

The electronic configuration of elements in outermost orbital is ns^2np^1 to ns^2np^6 (except He) known as p-block elements. (where $n = 2$ to 6). These elements are placed in right of transition metals in modern periodic table. Due to difference in inner core electronic configuration, the elements show variation in physical and chemical properties. The first element of the group shows anomalous behaviour in some properties from other elements of that group.

Group	13	14	15	16	17	18
2P	B	C	N	O	F	Ne
3P	Al	Si	P	S	Cl	Ar
4P	Ga	Ge	As	Se	Br	Kr
5P	In	Sn	Sb	Te	I	Xe
6P	Tl	Pb	Bi	Po	At	Rn

Atomic Radius, metallic character ↓

Electro negativity, Ionisation Enthalpy, oxidizing agent ↑

● Atomic radius metallic character

Generally in the period, electronegativity, ionization enthalpy and oxidising power increases as the atomic number increases. While in group, it decreases as the atomic number increases. Generally, in group atomic radius, van der waals radius and metallic character increases as the atomic number increases. Due to these characteristics of the p-block elements, metal, non-metal and metalloids are included in same group. These characteristics are decreasing in a period as the atomic number increases.

● General oxidation state of p-block elements

Group	13	14	15	16	17	18
Oxidation State	B	C	N	O	F	Ne
	+3	+4, -4	+5 to -3	-1, -2	-1	-
	Al	Si	P, As	S, Se, Te	Cl, Br, I	Xe
	+3	+4	+3, +5, -3	-2, +2	-1, +1, +3	+2, +4
				+4, +6	+5, +7	+6, +8
	Ga, In, Tl	Ge, Sn, Pb	Sb, Bi			
	+3, +1	+4, +2	+4, +2			

p-block elements have valence shell electronic configuration ns^2np^{1-6} where $n = 2$ to 6 and hence the value of maximum oxidation state of these elements is obtained by subtracting 10 from its group number. On moving down the group from 13 to 16 the oxidation state which are two units less than the highest oxidation state becomes more stable. This trend is called **inert pair effect**.

● **Group 13 elements (Boron group)**

No.	Elements	Symbol	Atomic no.	Electronic Configuration with inter gas core
(1)	Boron	(B)	5	[He] $2s^2 2p^1$
(2)	Aluminium	(Al)	13	[Ne] $3s^2 3p^1$
(3)	Gallium	(Ga)	31	[Ar] $3d^{10} 4s^2 4p^1$
(4)	Indium	(In)	49	[Kr] $4d^{10} 5s^2 5p^1$
(5)	Thallium	(Tl)	81	[Xe] $4f^{14} 5d^{10} 6s^2 6p^1$

Electronic configuration : The group 13 includes Boron (B), Aluminium (Al), Gallium (Ga), Indium (In) and Thallium (Tl). The valence shell electronic configuration is $ns^2 np^1$ where $n = 2$ to 6 . Hence, there are two electrons in S orbital and one electron in p-orbital, therefore in total three electrons are there.

● **Occurrence**

The abundance of boron in earth's crust is less than 0.0001 % by weight.

The boron is found in California (USA) and in Turkey state.

While in India it is found as borax in Puga valley of Ladakh region in Kashmir and also in Sambhar lake of Rajasthan.

Some important ores of aluminium are : Bauxite, Orthoclase, Cryolite, Corundum, Beryl, Mica.

Minerals : Borax	$(Na_2B_4O_7 \cdot 10H_2O)$	Earth crust : largest by weight : O (45.5 %)
Kernite	$(Na_2B_4O_7 \cdot 4H_2O)$	Second largest by weight : Si (27.7 %)
Colemanite	$(Ca_2B_6O_{11} \cdot 2H_2O)$	Third largest by weight : Al (8.3 %)
Orthoboric acid	(H_3BO_3)	
Minerals : Bauxite	$Al_2O_3 \cdot xH_2O$	
Orthoclase	$KAlSi_3O_8$	
Cryolite	Na_3AlF_6	
Corundum	Al_2O_3	
Beryl	$Be_3Al_2Si_6O_{18}$	
Mica	$KAl_2(Si_3AlO_{10})(OH)_2$	

In India, mica is found in Madhya Pradesh, Karnataka, Orissa and Jammu. India is the world's largest supplier of mica. Gallium, Indium and Thallium are less abundant. Gallium (0.1 – 1 %) is found in the mineral Germanite which is a complex sulphide of Zn, Cu, Ge and As while the traces of Indium are found in sulphide ore of zinc. Thallium is found in lead sulphide ore.

● **Variation in properties**

(1) **Atomic radii and ionic radii :** In the elements of boron group as the atomic number increases, the atomic radius increases. Similar trends can be observed in ionic radius. The atomic radius of Al (143 pm) is more than atomic radius of Ga (135 pm).

(2) **Ionization Enthalpy :** The order of first ionization enthalpy ($\Delta_i H_1$) for boron group elements is $B > Al < Ga > In < Tl$. The value of $\Delta_i H_2$ and $\Delta_i H_3$ are very high.

