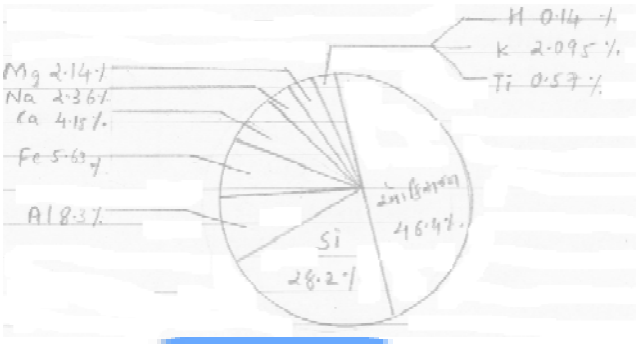
UNIT : 12 GENERAL PRINCIPLES AND PROCESSES OF ISOLATION OF METALS

Important Points

Occurrence of elements: Highly electropositive metals of S-block occur in nature in combined state with several anions. The lesser electropositive metal like chloride, silicate, carbonate (p & s block) occur as sulphides; while noble metals like Au, Pt, Ag are dative that is free state.

Abundance:



Ten abundant elements in Earth's crust:

Mineral: The chemical compounds or metal compounds which occur naturally in earth's crust are known as minerals.

Ores: The minerals from which metal can be extracted economically are known as ores.

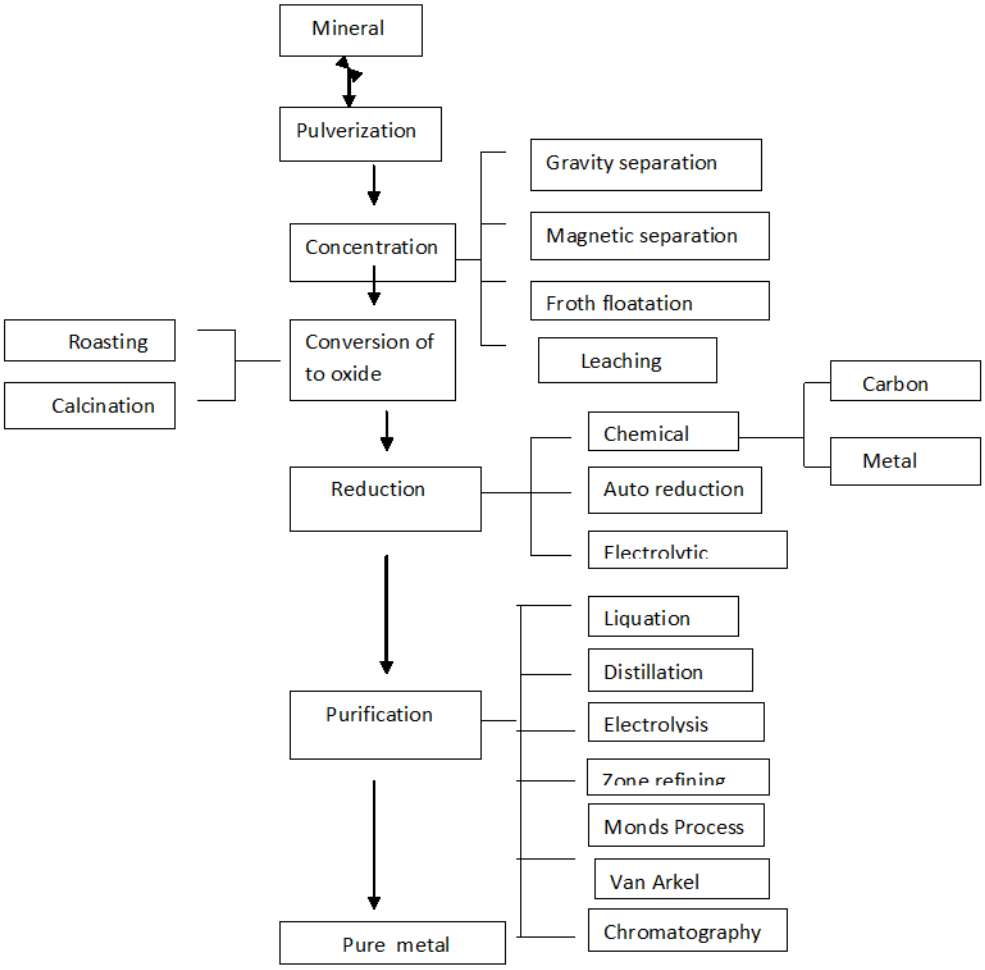
It can be concluded that "all minerals are not ores but all ores are minerals".

Principal Ores of some metals:

Metal	Ore	Composition
Al	Bauxite	$Al_2O_3.2H_2O$
	Corundum	Al_2O_3
	Diaspora	$Al_2O_3.H_2O$
	Cryolite	$Na3AlF_6$
	China Clay	$Al_2O_3.2SiO_2.2H_2O$
	Mica	$K_2O.3Al_2O_3.6SiO_2$
	Feldspar	$KAlSi_3O_8$
Cu	Malachite	$CuCO_3.Cu(OH)_2$
	Azurite	$2CuCO_3.Cu(OH)_2$
	Copper pyrites	$CuFeS_2$
	Copper Glance	Cu_2S
Fe	Iron Pyrites	FeS_2
	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
	Limonite	$Fe_2O_3.3H_2O$
	Siderite	$FeCO_3$
Zn	Zinc Blend /Sphalerite	ZnS
	Calamine	$ZnCO_3$
	Zincite	ZnO

Definitions for Metallurgical terms:

1) Gangue: The impurities present in ores are called gangue.
2) Crushing: Process of breaking of lumps of ore into small pieces is called crushing.
3) Pulverization: It is a process of conversion of smaller pieces of ore into fine powder is known as pulverization.
4) Concentration, Benefaction or Dressing: The removal of impurities from ores is known as concentration, benefaction or dressing.
5) Leaching: The treatment of ore with a suitable reagent so as to make it soluble while the impurities remain insoluble.
6) Calcination: Heating of the ore below its fusion temperature in absence of air is known calcinations. Commonly used to convert hydrated oxides, hydroxides, carbonates to oxide. It is carried out normally in a reverberatory furnace.
7) Roasting: The process of heating ore in presence of air below its melting point. It is used for sulphide ores and is carried out in reverberatory or blast furnace.
8) Smelting: It involves reduction of ore to the molten metal at high temperature.
9) Pyrometallurgy: The process of extracting the metal by heating the metal oxide with a suitable reducing agent.
10) Hydrometallurgy: It is the process of extraction of metal from aqueous solution.



