + 2Cr → $Cr_2O_3$ + 2Al

25.Which of the following is not true with respect to Ellingham diagram?

a) Free energy changes follow a straight line. Deviation occurs when there is a phase change.

b) The graph for the formation of $CO_2$ is a straight line almost parallel to free energy axis.

c) Negative slope of CO shows that it becomes more stable with increase in temperature.

d) Positive slope of metal oxides shows that their stabilities decrease with increase in temperature.

**Ans.** b) The graph for the formation of $CO_2$ is a straight line almost parallel to free energy axis.

## Additional Questions

1.Which metal is used for extraction of Au and Ag and also for galvanization of iron object?

a)Mg b) Zn c)Cr d)Co

**Ans.** b) Zn

2.Which of the following is not a mineral of aluminium?

a)Bauxite b) Cryolite

c) China clay d) Malachite

**Ans.** d) Malachite

3.Name the process by which elements such as germanium ,silicon and galium are refined.

a) Vapour phase method b) Electrolytic refining

c) Zone refining d) Van–Arkel method.

**Ans.** c) Zone refining

4.Which of the following will give respective metal by self reduction?

a)galena(Pbs) b)HgS c)ZnS d)both (a)and(b)

**Ans.** d)both (a)and(b)

5.In the extraction of copper from its sulphide ore, the metal is finally obtained by the reduction of cuprous oxide with

a)Iron sulphide(FeS) b) Carbon monoxide(CO)

c) Copper (I)sulphide ($Cu_2S$) d) Sulphur dioxide ($SO_2$)

**Ans.** c)Copper (I)sulphide ($Cu_2S$)

6.Which of the following mineral contains calcium as well as magnesium?

a) Zinc blende b) Aragonite c) Dolomite d) Carnalite

**Ans.** c) Dolomite

7.In the froth-floatation process the collectors such as pine oil and xanthates ,etc enhances.

a) Non –wettability of the mineral particles in froth

b) Non –wettability of the mineral particles in water

c) Non –wettability of the gangue particles in froth

d) Non –wettability of the gangue particles in water.

**Ans.** b) Non –wettability of the mineral particles in water

8.Concentration 0f copper glance is done by

a) leaching b) magnetic separation

c) froth flotation d) hydraulic washing

**Ans.** c) froth flotation

9. Zone refining is based on

a) fractional distillation b) simple distillation

c) sublimation d) fractional crystallization

**Ans.** d) fractional crystallization

10.Identify the halide ore among the following .

a) Epsom salt b) Pyrolusite c) Anglesite d) Rock salt

**Ans.** d) Rock salt

11.The process of heating of copper pyrites to remove sulphur is called

a)froth flotation b)roasting c) calcination d) smelting

**Ans.** b)roasting

12.Ignition mixture used in aluminothermic process is

a) $Cr+Al_2O_3$ b)$Mg+BaO_2$ c) $Al+Cr_2O_3$ d) $Ba+MgO$

**Ans.** b)$Mg+BaO_2$

13.Malachite has _____ composition.

a) $2CuCO_3.Cu(OH)_2$ b) $CuCO_3Cu(OH)_2$ c) $Cu_2O$ d) $Cu_2S$

**Ans.** b) $CuCO_3Cu(OH)_2$

14.Zinc blende is

a)ZnS b) PbS c) $Ag_2S$ d) $Cu_2S$

**Ans.** a)ZnS

15.In acid leaching process, the insoluble sulphide is converted into soluble sulphate and elemental

a)Carbon b) Lead c) Sulphur d) Zinc

**Ans.** c) Sulphur

16.Sulphide ore is converted to oxide form by using the process

a) Calcination b) Roasting c) Smelting d) Leaching

**Ans.** b) Roasting

17.Magnetic separation it is based on the difference in the _____of the ore and the impurities.

a) Magnetic properties b) Chemical properties

c) Physical properties d) Melting point .

**Ans.** a) Magnetic properties

18.Zinc is extracted from zinc blende by

a) Carbon reduction process b) Nitrogen reduction process
c) Oxygen reduction process d) All of these.
**Ans.** a) Carbon reduction process

19.Gibb's free energy is given by _____
a) $\Delta G^o = -nFE^o$ b) $\Delta G^o = nF$ c) $\Delta G^o = nFE^o$ d) $\Delta E^o = -nFG^o$
**Ans.** a) $\Delta G^o = -nFE^o$

20.$Na[Ag(CN)_2]$ is _____.
a) Sodium aurocyanide b) Sodium meta aluminate
c) Aluminosilicate d) Sodium dicyano argentate
**Ans.** d) Sodium dicyano argentate

21.Semi conductors are purified by method _____
a) Zone refining b) Electrolytic refining
c) Mond's process d) Bessemerisation
**Ans.** a) Zone refining

22.Magnesite is
a) magnesium oxide b) magnesium carbonate
c) magnesium sulphate d) magnesium chloride
**Ans.** b) magnesium carbonate

23.In the metallurgy of iron, limestone is added to coke .which acts as a
a) reducing agent b) oxidizing agent c) slag d) Flux
**Ans.** d) Flux

24.Froth flotation process is suitable for concentrating _____ore.
a) Oxide b) Carbonate c) Sulphide d)Halide
**Ans.** c) Sulphide

25.Metal oxide is converted into metal by
a) Calcination b) Roasting c) Smelting d) Bessemerisation
**Ans.** c) Smelting

26.Sodium cyanide solution is used to extract_____ from its ores.
a)Copper b)Silver c)Gold d) Both (b) and (c).
**Ans.** d) Both (b) and (c).

