6 General Principles and Processes of Isolation of Elements

Facts that Matter

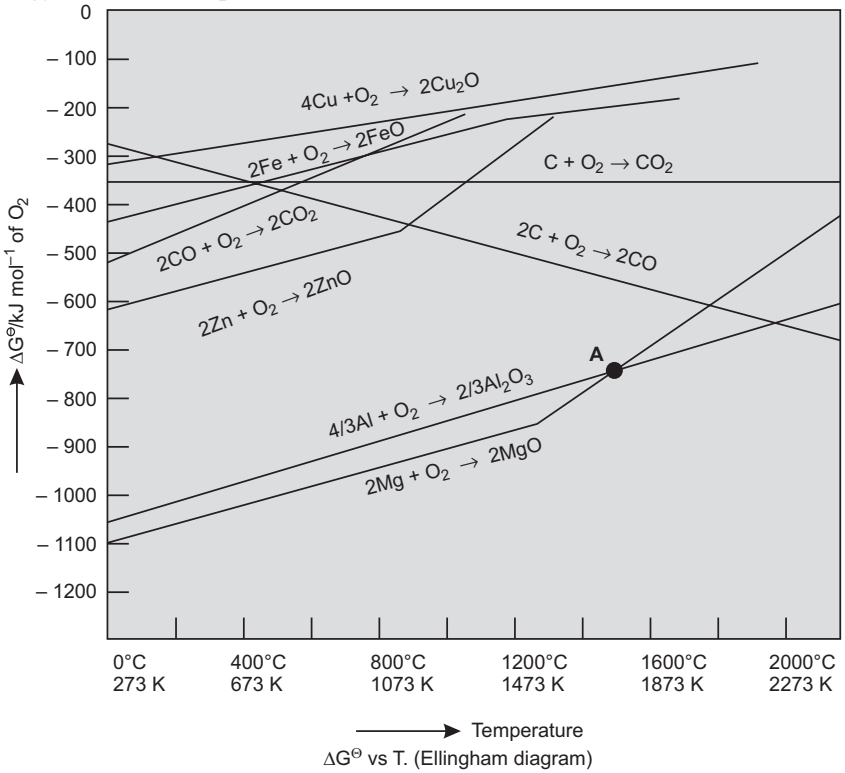
- **Mineral:** A mineral is naturally occurring chemical substance in the earth's crust obtained by mining that contains metal in its native state.
- **Ore:** The mineral from which the metal is conveniently and economically extracted is called an ore.
- **Metallurgy:** The entire scientific and technological process used for the isolation of the metals from its ores is known as metallurgy.
- **Gangue:** The impurities associated with the minerals are known as gangue or matrix.
- **Slag:** A compound formed when gangue is combined with flux is called slag.
- **Depressants:** The chemical compound which is used to prevent one kind of sulphide ore to go with froth in the presence of another sulphide ore. **Example;** NaCN
- **Collectors:** These substances increases the non-wettability of the ore particles. **Example:** Pine oil, fatty acids
- **Leaching:** When concentration of the ore is done using certain chemicals, then this process of concentration is called leaching. **Example:** Bauxite, Ag and Au ores are concentrated by this method.
- **Pyrometallurgy:** The process of thermal reduction of an oxide by varying the temperature of a reducing agent is called pyrometallurgy.
- **Copper matte:** It is a combination of Cu_2S and FeS obtained by roasting of copper pyrites in a reverberatory furnace.
- **Blister copper:** The solidified copper obtained after the reduction of copper matte has blistered appearance. This is called blister copper.
- **Name and formula of some important ores:**

Table-1: Principal Ores of some Important Metals

Metal	Ores	Composition
Aluminium	Bauxite	$AlO_x(OH)_{3-2x}$ [where $0 < x < 1$]
	Kaolinite (a form of clay)	$[Al_2(OH)_4Si_2O_5]$
Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
	Siderite	$FeCO_3$
	Iron pyrites	FeS_2

Copper	Copper pyrites	$CuFeS_2$
	Malachite	$CuCO_3.Cu(OH)_2$
	Cuprite	Cu_2O
	Copper glance	Cu_2S
Zinc	Zinc blende or Sphalerite	ZnS
	Calamine	$ZnCO_3$
	Zincite	ZnO

- **Thermodynamic principles of metallurgy:** Thermodynamic principles of metallurgy are based on the measurement of ΔG° of formation of oxide of a reducing agent from a metal oxide. If ΔG° of formation of the oxide of reducing agent is more –ve than the ΔG° of formation of the metal oxide then the reducing agent can reduce the given metal oxide into the metal spontaneously. –ve sign of the overall reaction shows its spontaneity. If the reactants and products of two reactions are put together in a system and the net ΔG of the two possible reactions is –ve, then the overall reaction will occur. So the process of interpretation involves coupling of the two reactions, getting the sum of their ΔG and looking for its magnitude and its *sign*. Such coupling is easily understood through Gibbs energy ($\Delta G^\ominus$) vs T plots for the formation of the oxides.



$\Delta G^\ominus$ vs T. (Ellingham diagram)

Examples:

1. Mg can reduce Al_2O_3.
2. Al can reduce ZnO.
3. C can reduce ZnO at higher temperature.
4. CO can reduce FeO at lower temperature.

5. At point 'A' reaction is at equilibrium.
6. Bend in the plot shows change in the phase.

- **Principles of different Refining Processes:**
  (*a*) **Distillation:** This purification method is based on the principle that metal to be purified (Zn, Hg) has lower boiling point that the impurity present in it.
  (*b*) **Liquation:** This purification method is based on the principle that metal to be purified (Sn, Pb) has lower melting point than the impurity present in it.
  (*c*) **Electrolytic refining:** This purification method is based on the principle that an impure metal undergoes oxidation and its ion undergo reduction from the electrolytic solution of the metal salt based on their E° values.
  (*d*) **Zone refining:** This purification method is based on the principle that impurities are more soluble in the molten state than in the solid state of the metal.
  (*e*) **Vapour phase refining:** This purification method is based on the principle that metal—
  (*a*) should form a volatile compound.
  (*b*) this volatile compound should decompose easily.

NCERT IN-TEXT QUESTIONS SOLVED

6.1. Which of the ores mentioned in Table 6.1 can be concentrated by magnetic separation method?

Ans. Ores which are magnetic in nature can be separated from the non-magnetic gangue particles by magnetic separation method. For example, ores of iron such as haematite (Fe_2O_3), magnetite (Fe_3O_4), siderite ($FeCO_3$) and iron pyrites (FeS_2) being magnetic can be separated from non-magnetic silica and other impurities by magnetic separation method.

6.2. What is the significance of leaching in the extraction of aluminium?

[*Delhi* 2017]

Ans. Aluminium usually contains silica (SiO_2), iron oxide (Fe_2O_3) and titanium oxide (TiO_2) as impurities. These impurities can be removed by the process of leaching. During leaching, the powdered bauxite ore is heated with a concentrated (45%) solution of NaOH at 473-523 K, where alumina dissolves as sodium meta-aluminate and silica (SiO_2) dissolves as sodium silicate leaving behind Fe_2O_3, TiO_2 and other impurities.

$$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \xrightarrow{473\text{–}523\ K} \underset{\text{sodium meta-aluminate}}{2Na[Al(OH)_4](aq)}$$

$$SiO_2(l) + 2NaOH(aq) \xrightarrow{473\text{–}523\ K} \underset{\text{Sodium silicate}}{Na_2SiO_3(aq)} + H_2O(l)$$

The impurities are filtered off and the solution of sodium meta-aluminate is neutralized by passing the CO_2 where hydrated alumina separates out while sodium silicate remains in the solution. The hydrated alumina thus obtained is filtered, dried and heated to give back pure alumina.

$$Al_2O_3.\ x\ H_2O(s) \xrightarrow{1473\ K} Al_2O_3(s) + x\ H_2O(g)$$

Thus, the significance of leaching in the extraction of aluminium is to prepare pure alumina from the bauxite ore.

