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Preface

"Nothing in life is to be feared, it is only to be understood.
Now is the time to understand more, so that we may fear less."

– ***Marie Curie***

Respected Principals, Correspondents, Head Masters / Head Mistresses, Teachers,

From the bottom of our heart, we at SURA Publications sincerely thank you for the support and patronage that you have extended to us for more than a decade.

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With due respect to Teachers, I would like to mention that this guide will serve as a teaching companion to qualified teachers. Also, this guide will be an excellent learning companion to students with exhaustive exercises and in-text questions in addition to precise answers for textual questions.

In complete cognizance of the dedicated role of Teachers, I completely believe that our students will learn the subject effectively with this guide and prove their excellence in Board Examinations.

I once again sincerely thank the Teachers, Parents and Students for supporting and valuing our efforts.
God Bless all.

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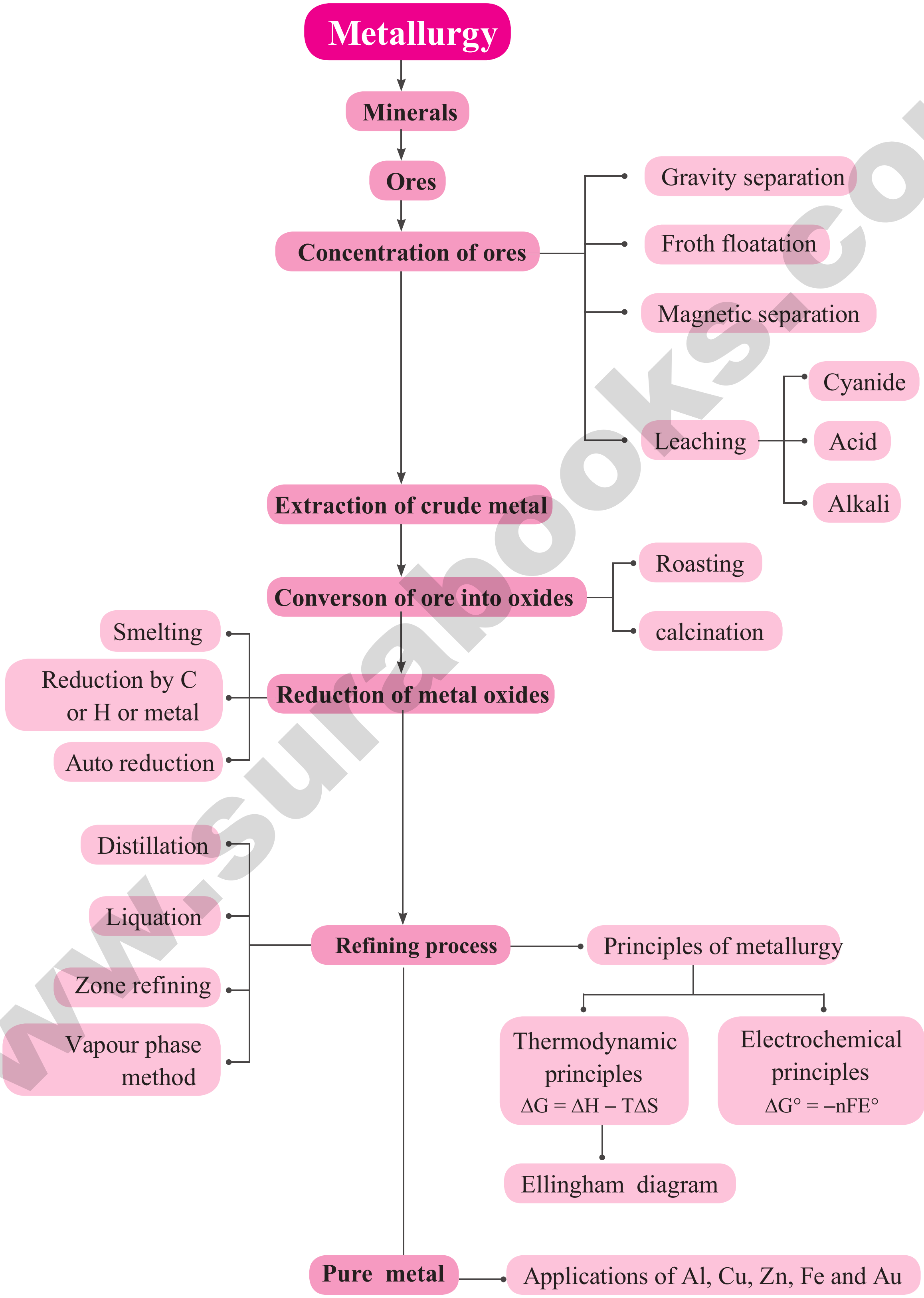
VOLUME - I

UNIT 1
METALLURGY

CHAPTER SNAPSHOT

CONCEPT MAP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Pure metal
Applications of Al, Cu, Zn, Fe and Au

FORMULAE TO REMEMBER

Metal	Ore	Composition	Metal	Ore	Composition
Aluminium	Bauxite	$Al_2O_3.nH_2O$	Zinc	Zinc blende or Sphalerite	ZnS
	Diaspore	$Al_2Si_2O_5(OH)_4$		Calamine	$ZnCO_3$
	Kaolinite	Al_2O_3		Zincite	ZnO
Iron	Haematite	Fe_2O_3	Lead	Galena	PbS
	Magnetite	Fe_3O_4		Anglesite	$PbSO_4$
	Siderite	$FeCO_3$		Cerrusite	$PbCO_3$
	Iron pyrite	FeS_2	Tin	Cassiterite (Tin stone)	SnO_2
	Limonite	$Fe_2O_3.3H_2O$	Silver	Silver glance (Argentite)	Ag_2S
Copper	Copper pyrite	$CuFeS_2$		Pyrargyrite (Ruby silver)	Ag_3SbS_3
	Copper glance	Cu_2S		Chlorargyrite (Horn Silver)	$AgCl$
	Cuprite	Cu_2O		Stefinite	Ag_5SbS_4
	Malachite	$CuCO_3.Cu(OH)_2$		Proustite	Ag_3AsS_3
	Azurite	$2CuCO_3.Cu(OH)_2$			

MUST KNOW DEFINITIONS

Mineral	:	A naturally occurring substance obtained by mining which contains the metal in free state or in the form of compounds like oxides, sulphides etc... is called a **mineral**.
Ores	:	Minerals that contains a high percentage of metal, from which it can be extracted conveniently and economically are called **ores**.
Concentration of Ore	:	The preliminary step in metallurgical process is removal of these impurities. This removal process is known as **concentration of ore**.
Roasting	:	**Roasting** is the method, usually applied for the conversion of sulphide ores into their oxides. The concentrated ore is oxidised by heating it with excess of oxygen in a suitable furnace below the melting point of the metal.
Calcination	:	**Calcination** is the process in which the concentrated ore is strongly heated in the absence of air.
Refining process	:	Removal of such impurities associated with the isolated crude metal is called **refining process**.

Ellingham diagram	:	The graphical representation of variation of the standard Gibbs free energy of reaction for the formation of various metal oxides with temperature is called **Ellingham diagram.**
Application of Ellingham diagram	:	**Ellingham diagram** helps us to select a **suitable reducing agent** and **appropriate temperature** range for reduction.
Electrolytic refining	:	In electrolytic refining of the metal : **Cathode** : Pure metal **Anode** : Impure metal **Electrolyte :** Acidified aqueous solution of salt of the metal

EVALUATION

Choose The Correct Answer

[Please refer to the Textbook Page No. 234 for the explanatory answers for MCQs.]

1. Bauxite has the composition *[HY. '19; May-'22]*

a) Al_2O_3 b) $Al_2O_3.nH_2O$
c) $Fe_2O_3.2H_2O$ d) None of these

[*Ans.* (b) $Al_2O_3.nH_2O$]

2. Roasting of sulphide ore gives the gas (A). (A) is a colourless gas. Aqueous solution of (A) is acidic. The gas (A) is *[FRT-'22]*

a) CO_2 b) SO_3 c) SO_2 d) H_2S

[*Ans.* (c) SO_2]

3. Which one of the following reaction represents calcinations?

a) $2Zn + O_2 \longrightarrow 2ZnO$
b) $2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$
c) $MgCO_3 \longrightarrow MgO + CO_2$
d) Both (a) and (c)

[*Ans.* (c) $MgCO_3 \longrightarrow MgO + CO_2$]

4. The metal oxide which cannot be reduced to metal by carbon is *[QY-'24]*

a) PbO b) Al_2O_3 c) ZnO d) FeO

[*Ans.* (b) Al_2O_3]

5. Which of the metal is extracted by Hall-Heroult process? *[April-'23]*

a) Al b) Ni c) Cu d) Zn

[*Ans.* (a) Al]

6. Which of the following statements, about the advantage of roasting of sulphide ore before reduction is not true?

a) ΔG_f° of sulphide is greater than those for CS_2 and H_2S.
b) ΔG_r° is negative for roasting of sulphide ore to oxide
c) Roasting of the sulphide to its oxide is thermodynamically feasible.
d) Carbon and hydrogen are suitable reducing agents for metal sulphides.

[*Ans.* (d) Carbon and hydrogen are suitable reducing agents for metal sulphides.]

7. Match items in column - I with the items of column – II and assign the correct code. *[June & QY-'23]*

	Column - I		Column - II
A	Cyanide process	(i)	Ultrapure Ge
B	Froth floatation process	(ii)	Dressing of ZnS
C	Electrolytic reduction	(iii)	Extraction of Al
D	Zone refining	(iv)	Extraction of Au
		(v)	Purification of Ni

	A	B	C	D
(a)	(i)	(ii)	(iii)	(iv)
(b)	(iii)	(iv)	(v)	(i)
(c)	(iv)	(ii)	(iii)	(i)
(d)	(ii)	(iii)	(i)	(v)

[Ans. (c) A - (iv), B - (ii), C - (iii), D - (i)]

8. Wolframite ore is separated from tinstone by the process of *[PTA - 2; Mar-2020; HY-'23,'24]*
a) Smelting
b) Calcination
c) Roasting
d) Electromagnetic separation
[Ans. (d) Electromagnetic separation]

9. Which one of the following is not feasible
a) $Zn_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Cu_{(s)} + Zn^{2+}_{(aq)}$
b) $Cu_{(s)} + Zn^{2+}_{(aq)} \longrightarrow Zn_{(s)} + Cu^{2+}_{(aq)}$
c) $Cu_{(s)} + 2Ag^{+}_{(aq)} \longrightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)}$
d) $Fe_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Cu_{(s)} + Fe^{2+}_{(aq)}$
[Ans. (b) $Cu_{(s)} + Zn^{2+}_{(aq)} \longrightarrow Zn_{(s)} + Cu^{2+}_{(aq)}$]

10. Electrochemical process is used to extract
a) Iron b) Lead
c) Sodium d) Silver
[Ans. (c) Sodium]

11. Flux is a substance which is used to convert
a) Mineral into silicate
b) Infusible impurities to soluble impurities
c) Soluble impurities to infusible impurities
d) All of these
[Ans. (b) Infusible impurities to soluble impurities]

12. Which one of the following ores is best concentrated by froth – floatation method? *[Govt.MQP_'19; FRT-'22; June-'24]*
a) Magnetite b) Haematite
c) Galena d) Cassiterite
[Ans. (c) Galena]

13. In the extraction of aluminium from alumina by electrolysis, cryolite is added to
a) Lower the melting point of alumina
b) Remove impurities from alumina
c) Decrease the electrical conductivity
d) Increase the rate of reduction
[Ans. (a) Lower the melting point of alumina]

14. Zinc is obtained from ZnO by *[FRT & July '22]*
a) Carbon reduction
b) Reduction using silver
c) Electrochemical process
d) Acid leaching **[Ans. (a) Carbon reduction]**

15. Extraction of gold and silver involves leaching with cyanide ion. Silver is later recovered by *(NEET-'17)*
a) Distillation b) Zone refining
c) Displacement with zinc
d) liquation
[Ans. (c) Displacement with zinc]

16. Considering Ellingham diagram, which of the following metals can be used to reduce alumina? *(NEET-'18; QY-'23)*
a) Fe b) Cu c) Mg d) Zn
[Ans. (c) Mg]

17. The following set of reactions are used in refining Zirconium *[Aug-'21]*

$$Zr(\text{impure}) + 2I_2 \xrightarrow{523K} ZrI_4.$$

$$ZrI_4 \xrightarrow{1800K} Zr(\text{pure}) + 2I_2$$

This method is known as
a) Liquation b) Van Arkel process
c) Zone refining d) Mond's process
[Ans. (b) van Arkel process]

18. Which of the following is used for concentrating ore in metallurgy?
a) Leaching b) Roasting
c) Froth floatation d) Both (a) and (c)
[Ans. (d) Both (a) and (c)]

19. The incorrect statement among the following is *[QY. '19; Sep-2020]*
a) Nickel is refined by Mond's process.
b) Titanium is refined by Van Arkel's process.
c) Zinc blende is concentrated by froth floatation.
d) In the metallurgy of gold, the metal is leached with dilute sodium chloride solution.
[Ans. (d) In the metallurgy of gold, the metal is leached with dilute sodium chloride solution]

20. In the electrolytic refining of copper, which one of the following is used as anode? *(Mar-'24)*
a) Pure copper b) Impure copper
c) Carbon rod d) Platinum electrode
[Ans. (b) Impure copper]

21. Which of the following plot gives Ellingham diagram?

a) ΔS Vs T b) ΔG° Vs T

c) ΔG° Vs $\frac{1}{T}$ d) ΔG° Vs T^2

[*Ans.* (b) ΔG° Vs T]

22. In the Ellingham diagram, for the formation of carbon monoxide

a) $\left(\frac{\Delta S^\circ}{\Delta T}\right)$ is negative

b) $\left(\frac{\Delta G^\circ}{\Delta T}\right)$ is positive

c) $\left(\frac{\Delta G^\circ}{\Delta T}\right)$ is negative

d) initially $\left(\frac{\Delta T}{\Delta G^\circ}\right)$ is positive, after 700°C, $\left(\frac{\Delta G^\circ}{\Delta T}\right)$ is negative

[*Ans.* (c) $\left(\frac{\Delta G^\circ}{\Delta T}\right)$ is negative]

23. Which of the following reduction is not thermodynamically feasible? *[PTA - 3]*

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

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

c) $3TiO_2 + 4Al \longrightarrow 2\ Al_2O_3 + 3Ti$

d) none of these

[*Ans.* (b) $Al_2O_3 + 2Cr \longrightarrow Cr_2O_3 + 2Al$]

24. Which of the following is not true with respect to Ellingham diagram?

a) Free energy changes follow a straight line. Deviation occurs when there is a phase change.

b) The graph for the formation of CO_2 is a straight line almost parallel to free energy axis.

c) Negative slope of CO shows that it becomes more stable with increase in temperature.

d) Positive slope of metal oxides shows that their stabilities decrease with increase in temperature.

[*Ans.* (b) The graph for the formation of CO_2 is a straight line almost parallel to free energy axis.]

Q & A Answer the Following Questions

1. What are the differences between minerals and ores? *[QY_'19 & '23; Sep-2020; FRT, May-'22; Mar-'24]*

Ans.

Minerals	Ores
A naturally occurring substance obtained by mining which contains the metal in free state or in the form of compounds.	Ore contains a high percentage of metal, from which it can be extracted conveniently and economically.
All minerals are not ores	All ores are Minerals
It contains a low percentage of metal.	It contains a high percentage of metals
Ex : Mineral of Al is bauxite and china clay	**Ex :** Ore of Al is bauxite

2. What are the various steps involved in extraction of pure metals from their ores? *[June & QY-'24]*

Ans. The extraction of crude metals from the concentrated ores is carried out in two steps namely,

(i) Conversion of the ore into oxides of the metal of interest and

(ii) Reduction of the metal oxides to elemental metals.

3. What is the role of quick lime in the extraction of Iron from its oxide Fe_2O_3?

Ans. *(i)* Quick lime acts as a Flux.

(ii) It combine with silica and get converted into Calcium silicate called as slag.

$$\underset{\text{Flux}}{CaO_{(s)}} + \underset{\text{Gangue}}{SiO_{2(s)}} \longrightarrow \underset{\text{Slag}}{CaSiO_{3(s)}}$$

4. Which type of ores can be concentrated by froth floatation method? Give two examples for such ores. *[FRT-'22; April & QY-'23 & '24]*

Ans. *(i)* Sulphide ores can be concentrated by froth floatation method.

(ii) **Ex :** Lead sulphide **galena** (PbS) and zinc blende (ZnS).

5. Describe a method for refining nickel. *[PTA - 3; May-'22; June & HY-'23]*

Ans. Mond process for refining nickel :

(i) The impure nickel is heated in a stream of carbon monoxide at around 350K.

(ii) The nickel reacts with the CO to form a highly volatile nickel tetracarbonyl.

(iii) The solid impurities are left behind.

$$Ni_{(s)} + 4CO_{(g)} \xrightarrow{350\ K} [Ni(CO)_4]_{(g)}$$

(iv) On heating the nickel tetracarbonyl around 460K, the complex decomposes to give pure metal.

$$[Ni(CO_4)]_{(g)} \xrightarrow{460\ K} Ni_{(s)} + 4CO_{(g)}$$

6. Explain zone refining process with an example. *[PTA - 6; Mar-2020; FRT-'22; April-'23; QY-'24]*

Ans. *(i)* This method is based on the Fractional Crystallisation. The impure metal is melted and allowed to solidify, the impurities prefer to remain in the molten region.