Different methods of concentration of ores:

1) Gravity separation: Principle used: difference in specific gravity.
2) Magnetic separation: Principle used: difference in magnetic properties.
3) Froth Flotation: Principle used: differential wetting properties.
   I. Substances used: Frothing agent & collecting agent like pine oil and Sodium Ethyl Xanthate respectively.
   II. Froth Stabilizers: Cresols and Aniline.
   III. Depressant: Used to prevent certain type of particles from forming the froth.
4) Leaching: The ore is treated with chemical to make it soluble. It is also used in concentration of noble metals like Gold, Silver, which occur in Free State.

Different methods of reduction

Chemical reduction:

Using Carbon: Carbon is useful as a reducing agent because it is very cheap and can be used for reduction of several metal oxides. The ore is mixed with coke with flux and heated to high temperature. This is called smelting or pyrometallurgy.

Using more reactive metals: For extraction of lesser electropositive metal, Al powder can be used. The process is known Aluminothermite or Thermite.

Oxides of Cr, Mn are reduced by Aluminum.

Auto reduction: Reducing agent is not required. $Cu_2S + Cu_2O \rightarrow 4Cu + SO_2$

Electrolytic reduction: Highly electropositive metals like Na, Mg, Ca etc cannot be reduced using carbon, carbon monoxide or metal. Therefore these elements are extracted electrolyitcally using fused salts of the metal. It is mainly used for S-block elements and Al.

Different methods used in refining

The removal of impurities from metals after extraction is known as refining. The refining technique depends upon the nature of impurity and metal and the use to which the metal is put.

Refining techniques can be classified into 2 types:

(1) Physical (2) Chemical.

Physical:

Method	Principle or property	Process	Metals purified
Liquation	Difference in fusibility of metal impurities.	Heated on a sloping hearth. Impurities remain behind and metal flows down.	Bi, Sn, Pb, Hg.
Distillation	Used for volatile metal. Difference in volatile character.	Metal is heated and vapor of pure metal are condensed in a receiver.	Zn, Cd,Hg
Zone refining	Difference in solubility of impurity in molten and solid state.	The circular heater is fitted round a rod of impure metal and is slowly moved down the rod.	Very high purity viz Ge, Ga

Chemical:

Method	Principle or property	Process	Metals purified
Poling	Oxidation or Reduction	Molten metal is stirred with green log of wood. The impurities like carbon are oxidized to CO_2. Oxide of metal is reduced by the hydrocarbon.	Cu, Sn metals containing their own oxides as impurity.
Vapour phase refining (a) Mond's process (b) Van Arkel	Conversion of volatile compound and then decomposition	Impure + I_2 -$\xrightarrow{\Delta}$ metal Metal oxide-$\xrightarrow{\Delta}$ vapors Metal(pure) + I_2 $Ni + CO + \rightarrow Ni(CO)_4$ T=330-350K $Ni(CO)_4 \rightarrow Ni + 4CO$ T=450-470K $Zr_{(S)} + I_{2(g)} \rightarrow ZrI_{4(g)} \rightarrow Zr_{(g)} + 2I_{2(g)}$ Heat is required.	Ultra pure metals Ni, Zr Ni Zr
Chromatography	Differential adsorption of various compounds of the absorbent		
Electrolysis	Oxidation-reduction	Electrolyte -Soluble salt of the metal to be purified Anode :Impure metal Cathode:Pure metal	Cu, Ag

Thermodynamic principles of metallurgy:

The basic concepts of thermodynamics are useful in selection of reducing agent for a particular oxide.

Free energy of changes during reduction process are important. For a reaction to be spontaneous free energy changes must be negative. Any compound with lower value of standard free energy of formation is more stable. They are converted to oxide prior to reduction.

$\Delta G = \Delta H - T\Delta S$ ΔG= Change in free energy

T= Temperature in Kalvin

ΔS= Enthalpy change

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

$= -2.303\ RT \log_{10} K$ K= equation constant

R= Universal gas constant

If K value is high, it indicted [P] >> [R] & ΔG^0 becomes more negative

Eg. $2Mg_{(s)} + O_{2(g)} \quad 2MgO_{(s)-}$ $\Delta G_{1000'c}$= -941KJ/mole

$2C_{(s)} + 2CO_{(g)}$ $\Delta G_{1000'c}$= -439 KJ/mole

$MgO + C \rightarrow Mg + CO$

$\Delta G = \Sigma G_p - \Sigma G_r$

$= -439 + 941$

$= +502$

Since ΔG is +ve carbon cannot be used as reducing agent

$2Zn + O_2 \rightarrow 2ZnO$ $\Delta G_{1100'c}$ = -360 KJ mol^{-1}

$2C + O_2 \rightarrow 2CO$ $\Delta G_{1100'c}$ = -460 KJ $mole^{-1}$

$\Sigma G = \Sigma G_p - \Sigma G_r$

$= -460 - (-360)$

$= -100$ KJ mol^{-1}

Reduction is possible.