27.In Hall-Herold process, _____act as an anode.
a)Carbon blocks b) Hydrogen c)Copper rods d)Zinc rods
**Ans.** a)Carbon blocks

28. Find the odd one out
a) Sphalerite b) Galena c) Azurite d) Iron pyrite
**Ans.** c) Azurite

29. Which is not refined by liquation?
a) Tin b) Zinc c) Lead d) Bismuth

**Ans.** b) Zinc

30. In froth floatation sodium ethyl Xanthate is used as a

a) Collector b) depressing agent c) frothing agent d) Flux

**Ans.** a) Collector

31. Metals which do not form carbides with carbon at reduction temperature can be extracted from their oxides by

a) Reduction by metal b) Reduction by hydrogen

**Ans.** c) Reduction by carbon d) Auto reduction

c) Reduction by carbon

32. If the e.m.f of the net redox reaction is positive, its ΔG is

a) Positive b) Negative c) Zero d) One

**Ans.** b) Negative

33. Which is used in making luminous paints, fluoroscent lights and x - ray screens?

a) Brass b) Zinc sulphide c) Cast iron d) Gold nano particles

**Ans.** b) Zinc sulphide

34. Which is used for increasing the efficiency of solar cells?

a) Brass b) Zinc sulphide c) Cast iron d) Gold nanoparticles

**Ans.** d) Gold nanoparticles

35. Which method is based on the solubility of the ore in a suitable solvent

a) Gravity separation b) Hydraulic wash

c) Leaching d) Magnetic separation

**Ans.** c) Leaching

36. The process of Gold is reduced to its elemental state (Zero oxidation state) is called

a) oxidation b) cementation c) galvanization d) smelting

**Ans.** b) cementation

37. Which of the following ores undergoing Ammonia leaching process ?

a) Ni, Cu, CO b) Fe , Cu, Co c) Zn, Cu, Al d) Hg, Zn, Al

**Ans.** a) Ni, Cu, CO

38. Tin stone,Chromite and Pyrolusite are concentrated by

a) Gravity separation b) Hydraulic wash

c) Froth flotation d) Magnetic separation

**Ans.** d) Magnetic separation

39.The process of ore into metal oxide with absence of air is called

a) Oxidation b) Cementation c) Galvanization d) Calcination

**Ans.** d) Calcination

40. Which oxides will decompose on heating even in the absence of a reducing agent.

a) $Ag_2O$, HgO b) FeO, CaO c) $SiO_2$, FeO d) MgO, HgO

**Ans.** a) $Ag_2O$, HgO

41. Which is the correct order of reactivity of metals

a) Zn > Cu < Ag b) Zn < Cu < Ag c) Cu > Zn < Ag d) Zn > Cu > Ag

**Ans.** d) Zn > Cu > Ag

42. Metals having low melting points such as tin, lead, mercury and bismuth are refined by

a) Distillation b) Liquation c) Electrolytic d) Zone refining

**Ans.** b) Liquation

43. Which one is used in the manufacture of many products such as paints, rubber, cosmetics.

a) Zinc carbonate b) Zinc oxide c) Zinc metal d) Zinc sulphide

**Ans.** b) Zinc oxide

44. Which one is used for cutting tools and crushing machines.

a) Nickel steel b) Chrome steel

c) Chrome vanadium steel d) Nichrome

**Ans.** b) Chrome steel

45. Which one is used for making aeroplane parts

a) Cu b) Au c) Fe d) Zn

**Ans.** b) Au

46.Elingham diagram helps to select

a) suitable reducing agent b) appropriate temperature

c) both (a) and (b) d) oxidizing agent

**Ans.** c) both (a) and (b)

47.In Hall – Herold process calcium chloride helps to

a) increase the melting point b) decrease the melting point

c) maintain the temperature d) increase the boiling point

**Ans.** b) decrease the melting point

48. $Cr_2O_3$ can be reduced by

a) Aluminothermic process b) Mond's process

c) Cyande process d) hydrogen reduction

**Ans.** a) Aluminothermic process

49. Leaching process is a

a) reduction b) dehydration c) redox reaction d) dehydrogenation

**Ans.** c) redox reaction

50. The complex formed when NaCN is added to galena in which ZnS is the impurity

a) $2Na[Zn(CN)_4]$ b) $Na_2[Zn(CN)_4]$ c) $2Zn[Na(CN)^-_2]$ d) $Na_4[Zn(CN)_4]$

**Ans.** b) $Na_2[Zn(CN)_4]$

51. In the froth floatation process for the purification of ores the particles that because

a) they are light b) their surface is not easily wetted by water

c)they bear electrostatic charge d) they are insoluble

**Ans.** b) their surface is not easily wetted by water

52. In a metallurgical process , an acid flux is used for removing

a) slag b) basic flux c) acidic gangue d) basic gangue

**Ans.** d) basic gangue

53. Aluminium is extracted from alumina ($Al_2O_3$) by electrolysis of a molten mixture of

a) $Al_2O_3 + KF + Na_3AlF_6$ b) $Al_2O_3 + HF + NaAlF_4$

c) $Al_2O_3 + CaF_2 + NaAlF_4$ d) $Al_2O_3 + Na_3AlF_6 + CaF_2$

**Ans.** d) $Al_2O_3 + Na_3AlF_6 + CaF_2$

54. Oxide ores are concentrated by

a) hand picking b) hydraulic washing

c) froth floatation d) magnetic separation process

**Ans.** b) hydraulic washing

55. Froth flotation process is applicable for

a) oxide ores b) carbonate ores c) chloride ores d) sulphide ores

**Ans.** d) sulphide ores

56. Depressing agents used to separate ZnS from PbS is

a) NaCN b) NaCl c) $NaNO_3$ d) $NaNO_2$

