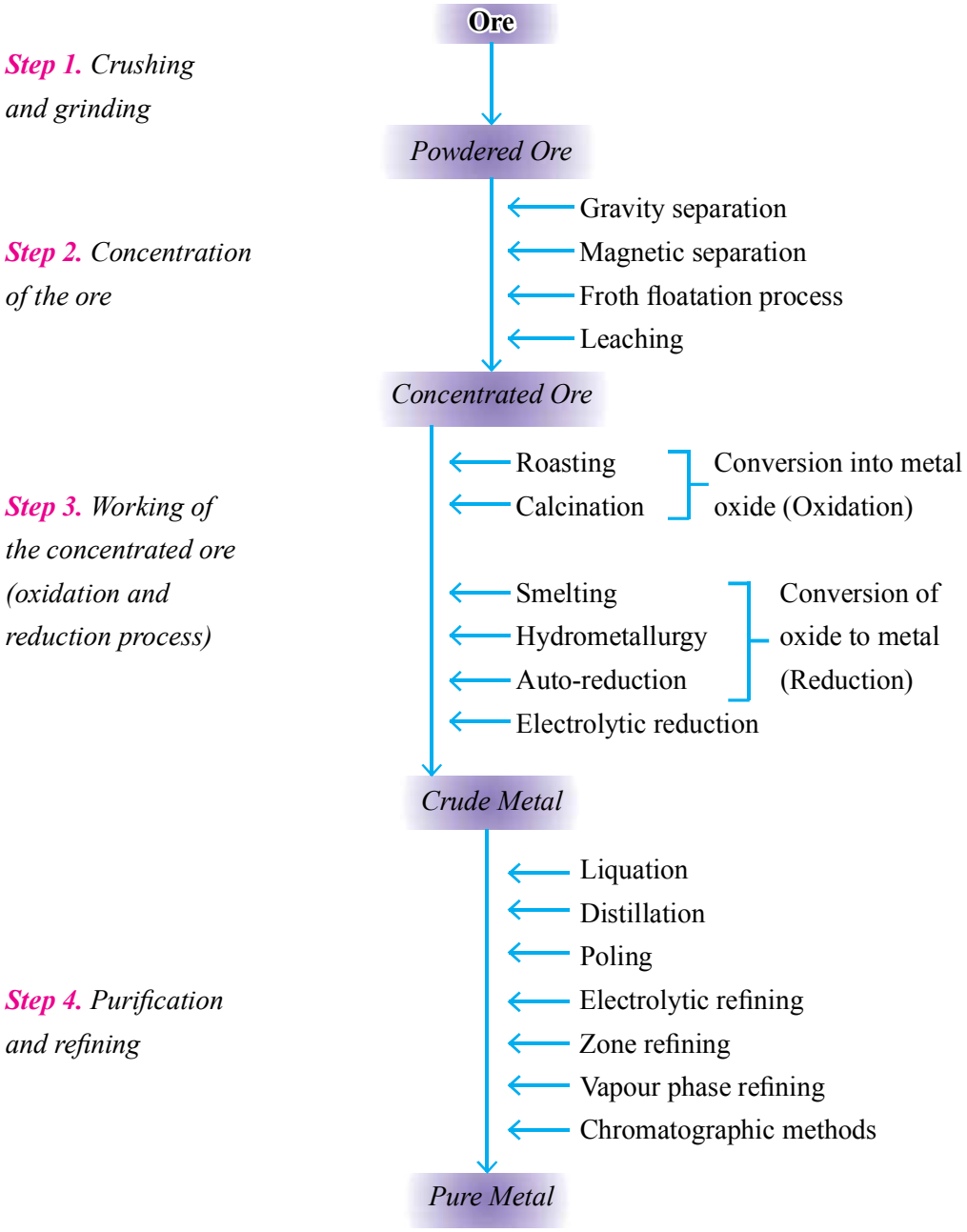
UNIT-6

GENERAL PRINCIPLES AND PROCESSES OF ISOLATION OF ELEMENTS

Flow-sheet diagram of metallurgical process is given below :