6.3. The reaction,

$$Cr_2O_3 + 2\,Al \longrightarrow Al_2O_3 + 2\,Cr\ (\Delta G^{\ominus} = -421\ kJ)$$

is thermodynamically feasible as is apparent from the Gibbs energy value. Why does it not take place at room temperature?

Ans. It does not take place at room temperature because ΔG is positive at room temperature.

6.4. Is it true that under certain conditions, Mg can reduce Al_2O_3 and Al can reduce MgO? What are those conditions?

Ans. Yes, it is true at moderate temperature.

$$2Mg + SiO_2 \longrightarrow 2MgO + Si$$

Silicon can reduce MgO at very high temperature.

$$2MgO + Si \longrightarrow 2Mg + SiO_2$$

NCERT TEXTBOOK QUESTIONS SOLVED

6.1. Copper can be extracted by hydrometallurgy but not zinc. Explain.

Ans. Copper is less reactive than hydrogen, therefore it can be extracted by hydro-metallurgy, whereas Zn cannot be extracted by hydrometallurgy because zinc is more reactive than hydrogen.

6.2. What is the role of depressant in froth floatation process?

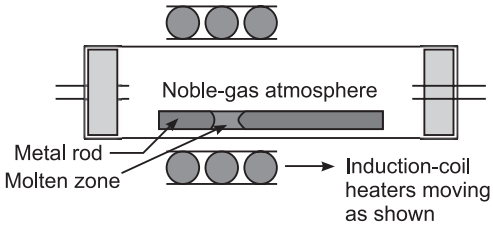
Ans. It prevents certain sulphides like ZnS to enter the froth in presence of PbS therefore, it helps in their separation. Sodium Cyanide is used as a depressant in the separation of ZnS from PbS.

6.3. Why is the extraction of copper from pyrites more difficult than that from its oxide ore through reduction?

Ans. Copper pyrites contain FeS which needs to be oxidised to FeO and then removed as $FeSiO_3$ (slag) whereas in oxide ore, such impurities are not present.

6.4. Explain (*i*) Zone refining (*ii*) Column chromatography.

Ans. (*i*) **Zone refining:** This method is based on the principle that impurities are more soluble in the melt than in the solid state of the metal. A circular mobile heater is fixed at one end of a rod of the impure metal

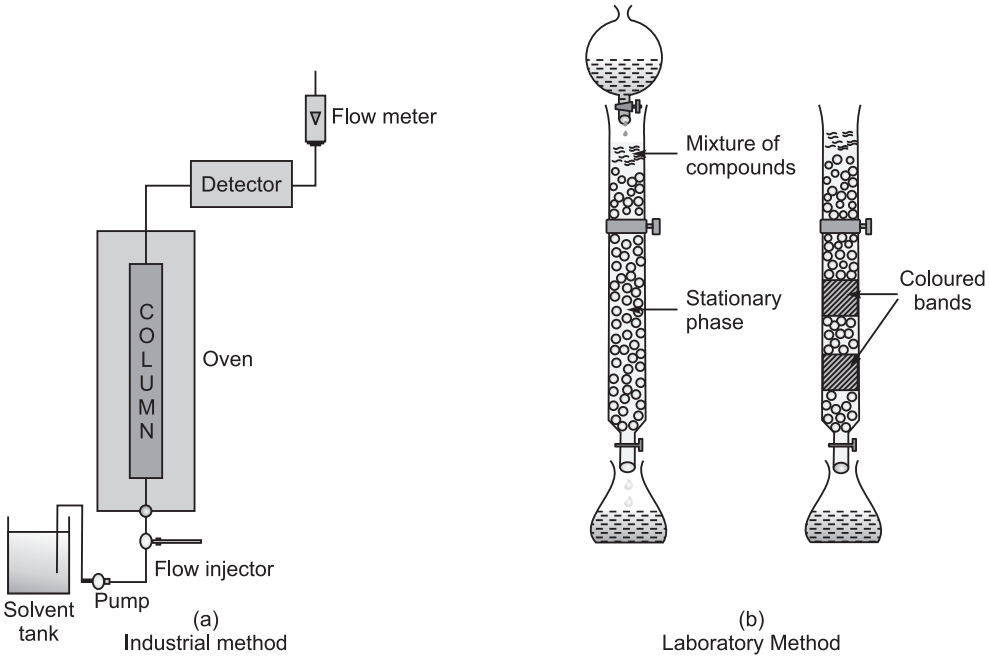


Zone refining process

As the heater moves forward, pure metal crystallises out of the melt and the impurities passes on into the adjacent molten zone. This process is repeated several times and the heater is moved in the same direction. At the ore end, impurities get concentrated. This end is cut off. This method is very useful for producing semiconductors and other metals of very high purity.

For example, germanium, silicon, boron, gallium and indium.

(*ii*) **Column chromatography:** In column chromatography Al_2O_3 is taken as adsorbent which acts as the stationary phase. The mixture of substances to be separated is dissolved in a suitable solvent called eluent which acts as the mobile phase. The components get separated due to differential adsorbing power. The component which has maximum adsorbing power moves slowest whereas substances which has least adsorbing power moves the fastest and thus they get separated.



Schematic diagrams showing column chromatography

6.5. Out of C and CO, which is a better reducing agent at 673 K?

Ans. CO (Carbon monoxide)

6.6. Name the common elements present in the anode mud in electrolytic refining of copper. Why are they so present?

Ans. The common elements present in the anode mud are antimony, selenium, tellurium, silver, gold and platinum. These elements, being less reactive are not affected by $CuSO_4$–H_2SO_4 solution and hence settles down under the anode as anode mud.

6.7. Write down the reactions taking place in different zones in the blast furnace during the extraction of iron.

Ans. At 500–800 K

$$3Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 + CO_2;$$
$$Fe_3O_4 + 4CO \longrightarrow 3Fe + 4CO_2$$
$$Fe_2O_3 + CO \longrightarrow 2FeO + CO_2$$

At 900–1500 K

$$C + CO_2 \longrightarrow 2CO$$
$$FeO + CO \longrightarrow Fe + CO_2$$
$$C + O_2 \longrightarrow CO_2$$

Above 1570 K

$$FeO + C \longrightarrow Fe + CO$$
$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$$
$$CaO + SiO_2 \longrightarrow CaSiO_3 \text{ (slag)}$$

6.8. Write chemical reactions taking place in the extraction of zinc from zinc blende.

Ans.
$$2ZnS\ (s) + 3O_2\ (g) \longrightarrow 2ZnO\ (s) + 2SO_2\ (g)$$
$$2ZnO + ZnS \longrightarrow 3Zn + SO_2$$

6.9. State the role of silica in the metallurgy of copper.

Ans. Role of silica in the metallurgy of copper is to remove iron oxide as slag. That is why it acts as flux.

6.10. What is meant by the term "chromatography"?

Ans. Chromatography is the process of isolation, separation and purification of coloured substances mostly. These days, even colourless substances can also be separated by chromatography.

6.11. What criterion is followed for the selection of the stationary phase in chromatography?

Ans. The stationary phase is selected in such a way that the impurities are more strongly adsorbed or are more soluble in the stationary phase than the element to be purified. Under these conditions when the column is extracted, the impurities will be retained by the stationary phase while the pure component is easily eluted.

6.12. Describe the method of refining of nickel.

Ans. When impure nickel is heated in a current of CO at 330–350 K, it forms a volatile nickel tetracarbonyl complex, leaving behind the impurities. The nickel tetracarbonyl thus obtained is then heated further at a higher temperature (450–470 K), where it undergoes thermal decomposition to give pure nickel.

$$Ni + 4CO \xrightarrow{330-350K} \underset{\text{Nickel tetracarbonyl}}{Ni(CO)_4}$$

$$Ni(CO)_4 \xrightarrow{450 \text{ to } 470K} \underset{\text{Pure Nickel}}{Ni} + 4CO$$

This method is commonly called as Monds's process for the refining of nickel.

