General Principles and Processes of Isolation of Elements

CHAPTER 06

INTRODUCTION

Metallurgy is the branch of science and technology that deals with the properties, behavior, and production of metals and alloys. It involves the study of various processes and techniques used to extract metals from their ores, purify them, and modify their properties to meet specific requirements. Here are some important notes on metallurgy:

1. **Ore:** Metallurgical processes start with the extraction of metals from their ores. Ores are naturally occurring rocks or minerals that contain a high concentration of desired metal elements. Common ores include hematite (iron ore), bauxite (aluminum ore), and galena (lead ore).

2. **Extraction of Metals:** The extraction of metals from ores can be achieved through various methods, including:
   a. **Pyrometallurgy:** Involves high-temperature processes such as smelting, where ores are heated in a furnace to remove impurities and obtain the metal in a more purified form.
   b. **Hydrometallurgy:** Involves the use of aqueous solutions or solvents to extract metals. This method is commonly used for low-grade ores or when the desired metal is more soluble in a liquid medium.
   c. **Electrometallurgy:** Relies on electrolysis, which uses an electric current to drive the reduction of metal ions into their elemental form.

3. **Refining:** After extraction, metals often undergo refining processes to further purify them. Refining methods may include electrolytic refining, zone refining, or fractional crystallization, depending on the metal and its impurities.

4. **Alloying:** Alloys are metallic materials composed of two or more elements, with at least one of them being a metal. Alloying is the process of combining different metals or adding non-metallic elements to a metal to improve its properties. Examples of alloys include steel (iron and carbon), bronze (copper and tin), and brass (copper and zinc).

5. **Heat Treatment:** Heat treatment techniques are employed to modify the mechanical, physical, and chemical properties of metals and alloys. Common heat treatment processes include annealing, quenching, tempering, and case hardening.

6. **Phase Diagrams:** Phase diagrams illustrate the relationships between temperature, pressure, and the different phases or states of a metal or alloy. They help predict the behavior of materials during heating, cooling, and alloying processes.
7. **Mechanical Testing:** Various tests are conducted to evaluate the mechanical properties of metals, including tensile strength, yield strength, hardness, and ductility. These tests help determine the suitability of a metal for different applications.

8. **Corrosion:** Metals can corrode when exposed to corrosive environments, leading to deterioration and loss of functionality. Understanding corrosion mechanisms and implementing protective measures, such as coating or alloy selection, is essential in preventing or minimizing corrosion.

9. **Metallurgical Processes:** Metallurgy involves several processes and techniques beyond extraction and refining, including casting, forging, rolling, extrusion, welding, and machining. These processes enable the shaping, forming, and fabrication of metals into desired products.

10. **Applications:** Metallurgy plays a crucial role in various industries, including automotive, aerospace, construction, electronics, energy, and manufacturing. Metals and alloys are used in a wide range of applications, from structural components to electrical conductors, from high-temperature materials to biomedical implants.

OCCURRENCE OF METALS

Type of Metal Occurrence	Description
Native Form	Metals occurring naturally in their pure elemental state. Examples include gold, silver, and copper. They are found as nuggets, grains, or veins in rocks or sediment deposits.
Combined Form	Metals occurring in compounds or minerals, chemically bonded with other elements. They are commonly found as ores. Examples include iron oxides (hematite, magnetite), aluminum oxide (bauxite), and lead sulfide (galena). Extraction and refining processes are often required to obtain the metal in its pure form.

MINERALS AND ORES

	Minerals	Ores
Definition	Naturally occurring inorganic solids with a definite chemical composition and a crystalline structure.	Rocks or minerals that contain a valuable or useful substance that can be extracted for economic gain.
Formation	Formed through geological processes.	Formed when minerals accumulate in high enough concentrations.
Examples	Quartz, feldspar, calcite, mica, hematite, etc.	Iron ore, copper ore, gold ore, silver ore, etc.
Physical properties	Varying physical properties such as color, hardness, luster, transparency, etc.	Physical properties depend on the specific metal contained in the ore.
Economic value	Not all minerals have economic value.	Ores are valuable and can be economically viable for extraction.
Extraction	Not all minerals are extracted for economic purposes.	Ores are mined and processed to extract the desired metal.
Industrial use	Some minerals have industrial or scientific uses.	Ores are used as a primary source for obtaining metals used in various industries.

- Flux is a substance that is added to ores in order to transform non-fusible gangue into a fusible compound, known as slag. Flux can be categorized as either acidic, such as SiO2, or basic, including compounds like CaO and MgO.