General Types of Ores of Metals

Type of Ore	Metal	Name of ore
1. Oxides	Iron	Haematite, Fe_2O_3
	Aluminium	Bauxite, $Al_2O_3.2H_2O$
	Copper	Cuprite, Cu_2O
	Zinc	Zincite, ZnO
	Manganese	Pyrolusite, MnO_2
2. Sulphides	Copper	Copper pyrites, $CuFeS_2$
	Lead	Galena, PbS
	Zinc	Zinc blende, ZnS
	Mercury	Cinnabar, HgS
3. Carbonates	Iron	Siderite, $FeCO_3$
	Copper	Malachite, $CuCO_3.Cu(OH)_2$
	Calcium	Limestone, $CaCO_3$
	Magnesium	Dolomite, $MgCO_3.CaCO_3$
4. Chloride	Sodium	Rock salt, NaCl
	Magnesium	Carnallite, KCl, $MgCl_2.6H_2O$
	Silver	Horn silver, AgCl
5. Sulphates	Calcium	Gypsum, $CaSO_4.2H_2O$
	Lead	Anglesite, $PbSO_4$
6. Silicates	Magnesium	Calcium magnesium silicate, $CaSiO_2.3MgSiO_2$ (Asbestos)

Various Types of Steel

Type of Steel	Carbon content	Properties	Uses
Mild Steel (Medium carbon steel)	0.2-0.5%	(i) It can be hardened by heat treatment. (ii) It has a good machining property. (iii) It is very good for welding.	(i) Lightly stressed machine fittings, turbine, motors, railway axels, crank shafts, fish plates, cross heads, etc.
Hard Steel	0.5-0.7%	(i) It can be imparted desired hardness by heat treatment. (ii) It can be welded with a great care.	Wheels for railways service, cushion springs, clutch springs, dies, set screws, etc.
Chrome Steel	1.5-2% Cr	Extremely hard	For making armour – piercing projectiles, crushing machinery and cutlery.
Stainless Steel	11.5% Cr 2% Ni	Resists corrosion	For making cutlery, utensils, surgical instruments, auto-mobile parts and cycle parts.

Note : NaCN is used as depressant when an ore contains both ZnS and PbS. It selectively prevents ZnS from coming to the froth but allows PbS to come with the froth in froth floatation process.

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark)

Q. 1. Name three metals which occur in native state in nature.

Ans. Au, Ag and Pt.

Q. 2. What are collectors in froth floatation process ? Give one example.

Ans. Pine oil.

Q. 3. Give the names and formulae of three ores which are concentrated by froth floatation process.

Ans. Galena (PbS), Zinc blende (ZnS), Cinnabar (HgS).

Q. 4. Among Fe, Cu, Al and Pb, which metal(s) cannot be obtained by smelting ?

Ans. Al.

Q. 5. What is the thermodynamic criteria for the feasibility of a reaction ?

Ans. ΔG should be –ve or log K = + ve.

Q. 6. Why can't aluminium be reduced by carbon ?

[*Hint :* Al is stronger reducing agent than carbon.]

Q. 7. Name the most important form of iron. Mention its one use.

Ans. Cast iron is used for making gutter pipes, castings, railway sleepers, toys etc.

Q. 8. Name the impurities present in bauxite ore.

Ans. SiO_2, Fe_2O_3 and TiO_2.

Q. 9. What is the composition of copper matte ?

[*Hint :* Cu_2S and FeS]

Q. 10. Which form of copper is called blister copper ?

[*Hint :* The solidified copper obtained has blistered appearance due to the evolution of SO_2, so it is called blistered copper.]

Q. 11. What are froth stabilizers ? Give two examples.

[*Hint :* Examples are cresol and aniline.]

Q. 12. A sample of galena is contaminated with zinc blende. Name one chemical which can be used to concentrate galena selectively by froth floatation method.

Ans. NaCN

Q. 13. What are the constituents of German silver ?

Ans. Cu = 25-30%, Zn = 25-30%, Ni = 40-50%]

Q. 14. Why is froth floatation process selected for concentration of the sulphide ore ?

Ans. Sulphide ore particles are wetted by oil (Pine oil) and gangue particles by water.

