Chapter - General Principles and Process of Isolation of Elements

Topic-1: Occurrence of Metals and Metallurgical Processes

1 MCQs with One Correct Answer

1. Calamine, malachite, magnetite and cryolite, respectively, are **[Adv. 2019]**
(a) $ZnCO_3$, $CuCO_3.Cu(OH)_2$, Fe_3O_4, Na_3A1F_6
(b) $ZnSO_4$, $Cu(OH)_2$, Fe_3O_4, Na_3AlF_6
(c) $ZnSO_4$, $CuCO_3$, Fe_2O_3, AlF_3
(d) $ZnCO_3$, $CuCO_3$, Fe_2O_3, Na_3AlF_6

2. In the cyanide extraction process of silver from argentite ore, the oxidising and reducing agents used are
(a) O_2 and CO respectively **[2012]**
(b) O_2 and Zn dust respectively
(c) HNO_3 and Zn dust respectively
(d) HNO_3 and CO respectively

3. Oxidation states of the metal in the minerals haematite and magnetite, respectively, are **[2011]**
(a) II, III in haematite and III in magnetite
(b) II, III in haematite and II in magnetite
(c) II in haematite and II, III in magnetite
(d) III in haematite and II, III in magnetite

4. Extraction of zinc from zinc blende is achieved by
(a) electrolytic reduction **[2007]**
(b) roasting followed by reduction with carbon
(c) roasting followed by reduction with another metal
(d) roasting followed by self-reduction

5. Which ore contains both iron and copper? **[2005S]**
(a) Cuprite (b) Chalcocite
(c) Chalcopyrite (d) Malachite

6. In the process of extraction of gold, **[2003S]**
Roasted gold ore $+CN^- + H_2O \xrightarrow{O_2} [X] + OH^-$
$[X] + Zn \longrightarrow [Y] + Au$
Identify the complexes [*Main X*] and [*Main Y*]
(a) $X = [\text{Main } Au(CN)_2]^-$, $Y = [\text{Main } Zn(CN)_4]^{2-}$
(b) $X = [\text{Main } Au(CN)_4]^{3-}$, $Y = [\text{Main } Zn(CN)_4]^{2-}$
(c) $X = [\text{Main } Au(CN)_2]^-$, $Y = [\text{Main } Zn(CN)_6]^{4-}$
(d) $X = [\text{Main } Au(CN)_4]^-$, $Y = [\text{Main } Zn(CN)_4]^{2-}$

7. Which of the following process is used in the extractive metallurgy of magnesium? **[2002S]**
(a) fused salt electrolysis
(b) self reduction
(c) aqueous solution electrolysis
(d) thermite reduction

8. Electrolytic reduction of alumina to aluminium by Hall-Heroult process is carried out **[2000S]**
(a) in the presence of NaCl
(b) in the presence of fluorite
(c) in the presence of cryolite which forms a melt with lower melting temperature
(d) in the presence of cryolite which forms a melt with higher melting temperature

9. The chemical processes in the production of steel from haematite ore involve **[2000S]**
(a) reduction
(b) oxidation
(c) reduction followed by oxidation
(d) oxidation followed by reduction

10. The chemical composition of 'slag' formed during the smelting process in the extraction of copper is **[2001S]**
(a) $Cu_2O + FeS$ (b) $FeSiO_3$
(c) $CuFeS_2$ (d) $Cu_2S + FeO$

11. In the commercial electrochemical process for aluminium extraction the electrolyte used is **[1999 - 2 Marks]**
(a) $Al(OH)_3$ in NaOH solution
(b) an aqueous solution of $Al_2(SO_4)_3$.
(c) a molten mixture of Al_2O_3 and Na_3AlF_6
(d) a molten mixture of $AlO(OH)$ and $Al(OH)_3$

12. In the alumino-thermite process, aluminium acts as **[1983 - 1 Mark]**
(a) an oxidizing agent (b) a flux
(c) a reducing agent (d) a solder

13. In the metallurgy of iron, when limestone is added to the blast furnace, the calcium ion ends up in **[1982 - 1 Mark]**
(a) slag (b) gangue
(c) metallic calcium (d) calcium carbonate

14. Copper can be extracted from **[1978]**
(a) Kupfernical (b) Dolomite
(c) Malachite (d) Galena

4 Fill in the Blanks

15. In extractive metallurgy of zinc, partial fusion of ZnO with coke is called ..... and reduction of the ore to the molten metal is called ..... .
(smelting, calcining, roasting, sintering) **[1988 - 1 Mark]**