CONCENTRATION OF ORES

The concentration of ores refers to the process of increasing the percentage of valuable minerals or metals in the extracted ore. This is done through various techniques, including physical and chemical methods. Here are some common methods used for concentrating ores:

1. **Froth Flotation:** This method utilizes the differences in the surface properties of minerals. The ore is finely ground and mixed with water and specific chemicals. Air bubbles are introduced into the mixture, and the hydrophobic (water-repelling) mineral particles attach to the air bubbles and float to the surface, forming a froth. The froth, containing the valuable minerals, is collected and further processed.

2. **Magnetic Separation:** This method is used for the concentration of magnetic ores, where the valuable mineral has magnetic properties. The crushed ore is passed through a magnetic separator, which attracts and separates the magnetic particles from the non-magnetic ones.

3. **Gravity Separation:** This method exploits the differences in density between the valuable mineral and the gangue. The ore is crushed and subjected to gravity separation techniques, such as jigging, shaking tables, or centrifugal concentrators, which separate the heavier mineral particles from the lighter gangue particles.

4. **Leaching:** In this method, a liquid solvent is used to selectively dissolve the desired mineral from the ore. Commonly used solvents include acids, such as sulfuric acid or hydrochloric acid. The leaching process helps in extracting valuable metals like copper, gold, or uranium from their ores.

5. **Smelting:** Smelting is a process used to separate the metal from its ore by heating the ore to a high temperature in the presence of a reducing agent, such as carbon. This technique is commonly used for ores containing metals like iron, copper, lead, and zinc.

6. The specific concentration method used depends on the type of ore and the desired minerals or metals to be extracted. Each method has its advantages and limitations, and the choice of method is determined by factors such as ore composition, economics, and environmental considerations.

ELLINGHAM DIAGRAM

The Ellingham diagram is a graphical representation that illustrates the thermodynamic stability of various metal oxides with respect to temperature. It provides valuable information about the feasibility of the reduction reactions of metal oxides with carbon or other reducing agents.

The Ellingham diagram is named after the English metallurgist Harold Ellingham, who developed it in the mid-20th century. It consists of a set of lines or curves representing the Gibbs free energy change (ΔG) for the formation of metal oxides at different temperatures.

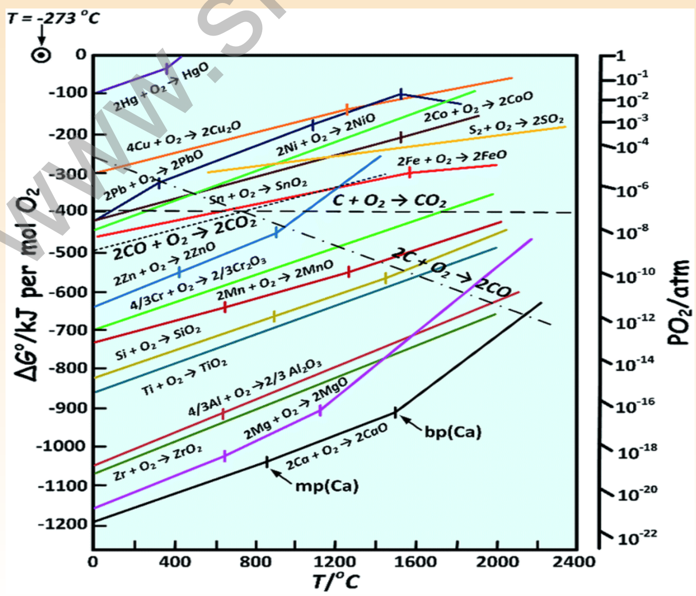
The diagram is typically plotted with the standard Gibbs free energy change ($\Delta G°$) on the vertical axis and the temperature on the horizontal axis. Each metal oxide is represented by a line or curve, indicating its stability range under standard conditions. The lower the line or curve, the more thermodynamically stable the metal oxide is.

The Ellingham diagram provides several important insights:

1. **Comparison of Oxide Stability:** The diagram allows for a comparison of the stability of different metal oxides. Oxides located higher on the diagram (higher $\Delta G°$ values) are less stable and easier to reduce, while oxides located lower on the diagram (lower $\Delta G°$ values) are more stable and require higher temperatures or stronger reducing agents for reduction.
2. **Determination of Suitable Reducing Agents:** By comparing the stability of different metal oxides, one can identify the most suitable reducing agents for the reduction of specific metal oxides. For example, carbon (as in the form of coke or charcoal) is commonly used to reduce metal oxides located above its own line on the diagram.