(3) **Metallic Character :** The elements of group 13 show variation in metallic character. The metallic character is higher in Al than that of B. So, Al is a good conductor of heat and electricity. The reduction potential values go on increasing from Al to Tl, so the values of electropositivity decreases as a result, metallic character decreases. Thus, B is non-metal, while Al is metal and in Indium, Gallium, Thallium, the metallic character decreases successively.

(4) Electronegativity : On moving down the elements of group 13, electronegativity decreases suddenly from B to Al and after that it increases gradually as moving from Al to Tl.

(5) Melting points and Boiling Points : The order of melting points of group 13 elements are in order $B > Al > Ga < In < Tl$. As the atomic number goes on increasing, the boiling points decrease gradually.

(6) Density : The density goes on increasing as the atomic number increases for the elements of group 13.

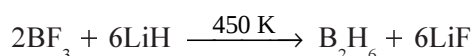
(7) Characteristics as reducing agents : The values of reduction potential increase from Al to Tl and so the reduction power decreases and the characteristics as reducing agent also decreases.

(8) Nature of compounds : The elements of group 13 have a decreasing tendency to form covalent bond compounds. The elements of group 13 have increasing tendency to form ionic compounds.

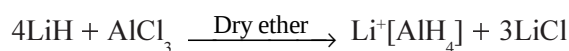
Oxidation State : In the electronic configurations of elements of group 13 they have two electrons in s-type orbital and one-electron in p-type orbitals, so total three electrons in outermost orbital, hence it possesses +3 oxidation state. The oxidation state of boron and aluminium is +3 while Ga, In and Tl have both +1 and +3 oxidation states. As the atomic number is increasing the stability of +3 oxidation state decreases and stability of +1 oxidation state increases.

● Trends in chemical Reactivity

(i) Hydride Compounds



Boron forms number of hydrides, most of hydrides having molecular formula $B_n H_{n+4}$ and $B_n H_{n+6}$ which is known as Borane. Other hydride elements are polymeric eg. $(AlH_3)_n$, $(GaH_3)_n$ and $(InH_3)_n$ their structure contains M...H...M bridge (M = Al, Ga, In). These hydrides are Lewis acids.



(Reducing agent)

(ii) Halide Compounds : The order of its strength is $BI_3 > BBr_3 > BCl_3 > BF_3$. In vapour form $AlCl_3$ exists in dimer form due to bridging of chlorine atoms. Al_2Cl_6 is Lewis acid. Ga and Tl also form MX_3 type halides where X = Cl, Br, I. The stability of MX_3 type halide increases as the atomic number increases.

(iii) Oxide and Hydroxide Compounds : The group 13 elements form oxides having formula M_2O_3 and hydroxide having formula $M(OH)_3$. The atomic number of element goes on increasing the acidic character decreases and the basic character goes on increasing.

(iv) Complex and Double Salt Compounds : In elements of group 13, in the electronic configuration of boron the d-orbital is absent. It forms only tetrahedral complex like $[BH_4]^-$, $[BF_4]^-$ etc. The electronic configuration of Al, Ga, In and Tl have d-orbital (in Al it is in form of $3d^0$), so they form octahedral complexes like $[MF_6]^{3-}$ with octahedral aqua ions can be described as $[M(H_2O)_6]^{3+}$, (where M = Al, Ga, In and Tl). Aluminium sulphate reacts with sulphate of NH_4^+ form double salts known as alums with formula $M_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ or $MAI(SO_4)_2 \cdot 12H_2O$ (where, M = Na^+ , K^+ , Rb^+ , and NH_4^+).

K_2SO_4 , $Al_2(SO_4)_3 \cdot 24H_2O$ known as double salt (alum). It is used to change hard water to soft water and as a mordant in chemicals of colour dye.

● **The anomalous behaviour of the first element (boron) of group 13**

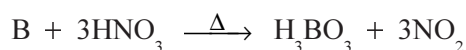
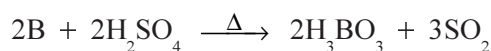
Boron is non-metal. Boron trihalide is monomeric. Boron does not react with water. Oxides and hydroxides of boron are acidic. Except boron, trihalides of other elements on hydrolysis result in complex ions.

● **Physical Properties and Chemical properties of Boron**

Physical properties : Boron is extremely hard substance. In order of hardness, it comes next to diamond. The melting point and boiling point of boron are very high. Boron is poor conductor of heat and electricity. Boron has two isotopes ^{10}B and ^{11}B and its relative abundances is 20% and 80% respectively. Boron has two allotropes. The colour of amorphous form is dark brown where as the crystalline form is found in black metallic luster.

Chemical properties : Boron reacts with strong oxidising agent.

Non metal dinitrogen, dioxygen and dihalogen react with boron at high temperature to give BN , B_2O_3 and BX_3 . Boron does not react with HCl but it reacts with con. HNO_3 and H_2SO_4 .



● **Boron reacts with fused alkalis like NaOH and KOH and converts into corresponding borates.**

$2B + 6MOH \xrightarrow{\Delta} 2M_3BO_3 + 3H_2$ ($M = Na$ or K) Boron reacts with some metals on heating and converts into borides which are very hard and solid substance having high melting point. e.g $B + Cr \xrightarrow{\Delta} CrB$ (Chromium boride).