**Ans.** a) NaCN

57. Which type of leaching process convert insoluble sulphide ore into soluble sulphates?

a) cyanide leaching b) alkali leaching c) acid leaching d) hand picking

**Ans.** c) acid leaching

## Answer the following questions

**Book Back**

**1.What is the difference between minerals and ores?**

| Minerals | Ores |
|---|---|
| Metal of interest present in small amount | Metal of interest present in high amount from which metal can be extracted conveniently and economically |
| All minerals are not ores | All ores are minerals |
| **Ex :** Clay – Mineral of aluminium | **Ex :** Bauxite – Ore of aluminium |

**2. What are the various steps involved in extraction of pure metals from their ores?**

1) Concentration of the ore.
2) Extraction of the crude metal.
3) Refining of the crude metal.

**3. What is the role of Limestone in the extraction of Iron from its oxide $Fe_2O_3$?**

In the extraction of iron , a basic flux limestone is used which decomposes to form CaO which reacts with silica gangue present in the iron ore is acidic in nature to form calcium silicate (slag)

$CaCO_3 \longrightarrow CaO + CO_2$

$CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (s)$

Flux Gangue slag

**4.Which type of ores can be concentrated by froth floatation method? Give two examples for such ores.**

Sulphide ores can be concentrated by froth floatation method.

**E.x :** Galena (PbS), Zinc blende (ZnS)

**5. Describe a method for refining nickel.**

- ✓ Impure nickel is heated in a stream of carbon monoxide at around 350K. Nickel reacts with CO to form a highly volatile nickel tetracarbonyl. The solid impurities are left behind.

  $Ni(s) + 4CO(g) \longrightarrow NiCO_4(g)$

- ✓ On heating nickel tetra carbonyl around 460K, the complex decomposes to give pure nickel.

  $Ni(CO)_4(g) \longrightarrow Ni(s) + 4CO(g)$

**6. Explain zone refining process with an example**

1) The principle used in this process is fractional crystallisation.
2) In this process the impure metal is taken in the form of a rod. One end of the rod is heated using a mobile induction heater, melting the metal on that portion of the rod.
3) When the heater is slowly moved to the other end pure metal crystallises while impurities will move on to the adjacent molten zone formed due to the movement of the heater.
4) As the heater moves further away, the molten zone containing impurities also moves along with it.
5) This process is repeated several times by moving the heater in the same direction again and again to achieve the desired purity level.
6) This process is carried out in an inert gas atmosphere to prevent the oxidation of metals.
7) Germanium, Silicon and gallium which are used as semiconductor are refined by this process.

**7. A) Predict the conditions under which**

**i) Aluminium might be expected to reduce magnesia.**

**ii) Magnesium could reduce alumina.**

**B) It is possible to reduce $Fe_2O_3$ by coke at a temperature around 1200K**

A) i) Ellingham diagram for the formation of $Al_2O_3$ and MgO intersects around 1600K. Above this temperature line of $\Delta G°(Mg, MgO)$ lies above the line of $\Delta G°(Al, Al_2O_3)$, Hence we can use aluminium to reduce magnesia above 1600K.

$$3MgO + 2Al \xrightarrow{1623\ K} Al_2O_3 + 3Mg$$

ii) $1.4Al + 3O_2 \rightarrow 2Al_2O_3$ $2.2Mg + O_2 \rightarrow 2MgO$

At the point of intersection of the $Al_2O_3$ and MgO curves in Ellingham diagram , $\Delta G°$ becomes zero for the reaction

$2Al_2O_3 + 2Mg \rightarrow 2MgO + 4Al$

Below that point magnesium can reduce alumina

B) In Ellingham diagram above 1000K carbon line lies below the formation of $Fe_2O_3$. Hence it is possible to reduce $Fe_2O_3$ by coke at a temperature around 1200K.

**8. Give the uses of zinc.**

1) Metallic zinc is used in galvanisation to protect iron and steel structures from rusting and corrosion.
2) It is used to produce die - castings in the automobile, electrical and hardware industries.
3) Zinc oxide is used in the manufacture of paints, rubber, cosmetics, pharmaceuticals, plastics, inks, batteries, textiles and electrical equipment.
4) Zinc sulphide is used in making luminous paints, fluorescent lights and x - ray screens.
5) Brass an alloy of zinc which is highly resistant to corrosion is used in water valves and communication equipment.

**9. Explain the electrometallurgy of aluminium.**

**Hall - Herold Process**

**Cathode** : Iron tanked lined with carbon

**Anode :** Carbon blocks

**Electrolyte :** 20% solution of alumina obtained from bauxite + Molten Cryolite + 10% calcium chloride (lowers the melting point of the mixture)

**Temperature:** Above 1270K

Ionisation of Alumina : $Al_2O_3 \longrightarrow 2Al^{3+} + 3O^{2-}$

**Reaction at cathode :** $2Al^{3+}(melt) + 3e^- \longrightarrow Al$

**Reaction at anode :** $6O^{2-}(melt) \longrightarrow 3O_2 + 12e^-$

Since carbon acts as anode the following reaction also takes place on it.