(ii) The impure metal is taken in the form of a rod.

(iii) When the metal rod is heated with a heater the metal melts.

(iv) The heater is slowly moved from one end to the other end.

(v) The impurity dissolves in the molten zone.

(vi) When the heater moves, the molten zone also moves.

(vii) This process is repeated again and again to get pure metal.

(viii) The process is carried in an inert gas atmosphere to prevent the oxidation of metals.

Example :

Elements such as Germanium (Ge), Silicon (Si) and Gallium (Ga) are refined using this process.

7. Using the Ellingham diagram,

(A) Predict the conditions under which

(i) Aluminium might be expected to reduce magnesia.

(ii) Magnesium could reduce alumina.

(B) It is possible to reduce Fe_2O_3 by coke at a temperature around 1200 K.

Ans. (A) (i)

✻ Ellingham diagram for the formation of Al_2O_3 and MgO intersects around 1600 K.

✻ Above this temperature aluminium lines lies below the magnesium line.

✻ Hence we can use aluminium to reduce magnesia above 1600 K.

(ii)

✻ In Ellingham diagram below 1600 K magnesium line lies below aluminium line.

✻ Hence, below 1600 K magnesium can reduce alumina.

(B)

(i) In Ellingham diagram above 1000 K carbon line lies below the iron line.

(ii) Hence, it is possible to reduce Fe_2O_3 by coke at a temperature around 1200 K.

8. Give the uses of zinc. *[PTA - 4]*

Ans. *(i)* Metallic zinc is used in **galvanising** metals such as iron and steel structures to protect them from rusting and corrosion.

(ii) Zinc is also used to produce die-castings in the automobile, electrical and hardware industries

(iii) Zinc oxide is used in the manufacture of many products such as paints, rubber, cosmetics, pharmaceuticals, plastics, inks, batteries, textiles and electrical equipment.

(iv) Zinc sulphide is used in making luminous paints, fluorescent lights and x-ray screens.

(v) Brass an alloy of zinc is used in water valves and communication equipment as it is highly resistant to corrosion.

9. Explain the electrometallurgy of aluminium. *[Govt.MQP_'19; June & HY-'24]*

Ans. Hell - Herold Process :

Cathode : Iron tank lined with carbon

Anode : Carbon blocks

Electrolytes : 20% solution of alumina obtained from bauxite + Molten cryolite + Calcium chloride (lowers the melting point of the mixture)

Temperature : Above 1270 K

Ionization of alumina

$$Al_2O_3 \longrightarrow 2Al^{3+} + 3O^{2-}$$

Reaction at cathode

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

Reaction at anode

$$6O^{2-}\ (melt) \longrightarrow 3O_2 + 12e^-$$

(i) Since carbon acts as anode the following reaction takes place.

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

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

(ii) During electrolysis anodes are slowly consumed due to the above two reactions.

(iii) Aluminium is formed at the cathode and settles at the bottom.

(iv) Net electrolysis reaction is

$$4Al^{3+}\text{ (melt)} + 6O^{2-}\text{ (melt)} + 3C_{(s)} \longrightarrow 4Al_{(l)} + 3CO_{2(g)}$$

10. Explain the following terms with suitable examples. *[PTA - 2; Sep-2020; FRT-'22; QY-'24]*

(i) Gangue (ii) Slag

Ans. (i) **Gangue :** The non-metallic impurities, rocky materials and siliceous matter, associated with the ore is called gangue.

Example : SiO_2 is the gangue present in the iron ore.

(ii) **Slag :** Slag is the fusible product formed when flux reacts with gangue during the extraction of metal.

Example :

$$\underset{\text{Flux}}{CaO_{(s)}} + \underset{\text{Gangue}}{SiO_2} \longrightarrow \underset{\text{(slag)}}{CaSiO_3}$$

11. Give the basic requirement for vapour phase refining. *[HY -'24]*

Ans. (i) The metal should form a volatile compound when treated with a suitable reagent.

(ii) Then the volatile compound is decomposed to give the pure metal.

12. Describe the role of the following in the process mentioned.

(i) Silica in the extraction of copper.

(ii) Cryolite in the extraction of aluminium. *[QY_'19]*

(iii) Iodine in the refining of Zirconium. *[QY_'19]*

(iv) Sodium cyanide in froth floatation.

Ans. (i) Silica, is used as an acidic flux is used to remove slag during the process of roasting.

(ii) Lowers the melting point to 1173K and improves the electrical conductivity of the aluminium.

(iii) To form a volatile compound which on further heating decomposes to give pure Zn.

(iv) Sodium cyanide is used as an depressing agent in froth flotation. It prevents other metal sulphides coming to the froth.

For Example, when impurities such as ZnS is present in galena (PbS), sodium cyanide (NaCN) is added to depresses the flotation property of ZnS by forming a layer of zinc complex $Na_2[Zn(CN)_4]$ on the surface of zinc sulphide.

13. Explain the principle of electrolytic refining with an example. *[HY-'19; July-'22]*

Ans. (i) Electrolytic refining is carried out in an electrolytic cell.

(ii) **Anode** : Impure metal

Cathode : Thin strips of pure metal

Electrolyte : Aqueous solution of the salts of the metal.

(iii) The metal of interest dissolves from the anode, pass into the solution while the same amount of metal ions from the solution will be deposited at the cathode.

(iv) During electrolysis, the less electropositive impurities in the anode, settle down at the bottom and are removed as anode mud.

(v) Electrolytic refining of silver as an example.

Cathode : Pure silver

Anode : Impure silver rods

Electrolyte : Acidified aqueous solution of silver nitrate.

(vi) When a current is passed through the electrodes the following reactions will take place

Reaction at anode

$$Ag_{(s)} \longrightarrow Ag^+_{(aq)} + 1e^-$$

Reaction at cathode

$$Ag^+_{(aq)} + 1e^- \longrightarrow Ag_{(s)}$$

(vii) During electrolysis, at the anode the silver atoms lose electrons and enter the solution.

(viii) The positively charged silver cations migrate towards the cathode and get discharged by gaining electrons and deposited on the cathode.

14. The selection of reducing agent depends on the thermodynamic factor: Explain with an example.

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

(ii) The thermodynamic factor has a major role in selecting the reducing agent for a particular reaction. Only that reagent will be preferred which will lead to a decrease in the free energy (AG°) at a certain specific temperature.

E.g – Carbon reduce ZnO to Zn but not CO.

✲ $ZnO + C \rightarrow Zn + CO$ ...(1)

✲ $ZnO + CO \rightarrow Zn + CO_2$ ...(2)

(iii) In the first case, there is increase in the magnitude of $\Delta S°$ while in the second case, it almost remains the same. In other words, $\Delta G°$ will have more negative value in the first case, when C is the reducing agent then in the second case when CO acts as the reducing agent.

(iv) Therefore, C is a better reducing agent.

15. Give the limitations of Ellingham diagram. *[June & HY-23]*

Ans. *(i)* Ellingham diagram is constructed based only on thermodynamic considerations.

(ii) It does not tell anything about the rate of the reaction.

(iii) The interpretation of ΔG is based on the assumption that the reactants are in equilibrium with the products which is not always true.

16. Write a short note on electrochemical principles of metallurgy.

Ans. *(i)* Electrochemical principles also find applications in metallurgical process.

(ii) The reduction of oxides of active metals such as sodium, potassium etc., by carbon is thermodynamically not feasible.

(iii) Such metals are extracted from their ores by using electrochemical methods.

(iv) In this technique, the metal salts are taken in a fused form or in solution form.

(v) The metal ion present can be reduced by treating it with some suitable reducing agent or by electrolysis.

(vi) Gibbs free energy change for the electrolysis process is given by the following expression

$$\Delta G° = -nFE°$$

(vii) Where n is number of electrons involved in the reduction process, F is the Faraday and E^0 is the electrode potential of the redox couple.

(viii) If E^0 is positive then the ΔG is negative and the reduction is spontaneous and hence a redox reaction is planned in such a way that the e.m.f of the net redox reaction is positive.

(ix) When a more reactive metal is added to the solution containing the relatively less reactive metal ions, the more reactive metal will go into the solution.

(x) For example,

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$$

$$Cu^{2+}_{(aq)} + Zn_{(s)} \longrightarrow Cu_{(s)} + Zn^{2+}_{(aq)}$$

EVALUATE YOURSELF

1. Write the equation for the extraction of silver by leaching with sodium cyanide and show that the leaching process is a redox reaction.

Ans. The crushed ore of argentite (Ag_2S) is leached with sodium cyanide solution. This reaction forms sodium Argento cyanide $Na[Ag(CN)_2]$

Step 1 :

$$Ag_2S + 4NaCN \rightleftharpoons 2Na[Ag(CN)_2] + Na_2S$$

The solution of sodium Argento cyanide combines with zinc dust and forms sodium tetra cyano zincate and precipitated silver.

Step 2 :

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

In the step 2, redox reaction take place.

$$\overset{(0)}{Zn} \longrightarrow \overset{(2+)}{Zn} \text{ (oxidation)}$$

$$\overset{(+1)}{Ag} \longrightarrow \overset{(0)}{Ag} \text{ (reduction)}$$

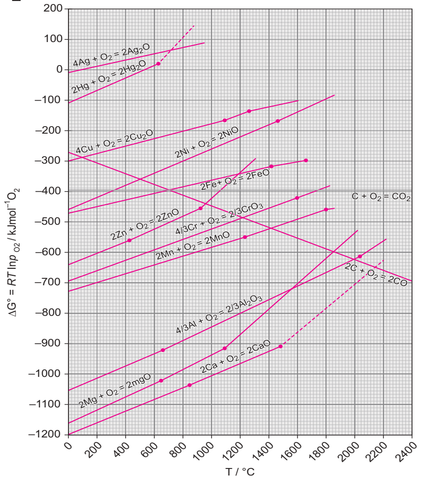
$$\overset{(0)}{Zn} \xrightarrow{\text{(oxidation)}} \overset{(2+)}{Na_2[Zn(CN)_4]}$$

$$\overset{(+1)}{Na[Ag(CN)_2]} \xrightarrow{\text{(reduction)}} \overset{(0)}{2Ag\downarrow}$$

2. Magnesite (Magnesium carbonate) is calcined to obtain magnesia, which is used to make refractory bricks. Write the decomposition reaction.

Ans. $MgCO_3 \xrightarrow{800° \text{ C to } 1000° \text{ C}} MgO + CO_2\uparrow$

3. Using Ellingham diagram (fig) indicate the lowest temperature at which ZnO can be reduced to Zinc metal by carbon. Write the overall reduction reaction at this temperature.



Ans. (*i*) Ellingham diagram for the formation of ZnO and CO intersects around 1200 K.

(*ii*) Below this temperature the carbon line lies above zinc line.

(*iii*) Hence ZnO is more stable than CO so the reduction is thermodynamically not feasible at this temperature range.

(*iv*) However above 1200 K carbon line lies below the zinc line, hence carbon can be used as a reducing agent above 1200 K.

$2Zn + O_2 \longrightarrow 2ZnO$ ......(1)

$2C + O_2 \longrightarrow 2CO$ ......(2)

(*v*) Reversing (1) and adding with eqn. (2)

$2ZnO \longrightarrow 2\,Zn + O_2$

$2C + O_2 \longrightarrow 2\,CO$

$2ZnO + 2C \longrightarrow 2Zn + 2CO$

4. Metallic sodium is extracted by the electrolysis of brine (aq.NaCl). After electrolysis the electrolytic solution becomes basic in nature. Write the possible electrode reactions.

Ans. **Brine is a solution of sodium chloride (molten state):** The process of electrolysis involves using an electric current to bring about a chemical change and make new chemicals. In the electrolysis of brine, sodium ions migrate to the cathode, where electrons enter the melt and are reduced to sodium metal.

$Na^+ + e^- \longrightarrow Na$ (at cathode)

Chloride ions migrate the other way toward the anode. They give up their electrons to the anode and are oxidised to chlorine gas.

$Cl^- \longrightarrow \frac{1}{2}Cl_2 + e^-$ (at anode)

Overall reaction:

$2NaCl \longrightarrow 2Na(s) + Cl_2\,(g)$

For aqueous solution of NaCl:

$H_2O + 2e^- \rightarrow H_2\uparrow + 2OH^-$ (at cathode)

$Cl^- \longrightarrow \frac{1}{2}Cl_2 + e^-$ (at anode)

Overall reaction:

$NaCl\ (aq) + H_2O(1) \rightarrow Na^+(aq) + OH^-(aq) + H_2(g) + \frac{1}{2}Cl_2(g)$

After electrolysis the electrolytic solution becomes basic in nature. [Due to formation of hydroxide (OH^-) ion].

(PTA) Model Questions And Answers

Choose the Correct Answer — 1 Mark

1. Sulphide ores of metals are usually concentrated by froth floatation process. Which one of the following sulphide ore offers an exception and is concentrated by chemical leaching. *[PTA - 4]*

a) Argentite b) galena c) Copper pyrites d) Sphalerite

[*Ans.* (a) Argentite]

2. Which method of purification represented by the equation? *[PTA - 5]*

$$\mathbf{Ti(impure) + 2I_2 \xrightarrow{550K} TiI_4 \xrightarrow{1800K} Ti(pure) + 2I_2}$$

a) Cupellation b) Zone refining c) Van - Arkel method d) Mond's process

[*Ans.* (c) Van - Arkel method]

3. The process of converting hydrated alumina into anhydrous alumina is called. *[PTA - 6]*

a) Roasting b) Smelting
c) Auto-reduction d) Calcination

[Ans. (d) Calcination]

4. Elements like silicon and Germanium to be used as a semiconductor is purified by

a) heating under vacuum *[PTA - 1]*
b) Van - Arkel method c) Zone refining
d) Electrolysis **[Ans. (c) Zone refining]**

Answer The Questions 2 marks

1. What is the role of depressing agent in froth floatation process? *[PTA - 1]*

Ans. When impurities such as ZnS is present in galena (PbS), sodium cyanide (NaCN) is added to depresses the flotation property of ZnS by forming a layer of zinc complex $Na_2[Zn(CN)_4]$ on the surface of zinc sulphide.

2. Describe the underlying principle of froth flotation process. *[PTA - 3]*

Ans. Froth flotation process is based on the principle that the ore particles are wetted by oil and the gangue particles by water. This is used for the concentration of sulphide ores.

Answer The Questions 3 marks

1. What is the role of graphite rods in the electro metallurgy of aluminium? *[PTA - 1]*

Ans. *(i)* Graphite rods act as **anode** during electrolytic reduction of alumina.

(ii) At anode, O_2 gas is produced which react with the carbon of anode (rods) to produce CO_2 gas.

(iii) So these graphite rods are consumed slowly and need to be replaced from time to time.

2. Define roasting. *[PTA - 4]*

Ans. In roasting, the concentrated ore is oxidised by heating it with excess of oxygen in a suitable furnace below the melting point of the metal.

$$2PbS + 3O_2 \xrightarrow{\Delta} 2PbO + 2SO_2 \uparrow$$

3. Explain calcination with an example. *[PTA - 4; Mar-'24]*

Ans. *(i)* Calcination is the process in which the concentrated ore is strongly heated in the absence of air.

(ii) During this process, the water of crystallisation present in the hydrated oxide escapes as moisture.

(iii) Any organic matter (if present) also get expelled leaving behind a porous ore.

(iv) This method can also be carried out with a limited supply of air.

(v) During calcination of carbonate ore, carbon dioxide is expelled

$$PbCO_3 \xrightarrow{\Delta} PbO + CO_2\uparrow$$

Answer The Questions 5 marks

1. Explain electrolytic refining of silver. *[PTA - 5]*

Ans. *(i)* Electrolytic refining of silver as an example.

Cathode : Pure silver
Anode : Impure silver rods
Electrolyte : Acidified aqueous solution of silver nitrate.

(ii) When a current is passed through the electrodes the following reactions will take place

Reaction at anode

$$Ag_{(s)} \longrightarrow Ag^+_{(aq)} + 1e^-$$

Reaction at cathode

$$Ag^+_{(aq)} + 1e^- \longrightarrow Ag_{(s)}$$

2. Explain extraction of copper from copper pyrites. *[PTA - 5]*

Ans. *(i)* In this method, a flux (a chemical substance that forms an easily fusible slag with gangue) and a reducing agent such as carbon, carbon monoxide (or) aluminium is added to the concentrated ore and the mixture is melted by heating at an elevated temperature (above the melting point of the metal) in a smelting furnace.

(ii) For example the oxide of iron can be reduced by carbon monoxide as follows.

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(s)} + 3CO_{2(g)}\uparrow$$

(iii) In this extraction, a basic flux, limestone (CaO) is used. Since the silica gangue present in the ore is acidic in nature, the limestone combines with it to form calcium silicate (slag).

$$\underset{\text{Flux}}{CaO_{(s)}} + \underset{\text{Gangue}}{SiO_{2(s)}} \longrightarrow \underset{\text{Slag}}{CaSiO_{3(s)}}$$

(iv) In the extraction of copper from copper pyrites, the concentrated ore is heated in a reverberatory furnace after mixing with silica, an acidic flux.