- Which statement is wrong for the heaviest metal in each group of p-block elements ?
 (A) Highest metallic property.
 (B) 2 unit less oxidation state compared to group.
 (C) It is semi metal.
 (D) Formation of positive ion species.
- Elements of group 13 shows oxidation state.
 (A) +3 (B) +1 (C) +1 and +3 both (D) +1, +2 and +3
- Which of the following has the least melting point ?
 (A) B (B) Al (C) Ga (D) Tl
- Match proper pair :

Mineral	Molecular formula
(P) Borax	(T) $Ca_2B_6O_{11} \cdot 2H_2O$
(Q) Kernite	(U) H_3BO_3
(R) Colemanite	(V) $Na_2B_4O_7 \cdot 4H_2O$
(S) Orthoboric acid	(W) $Na_2B_4O_7 \cdot 10H_2O$

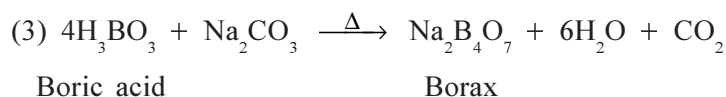
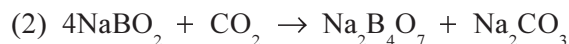
- (A) (P)-(W), (Q)-(V), (R)-(T), (S)-(U)
 (B) (P)-(U), (Q)-(W), (R)-(V), (S)-(T)
 (C) (P)-(T), (Q)-(U), (R)-(W), (S)-(V)
 (D) (P)-(V), (Q)-(T), (R)-(U), (S)-(W)

5. Correct order of ionization enthalpy of group 13 ?
 (A) $B > Al < Ga > In > Tl$ (B) $B > Al > Ga > In < Tl$
 (C) $B < Al < Ga < In < Tl$ (D) $B < Al > Ga > In > Tl$
6. Correct order of melting point of group 13 elements :
 (A) $B > Al > Ga > In > Tl$ (B) $B > Al > Ga < In < Tl$
 (C) $B < Al < Ga < In < Tl$ (D) $B > Al < Ga > In > Tl$
7. Al gives Al^{3+} ions but B does not give B^{3+} ions because ...
 (A) size of B is less than Al (B) value of $IE_1 + IE_2 + IE_3$ of B is more than Al
 (C) value of $IE_1 + IE_2 + IE_3$ of Al is more than B (D) both (A) and (B)
8. Correct order of acidic strength of boron trihalide :
 (A) $BI_3 > BBr_3 > BCl_3 > BF_3$ (B) $BI_3 < BBr_3 < BCl_3 < BF_3$
 (C) $BI_3 > BBr_3 > BF_3 > BCl_3$ (D) $BCl_3 > BBr_3 > BF_3 > BI_3$
9. Which oxide is the most basic ?
 (A) B_2O_3 (B) Al_2O_3 (C) Ga_2O_3 (D) Tl_2O
10. Which hydroxide is amphoteric ?
 (A) $Al(OH)_3$ (B) $B(OH)_3$ (C) $In(OH)_3$ (D) $Tl(OH)_3$
11. Which of the following form only tetrahedral complex ?
 (A) Al (B) B (C) Ga (D) Tl

Answers : 1. (C), 2. (C), 3. (C), 4. (A), 5. (A), 6. (B), 7. (D), 8. (A), 9. (D), 10. (A), 11. (B)

● Some Important Compounds of Boron

Borax powder ($Na_2B_4O_7$) or sodium tetraborate ($Na_2B_4O_7$). The impure form of borax is Tincal which contains 55% borax. It is found in certain dried up lakes of India, Tibet, Sri Lanka and California.



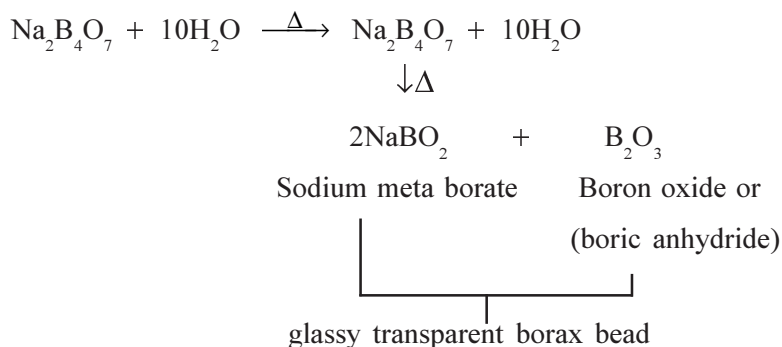
Properties of Borax : (a) Prismatic $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$

(b) Octahedral $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$

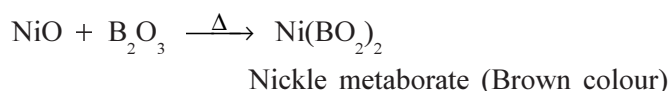
(c) Borax glass $\text{Na}_2\text{B}_4\text{O}_7$



● Borax Bead Test



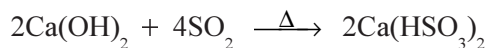
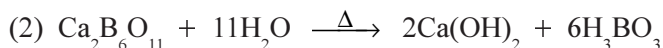
Coloured ions like Ni^{2+} , CO^{+2} , Cr^{2+} , Cu^{2+} , Mn^{2+} and heated, they are converted into their metaborates respectively and they are coloured and their colours are brown, blue, green and pink respectively.