$C(s) + O_2^{-}(melt) \longrightarrow CO + 2e^{-}$

$C(s) + 2O_2^{-}(melt) \longrightarrow CO_2 + 4e^{-}$

During electrolysis anodes are slowly consumed due to the above two reactions. Pure aluminium is formed at the cathode and settles at the bottom.

Net electrolysis reaction is

$4Al^{3+}(melt) + 6O^{2-}(melt) \longrightarrow 4Al_{(l)} + 3CO_{2(g)}$

**10.Explain the following terms with suitable examples. i) Gangue ii) Slag**

**i) Gangue**

The non metallic impurities, rocky materials and siliceous matter present in the ores are called gangue.

**E.x :** $SiO_2$ is the gangue present in the iron ore $Fe_2O_3$.

**ii) Slag**

Slag is a fusible chemical substance formed by the reaction of gangue with a flux.

In the extraction of iron , a basic flux limestone is used which decomposes to form CaO which reacts with silica gangue present in the iron ore is acidic in nature to form calcium silicate (slag)

$CaCO_3 \longrightarrow CaO + CO_2$

$CaO\,(s) + SiO_2\,(s) \longrightarrow CaSiO_3\,(s)$

Flux Gangue slag

**11.Give the basic requirement for vapour phase refining.**

- ✓ The metal should form a volatile compound ,when treated with a suitable reagent
- ✓ Then the volatile compound should decomposed to give the pure metal.

**12. Describe the role of the following in the process mentioned.**

**i) Silica in the extraction of copper.**

**ii) Cryolite in the extraction of aluminium.**

**iii) Iodine in the refining of Zirconium.**

**iv) Sodium cyanide in froth floatation.**

i) In the extraction of copper, silica acts as an acidic flux to remove FeO as slag $FeSiO_3$.

$FeO + SiO_2(s) \longrightarrow FeSiO_3$

**Flux** **Slag**

ii) Cryolite serves as an added impurity and lowers the melting point of the $Al_2O_3$.

iii) First Iodine forms a Volatile tetraiodide with impure metal, which decomposes to give pure metal. Impure zirconium metal is heated in an evacuated vessel with iodine to form the volatile zirconium tetraiodide ($ZrI_4$). The impurities are left behind, as they do not react with iodine.

iv) Sodium cyanide acts as a depressing agent in froth floatation process. When a sulphide ore of a metal of interest contains other metal sulphides the depressing agent sodium cyanide selectively prevent other metal sulphides from coming to the froth.

**13. Explain the principle of electrolytic refining with an example.**

Crude metal like silver is refined by electrolysis carried out in an electrolytic cell.

**Electro refining of silver**

1) **Cathode :** Pure silver
2) **Anode :** Impure silver rods.
3) **Electrolyte :** Acidified aqueous solution of silver nitrate.
4) On passing current the following reactions will take place.
5) **Reaction at anode :** $Ag\,(s) \longrightarrow Ag^{+}\,(aq) + 1e^{-}$
6) **Reaction at cathode :** $Ag^{+}\,(aq) + 1e^{-} \longrightarrow Ag$
7) During electrolysis, at the anode the silver atoms lose electrons and enter the solution. The positively charged silver cations migrate towards the cathode and get discharged by gaining electrons and deposited on the cathode.
8) Less electro positive impurities in the anode settle down as anode mud.

**14. The selection of reducing agent depends on the thermodynamic factor: Explain with an example.**

- ✓ A suitable reducing agent is selected based on the thermodynamic considerations.
- ✓ For a spontaneous reaction$\Delta G$ should be negative.
- ✓ Thermodynamically, the reduction of metal oxide with a given reducing agent can occur if $\Delta G$ for the coupled reaction is negative.
- ✓ Hence the reducing agent is selected in such a way that it provides a large negative $\Delta G$ value for the coupled reaction.
- ✓ Ellingham diagram is used to predict thermodynamic feasibility of reduction of oxides of one metal by another metal.

**For example**

1) Above 1623 K , Al has more negative $\Delta G^{o}$ value than Mg
2) Hence Al is used to reduce magnesia
3) Below 1623 K , Mg more negative $\Delta G^{o}$ value than Al

4) Hence Mg is used to reduce Al

**15. Give the limitations of Ellingham diagram.**

1) Ellingham diagram is constructed based only on thermodynamic considerations.
2) It gives information about the thermodynamic feasibility of a reaction.
3) It does not tell anything about the rate of the reaction.
4) It does not give any idea about the possibility of other reactions that might be taking place.
5) The interpretation of ΔG is based on the assumption that the reactants are in equilibrium with the product which is not always true.

**16. Write a short note on electrochemical principles of metallurgy.**

1) Reduction of oxides of active metals such as sodium, potassium etc. by carbon is thermodynamically not feasible.
2) Such metals are extracted from their ores by using electrochemical methods.
3) In this method the metal salts are taken in fused form or in solution form.
4) The metal ion present can be reduced by treating the solution with suitable reducing agent or by electrolysis.
5) Gibbs free energy change for the electrolysis is $\Delta G^\circ = -nFE^\circ$
   **n** = number of electrons involved in the reduction
   **F** = Faraday = 96500 coulombs
   **E°=** electrode potential of the redox couple.
6) If E° is positive, ΔG° is negative and the reduction is spontaneous.
7) Hence a redox reaction is planned in such a way that the e.m.f of the net redox reaction is positive.
8) A more reactive metal displaces a less reactive metal from its salt solution.Zinc is more reactive than copper and displaces copper from its salt solution.