(v) The ferrous oxide formed due to melting is basic in nature and it combines with silica to form ferrous silicate (slag).

(vi) The remaining metal sulphides Cu_2S and FeS are mutually soluble and form a copper matte.

$$2CuFeS_{2(s)} + O_{2(g)} \longrightarrow 2FeS_{(l)} + Cu_2S_{(l)} + SO_{2(g)}$$

$$2FeS_{(l)} + 3O_{2(g)} \longrightarrow 2FeO_{(l)} + 2SO_{2(g)}$$

$$\underset{\text{Flux}}{FeO_{(s)}} + \underset{\text{Gangue}}{SiO_{2(s)}} \longrightarrow \underset{\text{Slag}}{FeSiO_{3(s)}}$$

(vii) The matte is separated from the slag and fed to the converting furnace.

(viii) During conversion, the FeS present in the matte is first oxidised to FeO.

(ix) This is removed by slag formation with silica.

(x) The remaining copper sulphide is further oxidised to its oxide which is subsequently converted to metallic copper.

$$2Cu_2S_{(l,s)} + 3O_{2(g)} \longrightarrow 2Cu_2O_{(l,s)} + 2SO_{2(g)}$$

$$2Cu_2O_{(l)} + Cu_2S_{(l)} \longrightarrow 6Cu_{(l)} + SO_{2(g)}$$

(xi) The metallic copper is solidified and it has blistered appearance due to evolution of SO_2 gas formed in this process. This copper is called blistered copper.

Government Exam Questions And Answers

Choose the Correct Answer — 1 Mark

1. The metal which is used in packing material for food items : *[Sep-2020]*

(a) Zn (b) Zr (c) Al (d) Au

[Ans. (c) Al]

2. CaO (flux) + SiO_2 (gangue) → ? (slag) *[FRT-'22]*

(a) $CaSiO_2$ (b) $CaSiO_3$

(c) Ca_2SiO_4 (d) Ca_3SiO_4

[Ans. (b) $CaSiO_3$]

3. Titanium is purified by : *[FRT-'22]*

(a) Mond process (b) Electrolytic refining

(c) Van-Arkel process (d) Liquation

[Ans. (c) Van-Arkel process]

Answer The Questions — 2 Marks

1. Oxides like Ag_2O and HgO undergo self reduction. Why? *[QY_'19]*

Ans. Decomposition temperature of Ag_2O and HgO are 600 and 700 K respectively.

These oxides are unstable at moderate temperatures undergo self reduction.

2. Name the collector and depressing agent used in froth flotation process. *[HY_'19]*

Ans. *(i)* Sodium ethyl xanthate acts as a collector.

(ii) Sodium cyanide, Sodium carbonate are used as depressing agents in froth flotation process.

3. How is metal purified by distillation method? Give example. *[FRT-'22]*

Ans. Distillation method is employed for low boiling volatile metals like zinc (boiling point 1180 K) and mercury (630 K). In this method, the impure metal is heated to evaporate and the vapours are condensed to get pure metal.

Answer The Questions — 3 Marks

1. Explain how gold ore is leached by cyanide process *[Govt. MQP_'19]*

Ans. *(i)* Gold is usually found in native state.

(ii) The leaching process is intended to concentrate the gold metal.

$$4Au_{(s)} + 8\,NaCN^{-}_{(aq)} + 2H_2O_{(aq)} + O_{2(g)} \longrightarrow 4\,Na\,[Au(CN)_2]^{-}_{(aq)} + 4NaOH^{-}_{(aq)}$$

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

(iii) In this reaction, gold is reduced to its elemental state and the process is called cementation.

2. How is Ni purified by Mond process? *[FRT-'22]*

Ans. The impure nickel is heated in a stream of carbon monoxide at around 350 K. The nickel reacts with the CO to form a highly volatile nickel tetracarbonyl. The solid impurities are left behind.

$Ni\,(s) + 4\,CO\,(g) \longrightarrow [Ni(CO)_4]\,(g)$

On heating the nickel tetracarbonyl around 460 K, the complex decomposes to give pure metal.

$[Ni(CO)_4]\,(g) \longrightarrow Ni\,(s) + 4\,CO\,(g)$

3. Write a note on gravity separation method. *[May-'22]*

Ans. *(i)* In gravity separation method, the ore having high specific gravity is separated from the gangue that has low specific gravity by washing with running water.

(ii) Ore is crushed to a finely powdered form and treated with rapidly flowing current of water.

(iii) During this process the lighter gangue particles are washed away by the running water.

(iv) This method is generally applied to concentrate the native ore such as gold and oxide ores such as haematite (Fe_2O_3), tin stone (SnO_2) etc.

4. How is acid leaching done for the sulphide ores? (or) Explain Acid Leaching with an example. *[July-'22; HY-'23]*

Ans. *(i)* Leaching of sulphide ores such as ZnS, PbS etc., can be done by treating them with hot aqueous sulphuric acid.

$$2ZnS\,(s) + 2H_2SO_4(aq) + O_2\,(g) \longrightarrow 2ZnSO_4\,(aq) + 2S\,(s) + 2H_2O$$

(ii) In this process the insoluble sulphide is converted into soluble sulphate and elemental sulphur.

5. What is the role of silica in the extraction of copper? *[Mar-'24]*

Ans. *(i)* Copper is extracted form copper matte which contains iron as impurity.

(ii) Silica is added to remove this impurity as iron silicate in the form of **Fusible slag**.

$$\underset{\text{Impurity}}{FeO} + SiO_2 \longrightarrow \underset{\text{Iron silicate (slag)}}{FeSiO_3}$$

Answer The Questions — 5 Marks

1. In metallurgy roasting of ore is done below its melting points whereas smelting is done above its melting point Why? *[QY_'19]*

Ans. **Roasting :** Roasting is the method the sulphide ore is converted into oxide ore below its melting only it exist in solid.

Smelting : Smelting is a chemical substance that forms an easily fusible slag with gangue.

2. What are the main observations of Ellingham diagram? *[QY_'19]*

Ans. **Observations from the Ellingham diagram.**

(i) For most of the metal oxide formation, the slope is positive. It can be explained as follows. Oxygen gas is consumed during the formation of metal oxides which results in the decrease in randomness. Hence, ΔS becomes negative and it makes the term, $T\Delta S$ positive in the straight line equation.

(ii) The graph for the formation of carbon monoxide is a straight line with negative slope. In this case ΔS is positive as 2 moles of CO gas is formed by the consumption of one mole of oxygen gas. It indicates that CO is more stable at higher temperature.

(iii) As the temperature increases, generally ΔG value for the formation of the metal oxide become less negative and becomes zero at a particular temperature. Below this temperature, ΔG is negative and the oxide is stable and above this temperature ΔG is positive. This general trend suggests that metal oxides become less stable at higher temperature and their decomposition becomes easier.

(iv) There is a sudden change in the slope at a particular temperature for some metal oxides like MgO, HgO. This is due to the phase transition (melting or evaporation).

3. Explain froth flotation, with diagram. *[Aug-'21; QY-'23]*

Ans. *(i)* Froth flotation method is commonly used to concentrate sulphide ores such as galena (PbS), zinc blende (ZnS) etc.

(ii) In this method, the metallic ore particles which are preferentially wetted by oil can be separated from gangue.

(iii) In this method, the crushed ore is suspended in water and mixed with frothing agent such as pine oil, eucalyptus oil etc.

(iv) A small quantity of sodium ethyl xanthate which acts as a collector is also added.

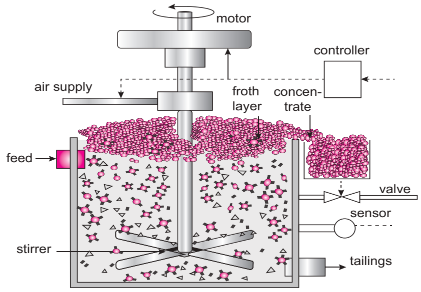
(v) A froth is generated by blowing air through this mixture.

(vi) The collector molecules attach to the ore particle and make them water repellent.

(vii) As a result, ore particles, wetted by the oil, rise to the surface along with the froth.

(viii) The froth is skimmed off and dried to recover the concentrated ore.

(ix) The gangue particles that are preferentially wetted by water settle at the bottom.



Froth Flotation

4. (i) What is auto reduction?
(ii) How is silver purified by electrolytic refining process? *[FRT-'22]*

Ans. (i) Simple roasting of some of the ores give the crude metal. In such cases, the use of reducing agents is not necessary. For example, mercury is obtained by roasting of its ore cinnabar (HgS)

$$HgS\,(s) + O_2\,(g) \longrightarrow Hg\,(l) + SO_2\uparrow$$

(ii) Cathode : Pure silver
Anode : Impure silver rods
Electrolyte : Acidified aqueous solution of silver nitrate.
When a current is passed through the electrodes the following reactions will take place

Reaction at anode $Ag\,(s) \longrightarrow Ag^+\,(aq) + 1e^-$
Reaction at cathode $Ag^+\,(aq) + 1e^- \longrightarrow Ag(s)$

During electrolysis, at the anode the silver atoms lose electrons and enter the solution. The positively charged silver cations migrate towards the cathode and get discharged by gaining electrons and deposited on the cathode.

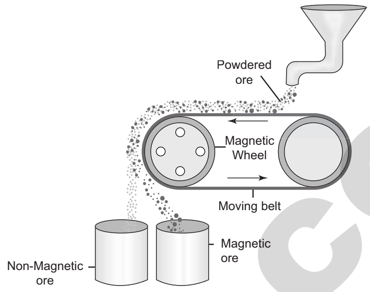
5. How are ores concentrated by magnetic separation method? *[FRT-'22]*

Ans. (i) This method is applicable to ferromagnetic ores and it is based on the difference in the magnetic properties of the ore and the impurities.

(ii) For example tin stone can be separated from the wolframite impurities which is magnetic.

(iii) Similarly, ores such as chromite, pyrolusite having magnetic property can be removed from the non magnetic siliceous impurities. The crushed ore is poured on to an electromagnetic separator consisting of a belt moving over two rollers of which one is magnetic.

(iv) The magnetic part of the ore is attracted towards the magnet and falls as a heap close to the magnetic region while the nonmagnetic part falls away from it as shown in the figure.



Magnetic separation

6. (i) What is the role of quick lime in the extraction of Iron from its oxide Fe_2O_3?
(ii) What is chemical leaching? *[FRT-'22]*

Ans. (i)
- Quick lime acts as a Flux.
- It combine with silica and get converted into Calcium silicate called as slag.

$$\underset{\text{Flux}}{CaO_{(s)}} + \underset{\text{Gangue}}{SiO_{2(s)}} \longrightarrow \underset{\text{Slag}}{CaSiO_{3(s)}}$$

(ii)
- Leaching method is based on the solubility of the ore in a suitable solvent and the reactions in aqueous solution.
- In this method, the crushed ore is allowed to dissolve in a suitable solvent, the metal present in the ore is converted to its soluble salt or complex while the gangue remains insoluble.

7. Write about the liquation process? *[June-'23]*

Ans. (i) Liquation is employed to remove the impurities with high melting points from metals having relatively low melting points.

(ii) In this process, the crude metal is heated to form fusible liquid and allowed to flow on a sloping surface.

(iii) The impure metal is placed on sloping hearth of a reverberatory furnace and it is heated just above the melting point of the metal in the absence of air, the molten pure metal flows down and the impurities are left behind.

(iv) The molten metal is collected and solidified.

Additional Questions and Answers

Choose the Correct Answer 1 Mark

1. Which metal is used for extraction of Au and Ag and also for galvanisation of iron objects?

a) Mg b) Zn c) Cr d) Co

[*Ans.* (b) Zn]

2. Which of the following is not a mineral of aluminium?

a) Bauxite b) Cryolite
c) China clay d) Malachite

[*Ans.* (d) Malachite]

3. Which of the following is commonly used to produce foam in froth floatation process?

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

[*Ans.* (a) Pine oil]

4. Name the process by which elements such as germanium, silicon and gallium are refined.

a) Vapour phase method
b) Electrolytic refining
c) Zone refining
d) Van-Arkel method [*Ans.* (c) Zone refining]

5. Among the following, one does not belong to calcination. Pick the odd one out.

a) $PbCO_3 \xrightarrow{\Delta} PbO + CO_2 \uparrow$
b) $CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \uparrow$
c) $PbSO_3 \xrightarrow{\Delta} PbO + 2SO_2 \uparrow$
d) $ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \uparrow$

[*Ans.* (c) $PbSO_3 \xrightarrow{\Delta} PbO + 2SO_2 \uparrow$]

6. Which of the following is incorrect with respect to metallurgy of iron in the blast furnace?

a) Zone of combustion : $C + O_2 \rightarrow CO_2$
b) Zone of heat absorption : $CO_2 \rightarrow C + O_2$
c) Zone of slag formation : $CaO + SiO_2 \rightarrow CaSiO_3$
d) Zone of reduction : $Fe_2O_3 + 3C \rightarrow 3CO + 2Fe$

[*Ans.* (b) Zone of heat absorption : $CO_2 \rightarrow C + O_2$]

7. Identify the metal that occurs in free state.

a) Al b) Au c) Mg d) Ca

[*Ans.* (b) Au]

8. Which of the following will give respective metal by self reduction?

a) Galena (PbS) b) HgS
c) ZnS d) Both (a) & (b)

[*Ans.* (d) Both (a) & (b)]

9. In the extraction of copper from its sulphide ore, the metal is finally obtained by the reduction of cuprous oxide with

a) Iron sulphide (FeS)
b) Carbon monoxide (CO)
c) Copper (I) sulphide (Cu_2S)
d) Sulphur dioxide (SO_2)

[*Ans.* (c) Copper (I) sulphide (Cu_2S)]

10. Which among the following reaction represents the formation of slag?

a) $CaO_{(s)} + SiO_{2(s)} \longrightarrow CaSiO_{3(s)}$
b) $2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$
c) $Fe_2O_3 + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$
d) $CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)}$

[*Ans.* (a) $CaO_{(s)} + SiO_{2(s)} \longrightarrow CaSiO_{3(s)}$]

11. Which one of the following element is present as an impurity in pig iron?

a) Phosphorus b) Manganese
c) Carbon d) Silicon

[*Ans.* (c) Carbon]

12. Which of the following mineral contains calcium as well as magnesium?

a) Zinc blende b) Aragonite
c) Dolomite d) Carnalite

[*Ans.* (c) Dolomite]

13. Concentration of copper glance is done by

a) leaching b) magnetic separation
c) froth flotation d) hydraulic washing

[*Ans.* (c) froth flotation]

14. Identify the decreasing order of carbon content in different forms of iron.

a) Wrought iron > Pig iron > Cast iron
b) Cast iron > Pig iron > Wrought iron
c) Pig iron > Cast iron > Wrought iron
d) Cast iron > Wrought iron > Pig iron

[*Ans.* (c) Pig iron > Cast iron > Wrought iron]

15. Sodium, magnesium and aluminum can be obtained from their ore by

a) electro metallurgy b) pyro metallurgy
c) hydro metallurgy d) smelting

[*Ans.* (a) electro metallurgy]

16. The blistered appearance of Cu obtained from the reverberatory furnace is due to evolution of

a) CO_2 gas b) SO_2 gas c) NO_2
d) Due to evaporation of volatile materials

[*Ans.* (b) SO_2 gas]

17. Identify the halide ore among the following.

a) Epsom Salt b) Pyrolusite
c) Anglesite d) Rock Salt

[*Ans.* (d) Rock Salt]

18. The process of heating of copper pyrites to remove sulphur is called

a) froth flotation b) roasting
c) calcination d) smelling

[*Ans.* (b) roasting]

Fill in the blanks :

1. Malachite has _______ composition.

a) $2CuCO_3.Cu(OH)_2$ b) $CuCO_3Cu(OH)_2$
c) Cu_2O d) Cu_2S

[*Ans.* (b) $CuCO_3Cu(OH)_2$]

2. Zinc blende is _______.

a) ZnS b) PbS c) Ag_2S d) Cu_2S

[*Ans.* (a) ZnS]

3. In acid leaching process, the insoluble sulphide is converted into soluble sulphate and elemental _______.

a) carbon b) lead
c) sulphur d) zinc

[*Ans.* (c) sulphur]

4. Sulphide ore is converted to oxide form by using the process __________.

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

[*Ans.* (b) Roasting]

5. Magnetic separation it is based on the difference in the _______ of the ore and the impurities.

a) magnetic properties
b) chemical properties
c) physical properties
d) melting point

[*Ans.* (a) magnetic properties]

6. Zinc is extracted from Zinc blende by __________

a) Carbon reduction process
b) Nitrogen reduction process
c) Oxygen reduction process
d) All of these

[*Ans.* (a) Carbon reduction process]

7. $ZnS + 3O_2 \xrightarrow{\Delta} 2ZnO + 2SO_2\uparrow$. The above equation is an example for _______.

a) calcination b) reduction
c) roasting d) leaching

[*Ans.* (c) roasting]

8. Gibb's free energy is given by __________

a) $\Delta G^\circ = -nFE^\circ$ b) $\Delta G^\circ = nF$
c) $\Delta G^\circ = nFE^\circ$ d) $\Delta E^\circ = -nFG^\circ$

[*Ans.* (a) $\Delta G^\circ = -nFE^\circ$]