3. **Prediction of Temperature Conditions:** The diagram provides information about the temperature at which a particular reduction reaction becomes favorable. The more negative the ΔG° value, the lower the temperature required for reduction. The Ellingham diagram is widely used in metallurgy and materials science to understand and optimize high-temperature processes such as metal extraction, refining, and alloy production. It aids in the selection of appropriate reaction conditions and helps to evaluate the energy requirements and feasibility of various metallurgical processes.

- The Ellingham diagram is a valuable tool for understanding the thermodynamics of metal oxide formation and reduction.
- It provides information about the thermodynamic stability of metal oxides with respect to temperature.
- The position of the lines or curves on the diagram reflects the relative stability of different metal oxides.
- Oxides higher on the diagram (higher ΔG° values) are less stable and more easily reduced, while oxides lower on the diagram (lower ΔG° values) are more stable and require higher temperatures or stronger reducing agents for reduction.
- The diagram allows for the comparison of the stability and reactivity of different metal oxides.
- It helps in selecting appropriate reducing agents for the reduction of metal oxides.
- The diagram provides insights into the temperature conditions required for reduction reactions.
- It has limitations such as idealized conditions, neglect of kinetic factors, and limited scope.
- The diagram serves as a qualitative guide but may not provide precise numerical values or account for complex reactions.
- Despite its limitations, the Ellingham diagram remains a valuable tool in metallurgy and materials science for assessing the feasibility of reduction reactions and aiding in the selection of suitable conditions.



REFINING

Refining is the process of purifying substances, such as metals or petroleum products, by removing impurities or undesirable components through techniques like smelting, electrolysis, or chemical reactions. It improves the quality and purity of the material for various industrial applications.

METHODS OF REFINING

- **Distillation:** Used for refining liquids with different boiling points by heating the mixture, vaporizing the components, and condensing them into separate fractions.
- **Smelting:** In metallurgy, this method involves heating raw metals to high temperatures to melt them and separate impurities or unwanted elements.
- **Electrolysis:** Electrochemical method used to purify metals, involving passing an electric current through a molten metal compound or an electrolyte solution to deposit pure metal at the cathode.
- **Chemical Refining:** Involves chemical reactions to remove impurities or separate components, commonly used in refining vegetable oils.
- **Hydrometallurgical Processes:** Utilizes aqueous solutions and chemical reactions to extract and refine metals, involving leaching, purification, and recovery through techniques like precipitation and solvent extraction.
- **Fractional Crystallization:** Used for refining solid substances by dissolving and cooling the substance repeatedly to selectively remove impurities and obtain a purer solid product.

REFINING METHODS

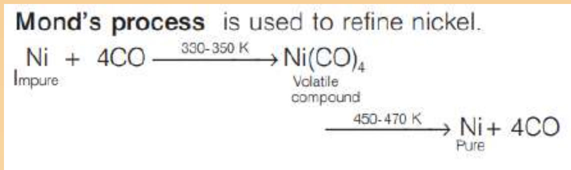
1. Mond Process:

The Mond process is a method for refining nickel. It was developed by Ludwig Mond in the late 19th century. The main objective of the Mond process is to remove impurities, particularly carbon and sulfur, from nickel to obtain a purer and more valuable product.

The process involves the following steps:

1. **Purification:** The impure nickel is first purified through various chemical processes to remove other metals and impurities.
2. **Formation of Nickel Carbonyl:** The purified nickel is then reacted with carbon monoxide (CO) at a high temperature (around 50-60°C) to form nickel carbonyl (Ni(CO)4). This compound is volatile and can be easily vaporized.
3. **Decomposition of Nickel Carbonyl:** The nickel carbonyl vapor is then decomposed at a higher temperature (around 200-250°C) to obtain pure nickel. The decomposition reaction releases carbon monoxide, leaving behind pure nickel as a solid product.

4. **Recycling of Carbon Monoxide:** The carbon monoxide gas released during the decomposition step is recycled and reused in the formation of nickel carbonyl, making the process more efficient and environmentally friendly.
5. The Mond process is particularly effective in removing carbon and sulfur impurities from nickel, which are known to negatively impact its properties and applications. The resulting refined nickel is suitable for various industrial uses, including the production of stainless steel, alloys, and batteries.



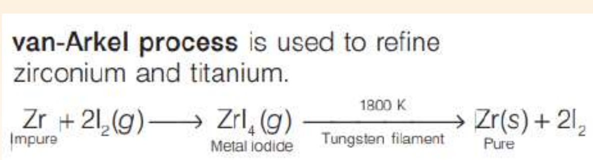
2. Van Arkel Method:

The Van Arkel method, also known as the iodide process, is a technique used for refining reactive metals, such as titanium and zirconium, to achieve high purity levels. It was developed by Anton Eduard van Arkel in the early 20th century.