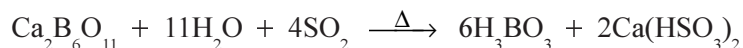
Uses : To perform borax bead test in qualitative analysis. Manufacturing of enamels and glazing of earthen pots. In preparation of candles. Due to its antiseptic properties, it is used in preparation of medical soap. In making optical glass. In softening of hard water.

● Boric acid (H_3BO_3)

Its trivial name is orthoboric acid.

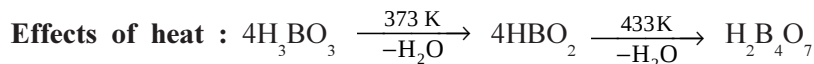


Net reaction



(3) On hydrolysis of BCl_3 and BN they give boric acid.

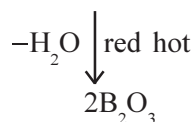
Properties : Boric acid is a white crystalline solid substance with a soft soapy touch. Sparingly soluble in cold water. Fairly soluble in hot water.



Orthoboric acid

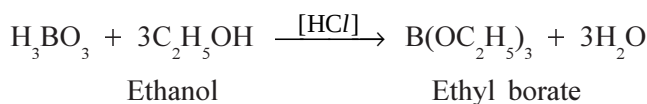
Metaboric acid

Tetraboric acid

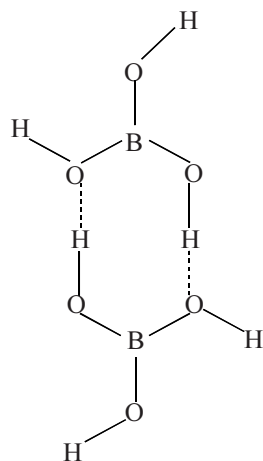


Boron oxide

Weak monobasic acid and acts as a lewis acid.



Structure of boric acid (H_3BO_3)

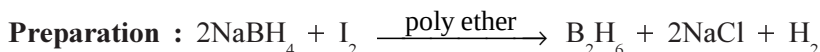


Uses : In food industry. In the preparation of pigments and borax. Used (in medicine) as an eye wash. Used in the manufacturing of enamels and pottery glazes.

● **Boron Hydrides :** B_2H_6 (diborane)

General formula : $B_nH_{n_z+4}$ and $B_nH_{n_z+6}$

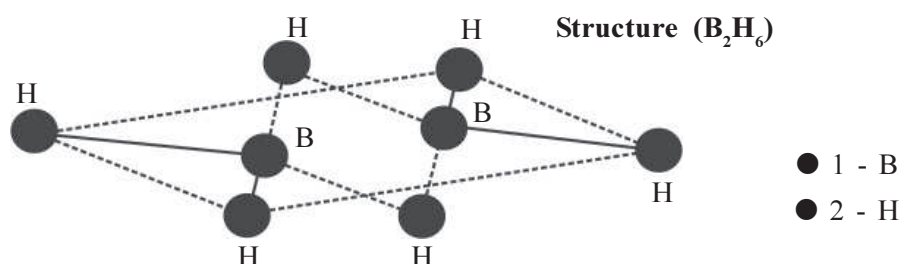
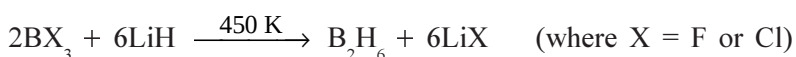
Boron hydrides : B_2H_6



Sodium Borohydride

Diborane

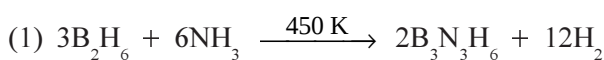
Industrial Reaction :



Properties : Colourless and highly toxic gas.



(air) $\Delta H = -2008\text{ KJ mole}^{-1}$

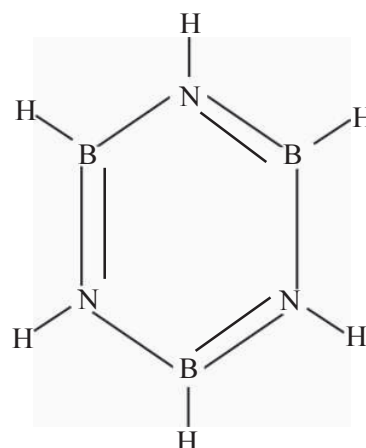


(Borazine)

(Inorganic Benzene)



(Boric acid)



● **Structure of diborane**

Uses of Boron and its Compounds : Isotope of boron ^{10}B has ability to absorb neutrons and therefore used as metal borides, in nuclear reactor as a protective shield and the controlling rods and also used in chemotherapy to cure cancer. Boron fibres are used in making light composite materials for air craft industries. Boron and Boric acid are used in manufacturing of heat resistant borosilicate pyrex glass. In metallurgy as a flux for soldering metals. Porcelain enamels. Borax bead test. A mild antiseptic. Cleaning skin (leather), preservative. The heat of combustion for diborane is very high, so it is used as a high energy fuel.