9. $Na[Ag(CN)_2]$ is _______.

a) Sodium aurocyanide
b) Sodium meta aluminate
c) Alumino silicate
d) Sodium dicyano argentate

[*Ans.* (d) Sodium dicyano argentate]

10. $Zn_{(s)} + 2[Au(CN)_2]^-_{(aq)} \longrightarrow [Zn(CN)_4]^{2-}_{(aq)} + 2Au_{(s)}$
In the above equation, the oxidation state of metallic gold is _____

a) 1 b) 0 c) +2 d) –2

[*Ans.* (b) 0]

11. Semiconductors are purified by ______ method.

a) Zone refining b) Electrolytic refining
c) Mond's process d) Bessemerisation

[*Ans.* (a) Zone refining]

12. Magnesite is ______.

a) Magnesium oxide b) Magnesium carbonate
c) Magnesium sulphate
d) Magnesium chloride

[*Ans.* (b) Magnesium carbonate]

13. The following set of reaction is used for refining titanium. This method is known as ______

$$Ti_{(s)} + 2I_{2(s)} \longrightarrow TiI_4 \text{ (vapour)}$$
$$TiI_4 \text{ (vapour)} \longrightarrow Ti_{(s)} + 2I_{2(s)}$$

a) Hall Herold process
b) Mond process
c) Van-Arkel process
d) Alumino thermic process

[*Ans.* (c) Van-Arkel process]

14. In the metallurgy of iron, limestone is added to coke, which acts as a ________

a) Reducing agent b) Oxidising agent
c) Slag d) Flux

[*Ans.* (d) Flux]

15. A mixture containing sulphides of copper and iron is called _______

a) mineral b) ore
c) matte d) matrix

[*Ans.* (c) matte]

16. Cinnabar is the sulphide ore of _______ metal.

a) Zn b) Pb c) Hg d) Ag

[*Ans.* (c) Hg]

17. The percentage of carbon in high carbon steel is __________.

a) 0.5 – 1% b) 0.15 – 1.5%
c) 0.15 – 1.5% d) 0.15 – 0.3%

[*Ans.* (b) 0.15 – 1.5%]

18. Galena is _______

a) PbS b) ZnS c) Ag_2S d) FeS_2

[*Ans.* (a) PbS]

19. Froth floatation process is suitable for concentrating _______ ores.

a) oxide b) carbonate
c) sulphide d) halide

[*Ans.* (c) sulphide]

20. Steel is an alloy of _________

a) iron and carbon b) iron and calcium
c) copper and carbon d) copper and iron

[*Ans.* (a) iron and carbon]

21. Sodium cyanide solution is used to extract _____ from its ores.

a) copper b) silver
c) gold d) both (b) and (c)

[*Ans.* (d) both (b) and (c)]

22. In the thermite process _____ is used as a reducing agent.

a) Al b) CO c) C d) CO_2

[*Ans.* (a) Al]

23. $HgS_{(s)} + O_{2(g)} \longrightarrow Hg_{(l)} + SO_2\uparrow$

The above reaction is an example of ______ reduction.

a) metal b) hydrogen
c) carbon d) auto

[*Ans.* (d) auto]

ASSERTION & REASON :

Direction : In each of the following questions a statement of assertion (A) is given and a corresponding statement of reason (R) is given just below it. Mark the correct statement as.

a) Both (A) and (R) are true and (R) is the correct explanation of (A)
b) Both (A) and (R) are true but (R) does not explain (A)
c) (A) is true but (R) is false
d) Both (A) and (R) are false

1. Assertion (A) : Aluminium is used in the design of chemical reactors, medical equipments, refrigeration units and gas pipelines.

Reason (R) : Aluminium shows high resistance to corrosion.

[*Ans.* (a) Both (A) and (R) are true and (R) is the correct explanation of (A)]

2. Assertion (A) : Metallic zinc is used in galvanising metals such as iron and steel.

Reason (R) : Zinc is also used to produce die castings.

[*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

3. Assertion (A) : Zone refining is carried out in an inert gas atmosphere.

Reason (R) : The metal is treated with a suitable reagent which can form a volatile compound with the metal.

[*Ans.* (c) (A) is true but (R) is false]

4. Assertion : Cuprite is concentrated by froth floatation process.

Reason : Cuprite is the sulphide ore

[*Ans.* (d) Both (A) and (R) are false]

5. **Assertion** : Roasting process is involved in the metallurgy of Cu from malachite ore.

Reason : Roasting is the process of heating the ore in the absence of air.

[*Ans.* (d) Both (A) and (R) are false]

6. **Assertion** : Metallurgy of Ag from argentite is known as hydro-metallurgy.

Reason : Argentite is Ag_2S.

[*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

7. **Assertion** : Wrought iron is purest form of iron with respect to other forms.

Reason : It has less than 0.5% carbon .

[*Ans.* (a) Both (A) and (R) are true and (R) is the correct explanation of (A)]

8. **Assertion** : Aluminium metal is used as a reducing agent for the extraction of metals.

Reason : Aluminium has great affinity for oxygen.

[*Ans.* (a) Both (A) and (R) are true and (R) is the correct explanation of (A)]

9. **Assertion** : Carbon is used in blast furnace for reduction of Fe_2O_3.

Reason : The gangue present is silica which is acidic in nature.

[*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

10. **Assertion** : Ti can be purified by Van Arkel process

Reason : TiI_4 is a volatile compound which decomposes at a high temperature

[*Ans.* (a) Both (A) and (R) are true and (R) is the correct explanation of (A)]

11. **Assertion** : In the manufacturing of iron from haematite, silicon dioxide is added as flux.

Reason : Lime stone is used as acidic flux in many case.

[*Ans.* (d) Both (A) and (R) are false]

12. **Assertion** : Aluminothermic process is the extraction of chromium from chromic oxide.

Reason : Alumina has a high melting point

[*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

13. **Assertion** : A dilute solution of NaCN is used for leaching ores of silver and gold.

Reason : Impurities present in these ores dissolve in NaCN

[*Ans.* (c) (A) is true but (R) is false]

14. **Assertion** : Carbonate and sulphate are concentrated by froth floatation process

Reason : Pine oil wets the gangue particle

[*Ans.* (d) Both (A) and (R) are false]

15. **Assertion** : Galvanising is the process of coating iron and steel with metallic zinc.

Reason : Highly resistant to rusting and corrosion.

[*Ans.* (a) Both (A) and (R) are true and (R) is the correct explanation of (A)]

Correct statement (s):

1. **I. All ores are minerals**
II. All minerals are not ores.
III. Aluminium can be extracted from bauxite.
IV. Aluminium can be extracted from china clay.

a) Only I b) Only II
c) III & IV d) I, II & III

[*Ans.* (d) I, II & III]

2. **I. Copper is the first metal used by the human**
II. Aluminuim is used in galvanising metals
III. Aluminium is a good conductor of electricity
IV. Magnets can be made from iron.

a) Only I b) Only II
c) I, III & IV d) III & IV

[*Ans.* (c) I, III & IV]

3. **I. Ellingham diagram helps to select a suitable reducing agent**
II. Magnesite is calcinated to obtain magnesia.
III. Calcination is a process of cooling substances.
IV. Sulphur dioxide is harmful to the environment.

a) I, II & IV b) Only II
c) Only I d) III & IV

[*Ans.* (a) I, II & IV]

4. **I.** **Froth flotation is used to concentrate sulphide ores.**
II. **Magnetic separation is applicable for ferromagnetic ores.**
III. **Roasting method used to convert sulphide ores to oxides.**
IV. **Magnetic separation is used to concentrate heavy oxide ores.**
a) III & IV b) Only II
c) Only I d) I, II & III
[*Ans.* (d) I, II & III]

5. **I.** **Ores are associated with non-metallic impurities**
II. **Ores are associated with rocky materials**
III. **Removal of impurities is known as concentration of ore.**
IV. **Ellingham diagram shows the stability of different metal oxides.**
a) I, II, III & IV b) Only II
c) Only I d) III & IV
[*Ans.* (a) I, II, III & IV]

6. **Identify the correct statement(s) with respect to the following reaction.**

$$2Na[Al(OH)_4]_{(aq)} + CO_{2(g)} \longrightarrow Al_2O_3.xH_2O_{(s)} + 2NaHCO_{3(aq)}$$

(i) **CO_2 is acting as a reducing agent.**
(ii) **The solution is neutralised by passing CO_2 gas to form hydrates Al_2O_3 precipitate.**
(iii) **Insoluble sulphate is converted into soluble sulphate.**
(iv) **The precipitate is filtered off and heated around 1670 K to get pure Alumina.**
a) only (ii) b) only (iv)
c) both (ii) & (iv) d) both (i) and (iii)
[*Ans.* (c) both (ii) & (iv)]

Incorrect Statement (s):

1. **About "Electrolytic refining"**
a) The crude metal is refined by electrolysis.
b) The rods of impure metal are used as cathode.
c) Thin strips of pure metal are used as cathode.
d) Less electro-positive impurities removed as anode mud.
[*Ans.* (b) The rods of impure metal are used as cathode]

2. **About "Van-Arkel"**
a) Van-Arkel method used for refining Zirconium.
b) Aluminium is a bad conductor of heat.
c) Aluminium shows high resistance to corrosion.
d) Aluminium is a good conductor of heat
[*Ans.* (b) Aluminium is a bad conductor of heat.]

3. a) Aluminium is used to produce die-castings
b) Gold nanoparticles used as an catalysts
c) Copper is the first metal used by the human
d) Brass is an alloy of zinc and copper
[*Ans.* (a) Aluminium is used to produce die-castings]

4. a) Germanium is used as a semi conductor
b) Stainless steel is an important alloy of Aluminum
c) Zinc sulphide is used in making luminous paints.
d) Brass an alloy of zinc is used in water valves.
[*Ans.* (b) Stainless steel is an important alloy of Aluminum]

5. a) Metallic oxides can be reduced by an aluminothermic process.
b) Flux + gangue $\rightarrow$ slag
c) Silica gangue present in the ore is basic in nature
d) Cu_2S + FeS $\rightarrow$ Copper matter
[*Ans.* (c) Silica gangue present in the ore is basic in nature]

Match the following :

1.

	Ores		Formulae
1	Copper pyrite	a	$CuCO_3.Cu(OH)_2$
2	Malachite	b	$CuFeS_2$
3	Azurite	c	Cu_2O
4	Cuprite	d	$2CuCO_3.Cu(OH)_2$

	1	2	3	4
(a)	a	b	c	d
(b)	b	a	c	d
(c)	b	a	d	c
(d)	d	c	b	a

[Ans. (c) b a d c]

2.

	Metal		Ores
1	Calamine	a	Fe
2	Azurite	b	Zn
3	Limonite	c	Pb
4	Cerrusite	d	Cu

	1	2	3	4
(a)	a	b	c	d
(b)	b	d	a	c
(c)	c	d	a	b
(d)	d	a	b	c

[Ans. (b) b d a c]

3.

	LIST – I		LIST – II
1	Gravity separation	a	Tinstone
2	Froth floatation	b	Bauxite
3	Chemical method	c	Zinc Blende
4	Electro magnetic separation	d	Haematite

	1	2	3	4
(a)	a	d	b	c
(b)	a	b	c	d
(c)	c	a	d	b
(d)	d	c	b	a

[Ans. (d) d c b a]

4.

	LIST – I		LIST – II
1	Oxide ore	a	Copper pyrite
2	Sulphide ore	b	Anglesite
3	Sulphate ore	c	Calamine
4	Carbonate ore	d	Diaspore

	1	2	3	4
(a)	a	b	c	d
(b)	b	c	d	a
(c)	c	d	b	a
(d)	d	a	b	c

[Ans. (d) d a b c]

5.

	LIST – I		LIST – II
1	Liquation	a	Nickel
2	Mond's process	b	Copper
3	Zone refining	c	Tin
4	Electrolytic refining	d	Silicon

	1	2	3	4
(a)	d	b	c	a
(b)	b	a	d	c
(c)	c	a	d	b
(d)	d	c	b	a

[Ans. (c) c a d b]

Very Short Answer 2 Marks

1. What is metallurgy?

Ans. The various steps involved in the extraction of metals from their ores as well as refining of crude metals are collectively known as metallurgy.

2. Why should we have a eco-friendly metallurgical process?

Ans. *(i)* It is essential to design an eco-friendly metallurgical process that would minimize waste, maximize energy efficiency.

(ii) Such advances in metallurgy is vital for the economic and technical progress in the current era.

3. What is meant by concentration?

Ans. *(i)* The preliminary step in metallurgical process is removal of the impurities from the ore.

(ii) This process is known as concentration of ore.

4. Name some common methods of ore concentration.

Ans. *(i)* Gravity separation or Hydraulic wash

(ii) Froth flotation,

(iii) Leaching,

(iv) Magnetic separation.

5. Name the two steps involved in the extraction of crude metal.

Ans. *(i)* Conversion of ores into oxides.

(ii) Reduction of metal oxides.

6. Name the various refining process.

Ans. *(i)* Distillation

(ii) Liquation

(iii) Electrolytic refining

(iv) Zone refining

(v) Vapour phase method

(vi) Van-Arkel method

7. Discuss the use of an acidic flux in metallurgy.

Ans. SiO_2 is used in the metallurgy of copper to remove FeO as $FeSiO_3$ (slag) (i.e) acidic flux is used to remove basic impurities.

$$FeO + SiO_2 \longrightarrow FeSiO_3$$

8. Why are sulphide ores converted to oxide form before reduction to metal?

Ans. *(i)* Sulphide ores are **thermodynamically more stable** than CS_2 and hence cannot be converted by using coke as reducing agent.

(ii) Moreover CO_2 is more volatile and thermodynamically more stable than CS_2.

(iii) Thus $\Delta G°$ of a metal sulphide is not compensated by the energy of reaction of metal sulphide with coke.

(iv) Hence, it is better to convert the sulphide ore to oxide form and then subject to smelting (i.e) carbon reduction method.

9. Discuss the process of roasting with suitable example.

Ans. *(i)* Sulphide ores are generally roasted in reverberatory furnace in free supply of air below its melting point.

(ii) Ore changes to oxide with larger surface area and volatile impurities are removed.

$$2ZnS + 3O_2 \xrightarrow{\Delta} 2ZnO + 2SO_2$$

$$2PbS + 3O_2 \xrightarrow{\Delta} PbO + 2SO_2$$

10. Write the two similarities between calcination and roasting.

Ans. *(i)* The **end product** of both the processes is **oxide of metal**.

(ii) **Volatile impurities are removed** from the ore and surface area for the further reaction increases.

11. Name the ore that can be concentrated by magnetic separation method.

Ans. *(i)* Magnetite (Fe_3O_4), haematite (Fe_2O_3) are the ores which can be separated by the magnetic separation method.

(ii) In these ores, one component is magnetic in nature.

12. What are the various leaching processes?

Ans. The various leaching processes are

(i) Cyanide leaching,

(ii) Ammonia leaching,

(iii) Alkali leaching and

(iv) Acid leaching.

13. What is Ellingham diagram? (or) What does Ellingham diagram represent?

Ans. *(i)* The graphical representation of variation of the standard Gibbs free energy of reaction for the formation of various metal oxides with temperature is called Ellingham diagram.

(ii) Ellingham diagram helps us to select a suitable reducing agent and appropriate temperature range for reduction.

14. Name some depressing agents.

Ans. *(i)* Sodium cyanide and

(ii) Sodium carbonate.

15. What is distillation?

Ans. *(i)* Distillation is employed for low boiling volatile metals like zinc (boiling point 1180 K) and mercury (630 K).

(ii) In this method, the impure metal is heated to evaporate and the vapours are condensed to get pure metal.

16. Describe the role of SiO_2 in the extraction of Cu from Copper matte.

Ans. *(i)* Copper is extracted form copper matte which contains iron as impurity.

(ii) Silica is added to remove this impurity as iron silicate in the form of **Fusible slag**.

$$\underset{\text{Impurity}}{FeO} + SiO_2 \longrightarrow \underset{\text{Iron silicate (slag)}}{FeSiO_3}$$

17. Name and discuss the principle involved in obtaining silicon of high purity.

Ans. *(i)* Silicon is refined by **zone refining method**.

(ii) It is based on the principle that melting point of a substance is lowered by the presence of impurities.

(iii) Consequently when an impure molten metal is cooled, crystals of the pure metal are solidified and the impurities remain behind the remaining metal.

18. Give reason : Extraction of copper directly from sulphide ores is less favourable than that from its oxide ores through reduction.

Ans. *(i)* The standard free energy for the formation of $CuFeS_2$ (copper pyrites) is greater than those of CS_2 and H_2S.

(ii) Hence, $CuFeS_2$ cannot be reduced by carbon or hydrogen.

(iii) However, the free energy of copper oxide is less than that of CO_2.

(iv) That is the reason, extraction of copper is easier from its oxide ores through reduction.

SHORT ANSWER — 3 MARKS

1. Explain alkali leaching in the extraction of aluminum.

Ans. *(i)* In this method, the ore is treated with aqueous alkali to form a soluble complex.

(ii) Bauxite, an important ore of aluminum is heated with a solution of sodium hydroxide or sodium carbonate in the temperature range 470 - 520 K at 35 atm to form soluble sodium meta-aluminate leaving behind the impurities, iron oxide and titanium oxide.