16. In the basic Bessemer process for the manufacture of steel, the lining of the converter is made of ..... . The slag formed consists of ..... **[1980]**

17. In the thermite process ..... is used as reducing agent. **[1980]**

18. Casseterite is ore of ..... **[1980]**

6 MCQs with One or More than One Correct Answer

19. The treatment of galena with HNO_3 produces a gas that is **[Adv. 2022]**
(a) paramagnetic (b) bent in geometry
(c) an acidic oxide (d) colorless

20. The correct option(s) related to the extraction of iron from its ore in the blast furnace operating in the temperature range 900 – 1500 K is(are) **[Adv. 2022]**
(a) Limestone is used to remove silicate impurity.
(b) Pig iron obtained from blast furnace contains about 4% carbon.
(c) Coke (C) converts CO_2 to CO.
(d) Exhaust gases consist of NO_2 and CO.

21. The correct statement(s) related to the metal extraction processes is(are) **[Adv. 2021]**
(a) A mixture of PbS and PbO undergoes self-reduction to produce Pb and SO_2.
(b) In the extraction process of copper from copper pyrites, silica is added to produce copper silicate.
(c) Partial oxidation of sulphide ore of copper by roasting, followed by self-reduction produces blister copper.
(d) In cyanide process, zinc powder is utilized to precipitate gold from $Na[Main\ Au(CN)_2]$

22. Which among the following statement(s) is(are) true for the extraction of aluminium from bauxite? **[Adv. 2020]**
(a) Hydrated Al_2O_3 precipitates, when CO_2 is bubbled through a solution of sodium aluminate.
(b) Addition of Na_3AlF_6 lowers the melting point of alumina.
(c) CO_2 is evolved at the anode during electrolysis.
(d) The cathode is a steel vessel with a lining of carbon.

23. The cyanide process of gold extraction involves leaching out gold from its ore with CN^- in the presence of Q in water to form R. Subsequently, R is treated with T to obtain Au and Z. Choose the correct option(s) **[Adv. 2019]**
(a) Q is O_2 (b) T is Zn
(c) Z is $[Main\ Zn(CN)_4]^{2-}$ (d) R is $[Main\ Au(CN)_4]^-$

24. Extraction of copper from copper pyrite ($CuFeS_2$) involves **[Adv. 2016]**
(a) crushing followed by concentration of the ore by froth-flotation
(b) removal of iron as slag
(c) self-reduction step to produce 'blister copper' following evolution of SO_2
(d) refining of 'blister copper' by carbon reduction

25. Upon heating with Cu_2S, the reagent(s) that give copper metal is/are **[Adv. 2014]**
(a) $CuFeS_2$ (b) CuO (c) Cu_2O (d) $CuSO_4$

26. The carbon-based reduction method is **NOT** used for the extraction of **[Adv. 2013]**
(a) Tin from SnO_2
(b) Iron from Fe_2O_3
(c) Aluminium from Al_2O_3
(d) Magnesium from $MgCO_3.CaCO_3$

27. Extraction of metal from the ore **cassiterite** involves
(a) carbon reduction of an oxide ore **[2011]**
(b) self-reduction of a sulphide ore
(c) removal of copper impurity
(d) removal of iron impurity

28. The major role of fluorspar (CaF_2), which is added in small quantities in the electrolytic reduction of alumina dissolved in fused cryolite (Na_3AlF_6), is **[1993 - 1 Mark]**
(a) as a catalyst
(b) to make the fused mixture very conducting
(c) to lower the temperature of the melt
(d) to decrease the rate of oxidation of carbon at the anode.

29. Of the following, the metals that cannot be obtained by electrolysis of the aqueous solution of their salts are : **[1990 - 1 Mark]**
(a) Ag (b) Mg (c) Cu (d) Al
(e) Cr.

30. In the electrolysis of alumina, cryolite is added to : **[1986 - 1 Mark]**
(a) lower the melting point of alumina
(b) increase the electrical conductivity
(c) minimise the anode effect
(d) remove impurities from alumina

7 Match the Following

31. Match the anionic species given in **Column I** that are present in the ore(s) given in **Column II**. **[Adv. 2015]**

Column-I	Column-II
(A) Carbonate	(p) Siderite
(B) Sulphide	(q) Malachite
(C) Hydroxide	(r) Bauxite
(D) Oxide	(s) Calamine
	(t) Argentite

32. Match the conversions in **Column I** with the type(s) of reaction(s) given in **Column II**. **[2008 - 6M]**

Column I	Column II
(A) $PbS \rightarrow PbO$	(p) roasting
(B) $CaCO_3 \rightarrow CaO$	(q) calcination
(C) $ZnS \rightarrow Zn$	(r) carbon reduction
(D) $Cu_2S \rightarrow Cu$	(s) self reduction