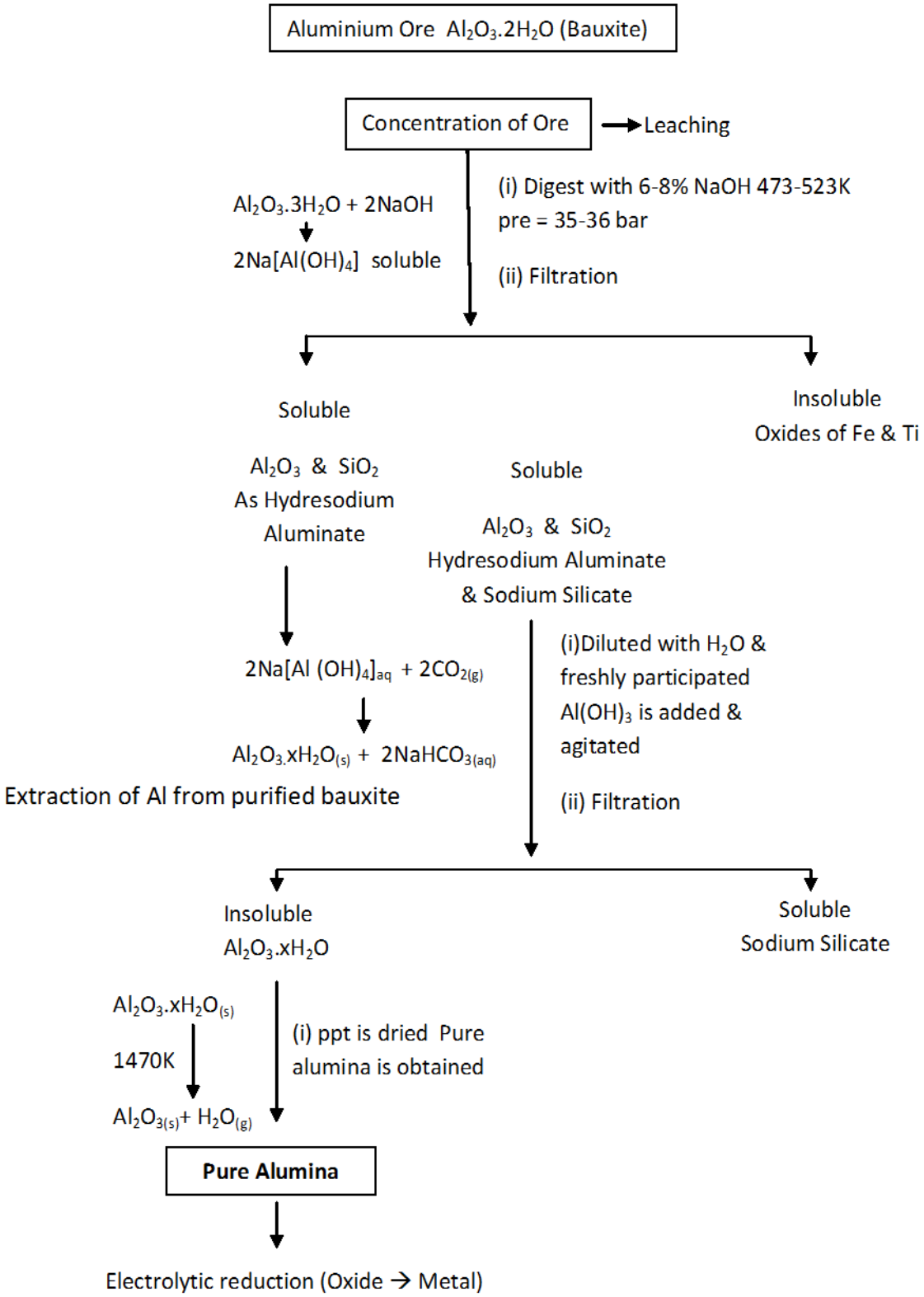
Electrochemical Principle

Electrode potential $\Delta G^0 = -nFE^0$

This concept is useful in electrolytic reduction. If E^0_{cell} is positive the ΔG^0 is negative. Therefore reaction is spontaneous.

Extraction of Aluminum

a) Bayer's Process



Reduction of alumina by electrolysis:

Method: Hall - Heroult Process:

Electrolyte: Molten Alumina &Cryolite (Cryolite or CaF_2 is added to lower the melting point.)

Electrodes: Anode –Carbon rods attached to copper rod

Cathode- Walls of electrolytic tank lined with graphite

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

Anode: $C_{(s)} + 2O^{2-}_{(\text{molten salt})} \rightarrow CO_{(g)} + 2e^-$

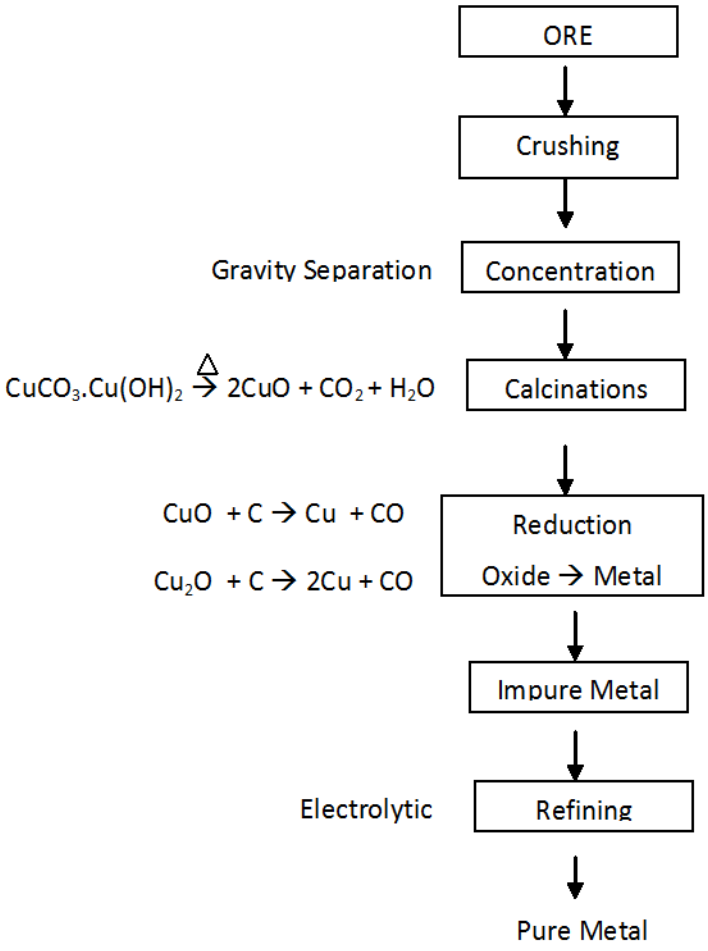
$C_{(s)} + 2O^{2-}_{(\text{molten salt})} \rightarrow CO_{2(g)} + 4e^-$

Aluminum is obtained at the bottom of tank .The anode is used up (chewing) & is replaced from time to time.