6.13. How can you separate alumina from silica in a bauxite ore associated with silica? Give equations, if any.

Ans. Alumina is reacted with sodium hydroxide solution to form aluminate which can be precipitated as hydrated aluminium oxide by passing carbon dioxide vapours. Silica reacts with sodium hydroxide solution to form sodium silicate which cannot be precipitated and it can be filtered off.

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

$$2Na[Al(OH)_4] + CO_2 \longrightarrow 2NaHCO_3 + Al_2O_3 \cdot xH_2O$$

$$2NaOH + SiO_2 \longrightarrow Na_2SiO_3 + H_2O$$

6.14. Giving examples, differentiate between 'roasting' and 'calcination'.

Ans. Calcination: It is a process in which an ore is heated in the absence of air so as to remove the volatile impurities. It is used to convert the carbonate ore into the corresponding oxide. It is also used to remove moisture and water of crystallisation in hydrated ores, *e.g.*

$$Fe_2O_3 \cdot xH_2O \xrightarrow{\text{heat}} Fe_2O_3 + xH_2O$$

$$\underset{\text{Calamine}}{ZnCO_3} \xrightarrow{\text{heat}} ZnO + CO_2$$

$$\underset{\text{Siderite}}{FeCO_3} \xrightarrow{\text{heat}} FeO + CO_2$$

$$\underset{\text{Malachite}}{CuCO_3 \cdot Cu(OH)_2} \xrightarrow{\text{heat}} 2CuO + H_2O + CO_2$$

$$\underset{\text{Dolomite}}{MgCO_3 \cdot CaCO_3} \xrightarrow{\text{heat}} MgO + CaO + 2CO_2$$

Roasting: It is a process in which a sulphide ore is heated in the presence of oxygen so as to convert it into its corresponding oxide.

$$2ZnS\ (s) + 3O_2\ (g) \longrightarrow 2ZnO\ (s) + 2SO_2\ (g)$$

$$\underset{\text{Galena}}{2PbS\ (s)} + 3O_2\ (g) \longrightarrow 2PbO\ (s) + 2SO_2\ (g)$$

$$\underset{\text{Iron pyrite}}{4FeS_2\ (s)} + 11O_2\ (g) \longrightarrow 2Fe_2O_3\ (s) + 8SO_2\ (g)$$

$$\underset{\text{Copper glance}}{2Cu_2S\ (s)} + 3O_2\ (g) \longrightarrow 2Cu_2O\ (s) + 2SO_2\ (g)$$

6.15 How is 'cast iron' different from 'pig iron'?

Ans.

Cast iron	Pig iron
(*i*) It contains low percentage of carbon content and other impurities. (*ii*) It is malleable and ductile.	(*i*) It contains more percentage of carbon content and other impurities like S, P, Si, *etc.* (*ii*) It is brittle.

6.16. Differentiate between minerals and ores.

Ans. **Minerals** are naturally occurring substances from which metals may or may not be extracted profitably.

Ores are those minerals from which metals can be extracted profitably.

6.17. Why copper matte is put in silica lined converter?

Ans. Copper matte chiefly consists of Cu_2S along with some FeS. When a blast of hot air is passed through the molten matte taken in a silica lined converter, FeS present in matte is oxidised to FeO which combines with silica (SiO_2) to form $FeSiO_3$ slag.

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

$$FeO + \underset{\text{silica}}{SiO_2} \longrightarrow \underset{\text{slag.}}{FeSiO_3}$$

When whole of the iron metal has been removed as slag, some of the Cu_2S undergoes oxidation to form Cu_2O which then reacts with more Cu_2S to form the copper metal.

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

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

Thus, copper matte is heated in a silica lined converter to remove the FeS present in matte as $FeSiO_3$ slag.

6.18. What is the role of cryolite in the metallurgy of aluminium?

Ans. It reduces the melting point of Al_2O_3 and increases its electrical conductivity.

6.19. How is leaching carried out in case of low grade copper ores?

Ans. The leaching process of the low grade copper ores is carried out with acids in the presence of air, when copper goes into the solution as Cu^{2+} ions. Thus,

$$2Cu\ (s) + 2H_2SO_4\ (aq) + O_2\ (g) \longrightarrow 2CuSO_4\ (aq) + 2H_2O\ (l)$$

or

$$Cu\ (s) + 2H^+\ (aq) + \frac{1}{2}O_2\ (g) \longrightarrow Cu^{2+}\ (aq) + H_2O\ (l)$$

6.20. Why is zinc not extracted from zinc oxide through reduction using CO?

Ans. The standard free energy of formation ($\Delta_f G^\ominus$) of CO_2 from CO is higher than that of the formation of ZnO from Zn. Therefore, CO cannot be used to reduce ZnO to Zn.

6.21. The value of $\Delta_f G^\ominus$ for formation of Cr_2O_3 is – 540 kJ mol^{-1} and that of Al_2O_3 is – 827 kJ mol^{-1}. Is the reduction of Cr_2O_3 possible with aluminium?

Ans. Yes, it is possible because $\Delta_r G^\ominus$ is –ve.

$$Cr_2O_3(s) + 2Al(s) \longrightarrow 2Cr(s) + Al_2O_3(s)$$

$$\Delta_r G^\ominus = \Delta_f G^\ominus\ Al_2O_3 - \Delta_f G^\ominus\ Cr_2O_3$$

$$\Delta_r G^\ominus = -827 - (-540) = -827 + 540 = -287 \text{ kJ mol}^{-1}$$

6.22. Out of C and CO which is a better reducing agent for ZnO?

Ans. Carbon is a better reducing agent than CO for ZnO.

6.23. The choice of a reducing agent in a particular case depends on thermodynamic factor. How far do you agree with this statement? Support your opinion with two examples.

Ans. Thermodynamic factor help us in choosing a suitable reducing agent for the reduction of a particular metal oxide to the metallic state as discussed below:

From the Ellingham diagram, it is clear that metals for which the standard free energy of formation ($\Delta_f G^\ominus$) of their oxides is more negative can reduce the metal oxides for which the standard free energy of formation ($\Delta_f G^\ominus$) of oxides is less negative.

6.24. Name the processes from which chlorine is obtained as a by-product. What will happen if an aqueous solution of NaCl is subjected to electrolysis?

Ans. Sodium metal is prepared by Down's process. It involves the electrolysis of a fused mixture of NaCl and $CaCl_2$ at 873 K. During electrolysis, sodium is discharged at the cathode while Cl_2 gas is obtained at the anode as a by product.

$$NaCl(s) \xrightarrow{\text{Electrolysis}} Na^+ \text{ (melt)} + Cl^- \text{ (melt)}$$

At cathode: $Na^+(\text{melt}) + e^- \longrightarrow Na(s)$

At anode: $Cl^-(\text{melt}) \longrightarrow Cl(g) + e^-$

$$2Cl(g) \longrightarrow Cl_2(g)$$

However, if an aqueous solution of NaCl is electrolysed, H_2 gas is evolved at the cathode, while Cl_2 gas is obtained at the anode.

6.25. What is the role of graphite in the electrometallurgy of aluminium?

Ans. Role of graphite in electrometallurgy of Al is to prevent the liberation of O_2 at the anode which may otherwise oxidise some of the liberated Al back to Al_2O_3.

6.26. Outline the principles of refining of metals by following methods:

(*i*) Zone refining (*ii*) Electrolytic refining (*iii*) Vapour phase refining.

Ans. (*i*) **Zone refining:** It is based on the principle that impurities are more soluble in the melt than in the solid state of the metal. The impure metal rod is heated with the help of circular heater from one end. The impurities move along with the heater and reach the other end which is discarded and pure metal is obtained.