33. Match the extraction processes listed in **Column I** with metals listed in **Column II** : **[2006 - 6M]**

Column I	Column II
(A) Self reduction	(p) Lead
(B) Carbon reduction	(q) Silver
(C) Complex formation and displacement by metal	(r) Copper
(D) Decomposition of iodide	(s) Boron

34. Match the following choosing one item from column **X** and the appropriate item from column **Y**:

[Multiple concept, 1986 - ½×8 = 4 Marks]

X	Y
(*i*) Lewis acid	(a) K electron capture
(*ii*) Philosopher's wool	(b) Zinc ore
(*iii*) Electrophile	(c) HCHO
(*iv*) Preservative	(d) NH_4^+
(*v*) Electron emission	(e) Small proton to neutron ratio
(*vi*) Bronsted acid	(f) SO_3
(*vii*) Black jack	(g) BF_3
(*viii*) X-ray emission	(h) ZnO

35. Match the following, choosing one item from column **X** and the appropriate item from column **Y**. **[1983 - 2 Marks]**

X	Y
(*i*) Al	(a) Calamine
(*ii*) Cu	(b) Cryolite
(*iii*) Mg	(c) Malachite
(*iv*) Zn	(d) Carnallite

8 Comprehension/Passage Based Questions

Copper is the most noble of the first row transition metals and occurs in small deposits in several countries. Ores of copper include chalcanthite ($CuSO_4.5H_2O$), atacamite ($Cu_2Cl(OH)_3$), cuprite (Cu_2O), copper glance (Cu_2S) and malachite ($Cu_2(OH)_2CO_3$). However, 80% of the world copper production comes from the ore chalcopyrite ($CuFeS_2$). The extraction of copper from chalcopyrite involves partial roasting, removal of iron and self-reduction. **[2010]**

36. Partial roasting of chalcopyrite produces

(a) Cu_2S and FeO (b) Cu_2O and FeO

(c) CuS and Fe_2O_3 (d) Cu_2O and Fe_2O_3

37. Iron is removed from chalcopyrite as

(a) FeO (b) FeS (c) Fe_2O_3 (d) $FeSiO_3$

38. In self-reduction, the reducing species is

(a) S (b) O^{2-} (c) S^{2-} (d) SO_2

10 Subjective Problems

39. Some reactions of two ores, A_1 and A_2 of the metal M are given below. **[2004 - 4 Marks]**

$$[A_1] \xrightarrow{\text{calcination}} \underset{\text{Black}}{[C]}\downarrow + CO_2 + H_2O$$

$$\xrightarrow{KI/HCl} [D]\downarrow + I_2$$

$$[A_2] \xrightarrow{\text{roasting}} [G]\uparrow + M;$$

$$[G] + K_2Cr_2O_7 \xrightarrow{H^+} \text{Green solution}$$

Identify A_1, A_2, M, C, D, and G, and explain using the required chemical reactions.

40. Write down reactions involved in the extraction of Pb. What is the oxidation number of lead in litharge? **[2003 - 2 Marks]**

41. When the ore haematite is burnt in air with coke around 2000°C along with lime, the process not only produces steel but also produces a silicate slag that is useful in making building materials such as cement. Discuss the same and show through balanced chemical equations. **[1998 - 4 Marks]**

42. State with balanced equations what happens when :

(*i*) Write balanced equations for the extraction of copper from copper pyrites by self-reduction. **[1990 - 2 Marks]**

(*ii*) Write balanced equations for the extraction of silver from silver glance by cyanide process. **[1988 - 1 Mark]**

43. Give the equations for the recovery of lead from Galena by air reduction. **[1987 - 1 Mark]**

44. What is the actual reducing agent of haematite in blast furnace? **[1987 - 1 Mark]**

45. Give reasons for the following :

(*i*) Why is chalcocite roasted and not calcinated during recovery of copper? **[1987 - 1 Mark]**

(*ii*) Metals can be recovered from their ores by chemical methods. **[1984 - 1 Mark]**

46. Give balanced equations for extraction of silver from its sulphide ore **[1982 - 2 Marks]**

47. Give balanced equations for the extraction of aluminium from bauxite by electrolysis. **[1982 - 2 Marks]**

48. Write the matching pairs: **[1980]**

Bleaching agent	Aluminium
Smelling salt	Carbon
Cryolite	Tin
Bell metal	Ammonium carbonate
Fluorspar	Ammonium phosphate
Fertilizer	Calcium
Anthracite	Chlorine

Examples :

Bleaching agent – Chlorine

Smelling salt – Ammonium carbonate

49. (a) Write the chemical equations involved in the extraction of lead from galena by self reduction process.