Q. 15. Write the reaction involved in the extraction of copper from low grade ores.

Ans. First step is leaching of ore with acid or bacteria then,

$Cu^{2+}(aq) + H_2(g) \rightarrow Cu(s) + 2H^+(g)$

Q. 16. Although aluminium is above hydrogen in the electrochemical series, it is stable in air and water. Why ?

[*Hint :* Due to formation of inert oxide Al_2O_3.]

Q. 17. Which method of purification is represented by the following reaction :

$$\underset{\text{impure}}{Ti_{(s)} + 2I_{2(g)}} \rightarrow TiI_{4(g)} \xrightarrow{\Delta} \underset{\text{pure}}{Ti_{(s)}} + 2I_{2(g)}$$

[*Hint :* Van Arkel method]

Q. 18. Zinc is used but not copper for the recovery for metallic silver from the complex $[Ag(CN)_2]^-$, although electrode potentials of both zinc and copper are less than that of Ag. Explain why ?

[*Hint :* Zinc reacts at faster rate as compared with copper, further zinc is cheaper than copper.]

Q. 19. Write the composition of moleten mixture which is electrolysed to extract aluminium.

[*Hint :* Molten $Al_2O_3 + Na_3AlF_6$ or CaF_2]

SHORT ANSWER-I TYPE QUESTIONS (2 Marks)

Q. 1. What is hydrometallurgy ? Give one example where it is used for metal extraction.

Ans. Leaching followed by reduction is called hydrometallurgy. It is used in extraction of copper.

Q. 2. Name the process for the benefaction/concentration of (i) an ore having lighter impurities, (ii) sulphide ore.

[*Hint :* (i) Gravity separation

(ii) Froth floatation]

Q. 3. Mention the role of cryolite in the extraction of aluminium.

[*Hint :* It lowers the melting point of the mixture and brings conductivity.]

Q. 4. Mention the role of following :

(a) SiO_2 in the metallurgy of Cu.

(b) $CaCO_3$ in the metallurgy of Fe.

(c) CO in the metallurgy of iron.

(d) I_2 in the purification of zirconium.

[*Hint :* (a) Flux

(b) $CaCO_3$ decomposed to CaO, which acts as flux.

(c) Reducing agent

(d) To form a volatile complex with Zr.]

Q. 5. Extraction of copper directly from sulphide ore is less favourable than from its oxide through reduction. Explain.

Ans. $2CuS\ (s) + C\ (s) \rightarrow CS_2\ (l) + 2Cu\ (s)$

$CuO\ (s) + C\ (s) \rightarrow CO\ (g) + Cu\ (s)$

G value is more –ve in second case as compared with first case.

Q. 6. The graphite electrodes in the extraction of 'aluminium' by Hall-Heroult process need to be changed frequently. Why ?

Q. 7. Write the chemical formulae of the following ores :

(a) Haematite **(b) Magnetite**

(c) Limonite **(d) Siderite**

Ans. (a) Fe_2O_3 (b) Fe_3O_4

(c) $Fe_2O_3.2H_2O$ (d) $FeCO_3$

Q. 8. Give equations for the industrial extraction of zinc from calamine.

Ans. $ZnCO_3 \rightarrow ZnO + CO_2$ (Calcination)

$ZnO + C \rightarrow Zn + CO$ (Reduction)

Q. 9. Name the elements present in anode mud during refining of copper. Why does it contain such elements ?

Ans. Au and Ag. They are not oxidized at anode. They are less electropositive than copper.

Q. 10. Write the chemical reactions taking place in different zones in the blast furnace for the extraction of iron from its ore.

[*Hint :* (i) $C + CO_2 \rightarrow 2CO$

(ii) $3Fe_2O_3 + CO \rightarrow 2Fe_2O_4 + CO_2$

(iii) $Fe_3O_4 + CO \rightarrow 2FeO + CO_2$

(iv) $FeO + CO \rightarrow Fe + CO_2$

(v) $CaCO_3 \rightarrow CaO + CO_2$

(vi) $CaO + SiO_2 \rightarrow CaSiO_3$

Q. 11. How are impurities separated from bauxite ore to get pure alumina ?

[*Hint :* By leaching.