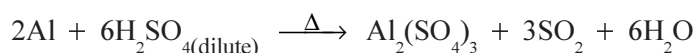
● **Properties of Aluminium**

Aluminium is a light, silvery white metal. It has high tensile strength, high electrical and thermal conductivity. (twice than that of Cu). It is highly electropositive. It readily reacts with O_2 and forms a protective layer of Al_2O_3 on its surface, which makes it passive.

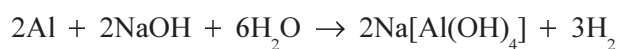
● Uses

In industries and in daily life. Forms useful alloys. In making utensils, aeroplane parts. It is used in aluminothermite process for obtaining the chromium and manganese metals from their oxides. As a strong reducing agent.

● Reaction of Aluminium with acids and bases



Aluminium reacts with concentrated HNO_3 and forms inactive, passive protective layer of Al_2O_3 on surface which stops the further reaction on its surface.



Sodium aluminate

12. Which is correct molecular structure of boron carbide ?

- (A) B_2C_3 (B) B_{13}C_2 (C) B_3C_{12} (D) B_{12}C_3

13. $\text{Ca}_2\text{B}_6\text{O}_{11} + 2\text{Na}_2\text{CO}_3 \xrightarrow{\Delta} 2\text{CaCO}_{3(s)} + \boxed{\text{X}} + 2\boxed{\text{Y}}$ what are X and Y respectively ?

- (A) $\text{Na}_2\text{B}_4\text{O}_7$, NaBO_2 (B) NaHCO_3 , NaBO_2 (C) $\text{Na}_2\text{B}_4\text{O}_7$, NaHCO_3 (D) Na_3BO_3 , NaHCO_3

14. Match the correct pair :

Ion	Colour in borax bead test
(P) Co^{2+}	(T) Pink
(Q) Cr^{3+}	(U) Brown
(R) Ni^{2+}	(V) Green
(S) Mn^{2+}	(W) Blue

(A) (P)-(W), (Q)-(V), (R)-(U), (S)-(T)

(B) (P)-(T), (Q)-(W), (R)-(V), (S)-(U)

(C) (P)-(U), (Q)-(T), (R)-(W), (S)-(V)

(D) (P)-(V), (Q)-(U), (R)-(T), (S)-(W)

15. Which of the following used in (medicine) as an eye wash ?

- (A) H_3BO_3 (B) B_2H_6 (C) HBO_2 (D) $\text{B}_3\text{N}_3\text{H}_6$

16. What is obtained by hydrolysis of BF_3 ?

- (A) $\text{H}_3\text{BO}_3 + \text{HF}$ (B) $\text{H}_3\text{BO}_3 + \text{HBF}_4$ (C) $\text{B}(\text{OH})_3 + \text{B}_2\text{O}_3$ (D) $\text{H}_3\text{BO}_3 + \text{F}_2$

17. Which compound is known as inorganic benzene ?

- (A) B_6H_6 (B) $\text{C}_3\text{N}_3\text{H}_3$ (C) $\text{B}_3\text{N}_3\text{H}_6$ (D) $\text{C}_5\text{H}_5\text{B}$

18. Which of the following statements are true and false for BF_3 ? T = true, F = False

(i) BF_3 acts as Lewis acid

(ii) BF_3 reacts with NH_3 give mix compound.

(iii) BF_3 is volatile at room temperature.

(iv) BF_3 Combine with ether give boron tri fluoride etherate.

- (A) TTTT (B) FTFT (C) TTFT (D) TTFT

19. Which compound gives pink coloured bead heated with manganese salt and boric anhydride ?
 (A) $\text{Mn}_2\text{B}_4\text{O}_7$ (B) $\text{Mn}(\text{BO}_2)_2$ (C) MnO (D) None
20. How many σ and π bonds in borazine ?
 (A) $9\sigma, 6\pi$ (B) $12\sigma, 3\pi$ (C) $6\sigma, 9\pi$ (D) $15\sigma, 0\pi$
21. What is obtained when BCl_3 react with H_2O ?
 (A) $\text{H}_3\text{BO}_3 + \text{HCl}$ (B) $\text{B}_2\text{H}_6 + \text{HCl}$ (C) $\text{B}_2\text{O}_3 + \text{HCl}$ (D) None.
22. What is inorganic graphite ?
 (A) $\text{B}_3\text{N}_3\text{H}_6$ (B) B_3N_3 (C) SiC (D) $\text{Fe}(\text{CO})_5$
23. Which metal condense to expand in liquid form ?
 (A) Ga (B) Al (C) Zn (D) Cu
24. Potash alum dissolve in water to give
 (A) Acidic solution of H_2SO_4 (B) Basic solution
 (C) Acidic solution of HCl (D) Neutral solution
25. Which statement is not correct ?
 (A) Al is ionic in its all compounds.
 (B) Al is light in weight but high tensile strength
 (C) Al is strong reducing agent.
 (D) Al does not react with water vapour at high temperature.
26. What is the mix of 'amonal' used in bomb ?
 (A) $\text{Al} + \text{NH}_4\text{NO}_3$ (B) $\text{Al} + \text{Al}_2\text{O}_3 + \text{B}_2\text{O}_3$ (C) $\text{Al} + \text{KNO}_3$ (D) $\text{Al}_2\text{O}_3 + \text{C}$
27. In which of the following transfer of thallium tribromide at room temperature ?
 (A) TlBr (B) Tl_2Br_6 (C) TlBr_2 (D) $\text{Tl}[\text{TlBr}_4]$
28. Blue coloured precious stone named "Lapis Lazuli" included in which class of mineral ?
 (A) Sodium aluminosilicate (B) Zinc cobaltate
 (C) Basic copper carbonate (D) All above