(b) Match the following extraction processes with the appropriate metals listed below :

(i) Silver	(A) Fused salt electrolysis
(ii) Calcium	(B) Carbon reduction
(iii) Zinc	(C) Carbon monoxide reduction
(iv) Iron	(D) Amalgamation
(v) Copper	(E) Selfreduction **[1979]**

Topic-2: Purification and Uses of Metals

6 MCQs with One or More than One Correct Answer

1. The correct statement(s) related to processes involved in the extraction of metals is(are) **[Adv. 2023]**

(a) Roasting of malachite produces cuprite.

(b) Calcination of calamine produces zincite.

(c) Copper pyrites is heated with silica in a reverberatory furnace to remove iron.

(d) Impure silver is treated with aqueous KCN in the presence of oxygen followed by reduction with zinc metal.

2. The electrochemical extraction of aluminum from bauxite ore involves **[Adv. 2022]**

(a) the reaction of Al_2O_3 with coke (C) at a temperature > 2500°C.

(b) the neutralization of aluminate solution by passing CO_2 gas to precipitate hydrated alumina ($Al_2O_3 \cdot 3H_2O$).

(c) the dissolution of Al_2O_3 in hot aqueous NaOH.

(d) the electrolysis of Al_2O_3 mixed with Na_3AlF_6 to give Al and CO_2.

3. Copper is purified by electrolytic refining of blister copper. The correct statement(s) about this process is(are) **[Adv. 2015]**

(a) Impure Cu strip is used as cathode

(b) Acidified aqueous $CuSO_4$ is used as electrolyte

(c) Pure Cu deposits at cathode

(d) Impurities settle as anode-mud

10 Subjective Problems

4. Magnesium oxide is used for the lining of steel making furnace. **[1987 - 1 Mark]**

5. High purity metals can be obtained by zone refining method. **[1984 - 1 Mark]**

Answer Key

Topic-1 : Occurrence of Metals and Metallurgical Processes

1. (a) **2.** (b) **3.** (d) **4.** (b) **5.** (c) **6.** (a) **7.** (a) **8.** (c) **9.** (c) **10.** (b)
11. (c) **12.** (c) **13.** (a) **14.** (c) **15.** (sintering, smelting) **16.** (Magnesia and lime; calcium silicate)
17. (Aluminium) **18.** (Tin) **19.** (a, d) **20.** (a, b, c) **21.** (a, c, d) **22.** (a, b, c, d) **23.** (a,b,c) **24.** (a,b,c)
25. (b, c, d) **26.** (c, d) **27.** (a,c,d) **28.** (b, c) **29.** (b, d) **30.** (a, b)
31. A-(p, q, s), B-(t), C-(q, r), D-(r) **32.** (A) - p; (B) - q; (C) - p, r; (D) - p, s **33.** (A)- p, r; (B) - p, r; (C) - q; (D) - s
35. (c) **36.** (b) **37.** (d) **38.** (c)

Topic-2 : Purification and Uses of Metals

1. (b,c,d) **2.** (b, c, d) **3.** (b, c, d)

Hints & Solutions

Topic-1: Occurrence of Metals and Metallurgical Processes

1. (a) Calamine $\rightarrow ZnCO_3$
Malachite $\rightarrow CuCO_3.Cu(OH)_2$
Magnetite $\rightarrow Fe_3O_4$
Cryolite $\rightarrow Na_3AlF_6$

2. (b) The reactions involved in cyanide extraction process are :

$$\underset{\text{(argentite)}}{Ag_2S} + 4NaCN \rightarrow 2Na[Ag(CN)_2] + Na_2S$$

$$4Na_2S + \underset{\text{Oxiding agent}}{5O_2} + 2H_2O \rightarrow 2Na_2SO_4 + 4NaOH + 2S$$

$$2Na[Ag(CN)_2] + \underset{\text{(reducing agent)}}{Zn} \rightarrow Na_2[Zn(CN)_4] + 2Ag\downarrow$$

3. (d) (i) Haematite is Fe_2O_3 in which Fe is present in III oxidation state.
(ii) Magnetite (Fe_3O_4) is an equimolar mixture of FeO and Fe_2O_3.
Oxidation state of Fe in FeO is II.
Oxidation state of Fe in Fe_2O_3 is III.

4. (b) Extraction of Zn from ZnS (Zinc blende) is achieved by roasting followed by reduction with carbon.