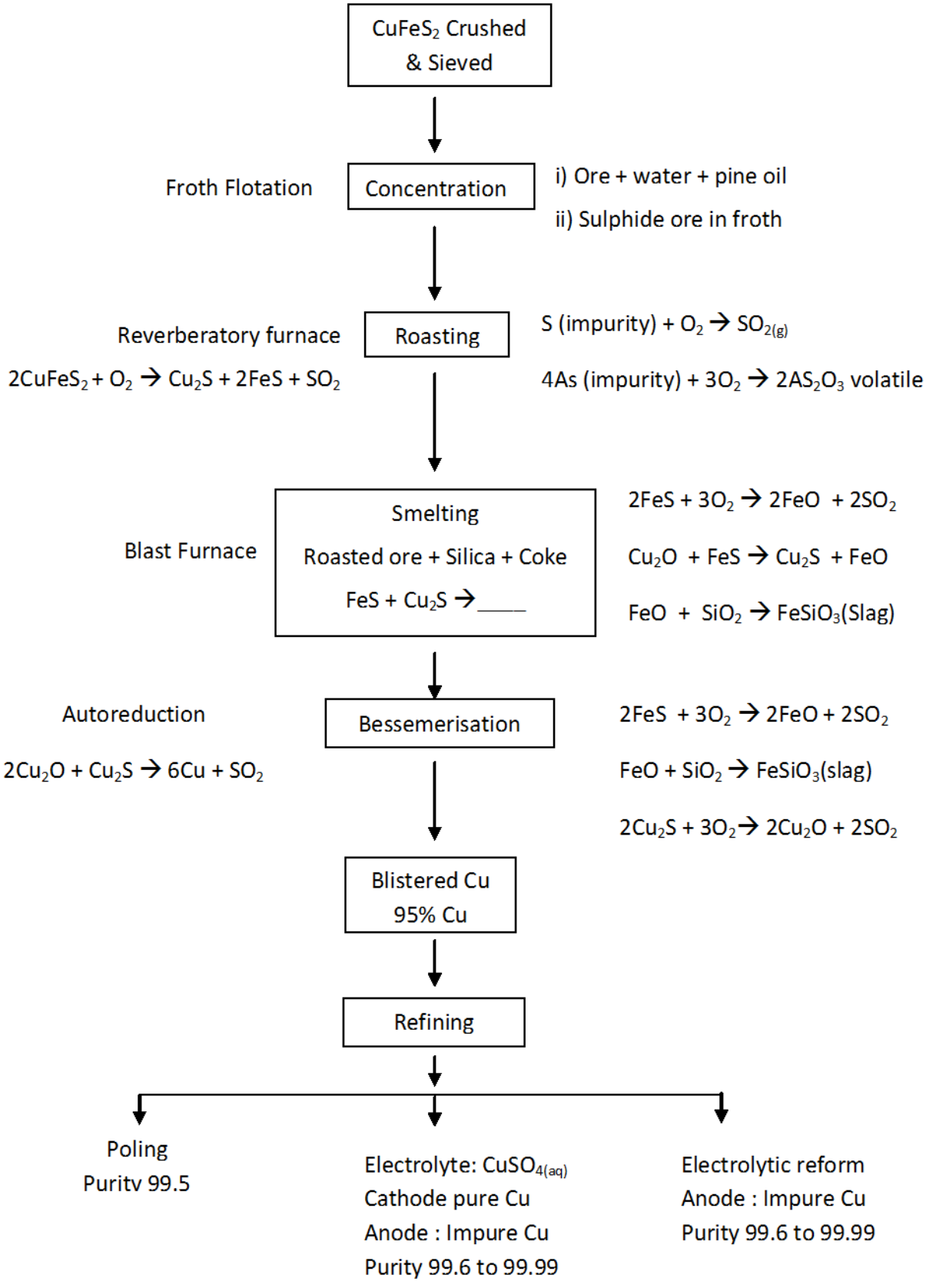
Extraction of Copper

Extraction of Copper depends on the type of ore

From oxide & carbonate ore



Extraction of Copper from Copper Pyrites ($CuFeS_2$)



Extraction of Iron

Hematite & Magnetite

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Crushing

↓

Magnetic Separation → Concentration

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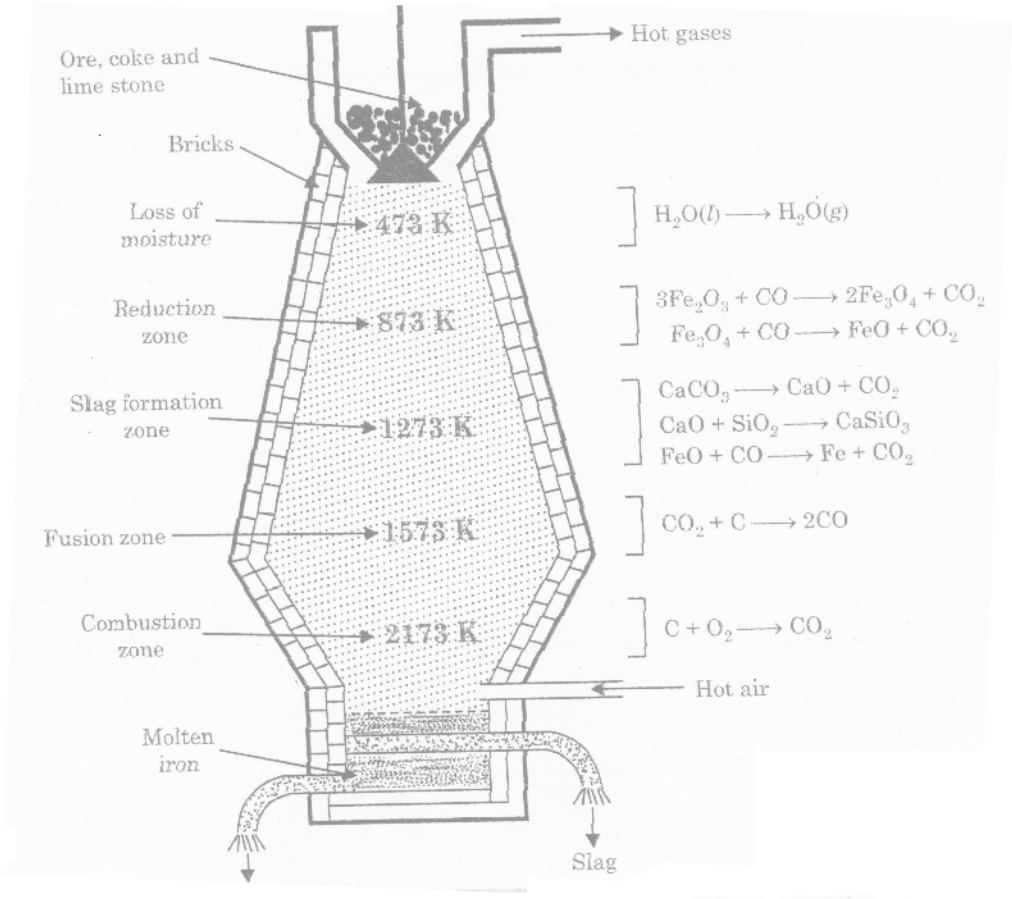
$FeCO_3 + O_2 \rightarrow Fe_2O_3 + 4CO_2$ → Calcinations