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \longrightarrow 2Na[Al(OH)_4]_{(aq)}$$

(iii) The hot solution is decanted, cooled, and diluted. This solution is neutralised by passing CO_2 gas, to the form hydrated Al_2O_3 precipitate.

$$2Na[Al(OH)_4]_{(aq)} + 2CO_{2(g)} \longrightarrow Al_2O_3.3H_2O_{(s)} + 2NaHCO_{3(aq)}$$

(iv) The precipitate is filtered off and heated around 1670 K to get pure alumina Al_2O_3.

2. What is cementation?

Ans. *(i)* Gold can be recovered by reacting the deoxygenated leached solution with zinc.

(ii) In this process the gold is reduced to its elemental state (zero oxidation sate) and the process is called **cementation**.

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

3. What is meant by ammonia leaching?

Ans. *(i)* When a crushed ore containing nickel, copper and cobalt is treated with aqueous ammonia under suitable pressure.

(ii) Ammonia selectively leaches these metals by forming their soluble complexes viz. $[Ni(NH_3)_6]^{2+}$, $[Cu(NH_3)_4]^{2+}$, and $[Co(NH_3)_5H_2O]^{3+}$ respectively from the ore leaving behind the gangue, iron(III) oxides/hydroxides and aluminosilicate.

4. Explain roasting with an example.

Ans. *(i)* Roasting is the method, usually applied for the conversion of sulphide ores into their oxides.

(ii) In this method, the concentrated ore is oxidised by heating it with excess of oxygen in a suitable furnace below the melting point of the metal.

(iii)
$$2PbS + 3O_2 \xrightarrow{\Delta} 2PbO + 2SO_2\uparrow$$
$$2ZnS + 3O_2 \xrightarrow{\Delta} 2ZnO + 2SO_2\uparrow$$
$$2Cu_2S + 3O_2 \xrightarrow{\Delta} 2Cu_2O + 2SO_2\uparrow$$

(iv) Roasting also removes impurities such as arsenic, sulphur, phosphorous by converting them into their volatile oxides.

(v) **Ex :** $4As + 3O_2 \longrightarrow 2As_2O_3\uparrow$
$$S_8 + 8O_2 \longrightarrow 8SO_2\uparrow$$
$$P_4 + 5O_2 \longrightarrow P_4O_{10}\uparrow$$

5. Distinguish Roasting and Calcination.

Ans.

Roasting	Calcination
Roasting is a process in which ore is heated in the presence of excess of air.	Calcination is a process in which ore is heated in the absence of air.
As a result of roasting the sulphide ores are converted into their oxides.	As a result of calcination, the carbonate ore is converted into its oxide.
$2PbS + 3O_2 \xrightarrow{\Delta} 2PbO + 2SO_2\uparrow$	$PbCO_3 \xrightarrow{\Delta} PbO + CO_2\uparrow$

Roasting removes impurities such as arsenic, sulphur, phosphorous by converting them into their volatile oxides. $4As + 3O_2 \longrightarrow 2As_2O_3$	During calcination of hydrated ore, the water of hydration is expelled as vapour.

6. What is vapour phase method?

Ans. *(i)* In vapour phase method, the metal is treated with a suitable reagent which can form a volatile compound with the metal.

(ii) Then the volatile compound is decomposed to give the pure metal.

(iii) Vapour phase method is used for refining nickel.

7. Before reduction, the ore is first converted into the oxide of metal of interest. Give reason.

Ans. *(i)* In the concentrated ore, the metal exists in positive oxidation state and hence it is to be reduced to its elemental state.

(ii) From the principles of thermodynamics, that the reduction of oxide is easier when compared to reduction of other compounds of metal and hence, before reduction, the ore is first converted into the oxide of metal of interest.

8. Write the complete set of reactions occurring in the zone of reduction in the blast furnace in the metallurgy of iron.

Ans. In Ellingham diagram, the graph of $CO \rightarrow CO_2$ conversion remains below $Fe \rightarrow Fe_2O_3$ upto 1073 K

(for $Fe \longrightarrow FeO$). SO, CO(g) act as reducing agent upto this temperature.

$$3\,Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 \quad (\text{ie. } FeO.Fe_2O_3) + CO_2$$

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

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

Also, graph of $C \longrightarrow CO$ is below the graph of $Fe \longrightarrow Fe_2O_3$ after 1123 K. So, carbon acts as reducing agent above this temperature.

$$Fe_2O_3 + C \longrightarrow 3\,CO + 2\,Fe.$$

9. What is coupling of reaction? How is it useful in metallurgy?

Ans. *(i)* If value of **ΔG is positive** for any reaction, then to make such reaction spontaneous, it is coupled with another reaction of large negative ΔG value, so that the sum of two ΔG becomes negative. This is known as coupling of reaction.

(ii) In the metallurgy, thermodynamically infeasible reaction is coupled with a reaction which has more negative ΔG, so that net **ΔG becomes negative**.

10. Explain how the metal oxide is converted into metal using carbon as a reducing agent.

Ans. *(i)* In this method the oxide ore of the metal is mixed with coal (coke) and heated strongly in a furnace (usually in a blast furnace).

(ii) This process can be applied to the metals which do not form carbides with carbon at the reduction temperature.

Eg : $ZnO_{(s)} + C_{(s)} \longrightarrow Zn_{(s)} + CO_{(g)}\uparrow$

11. How oxides of metals are reduced by hydrogen?

Ans. *(i)* This method can be applied to the oxides of the metals (Fe, Pb, Cu) having less electro-positive character than hydrogen.

$$Ag_2O_{(s)} + H_{2(g)} \longrightarrow 2Ag_{(s)} + H_2O_{(l)}$$

(ii) Nickel oxide can be reduced to nickel by using a mixture of hydrogen and carbon monoxide (water gas)

(iii) $2NiO_{(s)} + CO_{(g)} + H_{2(g)} \longrightarrow 2Ni_{(s)} + CO_{2(g)} + H_2O_{(l)}$

12. What is meant by aluminothermic process?

Ans. *(i)* Metallic oxides such as Cr_2O_3 can be reduced by an aluminothermic process.

(ii) In this process, the metal oxide is mixed with aluminium powder and placed in a fire clay crucible.

(iii) To initiate the reduction process, an ignition mixture (usually magnesium and barium peroxide) is used.

$$BaO_2 + Mg \longrightarrow BaO + MgO$$

(iv) During the above reaction a large amount of heat is evolved (temperature up to 2400°C, is generated and the reaction enthalpy is : 852 kJ mol^{-1}) which facilitates the reduction of Cr_2O_3 by aluminium power.

$$Cr_2O_3 + 2Al \xrightarrow{\Delta} 2Cr + Al_2O_3$$

13. List the applications of gold.

Ans. *(i)* Gold, is used for coinage, and has been used as standard for monetary systems in some countries.

(ii) It is used extensively in jewellery in its alloy form with copper.

(iii) It is also used in electroplating to cover other metals with a thin layer of gold which are used in watches, artificial limb joints, cheap jewellery, dental fillings and electrical connectors.

(iv) Gold nanoparticles are also used for increasing the efficiency of solar cells and also used a catalysts.

14. Mention the uses of copper.

Ans. *(i)* Copper is used for making coins and ornaments along with gold and other metals.

(ii) Copper and its alloys are used for making wires, water pipes and other electrical parts.

15. Copper and silver lie low in the electrochemical series and yet they are found in the combined state as sulphides in nature. Comment.

Ans. *(i)* At higher temperature, the reaction between copper and sulphur becomes feasible.

(ii) So they combine together and copper exists as copper sulphides in nature.

(iii) Besides this due to high polarising power of copper and silver ions, their sulphides are more stable.

16. Support the statement given below with relevant examples.

"The choice of a reducing agent in a particular case depends on the thermodynamic factor".

Ans. The statement is correct. We consider both relations,

$\Delta G = \Delta H - T\Delta S$ (or) $\Delta G° = -RT \ln K$

For a particular reducing agent to work with a metallic oxide,

(i) The value of ΔG should be **negative**.

(ii) ΔS should be **positive**.

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

Ans. $\Delta G°$ for the conversion of Zn into ZnO is approximately – 650 kJ and for the conversion of CO into CO_2 is approximately – 450kJ (ie).

$2Zn + O_2 \longrightarrow 2\,ZnO$; $\Delta G° = -650$ kJ

$2CO + O_2 \longrightarrow 2\,CO_2$; $\Delta G° = -450$ kJ

For the reaction,

$2ZnO + 2\,CO \longrightarrow 2\,Zn + 2\,CO_2$; $\Delta G° = +200$ kJ

Positive value of shows that the reaction is not feasible. That is why, CO cannot be used for the reduction of ZnO into Zn.

18. (i) Which of the following metals cannot be extracted by the smelting process : Al, Zn, Fe and Pb. Give reasons.

(ii) Which one is a good reducing agent (C or CO) for Fe_2O_3, below 1073 K?

Ans. *(i)* Aluminium cannot be extracted by smelting process due to the following reasons.

(a) Aluminium (Al) being highly electro-positive element has very strong affinity for oxygen. So, Al_2O_3 is very stable compound and cannot be reduced by C.

(b) On heating Al_2O_3 with C, aluminium carbide is formed

$$2Al_2O_3 + 9C \longrightarrow Al_4C_3 + 6CO.$$

(ii) Below 1073 K, CO is more effective, because the $\Delta G°$ value for the conversion of CO into CO_2 is more negative.

19. What are the applications of the Ellingham diagram?

Ans. *(i)* Ellingham diagram helps us to select a suitable reducing agent and appropriate temperature range for reduction.

(ii) From the Ellingham diagram, we can infer the relative stability of different metal oxides at a given temperature.

(iii) Ellingham diagram is used to predict thermodynamic feasibility of reduction of oxides of one metal by another metal.

Long Answer 5 Marks

1. Explain refining of titanium by Van-Arkel method.

Ans. *(i)* Van-Arkel method is based on the thermal decomposition of metal compounds which lead to the formation of pure metals.

(ii) Titanium and zirconium can be purified using this method.

(iii) For example, the impure titanium metal is heated in an evacuated vessel with iodine at a temperature of 550 K to form the volatile titanium tetra-iodide.(TiI_4).

(iv) The impurities are left behind, as they do not react with iodine.

$$Ti_{(s)} + 2I_{2(s)} \xrightarrow[\Delta]{550K} TiI_4 \text{ (vapour)}$$

(v) The volatile titanium tetraiodide vapour is passed over a tungsten filament at a temperature around 1800 K.

(vi) The titanium tetraiodide is decomposed and pure titanium is deposited on the filament.

(vii) The iodine is reused.

$$TiI_4\text{(vapour)} \xrightarrow[\Delta]{1800K} Ti_{(s)} + 2I_{2(s)}$$

2. List out the application of aluminum.

Ans. *(i)* Many heat exchangers/sinks and cooking vessels are made of aluminum.

(ii) It is used as wraps (aluminum foils) and is used in packing materials for food items,

(iii) Aluminum alloys with copper, manganese, magnesium and silicon are light weight and strong and they are used in design of aeroplanes and other forms of transport.

(iv) Aluminum shows high resistance to corrosion, so it is used in the design of chemical reactors, medical equipments,refrigeration units and gas pipelines.

(v) Aluminium is a good electrical conductor and cheap, hence used in electrical overhead electric cables with steel core for strength.

3. List the applications of iron.

Ans. *(i)* Iron and its alloys are used everywhere including bridges, electricity pylons, bicycle chains, cutting tools and rifle barrels.

(ii) Cast iron is used to make pipes, valves and pumps stoves etc.

(iii) Magnets can be made from iron and its alloys and compounds.

(iv) An important alloy of iron is stainless steel, and it is very resistant to corrosion. It is used in architecture, bearings, cutlery, surgical instruments and jewellery.

(v) Nickel steel is used for making cables, automobiles and aeroplane parts.

(vi) Chrome steels are used for manufacturing cutting tools and crushing machines.

☆ ☆ ☆

UNIT TEST

Time : 40 min | Marks : 25

I. Choose the Correct Answer (5 × 1 = 5)

1. The chemical name of Horn silver is ______.

a) Chlorargyrite b) Silver glance
c) Prousitite d) Pyrargyrite

2. During the cyanide leaching of gold, the insoluble gangue formed is

a) gold cyanide b) aluminosilicate
c) gold silicate d) gold aluminosilicate

3. The metal oxide which cannot be reduced to metal by carbon is

a) PbO b) Al_2O_3 c) ZnO d) FeO

4. Removal of unreacted oxide ore, other metals, non metals associated with isolated crude metal is called _______

a) leaching b) bleaching
c) refining d) liquation

5. Match the following Metal with their Melting points.

	Metals		Melting points
1	Lead	a	545 K
2	Mercury	b	904 K
3	Tin	c	234 K
4	Bismuth	d	600 K

	1	2	3	4
(a)	d	c	b	a
(b)	a	b	c	d
(c)	b	c	a	d
(d)	c	b	a	d

II. Short Answer (2 × 2 = 4)

1. Give the basic requirement for vapour phase refining.
2. What is the role of Silica in the extraction of copper.

III. Answer In Paragraph (2 × 3 = 6)

1. Describe the method for refining nickel.
2. Give the uses of zinc.

IV. Long Answer (2 × 5 = 10)

1. Give the limitations of Ellingham diagram.
2. Write a short note on electrochemical principles of metallurgy.

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Answer Key

I.
1. a) Chlorargyrite
2. b) aluminosilicate
3. b) Al_2O_3
4. c) refining
5. a) d c b a

II.
1. *Refer Sura's Guide Book Back, Q.No. 11*
2. *Refer Sura's Guide Additional 2 Marks, Q.No. 17*

III.
1. *Refer Sura's Guide Book Back, Q.No. 5*
2. *Refer Sura's Guide Book Back, Q.N o. 8*

IV.
1. *Refer Sura's Guide Book Back, Q.No. 15*
2. *Refer Sura's Guide Book Back, Q.No. 16*

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UNIT 2

p-Block Elements - I

CHAPTER SNAPSHOT

CONCEPT MAP

General trends in properties of p-block elements

- Electronic configuration and oxidation state
- Metallic nature
- Ionisation Enthalpy
- Electro negativity
- Inert pair effect
- Anomalous properties
- Allotropism

BORAX

- Borax $Na_2B_4O_7.10H_2O$
- Boron Tri Flouride BF_3
- Boric acid H_3BO_3
- Diborane B_2H_6

Preparation, Properties, Structure and uses of the above compounds.

Carbon C

- **Carbondioxide CO_2**
- **Carbon Monoxide CO**

Preparation, Properties, Structure and uses.

FORMULAE TO REMEMBER

Borax	:	$Na_2B_4O_7.10H_2O$
Boric acid	:	H_3BO_3 or $B(OH)_3$
Di Borane	:	B_2H_6
Boron Fluoride	:	BF_3
Aluminium Chloride	:	$AlCl_3$
Silicon tetrachloride	:	$SiCl_4$
Silicones	:	R_2SiO
Potash Alum	:	$K_2SO_4.Al_2(SO_4)_3.\ 24H_2O$

Sodium Alum	:	$Na_2SO_4.Al_2(SO_4)_3.24H_2O$
Ammonium Alum	:	$(NH_4)_2SO_4.Al_2(SO_4)_3.24H_2O$
Chrome Alum	:	$K_2SO_4.Cr_2(SO_4)_3.24H_2O$
Nickel Tetra Carbonyl	:	$[Ni(CO)_4]$
Iron Penta Carbonyl	:	$[Fe(CO)_5]$
Chromium Hexa Carbonyl	:	$[Cr(CO)_6]$
Thortveitite	:	$Sc_2Si_2O_7$
Spodumene	:	$LiAl(SiO_3)_2$

MUST KNOW DEFINITIONS

Metallic Character	:	The tendency of an element to form a cation by loosing electrons is known as **electropositive** or **metallic character.**
Allotropism	:	Some elements exist in more than one crystalline or molecular forms in the same physical state. This property is called **allotropism**.
Hydroboration	:	Diborane adds on to alkenes and alkynes in ether solvent at room temperature. This reaction is called **hydroboration**.
Catenation	:	**Catenation** is the ability of an element to form chain of atoms.
Silicates	:	The mineral which contains silicon and oxygen in tetrahedral $[SiO_4]^{4-}$ units linked together in different patterns are called **silicates**.
Zeolites	:	Zeolites are three dimensional crystalline solids containing aluminium, silicon, and oxygen in their regular three dimensional framework.
Inert pair effect	:	In heavier post-transition metals, the outer s electrons (ns) have a tendency to remain inert and show reluctance to take part in the bonding, which is known as inert pair effect.

EVALUATION

Choose The Correct Answer

[Please refer to the Textbook Page No. 234 -235 for the explanatory answers for MCQs.]

1. An aqueous solution of borax is *[May-'22]*

a) neutral b) acidic
c) basic d) amphoteric

[*Ans.* (c) basic]

2. Boric acid is an acid because its molecule *(NEET)*

a) contains replaceable H^+ ion
b) gives up a proton
c) combines with proton to form water molecule
d) accepts OH^- from water, releasing proton.