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$
$$ZnO + C \longrightarrow Zn + CO$$

5. (c) Cuprite : Cu_2O; Chalcocite : Cu_2S; Chalcopyrite : $CuFeS_2$; Malachite: $Cu(OH)_2.CuCO_3$. We see that $CuFeS_2$ contains both Cu and Fe.

6. (a) $2Au + 4CN^- + H_2O + \frac{1}{2}O_2 \longrightarrow \underset{'X'}{2[Au(CN)_2]^-} + 2OH^-$

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

7. (a) $\underset{\text{(fused anhydrous)}}{MgCl_2} \rightarrow Mg^{+2} + 2Cl^-$

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

At anode : $2Cl^- - 2e^- \rightarrow Cl_2\uparrow$

8. (c) Al_2O_3 is mixed with cryolite (NO_3AlF_6) which lowers the melting point of the mixture and brings conductivity.

9. (c) Haematite ore (Fe_2O_3) is first reduced to cast iron which is then oxidised for removing carbon (impurity) as CO_2.

10. (b) During the extraction of copper, iron is present in the ore as impurity (FeS).
The ore together with a little coke and silica is smelted; FeS present as impurity in the ore is oxidized to iron oxide, which then reacts with silica to form fusible ferrous silicate which is removed as slag.

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2\uparrow;$$
$$FeO + SiO_2 \longrightarrow \underset{\text{(Slag)}}{FeSiO_3}$$

11. (c) Al_2O_3 is electrolyte, while Na_3AlF_6 is used to decrease the melting point of Al_2O_3 and to increase the conductivity.

12. (c) Al reduces Fe_2O_3 or Cr_2O_3 to respective metals and acts as a reducing agent.

$$Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2F$$

13. (a) $CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2$;

$$\underset{\text{Flux}}{CaO} + \underset{\text{impurity}}{SiO_2} \longrightarrow CaSiO_3\ (\text{slag}).$$

14. (c) Malachite is $CuCO_3.Cu(OH)_2$ which is ore of copper.

15. sintering, smelting.

16. Magnesia and lime; calcium silicate
The lining of converter is made of magnesia & lime. Slag formed consists of $CaSiO_3$.

17. Aluminium

$$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe + \text{Heat}$$

[Thermite reaction]

18. Tin. It is SnO_2.

19. (a, d)
The treatment of galena with HNO3 produces nitric oxide gas which is paramagnetic.
$PbS + HNO_3 \longrightarrow Pb(NO_3)_2 + S\downarrow + NO\uparrow + 4H_2O$
NO is colourless, neutral, paramagnetic gas.
NO is of linear geometry : $:N = \ddot{O}: \longleftrightarrow :\dot{N} = \ddot{O}:$

20. (a, b, c)
Exhaust gases do not cantain NO_2.

21. (a, c, d)
(a) $PbS + 2PbO \rightarrow 3Pb + SO_2$ (self reduction)
(b) Silica is added to remove impurity of Fe in the form of slag $FeSiO_3$. Hence, this statement is wrong.
(c) Sulphide ore is partially oxidized first by roasting and then self reduction of Cu takes place to produce blister copper.

$$Cu_2S + \frac{3}{2}O_2 \rightarrow Cu_2O + SO_2\uparrow$$

$Cu_2S + 2Cu_2O \rightarrow 6Cu + SO_2\uparrow$ (self reduction)

The molten copper obtained is poured into large container and allowed to cool and during cooling the dissolved SO_2 comes up to the surface and forms blisters. It is known as blister copper.

(d) $2\overset{+1}{Na}[\overset{+1}{Au}(CN)_2] + \underset{\text{Reducing Agent}}{\overset{0}{Zn}} \rightarrow Na_2[\overset{+2}{Zn}(CN)_4] + 2\overset{0}{Au}$

22. (a, b, c, d)

(a) $2Na[Al(OH)_4] + CO_2 \longrightarrow NaCO_3 + H_2O + 2Al(OH)_3(\downarrow)$

or

$Al_2O_3.2H_2O$

(b) Function of Na_3AlF_6 is to lower the melting point of electrolyte.

(c) During electrolysis of Al_2O_3, the reactions at anode are:

$$2Al^{3+}(\ell) + 3O^{2-}(\ell) \xrightarrow{\text{Al anode}} O_2(g) + 2e^-$$

$$C(\text{graphite}) + O_2 \longrightarrow CO(g) + CO_2(g)$$

(d) The steel vessel with a lining of carbon acts as cathode.