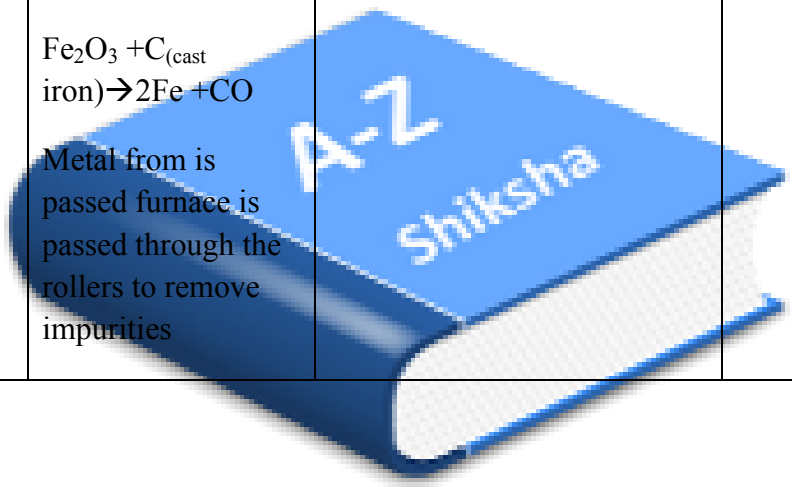
↓

Reduction or Smelting

Oxide → Metal



Types of iron	preparation	Impurities &Properties	Uses
Pig iron	Obtained from blast furnace	4%C &S ,P	Manufacture of cast iron
Cast iron	Blowing hot air in mixture of pig iron,iron scrap &coke	3%C Hard & brittle	Gutter pipes, Lamp posts, casting of articles like stoves etc. It does not rust.
Wrought iron	Heating cast iron in reverberatory furnace lined with hematite, limestone is added as flux to remove S,P,Si (impurities) $Fe_2O_3 + C_{(cast\ iron)} \rightarrow 2Fe + CO$ Metal from is passed furnace is passed through the rollers to remove impurities	Purest form of iron.It is extremely tough with high melting point &malleable.	Anchors, chains nails etc



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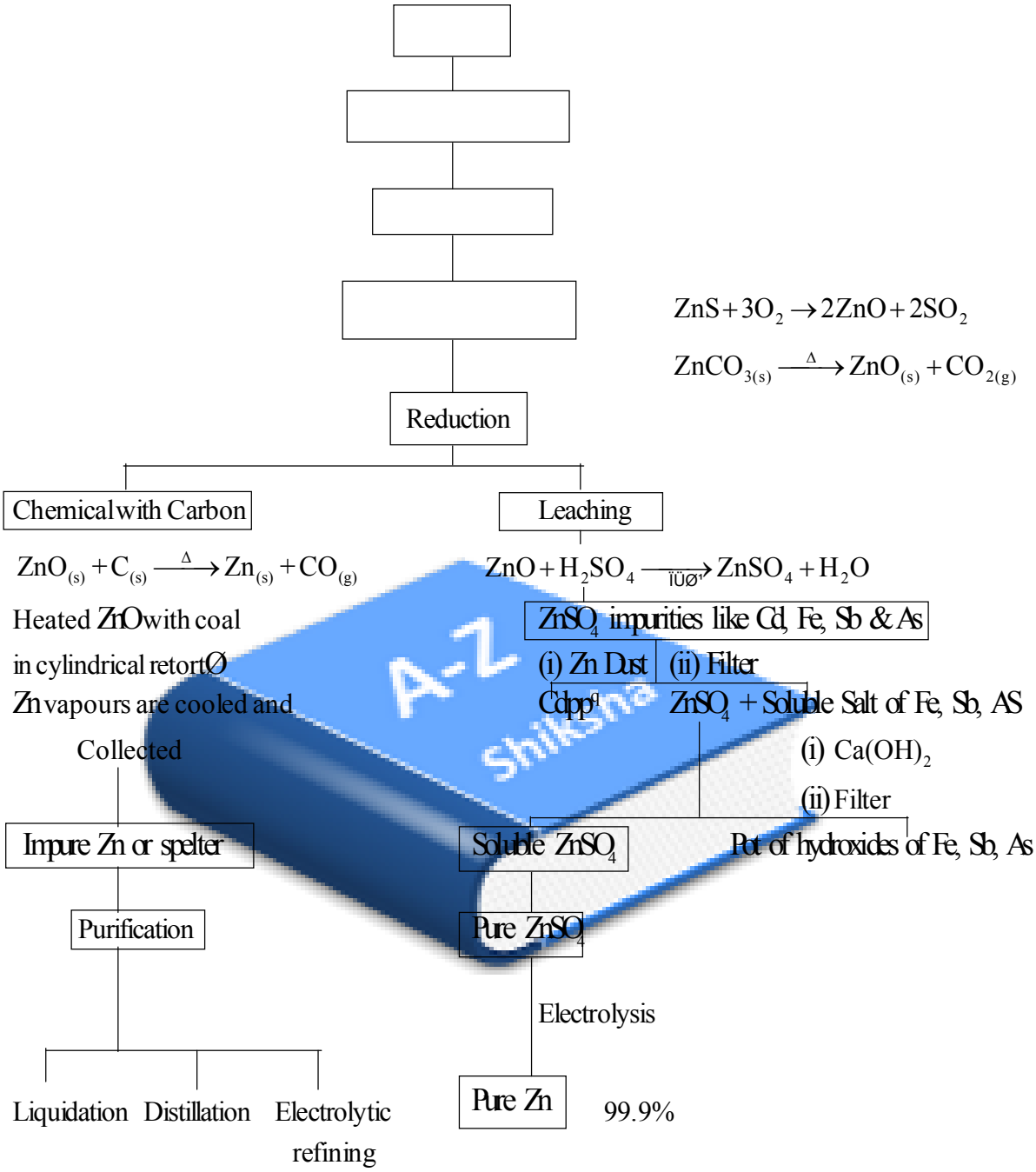


Manufacture of Zn Continued

M.C.Q.