The process involves the following steps:

1. **Formation of Metal Tetraiodide:** The impure metal is first converted into a volatile tetraiodide compound by reacting it with iodine at a high temperature. This reaction forms a volatile solid compound, such as titanium tetraiodide (TiI4) or zirconium tetraiodide (ZrI4).
2. **Sublimation and Deposition:** The metal tetraiodide compound is then sublimed at an elevated temperature, causing it to transition directly from a solid to a gas. The vapors are then condensed onto a cool surface, leading to the deposition of highly pure metal crystals.
3. **Recycling of Iodine:** The unreacted iodine is collected and recycled for reuse in the initial reaction, making the process more efficient and economical.

The Van Arkel method allows for the production of extremely pure metals, with impurity levels in the parts per million (ppm) range. The high purity is essential for applications that require materials with exceptional chemical and physical properties, such as aerospace components, surgical implants, and specialized laboratory equipment.



SOME IMPORTANT TERMS

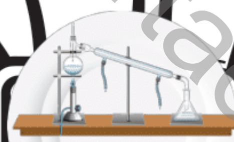
CHROMATOGRAPHY

Chromatography is a refining technique that separates substances based on their different properties using a stationary phase and a mobile phase. The sample is applied, components interact differently with the phases, and separation occurs. Components are detected and analyzed, and desired ones can be collected and further purified. Chromatography is versatile and widely used in refining various substances.

CALCINATION

Calcination in metallurgy involves heating a substance at high temperatures in a controlled atmosphere to remove volatile components and impurities. It prepares materials for further processing by driving off moisture and improving purity. It is essential for ore beneficiation, metal oxide production, catalyst activation, and material preparation. Calcination is conducted in specialized equipment and brings about chemical and physical changes in the material.

Principles and Processes of Isolation



Metallurgy: Entire scientific and technological process used for isolation of the metal from its ores.
- Concentration of ore
- Isolation of metal
- Purification of metal

Minerals naturally occurring chemical substances in the earth's crust obtainable by mining.

Ores : Minerals from which metal can be extracted chiefly, profitably and easily.

- Bauxite $Al_2O_3.xH_2O$
- Kaolinite $[Al_2(OH)_4 Si_2O_5]$
- Haematite Fe_2O_3
- Magnetite Fe_3O_4
- Siderite $FeCO_3$
- Copper pyrites $CuFeS_2$
- Malachite $CuCO_3.Cu(OH)_2$
- Cuprite Cu_2O
- Copper glance Cu_2S
- Zinc blende ZnS
- Calamine $ZnCO_3$
- Zincite ZnO

Thermodynamic principles of metallurgy

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

$\Delta G° = -RT \ln K$

- If ΔG is negative, reaction proceeds.
- If reactants and products of two reactions are put together in a system and net ΔG of the two possible reactions is negative, the overall reaction will occur.

Ellingham diagram
- Plots of $\Delta_f G°$ vs T for reaction.
- Straight line except with some change in phase
- Point in a curve below which ΔG is negative

Concentration of Ores

Hydraulic washing : Based on difference in gravities of the ore and gangue particles

Upward stream of running water is used to wash the powdered ore. Lighter gangue particles are washed away and heavier are left behind.

Magnetic Separation : Based on differences in magnetic properties of ore components

Finely ground ore is carried on conveyor belt which passes over a magnetic roller. Magnetic particles fall nearer to roller and vice versa.

Froth floatation process : Based on the difference in wetting properties of gangue and ore particles

Powdered ore is mixed with pine oil and water and agitated with air froth formed carries minerals is skimmed off and dried.

Leaching : Based on the solubility of ore in suitable solvent

Bayer's process :

$Al_2O_3.2H_2O + 2NaOH + H_2O \longrightarrow 2Na[Al(OH)_4] + CO_2 \longrightarrow$

$Al_2O_3.xH_2O + 2NaHCO_3 \xrightarrow{1470K} Al_2O_3 + xH_2O$

Extraction of crude metal from concentrated ore

Conversion to oxide
- Calcination: Heating when the volatile matter escapes leaving behind the metal oxide.
- Roasting: Ore is heated in a limited supply of air in a furnace at a temperature below the melting point of the metal.

Reduction of oxide to metal: Heating metal oxide with substances acting as a reducing agent which combines with the oxygen to get reduced easily.