[*Ans.* (d) accepts OH^- from water, releasing proton]

3. Which among the following is not a borane?

a) B_2H_6 b) B_3H_6
c) B_4H_{10} d) none of these

[*Ans.* (b) B_3H_6]

4. Which of the following metals has the largest abundance in the earth's crust?

a) Aluminium b) Calcium
c) Magnesium d) Sodium

[*Ans.* (a) Aluminium]

5. In diborane, the number of electrons that accounts for banana bonds is *[June-'23]*

a) six b) two c) four d) three

[*Ans.* (c) four]

6. The element that does not show catenation among the following p-block elements is

a) Carbon b) silicon *[June-'24]*
c) Lead d) germanium

[*Ans.* (c) Lead]

7. Carbon atoms in fullerene with formula C_{60} have *[April-'23; QY-'24]*

a) sp^3 hybridised b) sp hybridised
c) sp^2 hybridised
d) partially sp^2 and partially sp^3 hybridised

[*Ans.* (c) sp^2 hybridised]

8. Oxidation state of carbon in its hydrides

a) +4 b) −4 c) +3 d) +2

[*Ans.* (a) +4]

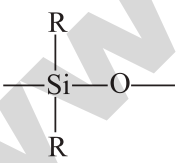
9. The basic structural unit of silicates is *[NEET; PTA-1]*

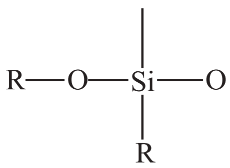
a) $(SiO_3)^{2-}$ b) $(SiO_4)^{2-}$
c) $(SiO)^{-}$ d) $(SiO_4)^{4-}$

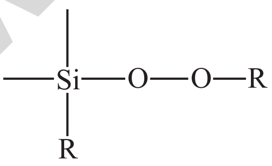
[*Ans.* (d) $(SiO_4)^{4-}$]

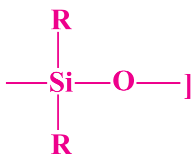
10. The repeating unit in silicone is

a) SiO_2

b) 

c) 

d) 

[*Ans.* (b) ]

11. Which of these is not a monomer for a high molecular mass silicone polymer?

a) Me_3SiCl b) $PhSiCl_3$
c) $MeSiCl_3$ d) Me_2SiCl_2

[*Ans.* (a) Me_3SiCl]

12. Which of the following is not sp^2 hybridised? *[Aug-'21; Mar-'24]*

a) Graphite b) graphene
c) Fullerene d) dry ice

[*Ans.* (d) dry ice]

13. The geometry at which carbon atom in diamond are bonded to each other is *[QY-'23; HY-'23]*

a) Tetrahedral b) hexagonal
c) Octahedral d) none of these

[*Ans.* (a) Tetrahedral]

14. Which of the following statements is not correct?

a) Beryl is a cyclic silicate
b) Mg_2SiO_4 is an orthosilicate
c) SiO_4^{4-} is the basic structural unit of silicates
d) Feldspar is not aluminosilicate

[*Ans.* (d) Feldspar is not aluminosilicate]

15. Match items in column - I with the items of column – II and assign the correct code.

Column - I		Column - II	
A	Borazole	**1**	$B(OH)_3$
B	Boric acid	**2**	$B_3N_3H_6$
C	Quartz	**3**	$Na_2[B_4O_5(OH)_4]\,8H_2O$
D	Borax	**4**	SiO_2

	A	B	C	D
(a)	2	1	4	3
(b)	1	2	4	3
(c)	1	2	3	4
(d)	None of these			

[Ans. (a) 2, 1, 4, 3]

16. Duralumin is an alloy of

a) Cu, Mn b) Cu, Al, Mg
c) Al, Mn d) Al, Cu, Mn, Mg

[*Ans.* (d) Al, Cu, Mn, Mg]

17. The compound that is used in nuclear reactors as protective shields and control rods is *[HY-'23]*

a) Metal borides b) Metal oxides
c) Metal carbonates d) Metal carbide

[*Ans.* (a) Metal borides]

18. The stability of +1 oxidation state increases in the sequence *[QY_'19]*

a) Al < Ga < In < Tl b) Tl < In < Ga < Al

c) In < Tl < Ga < Al d) Ga< In < Al < Tl

[*Ans.* (a) Al < Ga < In < Tl]

Answer the Following Questions

1. Write a short note on anamolous properties of the first element of p-block. *[Sep-2020; Aug-'21; QY-'23; June-'24]*

Ans. **Anamolous properties of the first element of p-block :** In p-block elements, the first member of each group differs from the other elements of the corresponding group. The following factors are responsible for this anomalous behaviour.

(i) Small size of the first member.

(ii) High ionisation enthalpy and high electronegativity.

(iii) Absence of d-orbitals in their valance shell.

2. Describe briefly allotropism in p- block elements with specific reference to carbon.

Ans. **Allotropism in p- block elements :**

(i) Some elements exist in more than one crystalline or molecular forms in the same physical state.

(ii) Carbon exists as diamond and graphite. This phenomenon is known as allotropism.

(iii) Other important allotropes of carbon are graphene, fullerenes, carbon nanotubes.

3. Give the uses of Borax. *[HY-'19 & '23; Aug-'21; June & QY-'24]*

Ans. *(i)* Borax is used for the identification of coloured metal ions.

(ii) In the manufacture optical and borosilicate glass, enamels and glazes for pottery.

(iii) It is also used as a flux in metallurgy and also acts as a preservative.

4. What is catenation? Describe briefly the catenation property of carbon. *[Mar, Sep-2020; July-'22]*

Ans. *(i)* Catenation is an ability of an element to form chain of atoms.

(ii) The following conditions are necessary for catenation. *[HY-'23]*

(a) The valency of element should be greater than or equal to two,

(b) Element should have the ability to bond with itself

(c) The self bond must be as strong as its bond with other elements

(d) Kinetic inertness of catenated compound towards other molecules.

(iii) Carbon possesses all the above properties and forms a wide range of compounds with itself and with other elements such as H, O, N, S and halogens.

5. Write a note on Fischer tropsch synthesis. *[PTA - 4; April & QY-'23 & '24]*

Ans. **Fischer Tropsch synthesis :**

The reaction of carbon monoxide with hydrogen at a pressure of less than 50 atm using metal catalysts at 500 - 700 K yields saturated and unsaturated hydrocarbons.

$$nCO + (2n+1)H_2 \longrightarrow C_nH_{(2n+2)} + nH_2O$$

$$nCO + 2nH_2 \longrightarrow C_nH_{2n} + nH_2O$$

6. Give the structure of CO and CO_2.

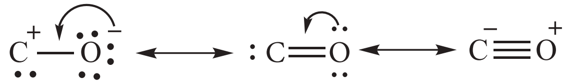
Ans. **Structure of CO :** *[QY-'24]*

(i) It has a linear structure.

(ii) Three electron pairs are shared between carbon and oxygen.

(iii) C-O bond distance is 1.128Å.

(iv) The structure can be considered as the resonance hybrid of the following two canonical forms.



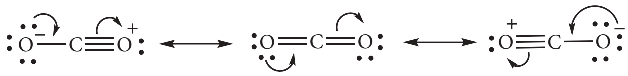
Structure of CO_2 :

(i) It has a liner structure.

(ii) Equal bond distance for the both C-O bonds.

(iii) There is two C-O sigma bond.

(iv) In addition there is 3c-4e covering all the three atoms.



7. Give the uses of silicones. *[April-'23; HY-'24]*

Ans. *(i)* Silicones are used for low temperature lubrication and in vacuum pumps, high temperature oil baths etc.

(ii) They are used for making water proofing clothes.

(iii) They are used as insulating material in electrical motor and other appliances.

(iv) They are mixed with paints and enamels to make them resistant towards high temperature, sunlight, dampness and chemicals.

8. Describe the structure of diborane. *[PTA - 3; April & QY-'23]*

Ans. *(i)* In diborane two BH_2 units are linked by two bridged hydrogens.

(ii) Therefore, it has eight B-H bonds.

(iii) However, diborane has only 12 valence electrons and are not sufficient to form normal covalent bonds.

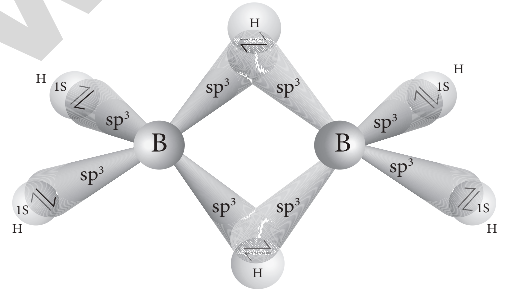
(iv) The four terminal B-H bonds are normal covalent bonds (two centre - two electron bond or 2c-2e bond).

(v) The remaining four electrons have to be used for the bridged bonds. i.e. two three centred B-H-B bonds utilise two electrons each. Hence, these bonds are three centre-two electron bonds (3c-2e). The bridging hydrogen atoms are in a plane as shown in the figure. In diborane, the boron is sp^3 hybridised.

(vi) Three of the four sp^3 hybridised orbitals contains single electron and the fourth orbital is empty.

(vii) Two of the half filled hybridised orbitals of each boron overlap with the 1s orbitals of two hydrogens to form four terminal 2c-2e bonds, leaving one empty and one half filled hybridised orbitals on each boron.

(viii) The Three centre - two electron bonds, B-H-B bond formation involves overlapping the half filled hybridised orbital of one boron, the empty hybridised orbital of the other boron and the half filled 1s orbital of hydrogen.



Structure of diborane

9. Write a short note on hydroboration. *[June-'23 & '24]*

Ans. *(i)* Diborane adds on to alkenes and alkynes in ether solvent at room temperature.

(ii) This reaction is called hydroboration and is highly used in synthetic organic chemistry, especially for anti Markovnikov addition.

$$B_2H_6 + 6RCH = CHR \longrightarrow 2(RCH_2\text{–}CHR)_3B$$

10. Give one example for each of the following

(i) icosagens *[June-'23]*

(ii) tetragens **(iii) pnictogens**

(iv) chalcogens *[June-'23]*

Ans. *(i)* icosagens - Boron

(ii) tetragens - Carbon

(iii) pnictogens - Nitrogen

(iv) chalcogens - Oxygen

11. Write a note on metallic nature of p-block elements.

Ans. *(i)* The tendency of an element to form a cation by losing electrons is known as electropositive or metallic character.

(ii) This character depends on the ionisation energy.

(iii) Generally on descending a group ionisation energy decreases and hence the metallic character increases.

(iv) In p-block, the elements present in lower left part are metals while the elements in the upper right part are non metals.

Group	Metals	Non-metals	Metalloids
13	Al, Ga, In, Tl	-	B
14	Sn, pb	C	Si, Ge
15	Bi	N, P	As, Sb
16	Po	O, S, Se	Te
17	-	F, Cl, Br, I, At	-
18	-	He, Ne, Ar, Kr, Xe, Rn	-

12. Complete the following reactions

a. $B(OH)_3 + NH_3 \longrightarrow$

b. $Na_2B_4O_7 + H_2SO_4 + H_2O \longrightarrow$

c. $B_2H_6 + 2NaOH + 2H_2O \longrightarrow$

d. $B_2H_6 + CH_3OH \longrightarrow$

e. $BF_3 + 9H_2O \longrightarrow$

f. $HCOOH + H_2SO_4 \longrightarrow$ *[QY-'23]*

g $SiCl_4 + NH_3 \longrightarrow$ *[QY_'19]*

h. $SiCl_4 + C_2H_5OH \longrightarrow$

i. $B + NaOH \longrightarrow$ *[QY_'19]*

j. $H_2B_4O_7 \xrightarrow{\text{Red hot}}$ *[QY-'23]*

Ans. a. $B(OH)_3 + NH_3 \xrightarrow{\Delta} BN + 3H_2O$

b. $Na_2B_4O_7 + H_2SO_4 + 5H_2O \longrightarrow 4H_3BO_3 + Na_2SO_4$

c. $B_2H_6 + 2NaOH + 2H_2O \longrightarrow 2NaBO_2 + 6H_2$

d. $B_2H_6 + 6CH_3OH \longrightarrow 2B(OCH_3)_3 + 6H_2$

e. $4BF_3 + 9H_2O \longrightarrow 4H_3BO_3 + 3H^+ + 3[BF_4]^-$

f. $HCOOH + H_2SO_4 \longrightarrow CO + H_2SO_4.H_2O$

g $SiCl_4 + NH_3 \xrightarrow[\text{ether}]{330K} Cl_3Si - NH - SiCl_3$

h. $SiCl_4 + C_2H_5OH \longrightarrow Si(OC_2H_5)_4 + 2Cl_2$

i. $2B + 6NaOH \longrightarrow 2Na_3BO_3 + 3H_2$

j. $H_2B_4O_7 \xrightarrow{\text{Red hot}} 2B_2O_3 + H_2O$

13. How will you identify borate radical? *[PTA - 5; Govt. MQP & QY_'19]*

(or)

Write ethylborate test. *[April-'23]*

Ans. *(i)* When boric acid or borate salt is heated with ethyl alcohol in presence of conc. sulphuric acid, an ester, triethylborate is formed.

(ii) The vapour of this ester burns with a green edged flame and this reaction is used to identify the presence of borate.

$$H_3BO_3 + 3C_2H_5OH \xrightarrow[H_2SO_4]{\text{Conc.}} B(OC_2H_5)_3 + 3H_2O$$

14. Write a note on zeolites. *[PTA - 2; QY_'19 & '24]*

Ans. *(i)* Zeolites are three-dimensional crystalline solids containing aluminium, silicon, and oxygen in their regular three dimensional framework.

(ii) They are hydrated sodium alumino silicates with general formula $Na_2O.(Al_2O_3).x(SiO_2).yH_2O$ (x = 2 to 10; y = 2 to 6).

(iii) Zeolites have porous structure in which the monovalent sodium ions and water molecules are loosely held.

(iv) The Si and Al atoms are tetrahedrally coordinated with each other through shared oxygen atoms.

(v) Zeolites are similar to clay minerals but they differ in their crystalline structure.

(vi) Zeolites have a three dimensional crystalline structure looks like a honeycomb consisting of a network of interconnected tunnels and cages.

(vii) Water molecules moves freely in and out of these pores but the zeolite framework remains rigid.

(viii) Another special aspect of this structure is that the pore/channel sizes are nearly uniform, allowing the crystal to act as a molecular sieve.

(ix) The removal of permanent hardness of water can be done using zeolites.

15. How will you convert boric acid to boron nitride? *[PTA - 3; HY-'23; Mar-'24]*

Ans. Fusion of urea with $B(OH)_3$, in an atmosphere of ammonia at 800 - 1200 K gives boron nitride.

$$B(OH)_3 + NH_3 \xrightarrow{\Delta} BN + 3H_2O$$

16. A hydride of 2nd period alkali metal (A) on reaction with compound of Boron (B) to give a reducing agent (C). Identify A, B and C. *[PTA - 1]*

Ans. *(i)* A hydride of 2nd period alkali metal (A) is **LiH**.

(ii) Compound of Boron (B) is **B_2H_6** diborane.

(iii) Reducing agent (C) is **$LiBH_4$**.

(iv) $2LiH + B_2H_6 \xrightarrow{\text{Ether}} 2LiBH_4$ (a strong reducing agent)

(v) A is LiH. B is B_2H_6. C is $LiBH_4$.
Lithium hydride Diborane Lithium boro hydride

Compound	Formula	Name
A	LiH	Lithium hydride
B	B_2H_6	diborane
C	$LiBH_4$	Lithium Boro hydride

17. A double salt which contains fourth period alkali metal (A) on heating at 500K gives (B). Aqueous solution of (B) gives white precipitate with $BaCl_2$ and gives a red colour compound with alizarin. Identify A and B.

Ans. *(i)* A double salt which contains 4th period alkali metal (A) is **$K_2SO_4.Al_2(SO_4)_3.24H_2O$**

(ii) $K_2SO_4Al_2(SO_4)_3.24H_2O \xrightarrow{500K} K_2SO_4.Al_2(SO_4)_3 + 24H_2O$

$(SO_4)_2 + BaCl_2 \longrightarrow Ba\,SO_4 \downarrow + 2Cl^-$

(Aqueous Solution of $K_2SO_4.Al_2(SO_4)_3$) (White precipitate)

$K_2SO_4.Al_2(SO_4)_3 \rightarrow Al + \text{alizarin} \rightarrow \text{red compound}$

(Aluminium ion of $K_2SO_4.Al_2(SO_4)_3$)

A	$K_2SO_4.Al_2(SO_4)_3 24H_2O$	Potash alum
B	$K_2SO_4.Al_2(SO_4)_3.$	Burnt alum

18. CO is a reducing agent. Justify with an example. *[PTA - 6]*

Ans. Thermodynamically CO_2 is more stable than CO, thus carbon monoxide has a relatively high tendancy to be oxidised to form carbon di oxide. As it is oxidised it reduces the other substance in the reaction.

Carbon monoxide acts as a strong reducing agent.

$$3CO + Fe_2O_3 \longrightarrow 2Fe + 3CO_2$$

Evaluate Yourself

1. Why group 18 elements are called inert gases? Write the general electronic configuration of group 18 elements.

Ans. *(i)* Group 18 consists of 6 elements, helium, neon, argon, krypton, xenon and radon. All these are gases and almost chemically inert. Since they have completely filled valence shell. (least reactive elements). Hence they are called inert gases.

(ii) The general electronic configuration of group 18 elements is ns^2, np^6.