1) The most abundant metal in the earth crust

a) Al b) Fe c) Ca d) Na

2) The impurities associated are

a) Flux b) Gangue c) Slag d) Ore

3) An ore after concentration was found to have basic impurities. The flux which can be used is

a) $CaCO_3$ b) SiO_2 c) FeO d) $Ca(OH)_2$

4) Choose the correct statement

a) All ore are mineral b) All mineral are ores

c) Minerals are not ores d) a & b

5) A metal oxide is reduced with a metal, M_1 of pd 3 & Gp 13. The process is known as ____ & the metal is

a) Pyrometallurgy & Mg b) Thermite & Ga c) Liquation & Al d) Thermite & Al

6) Diaspore & Corundum are ores of _____ & _____

a) Al & Fe b) Fe & Al c) Al & Al d) Si & Al

7) Choose the correct option

a) Siderite → $FeCO_3$ b) Limonite → Fe_2O_3 c) Calamine → $ZnCO_3$ d) a & c

8) The salt which is most unlikely to occur as mineral is

a) Bromide b) Sulphate c) Oxide d) Sulphides

9) During concentration of ore by froth flotation, the ore particles float on surface because:

a) Ores are insoluble b) Sulphides ores are lighter

c) The surface is not wetted by H_2O d) Difference in densities

10) An ore contains Pbs with impurity Zns. NaCN is added in the froth flotation process ZnS does not form the froth because

a) NaCN forms a complex of ZnS on surface of ZnS b) ZnS is not wetted by pine oil

c) ZnS is wetted by H_2O d) NaCN reacts with ZnS ionic compound

11) The method used for concentration of magnetic ore is

a) Gravity separation b) Froth floatation c) Magnetic separation d) Leaching

12) During froth flotation process the student observed that the froth was disappear after formation. The student added-----_____ to the container to overcome the difficulty

a) Pine oil b) Cresol c) Benzene d) NaCN

13) Silver ore is related with $NaCN_{(aq)}$ to

a) Reduce silver b) Extract pure silver

c) Refine silver d) To remove the impurities

14) The principle involved in leaching is

a) Difference in volatility b) Difference in density

c) Difference in solubility d) Soluble complex formation

15) Heating of ore in presence of O_2 below its melting point is known as

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

16) During electrolysis graphite is used as an electrode & not diamond because

a) Graphite is cheaper b) Graphite is soft

c) Graphite posses free electron while diamond doesn't d) Graphite is non reactive

17) Group 1 & 2 elements are extracted by

a) Thermite process b) Electrolytic method c) Bessomerisation d) Cupellation

18) Hydrometallurgy is used in extraction of

a) Sodium b) Manganese c) Iron d) Silver

19) Several metals are commercially produced by reduction of oxides by carbon. The oxides which can be reduced with carbon are

a) ZnO & Fe_2O_3 b) CaO & Cr_2O_3 c) BaO & U_3O_8 d) SiO_2 & Al_2O_3

20) Blister copper is

a) Pure copper b) Ore of Cu c) Alloy of Cu d) Impure copper

21) In Hall Heroult's process cryolite is added to alumina to

a) Increase the conductivity b) Lower the melting point

c) Increase the mobility of iron d) All of above

22) During extraction of metal charcoal powder is sprinkled on top of molten metal. This is useful in preventing

a) Oxidation of metal b) Formation of alloy c) Reduction d) a & b

23) zone refining is used to obtain ———— metal

a) Pure Cu b) Zirconium c) Ultrapure Si d) Nickel

24) Strongly

Metal + _____ → Volatile compound $\xrightarrow[\text{Strongly}]{\Delta}$ Pure Metal

This method is known as

a) Liquation b) Van Arkel c) Zone refining d) Distillation

25) _____ metal is purified by Mond's process

a) Zr b) Ti c) Ge d) Ni

26) The slag obtained during manufacture of Cu is

a) $CaSiO_3$ b) $FeSiO_3$ c) $CuSiO_3$ d) FeO

27) The principle used in zone refining

a) Fractional distillation b) Adsorption

c) Fractional crystallisation d) Chromatographic separation

28) In the reaction $2MO_{(s)} + C_{(s)} \rightarrow M_{(s)} + CO_{2(g)}$ the entropy of the reaction will

a) Decreases b) Increases

c) Remain constant d) May increases or decreases

29) In electrolytic refining of copper, anode mud contains

a) Earthly impurities b) Zn & Mn c) Noble metal d) Oxides of Cu

30) Zn is extracted from ZnS. The reducing agent used is _____ & method of refining is _____

a) Coke & Electrolysis b) Mg & Liquation

c) Coke & Zone refining d) Coke & fractional distillation

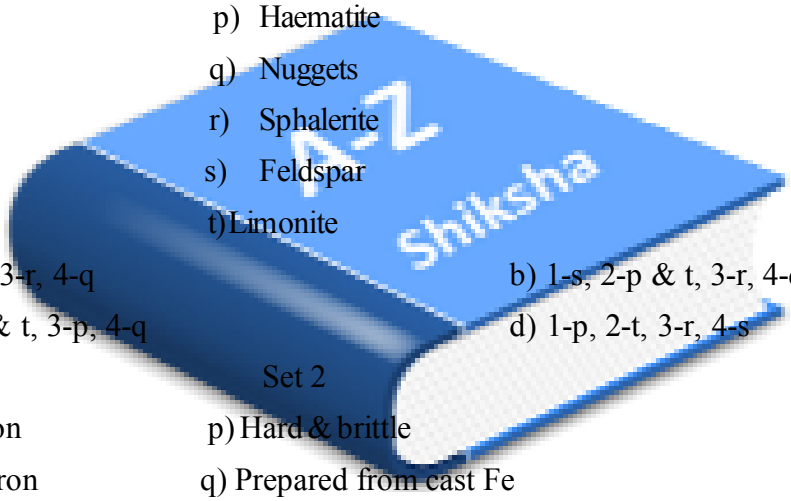
(31 To 40 are match the following sets.)

31)

Set 1	Set 2
1) Al	p) Haematite
2) Fe	q) Nuggets
3) Zn	r) Sphalerite
4) Ag	s) Feldspar
	t) Limonite

a) 1-p, 2-t, 3-r, 4-q b) 1-s, 2-p & t, 3-r, 4-q

c) 1-s, 2-r & t, 3-p, 4-q d) 1-p, 2-t, 3-r, 4-s



32)

Set 1	Set 2
1) Pig iron	p) Hard & brittle
2) Cast iron	q) Prepared from cast Fe
3) Wrought iron	r) Prepared by methyl pig iron
	s) Malleable
	t) Fe + 4% C

a) 1-t, 2-p & r, 3-q & s b) 1-t, 2-r , 3- s

c) 1-p, 2-r & t, 3-q & s d) 1-p, 2-s & r, 3-t & q

33)

Set 1	Set 2
1) Cr_2O_3 + Al	p) electrolysis
2) Zinc	q) Bayer's process
3) M_2O_3 + NaOH $\rightarrow$	r) Thermite
Soluble $\xrightarrow{\Delta} M_2O_3$	s) Hall Heroult

a) 1-r, 2-p, 3- s b) 1-r, 2-s, 3- p c) 1-s, 2-p, 3-q d) 1-r, 2-p, 3-q

34) Set 1 Set 2

1) Chromatography p) Chemical process
2) Poling q) Difference in solubility
3) Liquation r) Difference in melting point
4) Zone refining s) Low boiling point metal
t) Adsorption

a) 1-r, 2-p, 3-s, 4-q b) 1-q, 2-r, 3-p, 4-s c) 1-t, 2-p, 3-s, 4-q d) 1-p, 2-p, 3-s, 4-q