(*ii*) **Electrolytic refining:** In this method, impure metal is taken as anode whereas pure metal is taken as cathode.

Soluble salt of the metal is taken as the electrolyte. Impure metal changes into ions and it get attracted towards the cathode to form pure metal.

(*iii*) **Vapour phase refining:** In this process impure metal is treated with suitable reagent to form a volatile compound which get decomposed at high temperature to get pure metal.

6.27. Predict conditions under which Al might be expected to reduce MgO.

Ans. Above 1623 K, Al can reduce MgO to Mg, so that $\Delta_r G°$ becomes –ve and the process becomes thermodynamically feasible.

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

ADDITIONAL QUESTIONS SOLVED

I. Very Short Answer Type Questions

(1 Mark)

Q1. An ore sample of galena (PbS) is contaminated with zinc blende (ZnS). Name one chemical which can be used to concentrate galena selectively by froth floatation method. [CBSE 2009]

Ans. NaCN, sodium cyanide is used as a depressant.

Q2. What is meant by the term 'pyrometallurgy'?

Ans. The process of extracting the metal by heating the metal oxide with a suitable reagent is called pyrometallurgy.

Q3. The reaction, $Cr_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Cr(\Delta G° = -421kJ)$ is thermodynamically feasible as is apparent from Gibbs energy change. Then why does it not take place at room temperature?

Ans. Since in the given redox reaction all the reactants and the products at room temperature are solids, therefore it does not take place at room temperature.

Q4. Give the names of two chief ores of aluminium.

Ans. (*i*) Bauxite: $Al_2O_3 \cdot H_2O$
(*ii*) Cryolite: Na_3AlF_6

Q5. What is the principal ore of Iron?

Ans. Haematite: Fe_2O_3

Q6. Give the name of principal ore of Copper

Ans. Principal ore of copper is copper pyrite, $CuFeS_2$.

Q7. Name the most abundant element in the earth's crust?

Ans. Oxygen

Q8. Name the reducing agent used in the aluminothermic (thermite) process.

Ans. Aluminium

Q9. Name the process of heating in the presence of oxygen so as to convert sulphide ore to oxide ore.

Ans. Roasting.

Q10. Name the process which is used to concentrate or enrich the sulphide ores.

Ans. Froth-Floatation process.

Q11. By allowing crushed ore to flow in a current of water, the lighter impurities are washed away. Name the process.

Ans. Hydraulic washing (navigation)

Q12. Give the formula of (*i*) Haematite, (*ii*) Magnetite.

Ans. (*i*) Fe_2O_3, (*ii*) Fe_3O_4

Q13. What is the principle of separation of metal ions in qualitative analysis?

Ans. If ionic product exceeds K_{SP} compound of the metal is precipitated.

Q14. Name the process in which a particular mineral is dissolved selectively by using acids, bases or other reagents.

Ans. Leaching (chemical separation)

Q15. Name the method by which Na, K, Mg and Al can be extracted.

Ans. Electrolytic reduction

Q16. Name the metal present in (*i*) Chlorophyll, (*ii*) Haemoglobin

Ans. (*i*) Mg (*ii*) Fe

Q17. Name the element present in seaweeds.

Ans. Iodine

Q18. Give the composition of Dolomite.

Ans. Dolomite is $CaCO_3 \cdot MgCO_3$

Q19. Name sulphide ores of

(i) Fe *(ii)* Cu *(iii)* Hg
(iv) Ag *(v)* Pb *(vi)* Zn
(vii) Mn

Ans. (*i*) FeS_2 (Iron pyrites)
(*ii*) $CuFeS_2$ (Copper pyrites)
(*iii*) HgS (Cinnabar)
(*iv*) Ag_2S (Argentite)
(*v*) PbS (Galena)
(*vi*) ZnS (Zinc blende)
(*vii*) MnS (Manganese sulphide)

Q20. Name carbonate ores of
(*i*) Fe (*ii*) Zn (*iii*) Cu
(*iv*) Pb (*v*) Ca (*vi*) Mg

Ans. (*i*) $FeCO_3$ (Siderite)
(*ii*) $ZnCO_3$ (Calamine)
(*iii*) $CuCO_3 \cdot Cu(OH)_2$ (Malachite)
(*iv*) $PbCO_3$ (Cerrusite)
(*v*) $CaCO_3$ (Limestone)
(*vi*) $MgCO_3$ (Magnesite)

Q21. Name halide ores of
(*i*) Ag (*ii*) K (*iii*) Mg (*iv*) Ca

Ans. (*i*) AgCl (Horn silver)
(*ii*) KCl (Sylvine)
(*iii*) $KCl \cdot MgCl_2 \cdot 6H_2O$ (Carnalite)
(*iv*) $CaCl_2$ (Calcium Chloride)

Q22. Name oxide ore of
(*i*) Sn (*ii*) Fe (*iii*) Zn
(*iv*) Cu (*v*) Al (*vi*) Mn

Ans. (*i*) SnO_2 (Tin stone or Cassiterite)
(*ii*) $Fe_2O_3 \cdot xH_2O$ (Haematite)
(*iii*) ZnO (Zincite)
(*iv*) Cu_2O (Cuprite)
(*v*) $Al_2O_3 \cdot 2H_2O$ (Bauxite)
(*vi*) MnO_2 (Pyrolusite)

II. Short Answer Type Questions

(2 *or* 3 *Marks*)

Q1.
(*a*) Name the method used for the refining of
(*i*) Nickel
(*ii*) Zirconium
[*Delhi* 2013 C]
[*AI* 2014]

(*b*) The extraction of Au by leaching with NaCN involves both oxidation and reduction. Justify giving equation.
[*CBSE* 2009]

Ans.
(*a*) (*i*) Mond's process
(*ii*) van Arkel Method

(*b*) $4Au\ (s) + 8CN^-(aq) + 2H_2O\ (aq) + O_2(g) \longrightarrow 4\left[Au(CN)_2\right]^-_{(aq)} + 4OH^-(aq)$

$2\left[Au(CN)_2\right]^-_{(aq)} + Zn\ (s) \longrightarrow 2Au\ (s) + \left[Zn(CN)_4\right]^{-2}_{(aq)}$

In the first reaction Au changes into Au^+, *i.e.* its oxidation takes place. In the second reaction:

$$Au^+ \longrightarrow Au^\circ$$

i.e., reduction takes place.

Q2. Account for the following facts:
(*a*) The reduction of a metal oxide is easier if the metal formed is in liquid state at the temperature of reduction.
(*b*) The reduction of Cr_2O_3 with Al is thermodynamically feasible, yet it does not occur at room temperature.
(*c*) Pine oil is used in froth floatation method. [*CBSE* 2009]

Ans. (*a*) In liquid state entropy is higher than the solid form, this makes $\Delta_r G$ more negative.
(*b*) By increasing the temperature, fraction of activated molecules increases, which helps in crossing over the energy barrier.
(*c*) Pine oil enhances the non-wetting property of the ore particles and also acts as the froth collector.

Q3. Free energies of formation ($\Delta_f G$) of MgO(s) and CO(g) at 1273 K and 2273 K are given below.
$\Delta_f G$ MgO(s) = – 941 kJ/mol at 1273 K
$\Delta_f G$ MgO(s) = – 314 kJ/mol at 2273 K
$\Delta_f G$ CO(g) = – 439 kJ/mol at 1273 K
$\Delta_f G$ CO(g) = – 628 kJ/mol 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).
[*CBSE* 2009]

Ans. The reaction for the reducing action of carbon is

$$MgO(s) + C(s) \longrightarrow Mg(s) + CO(g)$$

$\Delta_r G = \Delta_f G\ (CO) - \Delta_f G\ (MgO)$
At 2273 K
= – 628 – (– 314)
= – 314 kJ/mol at 2273 K

At 1273 K

$\Delta_r G = -439 - (-941)$

$= +502$ kJ/mol at 1273 K

So carbon can be used as a reducing agent with MgO (*s*) at 2273 K.