Answers : 12. (B), 13. (A), 14. (A), 15. (A), 16. (B), 17. (C), 18. (D), 19. (C), 20. (B), 21. (A), 22. (B), 23. (A), 24. (A), 25. (A), 26. (A), 27. (D), 28. (A)

● **General Introduction of Group 14 Elements**

No.	Element	Symbol	Atomic No.	Electron configuration with inert gas core
1.	Carbon	(C)	6	$[\text{He}] 2s^2 2p_x^1 2p_y^1$
2.	Silicon	(Si)	14	$[\text{Ne}] 3s^2 3p_x^1 3p_y^1$
3.	Germanium	(Ge)	32	$[\text{Ar}] 3d^{10} 4s^2 4p_x^1 4p_y^1$
4.	Tin	(Sn)	50	$[\text{Kr}] 4d^{10} 5s^2 5p_x^1 5p_y^1$
5.	Lead	(Pb)	82	$[\text{Xe}] 4f^{14} 5d^{10} 6s^2 6p_x^1 6p_y^1$

Carbon shows catenation characteristics due to its small size, high electronegativity and very high carbon-carbon bond enthalpy. Compounds of carbon with metals, metalloids and with non-metals are called binary inorganic compounds. The compounds like calcium carbide, silicon carbide, carbon monoxide, carbon dioxide, hydrogen cyanide are inorganic compounds.

Occurrence : Carbon is the seventeenth most abundant element by weight. Silicon is the second most abundant (27.7%), by weight. Germanium occurs as a trace element. It is mainly recovered from the flue dust arising from roasting of zinc ores. Tin and lead are found in nature in the amount 2 ppm and 13 ppm respectively.

Galena (PbS) is the principle ore of lead. Found along with zinc blende (ZnS). Other ores of lead are anglesite (PbSO₄) and cerussite (PbCO₃).

● Variation in properties

Atomic radii : On moving down the group the atomic radii of group 14 elements go on increasing.

Ionization enthalpy : C > Si > Ge > Sn < Pb

Electropositivity (Metallic character) : On moving down the group 14 the electropositivity increases.

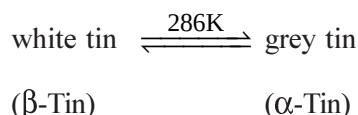
Electronegativity : The electronegativity decreases as the atomic number increases.

Melting points and Boiling points : The melting points and boiling points of group 14 elements are much higher than those of group 13 elements.

Density : On moving down in the elements of group 14, carbon to lead, regular increase in density.

Catenation : C >> Si > Ge = Sn > > Pb

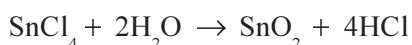
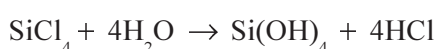
Allotropy : Carbon has number of allotropic forms out of which diamond, graphite and fullerene are the crystalline forms of carbon. Tin has two allotropes, white tin or β- tin. It gets stable at room temperature whereas grey tin or α- tin remains unstable. It can be obtained from β- tin at 286 K temperature.



● Oxidation states and trends in chemical reactivity

Group 14 elements have outermost valence shell electronic configuration ns²np² and hence, these elements have common oxidation state +4. Stability of +2 oxidation state increases in order, which can be given as Ge < Sn < Pb. Simple M⁴⁺ ions in this group are not known. Compounds with co-ordination number higher than 4, like eg. [SiF₅]⁻, [SiF₆]²⁻, [PbCl₆]²⁻. Stable compounds of MX₂ type for carbon and silicon are rare. The stability of divalent state increases in the order Ge < Sn < Pb. Ability to form p^π – p^π bonds with element itself and ability to form such bonds with other elements like dinitrogen and dioxygen decreases from carbon to lead. So, CO₂ is a gas but silica is a solid.

Si, Ge, Sn and Pb form MX₄ type tetrahedral and covalently bonded compounds. The ionic character and thermal stability of halides decreases with increasing atomic number of halogen and they are hydrolysed by water.



Ge, Sn and Pb also form MX₂ type halides.