Refining

Distillation : Impure metal is evaporated to obtain pure metal as distillate.
Liquation : Low melting metals is made to flow on a sloping surface.
Electrolytic refining : Impure metal anode, strip of same metal in pur form–cathode dipped in soluble salt of same metal.
Zone refining : Based on principle that impurities are more soluble in melt than in solid state of metal.
Vapour phase refining : Metal is converted into its volatile compound and collected elsewhere.
Chromatography : Based on principle that different components of a mixture are differentially adsorbed on an adsorbent.

Uses
- Al
  - As wrappers for chocolates
  - Fine dust in paints and lacquers
  - Extraction of Cr and Mn
  - Wires
- Cu
  - Wires
  - Water and steam pipes
  - Alloys
- Zn
  - Galvanising iron
  - In batteries
  - Dust is used as reducing agent
- Fe
  - Cast iron for casting stoves, railway slippers, gutter pipes, toys etc.
  - Manufacture of wrought iron and steel.

Oxidation reduction (extraction of Cl from brine)

Electrochemical principles of metallurgy

Electrolysis : Difference of two E° values equals Positive E° and Negative ΔG°, less reactive metal will come out of solution and more reactive to the solution.

Metallurgy of aluminium → Purified Al_2O_3 mixed with Na_3AlF_6 / CaF_2 → Fused matrix is electrolysed

Electrolysis (Hall–Heroult process)

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

Cathode : $Al^{3+}(melt) + 3e^- \longrightarrow Al_{(l)}$

Anode : $C_{(s)} + O^{2-}(melt) \longrightarrow CO(g) + 2e^-$

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

Extraction of zinc from zinc oxide

$ZnO + C \xrightarrow[1673K]{Coke} Zn + CO$

Extraction of copper from cuprous oxide

Roasting/smelting

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

$Cu_2O + C \longrightarrow 2Cu + CO$

$FeO + SiO_2 \longrightarrow FeSiO_3$

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

$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$ (Blister copper)