Q4. Explain the role of

(*i*) Cryolite in the electrolytic reduction of alumina.

(*ii*) Carbon monoxide in the purification of nickel. [*CBSE* 2009]

Ans. The role of cryolite is:

(*i*) to make alumina a good conductor of electricity.

(*ii*) to lower the fusion (melting point) temperature of Al_2O_3.

Q5. What is the chief ore of iron? Write chemical reactions taking place in the extraction of iron from its ore. [*CBSE* 2007]

Ans. Chief ore of iron is haematite (Fe_2O_3). Iron is obtained by the reduction of its ore, haematite (Fe_2O_3) in a blast furnace as follows:

The following reaction takes place in the blast furnace:

(*i*) Coke combines with oxygen to form carbon dioxide.

$C(s) + O_2(g) \longrightarrow CO_2(g) + \text{Heat}$

(*ii*) Due to the intense heat in the furnace, limestone ($CaCO_3$) decomposes to form calcium oxide and carbon dioxide:

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

(*iii*) The carbon dioxide so formed reacts with more coke to form carbon monoxide:

$CO_2(g) + C(s) \longrightarrow 2CO_2(g)$

(*iv*) The iron (III) oxide present in the ore is then reduced by carbon monoxide to form liquid iron. The molten iron is collected at the bottom of the furnace:

$$Fe_2O_3(s) + 3CO(g) \longrightarrow \underset{\text{Liquid form metal}}{2Fe\ (l)} + 3CO_2(g)$$

(*v*) Calcium oxide formed in the reaction (*ii*) reacts with silicon dioxide present in the ore to form molten calcium silicate known as slag:

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

Q6. (*a*) What are the main ores of iron?

(*b*) What is Pig Iron and cast iron?

(*c*) Give the uses of cast iron. [*AI CBSE* 2006]

Ans. (*a*) Main ores of iron:

(*i*) Haematite – Fe_2O_3

(*ii*) Magnetite – Fe_2O_4

(*b*) The iron obtained from the Blast furnace contains about 4% carbon and many impurities in smaller amount and is known as **pig iron.**

Cast iron: It is made by melting the pig iron with scrap iron and coke using hot air blast. It is extremely hard and brittle.

(*c*) **Uses of cast iron:**

(*i*) Cast iron is used for casting stones, railway sleepers, gutter pipes and toys *etc.*

(*ii*) It is used in the manufacture of wrought iron and steel.

Q7. Write the chemical reactions taking place in the extraction of copper from sulphide ores. [*CBSE* 2006]

Ans. Extraction of copper from cuprous oxide: Sulphide ore of copper is heated in the presence of oxygen to form Cu_2O and sulphur dioxide gas.

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

Reduction: The oxide can be reduced to metallic copper using coke as the reducing agent.

$Cu_2O + C \longrightarrow 2Cu + CO$

Q8. (*a*) Write the names of any two principal ores of zinc.

(*b*) What are its uses?

Ans. (*a*) The principal ores of zinc

(*i*) Zinc blende — (ZnS)

(*ii*) Calamine — ($ZnCO_3$)

(*iii*) Zincite — (ZnO)

(*b*) **Uses:**

(*i*) Zinc is used for galvanising iron.

(*ii*) Zinc dust is used as a reducing agent in the manufacture of dye-stuffs paints, *etc.*

Q9. Describe a method for refining nickel.

Ans. Monds process for Refining Nickel: In this process, Nickel is heated in a stream of carbon monoxide forming a volatile complex, Nickel tetracarbonyl.

$$Ni + 4CO \xrightarrow{330 - 350\ K} Ni(CO)_4$$

The carbonyl complex is subjected to further higher temperature, so that it is decomposed to form pure nickel metal

$$\underset{\text{Nickel tetracarbonyl}}{Ni(CO)_4} \xrightarrow{450 - 470\ K} \underset{\text{pure metal}}{Ni} + 4CO$$

Q10. Write the principal ores of each of the following metals:

(*i*) Iron

(*ii*) Copper

(*iii*) Zinc [*CBSE* 2005]

Ans. (*i*) **Iron:** haematite – Fe_2O_3

(*ii*) **Copper:** Malachite – $CuCO_3.Cu(OH)_2$

(*iii*) **Zinc:** Calamine – $ZnCO_3$

Q11. Write down the reactions taking place in different zones is the blast furnace during the extraction of iron? [*AI* 2005]

Ans. In the blast furnace, reduction of iron oxides take place at different temperature. Hot air is blown from the bottom of the furnace and coke is burnt to give a temperature upto 2200 K in the lower portion itself. The burning of coke supplies most of the heat required in this process. The CO formed in the lower portion and heat moves to the upper part of the furnace. The temperature is slightly lower in upper part.

The reduction of Fe_2O_3 takes place at about 500 – 800 K:

$$\underset{\text{(Iron ore)}}{3Fe_2O_3} + CO \longrightarrow 2Fe_3O_4 + CO_2$$

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

At 900–1500 K, carbon dioxide gas reacts with coke to give CO, which combines with FeO to give iron:

$$C + CO_2 \longrightarrow 2CO$$

$$FeO + CO \longrightarrow Fe + CO_2$$

Limestone is decomposed to form CaO which removes silicate impurity of the ore as slag.

$$\underset{\text{Limestone}}{CaCO_3} \longrightarrow CaO + CO_2$$

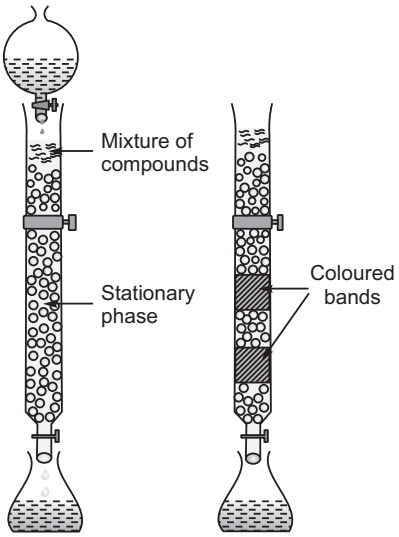
$$CaO + SiO_2 \longrightarrow CaSiO_3$$

The slag in molten state is separated out from the iron metal.

Q12. Outline the principles of refining of metal by chromatographic method. [*CBSE* 2005, 2017]

Ans. Chromatographic method: This method is based on the difference in the extent of adsorption of different components of a mixture on an adsorbent. Later the adsorbed components are removed by using suitable solvent depending upon the physical state of the moving medium and the adsorbent material. Schematic diagrams showing column chromatography is given below.

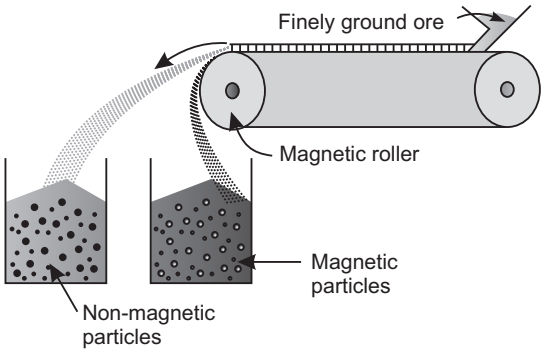
This method is very useful for the purification of the elements which are available in small quantities and impurities associated with them are not very different in chemical properties from the element to be purified.



Column chromatography
(Laboratory method)

Q13. Explain the magnetic separation process.

Ans. It is based on the difference in magnetic properties of the ore components. If either the ore or the gangue is capable of being attracted by a magnetic field, then such separation is carried out. The grounded ore is carried on a conveyer belt which passes over a magnetic roller by which the magnetic and non-magnetic particles gets separated.