(PTA) Model Questions And Answers

Choose the Correct Answer — 1 Mark

1. Ortho boric acid on dehydration at 373 K produces mainly *[PTA - 3]*

a) metaboric acid b) boric anhydride

c) Boron metal and Oxygen

d) tetraboric acid. **[*Ans.* (a) metaboric acid]**

2. Assertion : Aqueous solution of potash Alum is acidic *[PTA - 1]*

Reason : Aluminium sulphate undergo hydrolysis

a) Both assertion and reason are true and reason is the correct explanation of assertion

b) Both assertion and reason are true but reason is not the correct explanation of assertion

c) Assertion is true but reason is false

d) Both assertion and reason are false

[*Ans.* (a) Both assertion and reason are true and reason is the correct explanation of assertion]

3. On hydrolysis BF_3 gives Boric acid and converted to fluoroboric acid. The fluoroboric acid contains the species. *[PTA - 6]*

a) H^+, F^- & BF_3 b) H^+ & $[BF_4]^-$

c) $[H\,BF_3]^+$ & F^- d) H^+, B^{3+} & F^-

[*Ans.* (b) H^+ & $[BF_4]^-$]

Answer The Questions — 2 Marks

1. What is water gas equilibrium? *[PTA - 5]*

Ans. The equilibrium involved in the reaction between carbon dioxide and hydrogen, has many industrial applications and is called water gas equilibrium.

$$CO_2 + H_2 \rightleftharpoons CO + H_2O$$

Answer The Questions 3 marks

1. $AlCl_3$ is more stable where as $TlCl_3$ is highly unstable. Why? *[PTA - 2]*

Ans. **(i)** Aluminium(III)chloride is stable whereas thallium(III)chloride is highly unstable and disproportionates to thallium(I) chloride and chlorine gas.

(ii) This shows that in thallium the stable lower oxidation state corresponds to the loss of np electrons only and not ns electrons.

(iii) Thus in heavier post-transition metals, the outer s electrons (ns) have a tendency to remain inert and show reluctance to take part in the bonding, which is known as inert pair effect.

2. How is potash Alum prepared? *[PTA - 4; HY-'24]*

(or)

Write the preparation of potash alum? *[HY - '19]*

Ans. Alunite, the alum stone is the naturally occurring form and it is $K_2SO_4.Al_2(SO_4)_3.4Al(OH)_3$. When alum stone is treated with excess of sulphuric acid, the aluminium hydroxide is converted to aluminium sulphate. A calculated quality of potassium sulphate is added and the solution is crystallised to generate potash alum. It is purified by recrystallisation.

$$K_2SO_4.Al_2(SO_4)_3.4Al(OH)_3 + 6H_2SO_4 \longrightarrow K_2SO_4 + 3Al_2(SO_4)_3 + 12H_2O$$

$$K_2SO_4 + Al_2(SO_4)_3 + 24H_2O \longrightarrow K_2SO_4.Al_2(SO_4)_3.24H_2O$$

3. What are amphiboles? Give example. *[PTA - 5]*

Ans. **Double chain silicates (or amphiboles):** These silicates contains $[Si_4O_{11}]_n^{6n-}$ ions. In these silicates there are two different types of tetrahedra :

(a) Those sharing 3 vertices

(b) Those sharing only 2 vertices.

Examples :

Asbestos : These are fibrous and non-combustible silicates. Asbestos being carcinogenic silicates, their applications are restricted.

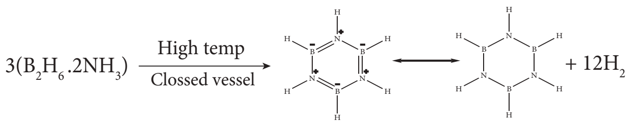
Answer The Questions 5 marks

1. Which is known as Inorganic benzene? How it is prepared? *[PTA - 1]*

Ans. Borazole or Borazine is known as Inorganic benzene. When diborane treated with excess ammonia at low temperatures gives diboranediammonate. On heating at higher temperatures it gives inorganic benzene (borazole).

$$3B_2H_6 + 6NH_3 \xrightarrow{-153K} 3(B_2H_6.2NH_3)$$

$$\text{(or) } 3\left[BH_2(NH_3)_2\right]^+\left[BH_4\right]^-$$



$2B_3N_3H_6$ (Borazole or Borazine - Inorganic benzene)

Government Exam Questions And Answers

Choose the Correct Answer 1 mark

1. Which compound is used as flux in metallurgy? *[Govt. MQP_'19]*

a) Boric acid b) Borax

c) Diborane d) BF_3

[*Ans.* (b) Borax]

2. All the elements of group 17 and 18 are : *[HY-'19]*

a) metalloids b) metals

c) non-metals d) both (a) and (b)

[*Ans.* (c) non-metals]

3. Sodium Salt of tetraboric acid is known as : *[Sep-2020]*

(a) B_2H_6 (b) Na_2BO_3

(c) H_3BO_3 (d) $Na_2B_4O_7.10H_2O$

[*Ans.* (d) $Na_2B_4O_7.10H_2O$]

4. The element that shows lowest Catenation among the following p-block elements is : *[July-'22]*

(a) Carbon (b) Silicon

(c) Lead (d) Germanium

[*Ans.* (c) Lead]

5. Which is used as a Styptic agent to arrest bleeding? *[QY-'24]*

(a) Aluminium Chloride

(b) Potash Alum

(c) Silicones

(d) Borax **[*Ans.* (b) Potash Alum]**

Answer The Questions — 2 marks

1. Although Graphite and Diamond are allotropes of carbon, graphite is soft whereas diamond is hard. Why? *[QY_'19]*

Ans. *(i)* Both graphite and diamond are allotropes of carbon

(ii) In graphite, the carbon atoms only form 3 covalent bonds, creating hexagonally packed sheets of carbon. The sheets are held together by Weak Vander Waals forces, which make graphite softer than diamond.

(iii) Whereas, in diamond, each carbon atom forms 4 covalent bonds in tetrahedral structure. All four valence electrons of carbon are involved in bonding there is no free electrons for conductivity and which make diamond harder.

2. Give the uses of Potash alum. *[QY_'19]*

Ans. *(i)* It is used for purification of water.

(ii) It is also used for water proofing and textiles. It is used in dyeing, paper and leather tanning industries.

(iii) It is employed as a styptic agent to arrest bleeding.

3. What are silicates ? *[Mar-'24]*

Ans. The mineral which contains silicon and oxygen in tetrahedral $[SiO_4]^{4-}$ units linked together in different patterns are called silicates.

Answer The Questions — 3 marks

1. There is only a marginal difference in decrease in ionisation enthalpy from Aluminium to Thallium - Explain why? *[Mar-2020]*

Ans. The reason for decrease in ionisation enthalpy from Aluminium to Thallium is due to the presence of inner d and f-electrons which has poor shielding effect compared to s and p-electrons.

2. What are the uses of boric acid? *[May, July-'22; Mar-'24]*

Ans. *(i)* Boric acid is used in the manufacture of pottery glases, enamels and pigments.

(ii) It is used as an antiseptic and as an eye lotion.

(iii) It is also used as a food preservative.

Additional Questions and Answers

Choose the Correct Answer — 1 mark

1. Lewis acid character of boron trihalides is as a follows :

a) $BF_3 > BCl_3 > BBr_3 > BI_3$

b) $BCl_3 > BF_3 > BBr_3 > BI_3$

c) $BI_3 > BBr_3 > BCl_3 > BF_3$

d) $BI_3 > BF_3 > BCl_3 > BBr_3$

[*Ans.* (c) $BI_3 > BBr_3 > BCl_3 > BF_3$]

2. Select the incorrect statement regarding B_2H_6.

a) It contains B–B ionic bond

b) Each boron is sp^3 hybridised

c) It has two types of hydrogen bonds

d) it is used as a reducing agent.

[*Ans.* (a) It contains B–B ionic bond]

3. The stability of +1 oxidation state among Al, Ga, In and Tl increases in sequence

a) Tl < In < Ga < Al b) In < Tl < Ga < Al

c) Ga < In < Al < Tl d) Al < Ga < In < Tl

[*Ans.* (d) Al < Ga < In < Tl]

4. Which one of the following compounds has similar structure to that of graphite?

a) Boron nitride b) Boron Carbide

c) Aluminium Carbide

d) Aluminium Oxide **[*Ans.* (a) Boron nitride]**

5. Chemical formula of phosgene is

a) $COCl_2$ b) $CaOCl_2$

c) $CaCO_3$ d) $COCl$

[*Ans.* (a) $COCl_2$]

6. Which of the following oxide is amphoteric?

a) SiO_2 b) CO_2 c) SnO_2 d) CaO

[*Ans.* (c) SnO_2]

7. **Identify the electron – deficient species**
a) $(BH_3)_2$ b) $(SiH_3)_2$
c) PH_3 d) $(CH_3)_2$
[*Ans.* (a) $(BH_3)_2$]

8. **Which of the following statements about H_3BO_3 is not correct?**
a) It has a layer structure in which planar BO_3 units are joined by H–bonds
b) It is a strong tribasic acid
c) It is prepared by acidifying an aqueous solution of borax
d) It does not act as proton donor but acts as lewis acid by accepting hydroxyl ion.
[*Ans.* (b) It is a strong tribasic acid]

9. **Boron compounds behave as Lewis acid, because of their**
a) ionisation property
b) acidic nature c) covalent nature
d) electron deficient nature
[*Ans.* (d) electron deficient nature]

10. **Graphite has**
a) 2–d sheet structure
b) Vander waals force between successive layers of carbon sheets
c) sp^2 hybridised carbon linked with other three carbon atoms in hexagonal planar structure
d) All the above [*Ans.* (d) All the above]

11. **SiO_4^{4-} ion has _______ geometry**
a) Triangular b) Tetrahedral
c) Linear
d) Pentagonal bipyramidal
[*Ans.* (b) Tetrahedral]

Fill in the Blanks :

1. **On moving down the group 13, density ____**
a) decreases b) increases
c) First decreases then increases
d) remains same [*Ans.* (b) increases]

2. **Elements of group 13 mainly form covalent compounds because __________**
a) small size
b) electro negativity values are high
c) ionization energy is very high
d) both (a) and (c) [*Ans.* (d) both (a) and (c)]

3. **Oxidation state exhibited by group 13 elements is ________**
a) +1, +2 and +3 b) +1 and +3
c) +1 and +4 d) +2 +3 and +4
[*Ans.* (b) +1 and +3]

4. **Aluminium is used for making alloys because of its _______**
a) resistance to corrosion
b) poor conductivity
c) heaviness d) all of these
[*Ans.* (a) resistance to corrosion]

5. **All elements except carbon have the tendency to show maximum covalency of six _______**
a) due to presence of vacant d-orbitals
b) due to absence of vacant d-orbitals
c) due to presence of partially filled d-orbitals
d) due to presence of completely filled d-orbitals
[*Ans.* (a) due to presence of vacant d-orbitals]

6. **Group 14 elements have general electronic configuration _______**
a) ns^2 b) ns^2np^4
c) ns^2np^6 d) ns^2np^2 [*Ans.* (d) ns^2np^2]

7. **Allotropy is due to _________**
a) difference in chemical properties
b) difference in the number of atoms in the molecules
c) difference in the arrangement of atoms in the molecules in the crystal
d) None of these
[*Ans.* (c) difference in the arrangement of atoms in the molecules in the crystal]

8. **The silicates which contain discrete tetrahedral units are _________**
a) ortho silicates b) sheet silicates
c) pyro silicates
d) three dimensional silicates
[*Ans.* (a) ortho silicates]

9. **Silicones are ________**
a) ortho silicates
b) water repellent thermal insulators
c) both (a) and (b) d) None of these
[*Ans.* (c) both (a) and (b)]

10. Borax is ________

a) $Na_2[B_4O_5(OH)_4].8H_2O$

b) $Na_2[B_4O_5(OH)_6].7H_2O$

c) $Na_2[B_4O_3(OH)_8].6H_2O$

d) $Na_2[B_4O_2(OH)_{10}].5H_2O$

[*Ans.* (a) $Na_2[B_4O_5(OH)_4].8H_2O$]

Assertion & Reason :

Direction : In each of the following questions a statement of assertion (A) is given and a corresponding statement of reason (R) is given just below it. Mark the correct statement as.

a) (A) and (R) are true and (R) is the correct explanation of (A)

b) Both (A) and (R) are true but (R) does not explain (A)

c) (A) is true but (R) is false

d) Both (A) and (R) are false

1. **Assertion :** diborane containing eight –B–H bonds, on the plane.

 Reason : Boron in B_2H_6 is sp^2 hybridised.

 [*Ans.* (c) (A) is true but (R) is false]

2. **Assertion :** When borax is strongly heated it forms transparent glassy bead.

 Reason : Borax is the other name for sodium tetraborate decahydrate.

 [*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

3. **Assertion :** Boric acid is weak monobasic acid.

 Reason : Boric acid gives one H^+ ion.

 [*Ans.* (c) (A) is true but (R) is false]

4. **Assertion :** Carbon has maximum tendency of catenation among group 14.

 Reason : C–C bond strength is very strong.

 [*Ans.* (a) (A) and (R) are true and (R) is the correct explanation of (A)]

5. **Assertion :** Carbon shows an anomalous behaviour in group 14.

 Reason : Carbon has maximum covalency of 4.

 [*Ans.* (b) Both (A) and (R) are true but (R) does not explain (A)]

Correct statement (s):

1. I. The boron occurs mostly as borates.
 II. Boron does not react directly with hydrogen.
 III. The simplest borane is triborane.
 IV. Boron combines with halogen to form boron trihalides.

 a) Only I b) Only II
 c) III & IV d) I, II & IV

 [*Ans.* (d) I, II & IV]

2. I. Boric acid can be extracted from borax and colemanite.
 II. Boric acid is a colourful crystal.
 III. It is a very weak monobasic acid.
 IV. It accepts hydroxyl ion rather than donating proton.

 a) Only I b) Only II
 c) I, III & IV d) III & IV

 [*Ans.* (c) I, III & IV]

3. I. Aluminium chloride is obtained by heating a mixture of alumina and coke in a current of chlorine
 II. Anhydrous aluminium chloride is a hygroscopic substance.
 III. Anhydrous aluminium chloride is a colourless substance.
 IV. Aluminium chloride is a lewis base

 a) I, II & III b) Only II
 c) Only I d) III & IV

 [*Ans.* (a) I, II & III]

4. I. Potash alum is a white crystalline solid.
 II. It is soluble in water.
 III. It is used as a styptic agent
 IV. The aqueous solution is base.

 a) III & IV b) Only II
 c) Only I d) I, II & III

 [*Ans.* (d) I, II & III]

5. I. Graphene is an allotropic from of carbon
 II. CO is a strong reducing agent
 III. CO is a poisonous gas.
 IV. CO is used as a propellent

 a) I, II & III b) Only II
 c) Only I d) III & IV

 [*Ans.* (a) I, II & III]

Incorrect statement (s):

1. a) Boron has the capacity to absorb neutrons.
   b) Amorphous boron is used as a rocket fuel igniter.
   c) Boron is essential for the cell walls of plants.
   d) Boron shows reactivity at higher temperatures.

   [*Ans.* (a, b and c)]

2. a) In diborane two BH_2 units are linked by three bridged hydrogens.
   b) It has six B-H bonds.
   c) Diborane is used as a high energy fuel for propellant
   d) It is used in welding torches

   [*Ans.* (a & b)]

3. a) Alum is potassium aluminium sulphate
   b) Alum is extracted from colemanite
   c) Anhydrous aluminium chloride a catalyst in Friedel crafts reactions.
   d) Its a Lewis acid

   [*Ans.* (b) Alum is extracted from colemanite]

4. a) Carbon is found in the native form as graphite.
   b) Coal contains large quantities of carbon
   c) Clay is important source for carbon.
   d) Carbon exists in many allotropic forms.

   [*Ans.* (c) Clay is important source for carbon.]

5. a) General formula of silicones R_2 CO Si
   b) Silicones are high - temperature polymers
   c) Silicones are used for water proofing clothes
   d) They are good thermal and electrical conductors.

   [*Ans.* (a & d)]

Match the following :

1.

1	Potash alum	a	$K_2SO_4.Cr_2(SO_4)_3.24.H_2O$
2	Sodium alum	b	$K_2SO_4.Al_2(SO_4)_3.24.H_2O$
3	Ammonium alum	c	$Na_2SO_4.Al_2(SO_4)_3.24.H_2O$
4	Chrome alum	d	$(NH_4)_2SO_4.Al_2(SO_4)_3.24.H_2O$

	1	2	3	4
(a)	a	d	b	c
(b)	b	c	d	a
(c)	c	a	d	b
(d)	d	c	b	a

[*Ans.* (b) b c d a]

2.

1	Group 18	a	B-H bonds
2	Borax	b	Inert gases
3	Boric acid	c	Sodium salt
4	Diborane	d	Colourless crystal

	1	2	3	4
(a)	a	d	b	c
(b)	d	c	b	a
(c)	c	a	d	b
(d)	b	c	d	a

[*Ans.* (d) b c d a]

3.

1	Carbon	a	Non - flammable gas
2	Carbon dioxide	b	Poly siloxanes
3	Silicones	c	Alumino silicate
4	Beryl	d	Graphite

	1	2	3	4
(a)	a	d	b	c
(b)	d	a	b	c
(c)	c	a	d	b
(d)	b	c	d	a

[*Ans.* (b) d a b c]

4.