$Cu(s) + 2Ag^+(s) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$

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

## Evaluate Yourself

**1.Write the equation for the extraction of silver by teaching with sodium cyanide and show that the teaching process is a redox reaction.**

The crushed ore of argentite ($Ag_2S$) is leached with sodium cyanide solution. This reaction forms sodium argento cyanide $Na[Ag(CN)_2]$.

**Step 1:** $Ag_2S + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S$

The solution of sodium argento cyanide combines with zinc dust and forms sodium tetra cyano zincate and precipated silver.

Step 2: $Zn + 2\,Na[Ag(CN)_2] \longrightarrow Na_2[Zn(CN)_4] + 2\,Ag\downarrow$

(0) (oxidation) (2+)

In the step 2, redox reaction takes place,

$$\overset{(2+)}{Zn} \longrightarrow Zn \text{ (oxidation)}$$

$$\overset{(+1)}{Ag} \longrightarrow \overset{(0)}{Ag} \text{ (reduction)}$$

$$\overset{(0)}{Zn} \longrightarrow \overset{(+1)}{Na_2[Zn(CN)_4]}$$

$$\overset{(+1)}{Na[Ag(CN)_2} \longrightarrow \overset{(0)}{2Ag\downarrow}$$

(reduction)

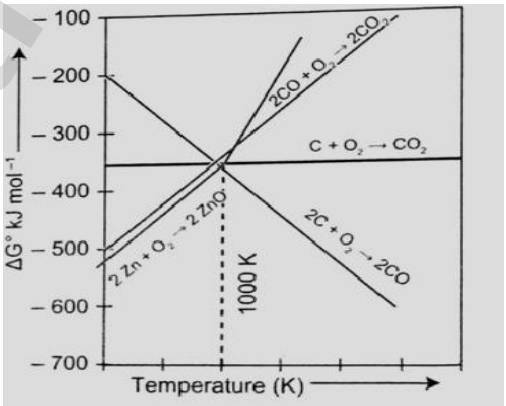
**2. Magnesite (Magnesium carbonate) is calcined to obtain magnesia, which is used to make refractory bricks. Write the decomposition reaction.**

Magnesite is a carbonate of magnesium. Magnesite when heated at 800˚C to 1000˚C at the $CO_2$ content in it is driven off. The residue so obtained is known as calcined magnesite.

$$\underset{\text{(Magnesite)}}{MgCO_3} \xrightarrow{800^\circ C \text{ to } 1000^\circ C} \underset{\text{(Magnesia)}}{MgO + CO_2\downarrow}$$

**3. Using Ellingham diagram indicate the lowest temperature at which ZnO can be reduced to Zinc metal by carbon. Write the overall reduction at this temperature.**

- ✓ Ellingham diagram shows variation in standard Gibbs free energy change with temperature for the formation of oxide.
- ✓ The Ellingham diagram shows straight line upward slope with formation of oxide, but in case of ZnO there is sudden change.
- ✓ Ellingham diagram helps in the selecting suitable reducing agent.
- ✓ By seeing the Ellingham diagram, the free energy formation($\Delta_f G^\circ$) of CO from C becomes lower temperatures above 1120 K while that of $CO_2$ from C becomes lower above 1323 K than $\Delta_f G^\circ$ of ZnO.
- ✓ As $\Delta_f G^\circ$ of $CO_2$ from CO is always higher than that of ZnO. So C can reduce ZnO to Zn but not CO. Thus carbon is better reducing agent than CO for ZnO.




**4. Metallic sodium is extracted by the electrolysis of brine (aq. NaCl). After electrolysis the electrolytic solution becomes basic in nature. Write the possible electrode reactions.**

Brine is a solution of sodium chloride (molten state).The process of electrolysis involves using an electric current to bring about a chemical change and make new chemicals. In the electrolysis of brine, sodium ions migrate to the cathode, where electrons enter to the melt and are reduced in sodium metal.

$$Na^+ + e \longrightarrow Na \text{ ( at cathode )}$$

Chloride ions migrate the other way toward the anode. They give up their electrons to the anode and are oxidized to chlorine gas.

$Cl^{-} \longrightarrow \frac{1}{2} Cl_2 + e^-$ ( at anode )

**Overall reaction:** $2NaCl \longrightarrow 2Na(s) + Cl_2(g)$

For aqueous solution of NaCl: $H_2O + 2e^- \longrightarrow H_2 \uparrow + OH^-$ ( at cathode )

$Cl^{-} \longrightarrow \frac{1}{2} Cl_2 + e^-$ ( at anode )

**Overall reaction:** $Nacl(aq) + H_2O(I) \longrightarrow Na^+(aq) + OH^- aq) + H_2(g) + \frac{1}{2} Cl_2(g)$

After electrolysis the electrolytic solution becomes basic in nature.

**Book Inside**

**Short Answers**

**1. What is concentration of ores?**

The removal of non metallic impurities, rocky materials and siliceous matter (called as gangue) from the ores is known as concentration of ores.