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

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

(iii) $Al_2O_3.xH_2O \rightarrow \underset{\text{(alumina)}}{Al_2O_3\ (s)} + xH_2O\ (g)$

Q. 12. Why is the reduction of a metal oxide easier if metal formed is in liquid state at the temperature of reduction ?

[*Hint :* Entropy is more positive when the metal is in liquid state as compared with solid state, so ΔG becomes more –ve.]

Q. 13. What is pyrometallurgy ? Explain with one example.

Ans. A process of reducing a metal oxide by heating with either coke or some other reducing agent. *E.g.,* Al, Mg etc.

$$ZnO + C \xrightarrow{975k} Zn + CO$$

Q. 14. Write the method to produce copper matte from copper pyrites.

[*Hint :* Froth floatation.]

Q. 15. Copper can be extracted by hydrometallurgy but not zinc. Explain why ?

[*Hint :* $E^{o}_{2n^{2+}} / 2n$ = – ve, $E^{o}_{cu^{+2}}$ /cu = + ve

Q. 16. Gibbs energy of formation ΔG_f^G of MgO (s) and CO (g) at 1273 K and 2273 K are given below :

ΔG_f [MgO (s)] = – 941 kJ mol^{-1} at 1273 K

ΔG_f [CO (g)] = – 439 kJ mol^{-1} at 1273 K

ΔG_f [MgO (s)] = – 314 kJ mol^{-1} at 2273 K

ΔG_f [CO (g)] = – 628 kJ mol^{-1} at 2273 K

On the basis of above data, predict the temperature at which carbon can be used as a reducing agent for MgO (s).

Ans. For the reaction, MgO (s) + C (s) → Mg (s) + CO (g)

At 1273 K, $\Delta G_r = \Delta G_f$[CO (g)] – ΔG_f[MgO (s)] = – 439 – (– 941) kJ mol^{-1} = 502 kJ mol^{-1}

At 2273 K, ΔG_r = – 628 – (– 314) kJ mol^{-1} = – 314 kJ mol^{-1}

The temperature is 2273 K.

SHORT ANSWER-II TYPE QUESTIONS (3 Marks)

Q. 1. State the principle of refining of metal by the following methods :

(a) Zone refining

(b) Electrolytic refining

(c) Vapour phase refining

[*Hint :*(a) The impurities are more soluble in the melt than in the solid state of the metal.

(b) Impure metal is made to act as anode, while the strip of same metal in pure form as cathode.]

Q. 2. How is pure copper obtained from its principle ore ? Write the chemical reactions occurring during the extraction.

[*Hint :* (i) $2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + O_2$

(ii) $Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

(iii) $Cu_2O + C \rightarrow 2Cu + CO$

(iv) $2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$]

Q. 3. Name the method of refining of the following metals :

(a) Hg (b) Sn (c) Cu (d) Ge (e) Ni (f) Zr

Ans. (a) Distillation, (b) Liquation, (c) Electrolytic refining, (d) Zone refining, (e) Mond process, (f) Van Arkel process]

Q. 4. The native silver forms a water soluble compound (B) with dilute aqueous solution of NaCN in the presence of a gas (A). The silver metal is obtained by the addition of a metal (C) to (B) and complex (D) is formed as a byproduct. Write the structures of (C) and (D) and identify (A) and (B) in the following sequence :

$Ag + NaCN + [A] + H_2O\ [B] + OH^- + Na^+\ [C] + [B][D] + Ag$

Ans. [A] = O_2

[B] = $Na[Ag(CN)_2]$

[C] = Zn

[D] = $Na_2[Zn(CN)_4]$

Q. 5. In the cynamide extraction process of silver pon argentite ore, name the oxidizing and reducing agents. Write the chemical equations of the reactions involved.

[*Hint :* $4Ag + 8NaCN + 2H_2O + O_2 \rightarrow 4Na[Ag(CN)_2] + 4NaOH$

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

MATCHING TYPE QUESTIONS

Match the items given in Column I and Column II in the following questions.