23. (a, b, c)

Gold extraction:

$$4Au + 8NaCN + 2H_2O + \underset{(Q)}{O_2} \rightarrow 4Na\underset{(R)}{[Au(CN)_2]} + 4NaOH$$

$$4Na\underset{(R)}{[Au(CN)_2]} + 2Zn \rightarrow 2Na_2\underset{(Z)}{[Zn(CN)_4]} + 4Au$$

24. (a, b, c)

Copper pyrite [$CuFeS_2$]

↓ Crushing into fine powder

Concentrated by froth floatation process

↓

Roasting take place in reverberatory furnace

$$\begin{cases} 2CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + 2FeS + SO_2 \\ \quad\quad\quad (\text{air}) \\ FeS + O_2 \xrightarrow{\Delta} FeO + SO_2 \end{cases}$$

↓ Smelting [Iron is removed as slag of $FeSiO_3$; $FeO + SiO_2$ (flux) $\xrightarrow{\Delta} FeSiO_3$ (l)(slag)]

Copper matte ($Cu_2S + FeS$)

↓ Self reduction [Self reduction occurs in Bessemer converter; $2Cu_2S + 3O_2 \longrightarrow 2Cu_2S + 2SO_2(\uparrow)$; $Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2(\uparrow)$]

(Blister copper)

↓

Refining of blister copper is done by poling followed by electrorefining but not by carbon reduction method.

25. (b, c, d)

(a) $2CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + 2FeS + SO_2$

(b) $4CuO \xrightarrow{\Delta} 2Cu_2O_2 + O_2$

$2Cu_2O + Cu_2S \xrightarrow{\Delta} 6Cu + SO_2$

(c) From above, Cu_2O gives copper metal.

(d) $CuSO_4 \xrightarrow{\Delta} CuO + SO_2 + \frac{1}{2}O_2$

From above, CuO also gives copper metal.

26. (c, d) Al from Al_2O_3 and Mg from $MgCO_3.CaCO_3$ are separately extracted by electrolytic reduction.

27. (a, c, d) Cassiterite (SnO_2) contains impurity of S, As, Fe, Cu *etc.*

Roasting : Concentrated ore is heated in a current of air impurities of iron and copper changed to their oxides and sulphates. SnO_2 is treated with coke to reduce it to Sn.

$SnO_2 + 2C \longrightarrow Sn + 2CO$

28. (b, c) To make the fused mixture very conducting and to reduce the temperature of the melt.

29. (b, d) Both Mg and Al have their reduction potentials less than that of water [$E^\circ = -0.83$ V]. Hence, their ions in the aqueous solution can not be reduced. Instead water will be reduced : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

30. (a, b) Because of high melting point (2050°C), pure alumina cannot be electrolysed. Hence a mixture of alumina, cryolite (m.p. 1000°C) and calcium fluoride (to lower the temperature of the melt) is electrolysed at about 900°C. The function of cryolite is to increase the electrical conductivity of the electrolyte, and to lower the temperature of the melt.

31. A-(p, q, s), B-(t), C-(q, r), D-(r)

$$\begin{cases} \text{Siderite} \rightarrow FeCO_3 \\ \text{Malachite} \rightarrow CuCO_3 \cdot Cu(OH)_2 \\ \text{Bauxite} \rightarrow Al_2O_3.xH_2O \text{ or } AlO_x(OH)_{3-2x}\ 0 < x < 1 \\ \text{Calamine} \rightarrow ZnCO_3 \\ \text{Argentite} \rightarrow Ag_2S \end{cases}$$

32. (A) - p; (B) - q; (C) - p, r; (D) - p, s

33. (A)- p, r; (B) - p, r; (C) - q; (D) - s

The oxides and sulphides of less active metals like Hg, Cu & Pb are unstable to heat and hence no reducing agent is required. They undergo self reduction.

(A) $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$;

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

$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$;

$PbS + 2PbO \longrightarrow 3Pb + SO_2$

Hence, (A) → (p), (r)

The oxides of less electropositive metals like Pb, Zn, Fe, Sn, Cu, etc. are reduced by strongly heating them with coke or coal.

(B) $PbO + C \longrightarrow Pb + CO_2$;

$2Cu_2O + C \longrightarrow 4Cu + CO_2$

Hence, (B) → (p), (r)

(C) Extraction from argentite (Ag_2S)

$Ag_2S + 2NaCN \rightleftharpoons Na_2S + 2AgCN$;

$AgCN + NaCN \longrightarrow \underset{\text{Sod. argentocyanide (soluble)}}{Na[Ag(CN)_2]}$

Zn, being more electropositive than Ag, displaces Ag from the complex.