Magnetic separation (schematic)

Q14. Complete the following reactions:

(*i*) $ZnS + O_2 \longrightarrow$ .....

(*ii*) $Fe_2O_3 + C \longrightarrow$ .....

(*iii*) $Al_2O_3 + C \longrightarrow$ .....

[*AI* 2003]

Ans. The complete reactions are:

(*i*) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$

(*ii*) $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$

(*iii*) $2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$

Q15. Explain the vapour phase refining method for extraction of metal. Give example.

Ans. **Vapour phase refining:** In this method, the metal is converted into its volatile compound and is collected elsewhere. It is then decomposed to give pure metal. There are two requirements:

(*i*) The metal should form a volatile compound with suitable reagent.

(*ii*) The volatile compound should be easily decomposable, so that recovery is easy.

Example: The Mond's process for the refining of nickel is based on vapour phase refining. In this process, nickel is heated in a stream of carbon monoxide forming a volatile complex, nickel tetracarbonyl.

$$Ni + 4CO \xrightarrow{330 - 350\ K} \underset{\text{Nickel tetracarbonyl}}{Ni(CO)_4}$$

The carbonyl then is complex decomposed to pure metal at high temperature.

$$Ni(CO)_4 \xrightarrow{450 - 470K} Ni + 4CO$$

Q16. What are chief ores of zinc? Write the chemical reactions taking place in the extraction of zinc from zinc blende.

Ans. The chief ores of zinc are:

(*i*) Zinc blende, ZnS

(*ii*) Calamine, $ZnCO_3$

(*iii*) Zincite, ZnO

Extraction of zinc: The zinc from zinc blende is extracted by roasting followed by reduction with coke.

(*a*) **Roasting:** The concentrated ore is heated with oxygen at 900°C in a reverberatory furnace to convert zinc sulphide to zinc oxide.

$$\underset{\text{(zinc blende)}}{2ZnS} + 3O_2 \longrightarrow \underset{\text{(zinc oxide)}}{2ZnO} + 2SO_2$$

(*b*) **Reduction:** The reduction of zinc oxide is done using coke.

$$ZnO + C \xrightarrow{673\ K} Zn + CO$$

The metal is distilled off and collected by rapid chilling.

Q17. Why is leaching of gold by metal cyanides carried out in the presence of oxygen? Give the chemical equation. Name the metal used as a reducing agent.

Ans. The presence of oxygen is necessary to convert gold into the oxidised state.

$$4Au + 8KCN + 2H_2O + O_2 \longrightarrow 4K[Au(CN)_2] + 4KOH$$

$$2K[Au(CN)_2] + Zn \longrightarrow K_2[Zn(CN)_4] + 2Au$$

Metal used in reducing agent = Zinc

Q18. Of the metals Ca, Pb, Al and Cu which ore is extracted from its ore by the electrolytic method and why?

Ans. Ca and Al are extracted by electrolytic reduction method because they are highly reactive metals and they are good reducing agents, therefore they cannot be extracted by chemical reduction method.

Q19. What is van-Arkel method of refining metals? Explain by giving an example.

Ans. This method is used for refining metals like *Zirconium* or *Titanium*. This method is very useful for removing all the oxygen and nitrogen present in the form of impurity in certain metals like Zr and Ti.

The crude metal is then heated in an evacuated vessel with iodine. The metal iodide being more covalent, volatilises:

$$Zr + 2I_2 \longrightarrow ZrI_4$$

The metal iodide is then decomposed on a tungsten filament, electrically heated to about 1800 K. The pure metal is thus deposited on the filament:

$$ZrI_4 \longrightarrow Zr + 2I_2$$

Q20. Copper and silver are below hydrogen in an electrochemical series and yet they are found in the combined state as sulphides in nature. Comment.

Ans. Copper and silver can react with sulphur at high temperature inside the earth crust to form their sulphides although they are less reactive than hydrogen.

Q21. Describe the principles of froth floatation process. What is the role of stabiliser and of a depressant? Give one example for each?

Ans. In this process mineral particles become wet by oils while the gangue particles by water. A rotating paddle agitates the mixture and draws air in it. As a result, froth is formed which carries the mineral particles. The froth is light and is skimmed off. It is then dried for the recovery of the ore particles.

Froth stabilisers—cresol/aniline. (Stabilise the froth)

Depressants—are used to prevent certain types of particles from forming the froth, *e.g.* sodium cyanide is used as a depressant in the separation of ZnS but it does not prevent PbS from coming into the froth. The two ores thus can be easily separated.

Q22. You are provided with samples of some impure metals such as zinc, copper and germanium. Which method would you recommend for the purification of each of these metals?

Ans. Purification of zinc — By electrolytic refining,

Purification of Cu — By electrolytic refining,

Purification of Ge — By Zone refining.

Q23. Discuss some of the factors which need consideration before deciding the extraction of metal from its ore.

Ans. Some of the factors which need consideration before deciding the extraction of metal from its ore are as follows:

(*i*) Type of impurity (*ii*) Type of metal
(*iii*) Available facility
(*iv*) Physical state of the ore.

Q24. Indicate the temperature at which carbon can be used as a reducing agent for FeO.

Ans. Carbon can be used as reducing agent above 1123 K.

Q25. Predict the mode of occurrence of the following three types of metals:
(*i*) Highly reactive (e.g., Na)
(*ii*) Moderately reactive (e.g., Fe)
(*iii*) Noble metal (e.g., Au)

Ans.
(*i*) Highly reactive metal *(e.g.*, Na) occurs in combined state such as rock salt (NaCl).
(*ii*) Moderately reactive (*e.g.*, Fe) occurs in combined state such as oxides (mainly).
(*iii*) Noble metal (*e.g.,* Au) occurs in free state.

Q26. Name the ores which are concentrated by froth floatation process. What is meant by a depressant?

Ans. ZnS (Zinc blende)
$CuFeS_2$ (Copper pyrites)
PbS (Galena)
These are the ores which are concentrated by the froth floatation process.
Depressants are used to prevent certain type of particles from forming the froth.
For example, NaCN acts as a depressant to separate ZnS from PbS.

Q27. Explain smelting with the help of example.

Ans. The process of extracting a metal by reduction of its oxide with carbon (in the form of coke, charcoal or carbon monoxide) is called smelting, *e.g.*
$Fe_2O_3 + 3O \longrightarrow 2Fe + 3CO_2$

Q28. Write briefly the steps to extract lead from galena. Write the chemical reactions involved.

Ans.
(*i*) **Concentration of Ore:** Galena (PbS) is concentrated with the help of froth floatation process.
(*ii*) **Roasting:** Concentrated ore is heated strongly in the presence of oxygen to form oxide.
$2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$
$PbS + 2O_2 \longrightarrow PbSO_4$
(*iii*) **Bessemerisation:**
$PbS + 2PbO \longrightarrow 3Pb + SO_2$
$PbS + PbSO_4 \longrightarrow 2Pb + 2SO_2$
(*iv*) **Electrolytic refining:** It is purified by electrolytic refining using $PbSiF_6$ and H_2SiF_6 as an electrolyte.
Impure Lead is used as anode and pure lead is used as cathode.
At anode: $\underset{\text{impure}}{Pb} \longrightarrow Pb^{2+} + 2e^-$
At cathode: $Pb^{2+} + 2e^- \longrightarrow Pb(s)$

Q29. Differentiate between the following:
(*i*) calcination and roasting (*ii*) gangue and flux.

Ans.

(*i*)

Calcination	Roasting
1. It is a process of heating ore in the absence of air so as to convert carbonate ores into oxides.	1. It is a process in which ore is heated in regular supply of air at a temperature below the melting point of the metal.
2. $CaCO_3 \xrightarrow{\text{heat}} CaO + CO_2$ $ZnCO_3 \xrightarrow{\text{heat}} ZnO + CO_2$	2. $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$ $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$

(*ii*) **Gangue:** The undesirable materials present in the ore are known as gangue.
Flux: Flux is a substance that chemically combines with gangue (earthy impurities) which may still be present in the roasted or the calcined ore to form an easily fusible materials called the slag.
Flux + Gangue $\longrightarrow$ Slag.