Extraction of iron from oxides

⟶ In blast furnace

$FeO_{(s)} + C_{(s)} \longrightarrow Fe_{(s/l)} + CO_{(g)}$

⟶ Reduction

(a) At 500 – 883 K

$2Fe_2O_3 + 3CO \xrightarrow{573-673K} 2Fe_3O_4 + CO_2\uparrow$

$Fe_3O_4 + 4CO \xrightarrow{773-883K} 3Fe + 4CO_2\uparrow$

$Fe_2O_3 + CO \xrightarrow{773-873K} 2FeO + CO_2\uparrow$

(b) At 900 – 1500K

$CO_2 + C \rightarrow 2CO(g)$; $FeO + CO \rightarrow Fe + CO_2$

$CaCO_3 \rightarrow CaO + CO_2$; $CaO + SiO_2 \rightarrow CaSiO_3$

(c) At 1500 – 2100 K

$C + O_2 \rightarrow CO_2$

$FeO + C \rightarrow Fe + CO$

Trace the Mind Map
- First Level
- Second Level
- Third Level

PRACTICE QUESTIONS

1. Which of the following is the process of extracting metal from its ore by heating in the presence of carbon?

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

2. Which metal is extracted by the Mond process?

a) Copper b) Nickel c) Iron d) Aluminium

3. Which of the following is not a ferrous metal?

a) Iron b) Steel c) Copper d) Cast Iron

4. Which metal is produced by the Hall-Héroult process?

a) Aluminum b) Copper c) Zinc d) Lead

5. Which of the following is an example of a non-ferrous metal?

a) Stainless steel b) Wrought iron c) Brass d) Cast iron

6. Which metal is primarily extracted by the Bayer process?

a) Aluminum b) Copper c) Iron d) Silver\

7. Which of the following is not a method of iron ore concentration?

a) Froth flotation b) Magnetic separation

c) Calcination d) Gravity separation

8. Which metal is commonly used for electrical wiring due to its high conductivity?

a) Copper b) Zinc c) Aluminium d) Nickel

9. Which process is used to convert cast iron into wrought iron?

a) Galvanization b) Annealing c) Tempering d) Puddling

10. Which metal is the primary component of stainless steel?

a) Copper b) Zinc c) Iron d) Chromium

11. The process of extracting metals from ores using microorganisms is called:

a) Hydrometallurgy b) Pyrometallurgy
c) Electrorefining d) Smelting

12. Which of the following is an example of a precious metal?

a) Copper b) Zinc c) Gold d) Aluminium

13. Which process is used to convert an ore into its oxide before reduction?

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

14. Which metal is commonly used for making car batteries?

a) Copper b) Lead c) Aluminium d) Nickel

15. The process of shaping metal by hammering or pressing is called:

a) Casting b) Forging c) Extrusion d) Rolling

16. Which metal is the primary component of brass?

a) Copper b) Zinc c) Iron d) Aluminium

17. The process of coating a metal with a thin layer of zinc is called:

a) Galvanization b) Anodizing c) Electroplating d) Passivation

18. Which metal is commonly used for making electrical wires and cables?

a) Copper b) Zinc c) Aluminium d) Nickel

19. The process of heating a metal to a high temperature and then slowly cooling it is called:

a) Annealing b) Tempering c) Quenching d) Hardening

20. Which metal is commonly used as a catalyst in the Haber-Bosch process for ammonia production?

a) Copper b) Nickel c) Iron d) Platinum

21. The process of strengthening a metal by heating and cooling it rapidly is called:

a) Annealing b) Tempering c) Quenching d) Hardening

22. Which metal is commonly used for making electrical contacts and switches?

a) Copper b) Zinc c) Aluminium d) Silver

23. The process of converting a metal into its oxide by heating in the presence of air is called:

a) Calcination b) Reduction c) Roasting d) Refining

24. Which metal is commonly used for making airplane wings and fuselage?

a) Copper b) Zinc c) Aluminium d) Nickel

25. The process of separating metals based on their densities is called:

a) Alloying b) Refining

c) Distillation d) Gravity separation

26. Which metal is commonly used for making electrical wires in household wiring?

a) Copper b) Zinc c) Aluminium d) Nickel

27. van-Arker method of purification of metals involves converting the metal to a
a) Volatile stable compound b) Non-volatile stable compound
c) Volatile unstable compound d) None of the above

28. In the electrolysis of alumina, cryolite is added to:
a) Lower the melting point of alumina and to increase the electrical conductivity
b) Minimise the anode effect
c) Remove impurities from alumina
d) None of the above

29. The pyrolusite ore contains:
a) Fe b) Al c) Mn d) Cu

30. Purest form of iron is
a) Pig iron b) Wrought iron c) Cast iron d) Steel

31. Pig iron is manufactured by:
a) An electric furnace b) A blast furnace c) An open hearth furnace d) None of these

32. During the process of electrolytic refining of copper, some metals present as impurity settle as 'anode mud'. These are

a) Fe and Ni b) Ag and Au c) Pb and Zn d) Se and Ag

33. By which process Pb and Sn are extracted respectively?

a) Carbon reduction—self reduction
b) Self reduction—carbon reduction
c) Electrolytic reduction—cyanide process
d) Cyanide process—electrolytic reduction

34. CO on passing over heated nickel gives:

a) $NiCO_3$ b) $Ni(CO)_4$ c) $CO_2 + H_2$ d) $CO + H_2$

35. 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)

36. Which of the following metal is thrown as anode mud during electrolytic refining of copper?

a) Zn b) Fe c) Ag d) Ni

37. The method of concentrating the ore which makes use of the difference in density between ore and impurities is called

a) Leaching b) Liquation
c) Levigation d) Magnetic separation

38. The reaction $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ in the metallurgical process of zinc is called

a) Roasting b) Smelting
c) Cupellation d) Calcinations

38. In electro-refining of metal the impure metal is made the anode and a strip of pure metal, the cathode, during the electrolysis of an aqueous solution of a complex metal salt. This method cannot be used for refining of:

a) Silver b) Copper c) Aluminium d) Sodium

39. Which metal is extracted by electrolytic reduction method?
a) Cu b) Al c) Ag d) Fe

40. The cheap and high melting point compound used in furnace lining is:
a) PbO b) CaO c) HgO d) ZnO

41. In the metallurgy of iron, when $CaCO_3$ is added to blast furnace, calcium ion appears as
a) Slag b) Gangue c) CaO d) Metallic Ca

42. Alloys of which metal are light and strong and are used in the manufacture of aeroplanes?
a) Cr b) Sn c) Fe d) Mg

43. Which of the following processes involves the roasting process?
a) $ZnCO_3 \longrightarrow ZnO + CO_2$
b) $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$
c) $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$
d) $Al_2O_3.2H_2O \longrightarrow Al_2O_3 + 2H_2O$

44. Which of the following ore is used for industrial extraction of aluminium in India?
a) Corundum b) Cryolite c) Bauxite d) Kaolin

45. Heating of carbonate ores to remove carbon is called as:
a) Roasting b) Calcination c) Smelting d) Fluxing

46. Coating of zinc on iron objects is commonly known as:
a) Electroplating b) Surface coating c) Galvanising d) Sheardising