**2. What is leaching?**

The process of dissolving metal present in an ore in a suitable solvent to form a soluble metal salt or complex leaving the gangue undissolved is called leaching.

**3. What is ammonia leaching?**

- ✓ Crushed ore containing nickel, copper and cobalt is treated with aqueous ammonia under suitable pressure.
- ✓ Ammonia selectively leaches these metals by forming their soluble complexes namely $[Ni(NH_3)_6]^{2+}$ , $[Cu(NH_3)_4]^{2+}$ from the ore leaving behind the gangue, iron(III) oxides/hydroxides and aluminosilicate.

**4. In the extraction of metal ore is first converted into metal oxide before reduction into metal. why?**

- ✓ In the concentrated ore the metal exists in positive oxidation state and hence it is to be reduced to elemental state.
- ✓ From the principles of thermodynamics the reduction of oxide is easier compared to the reduction of other compounds of metal.
- ✓ Hence before reduction the ore is first converted into metal oxide.

**5. How will you extract the metal by the process of reduction by carbon.**

- ✓ In this method oxide ore of the metal is mixed with coal (coke) and heated strongly in a blast furnace.
- ✓ This method can be applied to metals which do not form carbides with carbon at the reduction temperature.

$ZnO(s) + C \longrightarrow Zn_{(S)} + CO_{(g)} \uparrow$

**6. Explain auto reduction of metallic ores or give some example for the ore which does not need any reducing agent**

- ✓ Simple roasting of some of the metallic ores give the crude metal.
- ✓ Use of reducing agent is not necessary.
- ✓ Cinnabar is roasted to give mercury.

$$HgS(s) + O_2(g) \longrightarrow Hg + SO_2 \uparrow$$

**7. Give the applications of copper.**

1. Used for making coins and ornaments along with gold and other metals.
2. Copper and its alloys are used for making wires, water pipes and other electrical parts.

**8. Give the applications of gold.**

1. Used for coinage and has been used as standard for monetary systems in some countries.
2. Extensively used in jewellery in its alloy form with copper.
3. Used in electroplating to cover other metals with a thin layer of gold in watches, artificial limb joints, cheap jewellery, dental fillings and electrical connectors.
4. Gold nanoparticles are used for increasing the efficiency of solar cells.
5. Used as catalyst.

**9.What do you meant by Refining process ?**

- ✓ The metal extracted from its ore contains some impurities such as unreacted oxide ore, other metals, non metals etc...
- ✓ Removal of such impurities associated with the isolated crude metal is called refining process.

**10.Which method is used to refine volatile metals? Explain it**

- ✓ Distillation method is employed for low boiling volatile metals like zinc (boiling point 1180 K) and mercury (630 K).
- ✓ In this method, the impure metal is heated to evaporate and the vapours are condensed to get pure metal.

**11. Explain liquation with suitable example (or) how will refine the metals having low boiling liquid ?**

1. This method, is employed to remove the impurities with high melting points from metals having relatively low melting points such as tin (Sb; mp = 904 K), lead (Pb; mp = 600 K), mercury (Hg; mp =234 K), and bismuth (Bi; mp =545 K).
2. In this process, the crude metal is heated to form fusible liquid and allowed to flow on a sloping surface.

3. The impure metal is placed on sloping hearth of a reverberatory furnace and it is heated just above the melting point of the metal in the absence of air, the molten pure metal flows down and the impurities are left behind.
4. The molten metal is collected and solidified.

**12.What do you meant by cementation?**

Gold can be recovered by reacting the deoxygenated leached solution with zinc. In this process the gold is reduced to its elemental state (zero oxidation sate) and the process is called cementation.

$$Zn_{(s)} + 2[Au(CN)_2]^-_{(aq)} \longrightarrow 2[Zn(CN)_2]^-_{(aq)} + 2Au$$

**13.Explain Cyanide leaching**

In the concentration of gold ore , the crushed ore of gold is leached with aerated dilute solution of sodium cyanide. Gold is converted into a soluble cyanide complex. The gangue, aluminosilicate remains insoluble.

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

**14. What is Acid leaching**

Leaching of sulphide ores such as ZnS, PbS etc., can be done by treating them with hot aqueous sulphuric acid.

$$2ZnS\ (s) + 2H_2SO_4\ (aq) + O_2(g) \longrightarrow 2ZnSO_4\ (aq) + 2S\ (s) + H_2O$$

In this process the insoluble sulphide is converted into soluble sulphate and elemental sulphur

**15. ZnO can be reduced to the metal by heating with carbon but not $Cr_2O_3$.Jusitify your answer**

Carbon has more affinity for oxygen than zinc , whereas chromium has higher affinity for oxygen than zinc.Hence ZnO can be reduced to the metal by heating with carbon but not $Cr_2O_3$

**16.Write the differences between roasting and calcination**

| Roasting | Calcination |
|---|---|
| In this concentrated ore is oxidised by heating it with excess of oxygen in a suitable furnace below the melting point of the metal. | It is the process in which the concentrated ore is strongly heated in the absence of air or limited supply of air below the melting point of the metal |
| It is used for concentrating sulphide ores | It is used for concentrating carbonate ores |
| During this process $SO_2$ is released | During this process $CO_2$ is released |

**17.What is smelting?**

It is a process of reducing the roasted metallic oxide to metal in molten condition .In this process , impurities are removed by addition of flux as slag and reducing agent is added.