The stability of dihalides increases in order.



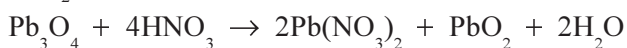
Form MO_2 type oxides.

Crystalline silicon dioxide occurs in quartz, cristobalite and tridymite minerals. Quartz is used as a piezoelectric crystal, crystal oscillator and in transducers. Silica gel is obtained by acidification of sodium silicate. When this gel is dehydrated, the obtained silica gel is extensively used in chromatography and for the drying of other substances and therefore, it acts as a drying agent.

SiO_2 is acidic but GeO_2 and SnO_2 are amphoteric while PbO_2 is basic.

Sn (IV) oxide is prepared by heating Sn and O_2 or reaction of Sn with con. HNO_3 .

SnO_2 is used in polishing powder and in manufacturing of glass and pottery.



PbO_2 is a strong oxidizing agent and liberates O_2 when treated with acids. Sn and Pb both form MO type stable oxides.



Tin oxalate

PbO exists in red, orange and yellow colour depending upon the method of preparation. It can be prepared by heating lead carbonate. On heating PbO with air in a reverbratory furnace at 773 K temperature gives red Pb_3O_4 . It is a combination mixture of 2(PbO) (PbO_2).

● Anomalous behaviour of carbon

Carbon differs from the other members of its group, because the atomic size of carbon is small and has higher electronegativity.

Carbon forms only four covalent bonds while other elements have d or d and f-orbitals. So, they can form more covalent bonds.

Carbon atom forms single bond : Moreover, double or triple bond with the other carbon atoms and some other atoms like O, N and S which are small in size.

If the atomic size of some other atoms are very big then overlapping of $p\pi - p\pi$ orbital does not remain effective.

The trend of catenation in carbon is maximum due to its high value of carbon single bond enthalpy (348 KJ mole^{-1}). While in other elements, this trends goes on decreasing.

Carbon forms only $p\pi - p\pi$ type bonding, while other elements form $p\pi - p\pi$ and also $d\pi - p\pi$ type of bonding.

29. Correct order of ionization enthalpy for group 14 elements ?

(A) $C > Si > Ge > Sn < Pb$

(B) $C > Si > Ge > Sn > Pb$

(C) $C < Si < Ge < Sn > Pb$

(D) $C < Si < Ge < Sn < Pb$

30. Which of the following has highest thermal stability ?

(A) CCl_4

(B) $SiCl_4$

(C) $SnCl_4$

(D) $PbCl_4$

31. Which of the following is heated to make SnO ?

(A) Tin oxalate

(B) Tin carbonate

(C) Tin bicarbonate

(D) Tin dioxide

32. What is obtained by hydrolysis of $PbCl_4$?

(A) PbO

(B) PbO_2

(C) Pb_3O_4

(D) $Pb(OH)_2$

33. Tin heated with hot concentrated HNO_3 gives

(A) $Sn(NO_3)_2$

(B) H_2SnO_3

(C) Na_2SnO_3

(D) Na_2SnO_2

34. What is the formula of lead oxide which women is used as minium (red-lead) on her head ?
 (A) PbO (B) PbO_2 (C) Pb_3O_4 (D) Pb_2O_3
35. What is the formula of meta stanic acid ?
 (A) H_2SnO_3 (B) HSnO_2 (C) H_4SnO_3 (D) H_2SnO_2

Answers : 29. (A), 30. (A), 31. (A), 32. (B), 33. (B), 34. (C), 35. (A)

● Carbon Catenation

The carbon atom has tendency to link with another carbon atom by covalent bond and forms chain or cyclic structure of carbon which is called catenation.

This trend is observed due to small size and high electronegativity of carbon atom. Tendency of catenation depends upon the bond enthalpy of covalent bond between two carbon atoms. Higher the bond enthalpy more is the tendency of catenation. The bond enthalpy of C–C is 348 KJmol^{-1} It is the highest than the other elements in its group so it forms a number of chain and cyclic structure compounds due to catenation and $p\pi - p\pi$ bond formation the carbon exhibits different allotropes.

(1) Diamond : Due to sp^3 hybridisation joins with other four carbon atoms by single covalent bond and forms three dimensional network structure. The distance between two carbon atoms is 154 pm bound to each other by covalent bonding and these bonds are very strong. So, diamond is extremely hard solid substance.

(2) Graphite : sp^2 hybridisation in carbon atom, it combines with other three carbon atoms and as a result hexagonal layer structure is formed. The distance between two carbon atoms is 141.5 pm and distance between two layers is 340 pm and have weak Van der waals attractive forces between the two layers. Graphite is soft.

(3) Fullerene : The crystalline form of carbon is made up of porous cage like molecules. It possesses C_{2n} structure. Mainly C_{60} with small quantity of C_{70} and traces of other fullerene, consisting of even number of carbon atom upto 350 or above. C_{60} molecule has shape like soccer ball and also called Buckminster Fullerene. Fullerene is also called bucky ball. It contains twelve rings having five carbon atoms and twenty rings having six carbon atoms. The ring structure having six carbon atoms is fused to both types of ring, while the ring structure having five carbon atoms is fused only to six membered ring. In sp^2 hybridisation, each carbon atom combines with other three carbon atoms with σ - bond. The remaining electron forms π -bond.