47. The temperature of the slag zone in the metallurgy of iron using blast furnace is
a) 1200 – 1500°C b) 1500 – 1600°C c) 400 – 700°C d) 800 – 1000°C

48. Sapphire is a mineral of:
a) Zn b) Cu c) Hg d) Al

49. Which represents calcination?
a) $2Ag + 2HCl + [O] \longrightarrow 2AgCl + H_2O$
b) $2Zn + O_2 \longrightarrow 2ZnO$
c) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$
d) $MgCO_3 \longrightarrow MgO + CO_2$

50. The matte is impure substance obtained during extraction of:

a) Cu b) Fe c) Pb d) Al

51. The following equation represents a method of purification of nickel by,

$$\underset{\text{Impure}}{Ni} + 2CO \xrightarrow{320K} Ni(CO)_4 \xrightarrow{420K} \underset{\text{Pure}}{Ni} + 4CO$$

This method is:

a) Cupellation b) Mond's process

c) Van Arkel method d) Zone refining

52. Softening of lead means:

a) Conversion of lead into PbO
b) Conversion of lead into Pb_3O_4
c) Removal of metallic impurities from lead
d) Washing lead with HNO_3 followed by dilute alkali solution

53. Which is not a mineral of aluminium?

a) Corundum b) Anhydrite c) Diaspore d) Bauxite

54. A common metal used as reductant for the extraction of metals from their oxides is:

a) Cr b) Al c) Co d) Fe

55. Extraction of Ag from commercial lead is possible by:

a) Parke's process b) Clarke's process

c) Pattinson's process d) Electrolytic process

56. Which set of elements is called chalcogens?

a) Cl, Br, I b) O, S, Se c) N, P, As d) C, Si, Ge

ANSWERS

1. b) Smelting: Smelting is the process of extracting metal from its ore by heating it in the presence of carbon, typically in a furnace. The carbon reacts with the metal oxide to produce the metal.
2. b) Nickel: The Mond process is used for the extraction of nickel. It involves the formation of nickel carbonyl, which is then decomposed to obtain pure nickel metal.
3. c) Copper: Copper is a non-ferrous metal. Ferrous metals contain iron as the primary component, while non-ferrous metals do not.
4. a) Aluminum: The Hall-Héroult process is used for the production of aluminum. It involves the electrolysis of alumina (aluminum oxide) dissolved in molten cryolite.
5. c) Brass: Brass is an alloy of copper and zinc. It is a commonly used non-ferrous metal alloy.
6. a) Aluminum: The Bayer process is used for the extraction of aluminum from bauxite. It involves dissolving alumina from bauxite ore using caustic soda.
7. c) Calcination: Calcination is not a method of iron ore concentration. It is a process of heating a substance to high temperatures in the absence of air or oxygen.
8. a) Copper: Copper is commonly used for electrical wiring due to its high electrical conductivity.
9. d) Puddling: Puddling is the process of converting cast iron into wrought iron by stirring it while it is in a molten state. This process removes impurities and produces wrought iron.
10. d) Chromium: Chromium is the primary component of stainless steel. It provides corrosion resistance and enhances the strength of the steel.
11. a) Hydrometallurgy: Hydrometallurgy is the process of extracting metals from ores using aqueous solutions or liquid reagents. It involves leaching, solvent extraction, and precipitation techniques.
12. c) Gold: Gold is a precious metal known for its rarity, beauty, and value. It is often used in jewelry and as a store of value.
13. c) Roasting: Roasting is the process of converting an ore into its oxide by heating it in the presence of air. This step is often done before the reduction process.
14. b) Lead: Lead is commonly used for making car batteries due to its high density and ability to store and release electrical energy.
15. b) Forging: Forging is the process of shaping metal by hammering or pressing it under high pressure. It increases the strength and durability of the metal.
16. a) Copper: Copper is the primary component of brass, along with zinc. Brass is a widely used alloy in various applications.
17. c) Galvanization: Galvanization is the process of coating a metal with a layer of zinc to protect it from corrosion. It is commonly used for steel structures and pipes.
18. a) Copper: Copper is commonly used for making electrical wires and cables due to its high electrical conductivity.
19. a) Annealing: Annealing is the process of heating a metal to a high temperature and then slowly cooling it to relieve internal stresses and improve its ductility.

20.. d) Platinum: Platinum is commonly used as a catalyst in the Haber-Bosch process for ammonia production. It facilitates the reaction between nitrogen and hydrogen.