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

Hence, (C) → (q)

(D) Among the halides of boron, BI_3 is unstable because of the large size of Iodine and small size of boron atom. Hence, it decomposes to give boron. Thus, (D) → (s).

34. (*i*) (g) (*ii*) (h) (*iii*) (f) (*iv*) (c) (*v*) (e) (*vi*) (d) (*vii*) (b) (*viii*) (a)

35. **(c)** (*i*) (b) (*ii*) (c) (*iii*) (d) (*iv*) (a)

36. **(b)** $2CuFeS_2 + O_2 \longrightarrow Cu_2S + SO_2 \uparrow + 2FeS$

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

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

37. **(d)** $FeO + SiO_2 \longrightarrow FeSiO_3$

38. **(c)** $Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

The reducing species is the one which gets oxidised. So, it is S^{2-} ion getting oxidised to S^{4+}.

39. Calcination of the ore A_1 to form CO_2 indicates that A_1 should be a carbonate. Further, reaction of A_1 with HCl and KI to evolve I_2 indicates that A_1 would also be hydroxide. So the possible formula for the ore, should be $CuCO_3.Cu(OH)_2$ which explains all the given reactions

$\underset{(A_1)}{CuCO_3.Cu(OH)_2} \xrightarrow{\text{calcination}} \underset{(C)\text{ black}}{2CuO} \downarrow + CO_2 + H_2O$

$\underset{(A_1)}{CuCO_3.Cu(OH)_2} + 4HCl \longrightarrow 2CuCl_2 + CO_2 + 3H_2O$

$2CuCl_2 + 4KI \longrightarrow \underset{(D)}{Cu_2I_2} \downarrow + 4KCl + I_2$

Roasting of A_2 gives gas G whose nature is identified as SO_2 as it gives green colour with acidified $K_2Cr_2O_7$. So A_2 should be sulphide of copper.

$\underset{(A_2)}{2Cu_2S} + 3O_2 \xrightarrow{\text{roasting}} 2Cu_2O + \underset{(G)}{2SO_2}$

$Cu_2S + 2Cu_2O \xrightarrow{\text{self reduction}} \underset{(M)}{6Cu} + SO_2$

$\underset{(G)}{3SO_2} + K_2Cr_2O_7 + H_2SO_4 \longrightarrow$

$K_2SO_4 + \underset{\text{(Green colour)}}{Cr_2(SO_4)_3} + 4H_2O$

40. $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$

$PbS + 2O_2 \longrightarrow PbSO_4$

$PbS + 2PbO \longrightarrow 3Pb + SO_2$

$PbS + PbSO_4 \longrightarrow 2Pb + 2SO_2$

Oxidation number of Pb in litharge (PbO) is +2

41. Haematite (Fe_2O_3) on burning with coke and lime at 2000 °C results in the following reactions.

$C + O_2 \rightarrow CO_2$

$CO_2 + O \rightarrow 2CO$

$3CO + Fe_2O_3 \rightarrow \underset{\text{(Steel)}}{2Fe} + 3CO_2$ (Reduction of Fe_2O_3 to form steel)

$\underset{\text{(Lime)}}{SiO_2} + \underset{\text{(Slag)}}{CaO} \rightarrow CaSiO_3$ (Slag, $CaSiO_3$ is used as building material)

42. (*i*)

$\underset{\text{(copper pyrites)}}{2CuFeS_2} + O_2 \xrightarrow{\Delta} Cu_2S + 2FeS + SO_2$

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

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

} Roasting

$Cu_2O + FeS \longrightarrow Cu_2S + FeO$

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

} Smelting with coke and sand

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

$Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2 \uparrow$

} Bessemerization

(*ii*) $\underset{\text{(silver glance)}}{Ag_2S} + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S$

$4Na_2S + SO_2 + 2H_2O \rightarrow 2Na_2SO_4 + 4NaOH + 2S$

[Na_2S is converted into Na_2SO_4 to avoid reversibility of first reaction]

$2NaAg(CN)_2 + Zn \rightarrow \underset{\text{Sod. Zincocyanide}}{Na_2[Zn(CN)_4]} + 2Ag$

43. **Recovery of Pb from galena :**

$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2 \uparrow$

$PbS + 2PbO \rightarrow 3Pb + SO_2$

44. Carbon monoxide is the actual reducing agent of haematite in blast furnace.

$3Fe_3O_4 + CO \longrightarrow 2Fe_3O_4 + CO_2$

$Fe_3O_4 + CO \longrightarrow 3FeO + CO_2$

45. (*i*) Excess of Air (used during roasting) is necessary for converting chalcocite (a sulphide ore) to oxide. Calcination does not convert it to oxide.