35) Set 1 Set 2

1) Earthly impurities p) Froth flotation
2) Sulphide ores q) Magnetic separation
3) Bauxide r) Gravity separation
4) Magnetite s) Leaching

a) 1-p, 2-r, 3-s, 4-q b) 1-r, 2-p, 3-s, 4-q c) 1-q, 2-r, 3-p, 4-s d) 1-s, 2-p, 3-r, 4-q

36) Given below are the different temperature reactions & products during extraction of iron in blast furnace

1) 500^0-800^0 K p) Pig iron
2) 1270^0 q) Molten slag
3) 2170^0 r) $C + O_2 \rightarrow 2CO$
4) 2170 s) $3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$
5) $> 2170^0$ t) $CaO + SiO_2 \rightarrow CaSiO_3$

a) 1-s,2 q,3r,4-p b) 1-s,t ; 2-r,3-q ,4-p
c) 1-r,s ;2-t,3-p,4-q d) 1-s,2-r,3-q,4-ps

37) Set 1 Set 2

1) Bauxite p) Bayers
2) Zinc blend q) Blast Furnace
3) Copper pyrites r) Hall-heroult
4) Haematite s) Bessemerisation
t) Fire Clay cylindrical retort

a) 1-r & p, 2-t, 3-s, 4-q b) 1-p, 2-t, 3-s, 4-q c) 1-r, 2-s, 3-s, 4-q d) 1-r, 2-t, 3-s, 4-q

38) Set 1 Set 2

1) Zn p) Automobiles
2) Wrought iron q) Galvanising
3) Steel r) Bell Meta
4) Copper s) Muntz Metal
t) Anchors

a) 1-s, 2-r, 3-t, 4-q b) 1-q & r, 2-t, 3-p, 4-r & s
c) 1-q, 2-s, 3-p, 4-r d) 1-q, 2-t, 3-p, 4-r & s

39) Set 1 Set 2

1) Electrolysis p) Wide range of temperature
2) Zone refining q) Adsorption
3) Blast furnace r) Electrode potential
4) Liquation s) Noble gas atmosphere
t) Low melting point

a) 1-r, 2-t, 3-p, 4-t b) 1-r, 2-s, 3-p, 4-t c) 1-r, 2-s & t, 3-p, 4-q d) 1-t, 2-s, 3-p, 4-r

40) Set 1 Set 2

1) Non spontaneous p) $\Delta G = 0$
2) spontaneous q) $K < 1$
3) Equilibrium r) ΔG decreases
s) $K > 1$
t)

a) 1-q, 2-r & s, 3-p & t b) 1-q, 2-r & s, 3-p c) 1-t, 2-r & s, 3-p d) 1-q, 2-r, 3-p

Questions 41 to 51 are assertion reason type

a) Statement 1 is correct, statement 2 is the correct reason for statement 1
b) Statement 1 is correct, statement 2 is correct but does not give reason of for statement 2
c) Statement 1 is correct, statement 2 is false
d) Statement 1 is false, statement 2 is correct

41) Statement 1) Magnesium is mainly extracted by electrolysis of molten electrolyte and not by chemical methods.
Statement 2) The $\Delta_i H$ of Mg is very low & hence it is very difficult to reduce $Mg^{2+}_{(aq)} \rightarrow Mg_{(s)}$

42) Statement 1) Cu is obtained by ____ . Then by pdt CO_2 obtained
Statement 2) The by-product obtained is SO_2 & is used in manufacture of sulphuric acid.

43) Statement 1) In Bayer's process the ore is heated with Conc. $Ca(OH)_2$.
Statement 2) The ore used in Bayer's process is atmospheric & is soluble in NaOH therefore ore is concentrated.

44) Statement 1) Froth flotation is used for concentration of sulphide ores.
Statement 2) Cresol is used as a depressant in froth flotation.

45) Statement 1) Metal oxide can be easily reduced with carbon
Statement 2) Metal oxide + C $\xrightarrow{\Delta}$ Melted + CO $\Delta G = -x$ KJ

46) Statement 1) $\Delta G = -nFE^0$ is applicable to metallurgy
Statement 2) If cell potential is negative electrolytic reduction of metal ions is possible

47) Statement 1) Ultra pure silicon is manufactured by vapour phase refining

Statement 2) Vapour phase refining gives ultra pure metals

48) Statement 1) Ni is converted to $Ni(CO)_4$ in Mond process

Statement 2) $Ni(CO)_4$ is volatiles & the compound can be easily disposable

49) Statement 1) Mercury is purified by distillation

Statement 2) Mercury has low melting point

True / false questions (50-58)

50)

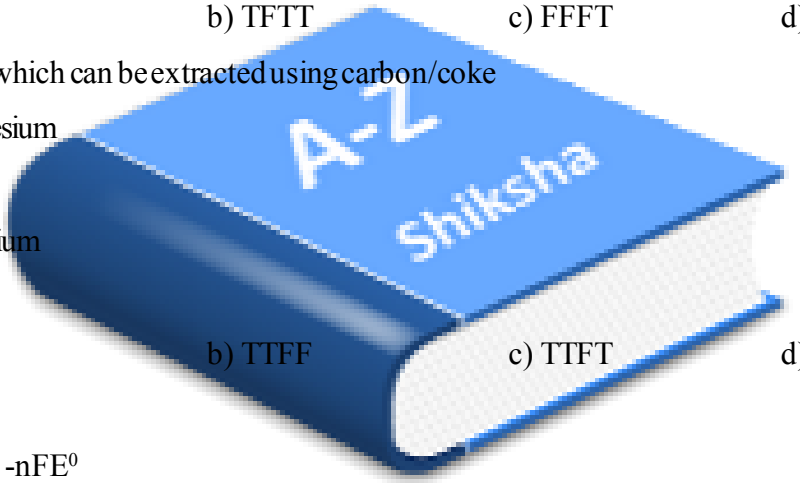
1) Ag & Au are manufacture by hydrometallurgy
2) Fe can be extracted by electrolytic method
3) Mg is extracted from aq $MgCl_2$ by passing electric current
4) Zn is extracted from Zinc blend by using coal or anthracite coal

a) TFFT b) TFTT c) FFFT d) FFTT

51) The metals which can be extracted using carbon/coke

1) Magnesium
2) Iron
3) Potassium
4) Zinc

a) FTTF b) TTFF c) TTFT d) FTFT



52)