21. c) Quenching: Quenching is the process of rapidly cooling a metal after heating to increase its hardness. It involves immersing the hot metal in a quenching medium such as water or oil.

22. d) Silver: Silver is commonly used for making electrical contacts and switches due to its high electrical conductivity and low resistance.

23. c) Roasting: Roasting is the process of converting a metal into its oxide by heating it in the presence of air. It is typically done before the reduction process to remove impurities and improve the efficiency of the reduction reaction.

24. c) Aluminium: Aluminium is commonly used for making airplane wings and fuselage due to its low density, high strength, and good corrosion resistance.

25. d) Gravity separation: Gravity separation is a method of separating metals based on their densities. It relies on the difference in density between the components to achieve separation.

26. a) Copper: Copper is commonly used for making electrical wires in household wiring due to its high electrical conductivity and good ductility.

27. (a)

$$\mathrm{Ti} + 2\mathrm{I}_2 \xrightarrow{500\ \mathrm{K}} \underset{\text{stable compound}}{\underset{\text{volatile}}{\mathrm{TiI}_4}} \xrightarrow{1700\ \mathrm{K}} \underset{\text{pure metal}}{\mathrm{Ti}} + 2\mathrm{I}_2$$

28. (a) Cryolite has these two functions during electrolysis of alumina.

29. (c) Pyrolusite is an ore of Mn containing MnO_2.

30. (b) Wrought or malleable iron is the purest form of iron

31. (b) __do___

32. (b) During electrolysis, noble metals (inert metals) like Ag, Au and Pt are not affected band separate as anode mud from the impure anode

33. (b)

$PbS + 2PbO \longrightarrow 3Pb + SO_2$ (Self reduction)

$SnO + C \longrightarrow Sn + CO$ (Carbon reduction)

34. (b) At about 330 K nickel is attacked by carbon monoxide with the formation of a volatile nickel carbonyl $Ni(CO)_4$.

35. (c) It involves auto-reduction.

a. $2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$

36. (c) In electrolytic refining of Cu, impurities of Fe, Ni, and Zn pass into solution and others like Au and Ag fall down, as anode mud.

37. (c) Levigation (gravity separation) in based on the difference in the specific gravities of the gangue particles and the ore particles.

38. (d) Sodium has high reactivity towards water.

39. (b) Metals like, Na, K, Mg, Ca, Al etc are reduced by electrolytic reduction

40. (b) It is a fact.

41. (a) In the metallurgy of iron, when $CaCO_3$ is added to balst furnace, it removes impurities from ore and forms slag.

$CaCO_3 \rightarrow CaO + CO_2$ (1070-1170 K)
$CaO + SiO_2 \rightarrow CaSiO_3$ (1470 K)
$3CaO + P_2O_5 \rightarrow Ca_3(PO_4)_2$

42. (d) Mg alloys are lighter.

43. (c) It is definition of roasting.

44. (c) Aluminium is mainly isolated from bauxite ($Al_2O_3.2H_2O$) ore which is generally contaminated with ferric oxide and silica

45. (b)

Calcination is a process in which the ore is heated strongly in the absence of air.

(i) It removes the volatile impurities like CO_2, SO_2, organic matter, moisture from the ore.
(ii)It removes water from the hydrated ore.
(iii)It removes carbon as CO_2 from a carbonate ore.

(ii) $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

46. (c) It is a fact.

47. (d) The temperature of the slag zone in the metallurgy of iron using blast furnace is 800-1000°C

48. (d) A natural crystalline form of blue, transparent corundum (Al_2O_3). The colour being due to traces of cobalt and other metals.

49 (d) Calcination involves decomposition of ore to remove volatile impurities.

50 (a)

$FeO + SiO_2 \longrightarrow FeSiO_3$ (Fusible slag)

$Cu_2O + FeS \longrightarrow Cu_2S + FeO$

Slag is removed from the slag hole while a molten mass containing mostly cuprous sulphide with a little ferrous sulphide called matte.

51. (b) Mond's process is used for the purification of Ni.

52 (c) It is a fact.

53 (b)

Bauxite ($Al_2O_3 . 2H_2O$)

Corundum (Al_2O_3)

Diaspore ($Al_2O_3 . H_2O$)

54 (b) Extraction of less electropositive metals say Cr, Mn, Cu, Ca, Ni, etc., can be done by heating their oxides with strong reducing agents, e.g., CO, CO + H + Na, Al, Mg, etc.

55 (a) Lead extracted from argentiferous galena contains small quantities of silver. Recovery of silver from argentiferous lead is an economical proposition and is carried out by Parke's process.

56 (b) Oxygen family is known as chalcogens.