(*ii*) Metals can be recovered by chemical methods because they occur as oxides, carbonates, sulphides which have to be calcined or roasted.

46. Equations for extraction of silver from its sulphide ore.

Cyanide Process :

$\underset{\text{(sulphide ore)}}{Ag_2S} + 2NaCN \rightarrow Na_2S + 2AgCN$

$AgCN + NaCN \rightarrow \underset{\text{Sod. argentocyanide (soluble)}}{Na[Ag(CN)_2]}$

$2Na[Ag(CN)_2] + Zn \rightarrow Na_2[Zn(CN)_4] + 2Ag \downarrow$

[Zn is more electropositive than Ag.]

47. Extraction of aluminium from bauxite :

At cathode :

$$[Al^{3+}(melt) + 3e^- \longrightarrow Al(l)] \times 2$$

At anode :

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

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

Net reaction :

$$2Al^{3+} + 2C + 3O^{2-} \longrightarrow 2Al + CO + CO_2$$

$$Al_2O_3 + 2C \longrightarrow Al + CO + CO_2$$

48.

Bleaching agent	⟶	Chlorine
Smelling salt	⟶	Ammonium carbonate
Cryolite	⟶	Aluminium
Bell metal	⟶	Tin
Fluorspar	⟶	Calcium
Fertilizer	⟶	Ammonium phosphate
Anthracite	⟶	Carbon

49. (a) Galena is roasted in excess of air in a reverberatory furnace

$$2PbS + 3O_2 \xrightarrow[(air)]{} 2PbO + 2SO_2$$

$$PbS + 2O_2 \longrightarrow PbSO_4$$

(b) It is followed by self reduction

$$PbS + PbSO_4 \longrightarrow 2Pb + 2SO_2$$

$$PbS + 2PbO \longrightarrow 3Pb + SO_2$$

(i) Silver	⟶	(D) Amalgamation
(ii) Calcium	⟶	(A) Fused salt electrolysis
(iii) Zinc	⟶	(B) Carbon reduction
(iv) Iron	⟶	(C) Carbon monoxide reduction
(v) Copper	⟶	(E) Self reduction

Topic-2: Purification and Uses of Metals

1. **(b, c, d)**

(a) Under roasting condition,

$$\underset{\text{malachite}}{CuCO_3 \cdot Cu(OH)_2} \rightarrow 2CuO + CO_2 + H_2O$$

(b) $\underset{\text{(Calamine)}}{ZnCO_3} \rightarrow \underset{\text{(Zincite)}}{ZnO} + CO_2 \uparrow$

(c) Copper pyrites is heated in a reverberatory furnace after mixing with silica. Which results into iron silicate as slag from iron oxide and copper is produced in the form of copper matte.

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

(d) $Ag + KCN + O_2 + H_2O \rightarrow \left[Ag(CN)_2\right]^- + KOH$

$$\downarrow Zn$$

$$Ag \downarrow + \left[Zn(CN)_4\right]^{2-}$$

2. **(b, c, d)**

(a) In electrochemical extraction of aluminium from bauxite ore does not involve the reduction of Al_2O_3 with (C)

(b) The neutralization of aluminate $[Al(OH)_4]^-$ solution is performed by passing CO_2 gas –

$$[Al(OH)_4]^- \xrightarrow{CO_2} \underset{\text{ppt.}[Al_2O_3 \cdot 3H_2O]}{Al(OH)_3 \downarrow} + OH^-$$

$$CO_2 + OH^- \longrightarrow CO_3^{2-} + H_2O$$

(c) Concentrated bauxite is carried out by heating the powdered Al_2O_3 in concentrated NaOH solution at 473 K – 523 K and 35 – 36 bar pressure.

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

(d) In electrolysis method Al_2O_3 is mixed with Na_3AlF_6 or CaF_2 to reduce the melting temperature of the mixture from 2050 °C to 900 °C.

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

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

3. **(b, c, d)** In electrolytic refining of blister Cu, acidified $CuSO_4$ is used as electrolyte, pure Cu deposits at cathode and impurities settle as anode mud. Impure metal act as an anode.

4. MgO is used for the lining of steel making furnace because it acts as basic flux and facilitates the removal of acidic impurities of Si, P and S from steel through slag formation.

5. *Zone refining* is based on the difference in solubility of impurities in molten and solid state of the metal. This method is used for obtaining metals of very high purity.

Ge, Si and Ga used as semi-conductors are refined in this manner. These metals can be easily melted and can easily crystallise out from the melt form.