1	Double chain silicates	a	Ring silicates
2	Cyclic silicates	b	Amphiboles
3	Pyro silicate	c	Pyroxenes
4	Chain silicate	d	Soro silicates

	1	2	3	4
(a)	a	d	b	c
(b)	d	a	b	c
(c)	c	a	d	b
(d)	b	a	d	c

[*Ans.* (d) b a d c]

5.

1	Zeolites	a	Potassium aluminium sulphate
2	Alum	b	Cell walls of plants
3	Amorphous boron	c	Hydrated sodium aluminium silicates
4	Boron	d	Rocket fuel ignites

	1	2	3	4
(a)	a	d	b	c
(b)	d	a	b	c
(c)	c	a	d	b
(d)	b	c	d	a

[*Ans.* (c) c a d b]

VERY SHORT ANSWER 2 MARKS

1. How is boric acid extracted from borax?

Ans. Boric acid can be extracted from borax.

$$Na_2B_4O_7 + H_2SO_4 + 5H_2O \longrightarrow 4H_3BO_3 + Na_2SO_4$$

2. Explain the formation of boron trifluoride.

Ans. (i) Boric acid reacts with calcium fluoride in presence of conc. sulphuric acid and gives boron trifluoride.

$$3CaF_2 + 3H_2SO_4 + 2B(OH)_3 \longrightarrow 3CaSO_4 + 2BF_3 + 6H_2O$$

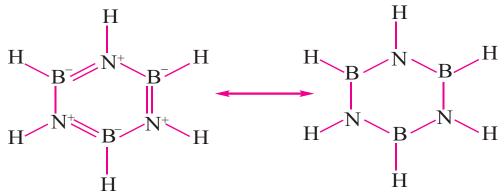
3. Name the two important ores of Boron.

Ans. (i) Borax - $Na_2[B_4O_5.(OH)_4].8H_2O$

(ii) Kernite - $Na_2[B_4O_5(OH)_4].2H_2O$.

4. Draw the structure of borazole. $B_3N_3H_6$.

Ans.



$2B_3N_3H_6$ *(Borazole or Borazine - Inorganic benzene)*

5. Write the reaction of diboranes with water and alkali.

Ans. Diboranes reacts with water and alkali to give boric acid and metaborates respectively.

$$B_2H_6 + 6H_2O \longrightarrow 2H_3BO_3 + 6H_2$$

$$B_2H_6 + 2NaOH + 2H_2O \longrightarrow 2NaBO_2 + 6H_2$$

6. What are the uses of boron trifluoride?

Ans. (i) Boron trifluoride is used for preparing HBF_4, a catalyst in organic chemistry

(ii) It is also used as a fluorinating reagent.

7. What is burnt alum?

Ans. On heating to 475 K potash alum loses water of hydration and swells up. The swollen mass is known as burnt alum.

8. What is phosgene? How is it prepared?

Ans. When carbon monoxide is treated with chlorine in presence of light or charcoal, it forms a poisonous gas carbonyl chloride, which is also known as phosgene. It is used in the synthesis of isocyanates.

$$CO + Cl_2 \longrightarrow COCl_2$$

9. What happens to CO_2 when dissolved in water?

Ans. The aqueous solution of carbon dioxide is slightly acidic as it forms carbonic acid.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

10. What is tetraethoxy silane? How is it obtained?

Ans. Tetraethoxy silane is $Si(OC_2H_5)_4$.

The chloride ion in silicon tetrachloride can be substituted by nucleophile such as OH, OR, etc.. using suitable reagents. For example, it forms silicic esters with alcohols.

$$SiCl_4 + 4C_2H_5OH \longrightarrow \underset{\text{Tetraethoxy silane}}{Si(OC_2H_5)_4} + 4HCl$$

11. Give the formula of chlorosilazanes. Explain its preparation from $SiCl_4$.

Ans. Chlorosilazanes is $Cl_3Si - NH - SiCl_3$

Silicon tetrachloride undergoes ammonialysis to form chlorosilazanes.

$$2SiCl_4 + NH_3 \xrightarrow[\text{Ether}]{330\text{ K}} Cl_3Si - NH - SiCl_3 + 2HCl$$

12. What are the uses of silicon tetra chloride?

Ans. (i) Silicon tetrachloride is used in the production of semiconducting silicon.

(ii) It is used as a starting material in the synthesis of silica gel, silicic esters, a binder for ceramic materials.

13. What are silicones?

Ans. (i) Silicones or poly siloxanes are organo silicon polymers with general empirical formula (R_2SiO).

(ii) These silicones may be linear or cross linked. Because of their very high thermal stability they are called **high –temperature polymers**.

14. Name the building block of zeolites. Why zeolites have high porosity?

Ans. (i) Zeolites have a three dimensional crystalline structure looks like a honeycomb consisting of a network of interconnected tunnels and cages.

(ii) Water molecules moves freely in and out of these pores hence they are highly porous.

15. (i) Silicones are used for making waterproof fabrics. Give reason.

(ii) Diamond – bad conductor of electricity.

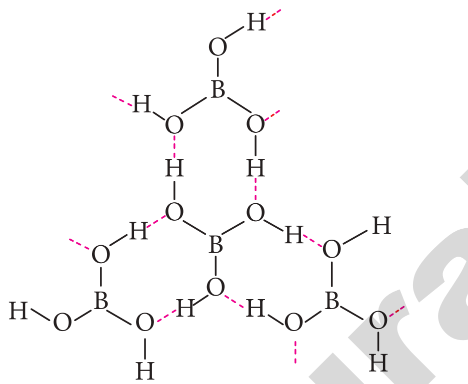
Ans. (i) All silicones are water repellent. This property arises due to the presence of organic side groups that surrounds the silicon which makes the molecule looks like an alkane.

(ii) In diamond, all four valance electrons of carbon are involved in bonding there is no free electrons for conductivity.

SHORT ANSWER — 3 MARKS

1. Draw the structure of boric acid.

Ans. Boric acid has a two dimensional layered structure. It consists of $[BO_3]^{3-}$ unit and these are linked to each other by hydrogen bonds.



Structure of boric acid

2. What happens to boranes are heated to high temperatures?

Ans. At high temperatures it forms higher boranes liberating hydrogen.

$$5B_2H_6 \xrightarrow[\text{U-tube}]{388\text{ K}} 2B_5H_{11} + 4H_2$$

$$2B_2H_6 \xrightarrow{198-373\text{ K}} B_4H_{10} + H_2$$

$$5B_2H_6 \xrightarrow[\text{sealed tube}]{373\text{K}} B_{10}H_{14} + 8H_2$$

$$5B_2H_6 \xrightarrow{473-523\text{K}} 2B_5H_9 + 6H_2$$

$$10B_2H_6 \xrightarrow{523\text{K}} 2B_5H_9 + 2B_5H_{10} + 11H_2$$

$$B_2H_6 \xrightarrow{\text{Red hot}} 2B + 3H_2$$

3. How is boron trifluoride obtained from boron trioxide?

Ans. (i) Boron trifuloride is obtained by the treatment of calcium fluoride with boron trioxide in presence of conc. sulphuric acid.

$$B_2O_3 + 3CaF_2 + 3H_2SO_4 \xrightarrow{\Delta} 2BF_3 + 3CaSO_4 + 3H_2O$$

(ii) It can also be obtained by treating boron trioxide with carbon and fluorine.

$$B_2O_3 + 3C + 3F_2 \longrightarrow 2BF_3 + 3CO$$

(iii) In the laboratory pure BF_3 is prepared by the thermal decomposition of benzene diazonium tetrafluoro borate.

$$C_6H_5N_2BF_4 \xrightarrow{\Delta} BF_3 + C_6H_5F + N_2$$

4. What are the uses of diborane?

Ans. (i) Diborane is used as a high energy fuel for propellant.

(ii) It is used as a reducing agent in organic chemistry.

(iii) It is used in welding torches.

5. How is aluminum chloride prepared from aluminum?

Ans. (i) When aluminium metal or aluminium hydroxide is treated with hydrochloric acid, aluminium trichloride is formed.

(ii) The reaction mixture is evaporated to obtain hydrated aluminium chloride.

$$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$$

$$Al(OH)_3 + 3HCl \longrightarrow AlCl_3 + 3H_2O$$

6. How is aluminium chloride prepared by McAfee process?

Ans. (i) Aluminium chloride is obtained by heating a mixture of alumina and coke in a current of chlorine.

$$2Al_2O_3 + 3C + 6Cl_2 \longrightarrow 4AlCl_3 + 3CO_2$$

(ii) On industrial scale it is prepared by chlorinating aluminium around 1000 K

$$2Al + 3Cl_2 \xrightarrow{1000\text{K}} 2AlCl_3$$

7. Give 3 uses of aluminium chloride.

Ans. (i) Anhydrous aluminium chloride is used as a catalyst in Friedel Crafts reactions *(ii)* It is used for the manufacture of petrol by cracking the mineral oils.

(iii) It is used as a catalyst in the manufacture on dyes, drugs and perfumes.

8. Describe the structure of graphite.

Ans. (i) **Graphite** is the most stable allotropic form of carbon at normal temperature and pressure.

(ii) It is soft and conducts electricity. It is composed of flat two dimensional sheets of carbon atoms.

(iii) Each sheet is a hexagonal net of sp^2 hybridised carbon atoms with a C-C bond length of 1.41 Å which is close to the C-C bond distance in benzene (1.40 Å).

(iv) Each carbon atom forms three σ bonds with three neighbouring carbon atoms using three of its valence electrons and the fourth electron present in the unhybridised p orbital forms a π-bond.

(v) These π electrons are delocalised over the entire sheet which is responsible for its electrical conductivity.

(vi) The successive carbon sheets are held together by weak vander Waals forces. The distance between successive sheet is 3.40 Å.

(vii) It is used as a lubricant either on its own or as a graphited oil.

9. Describe the structure of diamond.

Ans. (i) **Diamond** is very hard.

(ii) The carbon atoms in diamond are sp^3 hybridised and bonded to four neighbouring carbon atoms by σ bonds with a C-C bond length of 1.54 Å.

(iii) This results in a tetrahedral arrangement around each carbon atom that extends to the entire lattice.

(iv) Since all four valance electrons of carbon are involved in bonding there is no free electrons for conductivity.

(v) Being the hardest element, it used for sharpening hard tools, cutting glasses, making bores and rock drilling.

10. Describe the structure of fullerenes.

Ans. (i) **Fullerenes** are newly synthesised allotropes of carbon.

(ii) Unlike graphite and diamond, these allotropes are discrete molecules such as C_{32}, C_{50}, C_{60}, C_{70}, C_{76} etc..

(iii) These molecules have cage like structures.

(iv) The C_{60} molecules have a soccer ball like structure and is called buckminster fullerene or buckyballs.

(v) It has a fused ring structure consists of 20 six membered rings and 12 five membered rings.

(vi) Each carbon atom is sp^2 hybridised and forms three σ bonds & a delocalised π bond giving aromatic character to these molecules.

(vii) The C-C bond distance is 1.44 Å and C=C distance 1.38 Å.

11. Describe the structure of carbon nanotubes.

Ans. (i) Carbon nanotubes, have graphite like tubes with fullerene ends.

(ii) Along the axis, these nanotubes are stronger than steel and conduct electricity.

(iii) These have many applications in nanoscale electronics, catalysis, polymers and medicine.

LONG ANSWER — 5 MARKS

1. What are the various methods by which carbon-di-oxide is prepared?

Ans. (i) On industrial scale it is produced by burning coke in excess of air.

$$C + O_2 \longrightarrow CO_2 \qquad \Delta H = -394 \text{ kJ mol}^{-1}$$

(ii) Calcination of lime produces carbon dioxide as by product.

$$CaCO_3 \longrightarrow CaO + CO_2$$

(iii) Carbon dioxide is prepared in laboratory by the action of dilute hydrochloric acid on metal carbonates.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

2. How are silicates classified? Give an example for each type of silicate.

Ans. Silicates are classified into various types based on the way in which the tetrahedral units, $[SiO_4]^{4-}$ are linked together.

(i) **Ortho silicates (Neso silicates):** The simplest silicates which contain discrete $[SiO_4]^{4-}$ tetrahedral units are called ortho silicates or neso silicates.

Examples : Phenacite - Be_2SiO_4 (Be^{2+} ions are tetrahedrally surrounded by O^{2-} ions)

(ii) **Pyro silicate (or) Soro silicates):** Silicates which contain $[Si_2O_7]^{6-}$ ions are called pyro silicates (or) Soro silicates.

Example : Thortveitite - $Sc_2Si_2O_7$

(iii) **Cyclic silicates (or Ring silicates) :** Silicates which contain $(SiO_3)_n^{2n-}$ ions which are formed by linking three or more tetrahedral SiO_4^{4-} units cyclically are called cyclic silicates.

Example: Beryl $[Be_3Al_2(SiO_3)_6]$ (an aluminosilicate with each aluminium is surrounded by 6 oxygen atoms octahedrally)

(iv) **Inosilicates :** Silicates which contain '*n*' number of silicate units linked by sharing two or more oxygen atoms are called inosilicates.

They are further classified as chain silicates and double chain silicates.

(v) **Chain silicates (or pyroxenes) :** These silicates contain $[(SiO_3)_n]^{2n-}$ ions formed by linking '*n*' number of tetrahedral $[SiO_4]^{4-}$ units linearly. Each silicate unit shares two of its oxygen atoms with other units.

Example : Spodumene - $LiAl(SiO_3)_2$.

(vi) **Double chain silicates (or amphiboles):** These silicates contains $[Si_4O_{11}]_n^{6n-}$ ions. In these silicates there are two different types of tetrahedra :

(a) Those sharing 3 vertices

(b) Those sharing only 2 vertices.

Examples :

Asbestos : These are fibrous and non-combustible silicates.

(vii) **Sheet or phyllo silicates :** Silicates which contain $(Si_2O_5)_n^{2n-}$ are called sheet or phyllo silicates. In these, Each $[SiO_4]^{4-}$ tetrahedron unit shares three oxygen atoms with others and thus by forming two dimensional sheets.

Example : Talc, Mica etc.

(viii) **Three dimensional silicates (or tecto silicates) :** Silicates in which all the oxygen atoms of $[SiO_4]^{4-}$ tetrahedra are shared with other tetrahedra to form three-dimensional network are called three dimensional or tecto silicates. They have general formula $(SiO_2)_n$.

Examples : Quartz.

These tecto silicates can be converted into three dimensional aluminosilicates by replacing $[SiO_4]^{4-}$ units by $[AlO_4]^{5-}$ units. E.g. Feldspar, Zeolites etc.,

3. Distinguish between diamond and graphite.

Ans.

DIAMOND	GRAPHITE
C is sp^3 hybridised.	C is sp^2 hybridised.
Tetrahedral structure.	Hexagonal net structure.
Crystalline, transparent with extra brilliance.	Crystalline, opaque and shiny substance.
It is hard with high density and high melting point.	It is soft with low density and high melting point.
Bad conductor of heat and electricity.	Good conductor of heat and electricity.

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UNIT TEST

Time : 40 min Marks : 25

I. Choose the Correct Answer (5 × 1 = 5)

1. Silicones are _______.
a) Water repelling in nature
b) High in thermal stability
c) Both a & b
d) None of these

2. All the elements of group 17 and 18 are ____
a) Metalloids b) Metals
c) non-metals d) all the above

3. Duralumin is an alloy of _____
a) Cu, Mn b) Cu, Al, Mg
c) Al, Mn d) Al, Cu, Mn, Mg

4. Formula for phosgene is ________
a) $COCl_2$ b) $CaOCl_2$
c) $CaCO_3$ d) COCl

5. Assertion : In diborane containing eight B–H bonds on the plane.
Reason : Boron in B_2H_6 is sp^2 hybridised.
a) Both assertion and reason are true and the reason is the correct explanation of the assertion.
b) Both the assertion and reason are true but the reason is not the correct explanation of the assertion.
c) Assertion is true statement but reason is false.
d) Both assertion and reason are false statements.

II. Short Answer (2 × 2 = 4)

1. What are the uses of silicon tetra chloride?
2. Write a note on Fisher tropsch synthesis.

III. Answer In Paragraph (2 × 3 = 6)

1. Give the structure of CO and CO_2.
2. Describe the structure of graphite.

IV. Long Answer (2 × 5 = 10)

1. Distinguish between diamond and graphite.
2. How are silicates classified? Give an example for each type of silicate.

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Answer Key

I.
1. c) Both a & b
2. c) non-metals
3. d) Al, Cu, Mn, Mg
4. a) $COCl_2$
5. c) Assertion is true statement but reason is false.

II.
1. *Refer Sura's Guide Additional 2 Marks, Q.No. 12*
2. *Refer Sura's Guide Book Back Questions, Q.No. 5*

III.
1. *Refer Sura's Guide Book Back Questions, Q.No. 6*
2. *Refer Sura's Guide Additional 3 Marks, Q.No. 9*

IV.
1. *Refer Sura's Guide Additional 5 Marks, Q.No. 3*
2. *Refer Sura's Guide Additional 5Marks,Q.No. 2.*

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UNIT 3

p-BLOCK ELEMENTS - II

CHAPTER SNAPSHOT

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