Q30. Write the chemical reactions which take place in the following operations:
(*i*) Electrolytic reduction of Al_2O_3
(*ii*) Isolation of Zinc from zinc blende
(*iii*) Monds process of refining nickel

Ans. (*i*) At Cathode:

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

At anode:

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

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

(*ii*) Zinc blende (ZnS) is roasted to form oxides.

The reduction of zinc oxide is done by using coke.

$$ZnO + C \xrightarrow{\text{Coke, 673 K}} Zn + CO$$

(*iii*) $$Ni + 4CO \xrightarrow{330 - 350\ K} \underset{\text{Nickel tetracarbonyl}}{Ni(CO)_4}$$

$$Ni(CO)_4 \xrightarrow{450 - 470\ K} Ni + 4CO$$

Q31. Give examples of the following:
(*a*) Aluminothermic reduction
(*b*) Leaching

Ans.
(*a*) For the reduction of chromium or manganese oxide to ferric oxide

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

(*b*) In the extraction of aluminium, bauxite ore is treated with concentrated NaOH solution.

(*i*) $Al_2O_3(s) + 2OH^-(aq) + 3H_2O \longrightarrow 2Al(OH)_4^-(aq)$

(*ii*) $$Al(OH)_4^-(aq) \xrightarrow[CO_2]{\text{dilution}} Al(OH)_3(s) + OH^-(aq)$$

$$2Al(OH)_3(s) \xrightarrow{\text{heat}} Al_2O_3(s) + 3H_2O(g)$$

Q32. Give the chemical formula of:
(*i*) Chile salt petre
(*ii*) Iron pyrites
(*iii*) Dolomite.

Ans.
(*i*) Chile salt petre: $NaNO_3$
(*ii*) Iron pyrites: FeS_2
(*iii*) Dolomite: $CaCO_3$ $MgCO_3$

Q33. Describe the given methods for the refining of metals.
(*a*) Poling (*b*) Liquation

Ans.
(*a*) **Poling:** It is a process in which metal oxide is converted into the metal with the help of green poles which contains hydrocarbon which acts as a reducing agent.

(*b*) **Liquation:** It is used to purify those metals which have lower melting point than the impurity. For example, Sn has lower melting point than Fe in the impurity. Impure metal is heated at the top of a sloping furnace so that tin melts but iron does not. Molten tin flows down and pure tin is formed.

Q34. Give one example each of
(*i*) Acidic flux
(*ii*) Basic flux

Ans.
(*i*) Acidic flux: SiO_2
(*ii*) Basic flux: $CaCO_3$, $MgCO_3$

Q35. Give two important uses of the following metals:
(*a*) Na (*b*) Mg

Ans.
(*a*) Na: (uses)
(*i*) Na metal in liquid form is used as a coolant in nuclear reactor as a medium for heat exchange.
(*ii*) It is used for making tetraethyl lead which is used as anti knocking agent in petrol.

(*b*) Mg: (uses)
(*i*) It is used in making magnalium alloy which is used for kitchenwares.
(*ii*) It is used for cathodic protection of iron.

Q36. Suggest a condition under which magnesium could reduce alumina.

Ans. The two equations are:

(*a*) $\frac{4}{3}Al + O_2 \longrightarrow \frac{2}{3}Al_2O_3$

(*b*) $2Mg + O_2 \longrightarrow 2MgO$

At the point of intersection of the Al_2O_3 and MgO curves in Ellingham diagram. ΔG° becomes zero for the reaction:

$$\frac{2}{3}Al_2O_3 + 2Mg \longrightarrow 2MgO + \frac{4}{3}Al$$

Below that point magnesium can reduce alumina.

Q37. Although thermodynamically feasible, in practical, magnesium metal is not used for the reduction of alumina in the metallurgy of aluminium. Why?

Ans. Temperature below the point of intersection of Al_2O_3 and MgO curves, magnesium can reduce alumina. But magnesium is a much costlier metal than aluminium and hence the process will be uneconomical.

Q38. Why is the reduction of a metal oxide easier if the metal formed is in liquid state at the temperature of reduction?

Ans. The entropy is higher if the metal is in liquid state than when it is in solid state. The value of entropy change (ΔS) of the reduction process is more on +ve side when the metal formed is in liquid state and the metal oxide being reduced is in solid state. Thus, the value of ΔG° becomes more on negative side and the reduction becomes easier.

Q39. At a site copper ores are available and zinc and iron scraps are also available. Which of the two scraps would be more suitable for reducing and leached copper ore and why?

Ans. Zinc being above iron in the electrochemical series. (more reactive metal is zinc). The reduction will be faster in case when zinc scraps are used. But zinc is costlier metal than iron, so using iron scrap would be more economical.

Q40. Explain the principle of the method of electrolytic refining of metals. Give one example. [*CBSE* 2014]

Ans. Electrolytic refining:

Principle: In this method, an anode of a block of impure metal and a cathode of a thin sheet of pure metal, are suspended in an electrolytic solution which is the solution of a soluble salt of the metal, usually a double salt of the metal. For example, the pure form of copper is obtained by an electrolytic refining method. A slab of impure copper as the anode and a thin sheet of pure copper as the cathode are dipped in the electrolyte which is an acidic solution of copper sulphate. On passing electricity through the cell, copper is dissolved from the anode and deposited on the cathode.

Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

The impurities of iron, nickel, zinc and cobalt present in the blister copper being more electropositive pass into the solution as soluble sulphates. The impurities of antimony, selenium, tellurium, silver, gold and platinum being less electropositive.

Q41. (*i*) Name the method used for the refining of zirconium.

(*ii*) What is the role of CO in the extraction of Iron?

(*iii*) Reduction of metal oxide to metal becomes easier if the metal obtained is in liquid state. Why? [*CBSE* 2015]

Ans. (*i*) The Van Arkel method is used for the refining of zirconium.

(*ii*) CO acts as a reducing agent due to which iron in the ore reduces to iron metal.

(*iii*) Entropy of a metal in the liquid state is higher than that of the same metal in the solid state ($S_{liquid} > S_{solid}$). So, when the metal formed is in the liquid state and the metal oxide being reduced is in the solid state, the value of entropy change (ΔS) for the

reduction reaction is more on the positive side. When the value of $T\Delta S$ increases and that of ΔH remains the same, the value of $\Delta_r G°$ for the reduction reaction becomes negative and thus reduction becomes easier.

Q42. Give reasons:
(*i*) Name the method of refining of nickel.
(*ii*) What is the role of cryolite in the extraction of aluminium?
(*iii*) What is the role of limestone in the extraction of iron from its oxides?
[*CBSE* 2016]

Ans. (*i*) Mond's process.
(*ii*) The function of the cryolite is to lower the fusion temperature from 2050°C to 950°C and to enhance the conductivity.
(*iii*) Limestone decomposes to form CaO which reacts with silicate impurity in the blast furnace to form slag.
$CaCO_3 \rightarrow CaO + CO_2$
$CaO + SiO_2 \rightarrow CaSiO_3$ (slag)

III. Long Answer Type Questions

(5 *Marks*)

Q1. What do you mean by the term 'concentration of ores'? Describe briefly the various methods used for this purpose.