1) $\Delta G^0 = -nFE^0$
2) The above equation is the principle used in electrolytic reduction for manufacture of metals
3) $2Cu_2S_{(s)} + 3O_{2(g)} \xrightarrow{\Delta} 2Cu_2O_{(s)} + 2SO_{2(g)}$ ΔS is positive in this reaction
4) $\Delta G = \Delta H - T\Delta S$ if free energy change is negative the reaction is spontaneous

a) TFFT b) TTFT c) TTTT d) TFTF

53)

1) Kaolinite is an ore of Al
2) Sphalerite is an ore of sulphide of Cu
3) Malachite is an oxide ore of copper
4) sphalerite is iron carbonate

a) TFTT b) TTFT c) TFFT d) TFFF

54)

1) Ore is heated strongly during calcinations to remove all volatile impurities
2) Ore is heated with oxygen during roasting to convert sulphide to oxide
3) Cryolite is added to bauxite in Hall Heroult's process to increase solubility of bauxite in ____
4) After leaching of bauxite, it is directly used as an electrolyte

a) TTFF b) TTFT c) TTTF d) TFFT

55)

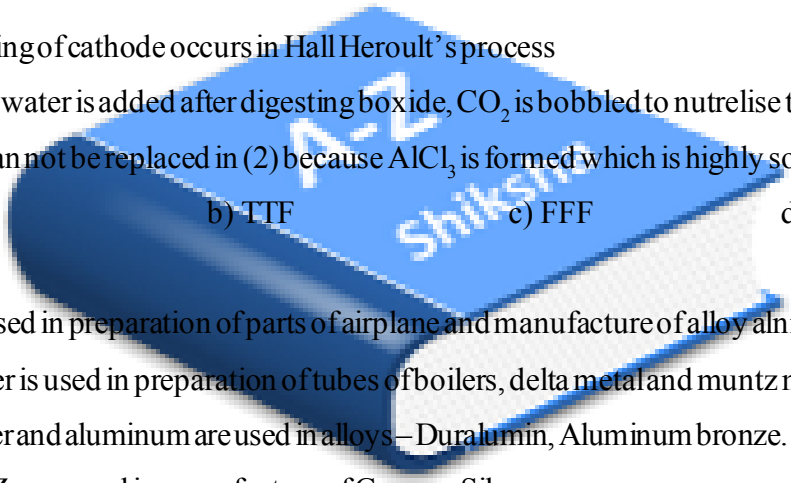
1. The reduction reaction by accepting electrons is known as electro nation
2. In extraction of Gold and silver by process of leaching $K > 1$
3. If $\Delta H = -1369$ KJ/ mol^{-1}, $\Delta S = +26$ J/mol^{-1} $T = 400K$ for the reaction
   $A + B \rightarrow C$ the reaction is non spontaneous

a) TTT b) TTF c) TFT d) TFF

56)

1. Chewing of cathode occurs in Hall Heroult's process
2. When water is added after digesting boxide, CO_2 is bobbled to nutrelise the solution
3. HCl can not be replaced in (2) because $AlCl_3$ is formed which is highly soluble

a) FTF b) TTF c) FFF d) FTT



57)

1. Al is used in preparation of parts of airplane and manufacture of alloy alnico.
2. Copper is used in preparation of tubes of boilers, delta metal and muntz metal.
3. Copper and aluminum are used in alloys – Duralumin, Aluminum bronze.
4. Cu & Zn are used in manufacture of German Silver.

a) TFTF b) TTFT c) TFFT d) TFTT

58)

1. Wet metallurgical process is used for pyrites ores of lower grade.
2. $2Cl^- + 2H_2O \rightarrow 2OH^- + H_2 + Cl_2$ The cell potential is -2.186V. This reaction will take place in forward direction.
3. Pure Zn metal is called spleter.
4. The abundance of Al is highest .Its place is third & is about 8.3% by weight.

a) TFFT b) TTTT c) FTFT d) FFFT

Linked Comprehension type:

59) Cassiterite (SnO_2) and ore of Tin contains $FeWO_4$ & $MnWO_4$ as impurities as well as small amounts of sulfur. SnO_2 is melted with cold, Lime stone and sand in a reveberatory furnace. The impure Tin Sn is purified by liquation

I. The ore is concentrated by

A) Froth flotation B) Magnetic separation

C) Leaching D) a & b

II. The impurities of sulfur can be removed by

A) Treatment with NaOH B) Treatment with HCl

C) Roasting D) Calcinations

III. If limestone and sand are added during smelting the nature of impurities are

A) Acidic and basic B) Amphotric C) Acidic D) Basic

(a) i-B, ii-C, iii-C, iv-B (b) i-C, ii-D, iii-D, iv-A

(c) i-A, ii-C, iii-B, iv-C (d) i-A, ii-C, iii-A, iv-B

55) ΔG^0_f for CuS, CaS, SO_2, CS_2 & CuO are -49, -1230, -300.4, +63.6 & - 127.2 KJ/ mol^{-1} respectively.

i. The most stable and unstable compounds are

A) SO_2 & CaS B) CaS & CS_2 C) CuS & SO_2 D) CaS & SO_2

ii. CuS & CaS are reduced with Carbon to give Cu or Ca and CS_2. The reaction which will be spontaneous is

A) Reduction of CuS because ΔG is positive

B) Reduction of CaS because ΔG is negative

C) Both are spontaneous because ΔG is positive

D) Both are non spontaneous because ΔG is positive

iii. The ΔG^0 for the reaction $2CuS + 3O_2 \rightarrow 2CuO + 2SO_2$ is _____ & the reaction is _____

A) – 756.8KJ & Spontaneous B) +756.8KJ & non- Spontaneous

C) -378.4KJ & Spontaneous D) +378.4 KJ & non-Spontaneous

(a) i-B, ii-D, iii-A (b) i-D, ii-C, iii-B (c) i-B, ii-D, iii-C (d) i-C, ii-B, iii-D

ANSWER KEY

1	A	16	C	31	B	46	C
2	B	17	B	32	A	47	D
3	B	18	D	33	D	48	A
4	A	19	A	34	C	49	A
5	D	20	D	35	B	50	A
6	C	21	B	36	D	51	D
7	D	22	A	37	A	52	B
8	B	23	C	38	D	53	C
9	C	24	B	39	B	54	A
10	A	25	D	40	B	55	B
11	C	26	B	41	A	56	D
12	b	27	C	42	D	57	B
13	D	28	B	43	D	58	A
14	D	29	C	44	C	59	D
15	A	30	D	45	A	60	A