**18.List out the common refining methods**

1. Distillation
2. Liquation
3. Electrolytic refining
4. Zone refining
5. Vapour phase method

**19.What is blister copper? How it is obtained ?**

- ✓ It is an impure copper.
- ✓ In Bessemerization process , the metallic copper is solidified and it has blistered appearance due to evolution of $SO_2$ gas formed in this process. This copper is called blistered copper**.**
- ✓

**20. Sulphide and carbonate ores are converted to oxide before reduction. Why?**

Since the reduction of oxide ores involves a decrease in Gibb's free energy making ΔG value more negative, it is easier to reduce oxides therefore suphide and carbonate ores are converted to oxides before reduction.

**21. What are Ellingham diagrams?**

Ellingham diagrams are graphical representation of variation of ΔG vs T for theformation of oxides of elements

**22. Give two examples of metal refined by a) Distillation b) Liquation c) Electrolytic refining**

a) Distillation – Zinc and Mercury
b) Liquation – Tin and Antimony
c) Electrolytic refining – Copper and Zinc

**23.What are the steps involved in extraction of crude metal?**

1. Conversion of metal into metal oxide
2. Reduction of metal oxide into metal

**Long answers**

**1. Explain froth floatation method.**

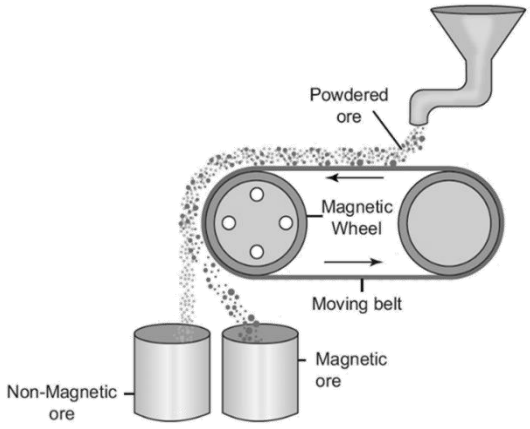
1. This is used to concentrate sulphide ores such as galena (PbS) Zinc blende (ZnS) etc.
2. Metallic ore particles preferentially wetted by oil can be separated from gangue.
3. Crushed ore is mixed with water and a frothing agent like pine oil or eucalyptus oil.
4. A small amount of sodium ethyl xanthate is added as a collector.
5. A froth is formed by blowing air through the mixture.
6. The collector molecules attach to the ore particles and make them water repellent.
7. As a result ore particles wetted by the oil rise to the surface along with the froth.
8. The froth is skimmed off and dried to recover the concentrated ore.
9. Gangue particles preferentially wetted by water settle at the bottom.
10. If the sulphide ore contains other metal sulphides as impurities, they are selectively prevented from coming to the froth by using depressing agents like sodium cyanide, sodium carbonate etc.
11. Sodium cyanide depresses the floatation property of the impurity ZnS present in galena (PbS) by forming a layer of zinc complex $Na_2[Zn(CN)_4]$ on the surface of ZnS.

**2. Explain about concentration of ore by Gravity separation (or) Hydraulic wash (or) How will you concentrate oxide ores**

1. In this method, the ore having high specific gravity is separated from the gangue that has low specific gravity by simply washing with running water.
2. Ore is crushed to a finely powdered form and treated with rapidly flowing current of water. During this process the lighter gangue particles are washed away by the running water.
3. This method is generally applied to concentrate the native ore such as gold and oxide ores such as hematite ($Fe_2O_3$), tin stone ($SnO_2$) etc.

**3. Explain about Magnetic separation (or) How will you concentrate ferromagnetic ores?**

1. This method is applicable to ferromagnetic ores and it is based on the difference in the magnetic properties of the ore and the impurities.
2. Tin stone can be separated from the wolframite impurities which is magnetic. Similarly, ores such as chromite, pyrolusite having magnetic property can be removed from the non magnetic siliceous impurities.
3. The crushed ore is poured on to an electromagnetic separator consisting of a belt moving over two rollers of which one is magnetic.



4. The magnetic part of the ore is attracted towards the magnet and falls as a heap close to the magnetic region while the nonmagnetic part falls away from it

**4. Explain about Van-Arkel method for refining zirconium/titanium [OR]**
**Explain the method to purify Titanium metal [OR]**
**How will you purify metals by using iodine ?**

1. It is based on the thermal decomposition of metal compounds which lead to the formation of pure metals.
2. Titanium and zirconium can be purified using this method.
3. The impure titanium metal is heated in an evacuated vessel with iodine at a temperature of 550 K to form the volatile titanium tetra-iodide.($TiI_4$).
4. The impurities are left behind, as they do not react with iodine

$$Ti\,(s) + 2I_2\,(s) \longrightarrow TiI_4\,(vapour)$$

5. The volatile titanium tetraiodide vapour is passed over a tungsten filament at a temperature aroud 1800 K.
6. The titanium tetraiodide is decomposed and pure titanium is deposited on the filament. The iodine is reused.

$$Ti\,(s) + 2I_2\,(s) \longrightarrow TiI_4\,(vapour)$$

**5.Give the Application of Al**

- ✓ Many heat exchangers/sinks and cooking vessels are made of aluminium.
- ✓ It is used as wraps (aluminium foils) and is used in packing materials for food items,
- ✓ Its alloys with copper, manganese, magnesium and silicon are used in design of aeroplanes and other forms of transport.
- ✓ It is used in the design of chemical reactors, medical equipments ,refrigeration units and gas pipelines.
- ✓ It is used in electrical overhead electric cables with steel core for strength.