Ans. Concentration of ores: The removal of unwanted earthy and silicious impurities from the ore is called ore-dressing or concentration of the ore.
The finely grounded ore is concentrated by the following methods:
(*i*) **Hand picking:** In case the impurities these are quite distinct from the ore so that these may be differentiated by nacked eye, these may be separated by hand picking.
(*ii*) **Hydraulic washing or levigation or gravity separation:** The process in which lighter earthy particles are freed from the heavier ore particles by washing with water is called levigation. This method is used when the ore particles are heavier than the earthy or rocky gangue particles.
(*iii*) **Electromagnetic separation:** This method of concentration is employed when either the ore or the impurities is associated with it are magnetic in nature. For example, chromite ($FeO.Cr_2O_3$) an ore of chromium magnetite (Fe_3O_4).
(*iv*) **Froth floatation:** This method is based upon the fact that the surface of sulphide ores is preferentially melted by oils while that of gangue is preferentially melted by water. The method is widely used for the concentration of sulphide ores such as Zinc blende (ZnS), copper pyrites ($CuFeS_2$), galena (PbS) *etc.*
(*v*) **Leaching:** The process consists in treating the powdered ore with a suitable reagent, which can selectively dissolve the ore but not the impurities.

Q2. Outline the principles of refining of metals by the following methods:
[CBSE 2017]
(*i*) Zone refining (*ii*) Electrolytic refining
(*iii*) Distillation

Ans. (*i*) **Zone refining:** This method is based on the principle that the impurities are more soluble in the melt than in the solid state of the metal.
A circular mobile heater is fixed at one end of the rod of the impure metal. The molten zone moves along with the heater which is moved forward. As the heater moves forward, the pure metal crystallises out of melt and the impurities pass on into the adjacent molten zone. The process is repeated several times and the heater is moved in the same direction at one end, impurities get concentrated. This method is very useful for producing semiconductor based other metals of very high purity like germanium, silicon, boron *etc.*

(*ii*) **Electrolytic refining:** In this method, the impure metals is made to act as anode. A strip of the same metal in pure form is used as cathode. They are put in a suitable electrolyte both containing soluble salt of the same metal. The move basic metal remains in the solution and the less basic ores go to the anode mud. The reactions are:

Anode: $M \longrightarrow M^{n+} + ne^-$

Cathode: $M^{n+} + ne^- \longrightarrow M$

Copper and zinc are refined by this method.

(*iii*) **Distillation:** In this method, the impure metal is evaporated to obtain the pure metal as a distillate. This method is very useful for low boiling metals like zinc and mercury.

Q3. Name the principle ore of aluminium and describe how aluminium metal is extracted from the ore.

Ans. Extraction of Aluminium:

Principle (main) ore of aluminium is:
Bauxite ($Al_2O_3.H_2O$)
Other ores are:

(*i*) Cryolite—Na_3AlF_6

(*ii*) Orthoclase — $KAlSi_3O_8$

Aluminium metal is extracted from bauxite by a two stage process:

(*i*) Pure (Al_2O_3) is obtained from bauxite.

(*ii*) Electrolysis of Al_2O_3 in molten cryolite (Na_3AlF_6) to obtain aluminium metal.

Stage I:

Leaching: The bauxite ore contains impurities like silica (SiO_2), iron oxide and titanium (IV) oxide. The ore is first treated with sodium hydroxide solution. Aluminium oxide and silica dissolve to form sodium aluminate and sodium silicate, respectively whereas iron oxide and TiO_2 is filtered off.

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

$$Na[Al(OH)_4] \xrightarrow{H_2O} Al(OH)_3 + NaOH$$

The aluminium hydroxide so obtained is filtered, dried and calcined (heated) at 1473 K to get pure alumina.

The process is known as Hall-Heroult process.

$$\underset{\text{Aluminium hydroxide}}{2Al(OH)_3} \longrightarrow \underset{\text{Pure Alumina}}{Al_2O_3} + 3H_2O$$

Stage II: The alumina is dissolved in molten cryolite ($Na_3[AlF_6]$) and then electrolysed in a large steel tank lined with graphite which acts as cathode. The anodes is made of carbon (graphite). On passing current, molten aluminium is produced at the cathode and oxygen gas is evolved at the anode. Oxygen at anode reacts with carbon producing CO and CO_2. The overall reactions may be written as:

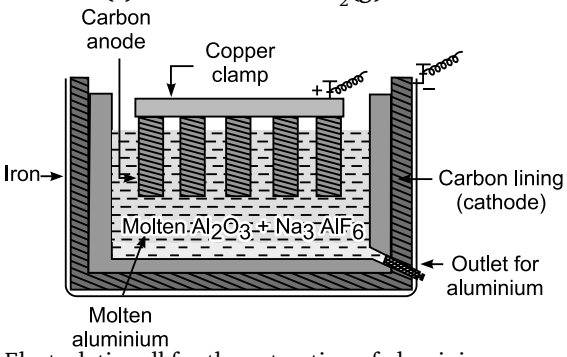
Cathode:

$2Al^{3+}(melt) + 6e^- \longrightarrow 2Al(l)$

Anode:

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

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



Electrolytic cell for the extraction of aluminium

IV. Value-Based Questions

Q1. An innovative washerwoman while washing a copper miner's clothes found that sand and similar dirt particle fell to the bottom, while the ore partiles stuck to the soapsuds and came to the top. The washerwoman discussed this matter with a client who was a chemist.

(*a*) What is the reason for this observation?

(*b*) What value do you get from this episode?

Ans. (*a*) The miner's clothes had particles of CuS/Cu_2S on it. This adhered to the froth and came up.

(*b*) Keen observation can lead to great discoveries.

Q2. Wrought iron is preferred over cast iron for making anchors and railway carriage couplings.

(*i*) Why?

(*ii*) What are the values associated with above?

Ans. (*i*) Wrought iron is resistant to rusting.

(*ii*) Scientific attitude.

Q3. Suresh who runs a school canteen decided to replace the Al containers used for storing water by steel containers even though steel is costlier.

(*i*) Why?

(*ii*) What is the value associated with this dicision?

Ans. (*i*) A layer of oxide of aluminium is formed when water is stored in the aluminium container for a long duration.

(*ii*) Critical thinking and self awareness.

Q4. What is the role of zinc metal in the extraction of silver? [*CBSE* 2014]

Ans. Silver is extracted from the ore-argentite (Ag_2S). This process of extraction of silver is called as cyanide process as sodium cyanide solution is used. The ore is crushed, concentrated and then treated with sodium cyanide solution. This reaction results into sodium argento cyanide $Na[Ag(CN)_2]$. The reaction is as follows:

$$AgS + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S$$

The solution of sodium argento cyanide combines with zinc dust. It forms sodium tetracyanozicate and precipitate silver. This precipitated silver is called as spongy silver. The reaction is as follows:

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

The spongy silver is fused with potassium nitrate to get pure silver. This silver so obtained is purified by electrolytic process.

V. HOTS Questions

Q1. Explain why thermite process is quite useful for repairing the broken parts of a machine?

Ans. In thermite process, oxides of metal are reduced by aluminium in which large amount of heat is evolved, *i.e.*, metal is in the molten state and is allowed to fall in between the broken parts of a machine.

$$Fe_2O_3(s) + 2Al(s) \xrightarrow{\text{heat}} Al_2O_3 + 2Fe(l) + \text{heat}$$

Q2. Why is Zinc and not Copper used for the recovery of Silver from the complex $[Ag(CN)_2]$?

Ans. Zinc is a stronger reducing agent and more electropositive than Copper.

($E^\circ = +0.34$ V)

Q3. How does NaCN act as a depressant in preventing ZnS from forming the froth?

Ans. NaCN forms a layer of zinc complex, $Na_2[Zn(CN)_4]$ on the surface of ZnS and thereby prevents it from the formation of the froth.

Q4. What is pyrometallurgy?

Ans. Extraction of metals using heat is called pyrometallurgy. It involves concentration of ores, roasting, calcination, smelting, reduction and refining of metals. Sulphide, carbonate, oxide ores etc. are subjected to pyrometallurgy.

Q5. What is the role of collector in froth floatation process?

Ans. Collector enhances the non-wettability of the mineral particles.

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