Q. 1. Match the items of Column I with items of Column II and assign the correct code :

Column I		Column II	
(A)	Pendulum	(1)	Chrome steel
(B)	Malachite	(2)	Nickel steel
(C)	Calamine	(3)	Na_3AlF_6
(D)	Cryolite	(4)	$CuCO_3.Cu(OH)_2$
		(5)	$ZnCO_3$

Q. 2. Match the items of Column I with items of Column II and assign the correct code :

Column I		Column II	
(A)	Coloured bands	(1)	Zone refining
(B)	Impure metal to volatile complex	(2)	Fractional distillation
(C)	Purification of Ge and Si	(3)	Mond process
(D)	Purification of mercury	(4)	Chromatography
		(5)	Liquation

Q. 3. Match the items of Column I with items of Column II and assign the correct code :

Column I		Column II	
(A)	Cyanide process	(1)	Ultrapure Ge
(B)	Froth floatation process	(2)	Dressing of ZnS
(C)	Electrolytic reduction	(3)	Extraction of Al
(D)	Zone refining	(4)	Extraction of Au
		(5)	Purification of Ni

Q. 4. Match the items of Column I with items of Column II and assign the correct code :

Column I		Column II	
(A)	Sapphire	(1)	Al_2O_3
(B)	Sphalerite	(2)	NaCN
(C)	Depressant	(3)	Co
(D)	Corundum	(4)	ZnS
		(5)	Fe_2O_3

Q. 5. Match the items of Column I with items of Column II and assign the correct code :

Column I		Column II	
(A)	Blistered Cu	(1)	Aluminium
(B)	Blast furnace	(2)	$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$
(C)	Reverberatory furnace	(3)	Iron
(D)	Hall-Heroult process	(4)	$FeO + SiO_2 \rightarrow FeSiO_3$
		(5)	$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$

Answers

1.	(A) – (2)	(B) – (4)	(C) – (5)	(D) – (3)
2.	(A) – (4)	(B) – (3)	(C) – (1)	(D) – (2)
3.	(A) – (4)	(B) – (2)	(C) – (3)	(D) – (1)
4.	(A) – (3)	(B) – (4)	(C) – (2)	(D) – (1)
5.	(A) – (2)	(B) – (3)	(C) – (4)	(D) – (1)

VALUE BASED QUESTIONS (4 Marks)

Q. 1. Ram and Shyam were extracting aluminium from purified Al_2O_3. Ram used electrolytic cell for the reduction of Al_2O_3 but Shyam added cryolite in Al_2O_3 in the electrolytic cell to obtain aluminium.

(a) Who will obtain aluminium easily ?

(b) Mention two functions of cryolite in this reduction process.

(c) What is the role of graphite anode in the metallurgy of Al ?

(d) What values are learnt by the use of cryolite (Na_3AlF_6) in the extraction of aluminium ?

Q. 2. Steel finds different uses and alloy steel is obtained when other metal like Cr, Ni are added to form nickel steel, chrome steel and stainless steel.

(a) What is alloy steel ?

(b) Why do transition metals form alloys ?

(c) A person wants to manufacture cycles and motor cycles in his factory. Name the alloy steel he should use for manufacturing the same.

(d) Name the value learnt by the selection of a proper type of steel.

Q. 3. A person met to a housewife and motivated her for cleansing of gold ornaments at very low cost. Housewife gave gold ornaments to him. He placed them into a solution containing 1 part conc. HNO_3 and 3 parts conc. HCl. After sometime he showed the shiny gold ornaments to her. In the mean time, housewife's daughter

Pinki, a student of chemistry of Class XII, returns from school. She took the cleansing solution in her custody and the cleaner ran away. She explained all the chemistry behind the incident to her mother.

(a) Name the solution used by cleaner for cleansing of gold ornaments.

(b) How can we recover the gold from the solution used for cleansing purpose ?

(c) Write the reaction that takes place between the solution and gold ornaments.

(d) What values are learnt from the incident ?