**6.Explain about alkali leaching [OR]**
**How will you get pure alumina from impure alumina using leaching ? [OR]**
**What is the significance of leaching in the extraction of aluminium?**

- ✓ In this method, the ore is treated with aqueous alkali to form a soluble complex.
- ✓ Bauxite, an important ore of aluminium is heated with a solution of sodium hydroxide or sodium carbonate in the temperature range 470 - 520 K at 35 atm to form soluble sodium meta-aluminate leaving behind the impurities, iron oxide and titanium oxide.

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

- ✓ The hot solution is decanted, cooled, and diluted. This solution is neutralised by passing $CO_2$ gas, to the form hydrated $Al_2O_3$ precipitate.

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

✓ The precipitate is filtered off and heated around 1670 K to get pure alumina $Al_2O_3$.

**7.Explain about extraction of copper from copper pyrite**

1. Ore is concentrated by froth flotation process
2. The concentrated ore is heated in a reverberatory furnace after mixing with silica, an acidic flux. The ferrous oxide formed due to melting is basic in nature and it combines with silica to form ferrous silicate (slag).
3. The remaining metal sulphides $Cu_2S$ and FeS are mutually soluble and form a copper matte.

   $2CuFeS_2\,(s) + O_2\,(g) \longrightarrow 2FeS\,(l) + 2Cu_2S\,(l) + 2SO_2\,(g)$

   $FeS\,(l) + O\,(g) \longrightarrow FeO\,(l) + SO_2\,(g)$

   $FeO\,(s) + SiO_2\,(s) \longrightarrow FeSiO_3\,(s)$

   Flux Gangue Slag
4. The matte is separated from the slag and fed to the converting furnace. During conversion, the FeS present in the matte is first oxidised to FeO. This is removed by slag formation with silica. The remaining copper sulphide is further oxidised to its oxide which is subsequently converted to metallic copper as shown below.
5. The metallic copper is solidified and it has blistered appearance due to evolution of $SO_2$ gas formed in this process. This copper is called blistered copper.

   $Cu_2S\,(l,s) + 3O_2\,(g) \longrightarrow 2Cu_2S\,(l,s) + 2SO_2\,(g)$

   $2Cu_2O\,(l) + Cu_2S\,(l) \longrightarrow 6Cu\,(l) + SO_2\,(g)$

**8.Explain the Observations from the Ellingham diagram.**

1. For most of the metal oxide formation, the slope is positive. It can be explained as follows. Oxygen gas is consumed during the formation of metal oxides which results in the decrease in randomness. Hence, $\Delta S$ becomes negative and it makes the term, $T\Delta S$ positive in the straightline equation.

2. The graph for the formation of carbon monoxide is a straight line with negative slope. In this case $\Delta S$ is positive as 2 moles of CO gas is formed by the consumption of one mole of oxygen gas. It indicates that CO is more stable at higher temperature.

3. As the temperature increases, generally $\Delta G$ value for the formation of the metal oxide become less negative and becomes zero at a particular temperature. Below this temperature, $\Delta G$ is negative and the oxide is stable and above this temperature $\Delta G$ is positive. This general trend suggests that metal oxides become less stable at higher temperature and their decomposition becomes easier.

4. There is a sudden change in the slope at a particular temperature for some metal oxides like MgO, HgO. This is due to the phase transition (melting or evaporation).

**9. Explain the Applications of the Ellingham diagram**

It helps us to select a suitable reducing agent and appropriate temperature range for reduction.

1. Ellingham diagram for the formation of $Ag_2O$ and HgO is at upper part of the diagram and their decomposition temperatures are 600 and 700 K respectively. It indicates that these oxides are unstable at moderate temperatures and will decompose on heating even in the absence of a reducing agent.
2. Ellingham diagram is used to predict thermodynamic feasibility of reduction of oxides of one metal by another metal. Any metal can reduce the oxides of other metals that are located above it in the diagram.
3. The carbon line cuts across the lines of many metal oxides and hence it can reduce all those metal oxides at sufficiently high temperature.

**10. Explain aluminothermite process**

Metallic oxides such as $Cr_2O_3$ can be reduced by an aluminothermite process.

In this process, the metal oxide is mixed with aluminium powder and placed in a fire clay crucible. To initiate the reduction process, an ignition mixture (usually magneisium and barium peroxide) is used.

$$BaO_2 + Mg \longrightarrow BaO + MgO$$

During the above reaction a large amount of heat is evolved (temperature up to 2400°C, is generated and the reaction enthalpy is : 852 kJ mol-1) which facilitates the reduction of $Cr_2O_3$ by aluminium power.

$$Cr_2O_3 + 2Al \longrightarrow 2Cr + Al_2O_3$$

**11.Give the application of iron**

- Its alloys are used everywhere including bridges, electricity pylons, bicycle chains, cutting tools and rifle barrels.
- Cast iron is used to make pipes, valves and pumps stoves etc...
- Magnets can be made of iron and its alloys and compounds.
- An important alloy of iron is stainless steel, and it is very resistant to corrosion. It is used in architecture, bearings, cutlery, surgical instruments and jewellery.
- Nickel steel is used for making cables, automobiles and aeroplane parts.
- Chrome steels are used for manufacturing cutting tools and crushing machines