In fullerene the carbon-carbon single and double bonds with distance 143.5 pm and 138.3 pm are there respectively. C_{60} and C_{70} fullerene are soluble in toluene solvent and give purple and orange-red coloured solution.

● Chemical Properties (Chemical Reactions)

With oxygen : $\text{C} + \text{O}_2 \rightarrow \text{CO}_2 + \text{Energy}$

Reductoin : $\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 2\text{Fe} + 3\text{CO}$

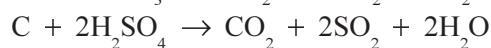
$\text{PbSO}_4 + 4\text{C} \rightarrow 4\text{CO} + \text{PbS}$

$\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$

Reaction with other elements : $\text{C} + 2\text{S} \rightarrow \text{CS}_2$ (Carbon disulphide)



Reaction With acid :



● **Uses of some important compounds of carbon**

Halides of carbon : Its order of stability is $\text{CF}_4 > \text{CCl}_4 > \text{CBr}_4 > \text{CI}_4$

Uses : Fire extinguisher. Freon used in refrigerator as a coolant. CCl_4 is used as medicine for bookworm in intestine.

Carbon disulphide (CS_2) : **Uses :** Manufacture of viscose yarn. An insecticide for curing infected seeds. In vulcanisation of rubber. As solvent in the manufacture of varnishes and matchsticks. In the manufacture of carbon tetrachloride.

Carbide Compounds : The compounds of carbon with high electropositive elements are known as carbide compounds.

Uses : (i) SiC : SiC which is known as carborandum, is very hard, so used as refractory and abrasive for sharpening and grinding metals and other substances.

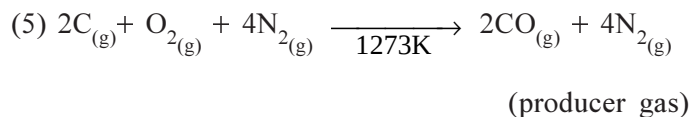
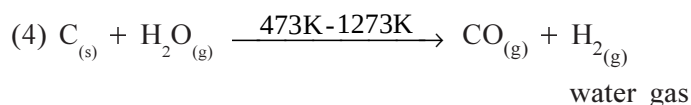
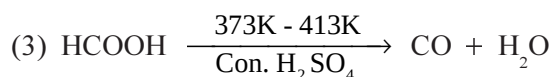
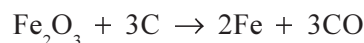
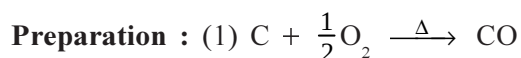
(ii) WC : WC is used for making tools and mould, for making coins etc.

(iii) CaC_2 : CaC_2 is used for preparing acetylene and is used for welding and in manufacturing of number of organic compounds such as ethyl alcohol, acetic acid etc....

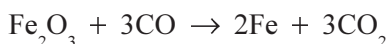
(iv) Be_4C : Be_4C is very hard and is used as a shield against radioactive radiation.

● **Oxides of carbon**

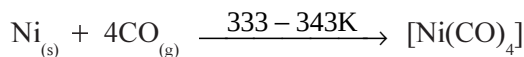
(i) Carbon Monoxide (CO)



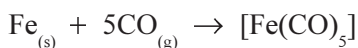
Properties : Reducing character : $\text{ZnO} + \text{CO} \rightarrow \text{Zn} + \text{CO}_2$



Formation of metal carbonyl character



Nickel tetracarbonyl

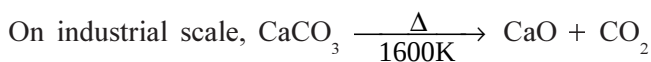
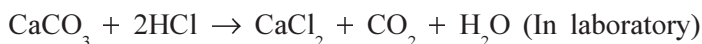
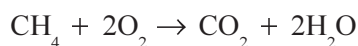
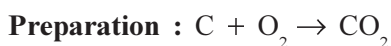


Iron pentacarbonyl

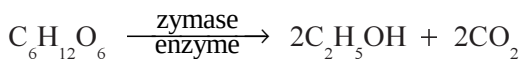
● Uses

- Extraction of some metals from their oxides : $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
- In Mond's carbonyl process.
- As a fuel in the form of water gas and producer gas.
- In manufacturing of methyl alcohol and formic acid.
- In manufacturing of magnetic tapes (Iron carbonyl) for tape recorder.

(ii) Carbon Dioxide (CO_2)



Lime

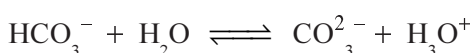
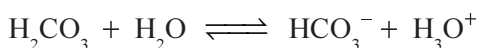


ethanol

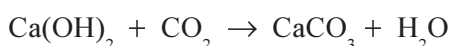
Properties : 1.5 times heavier than air. It is not poisonous but it does not support life of animal and human being but they die in its presence due to lack of O_2 gas. It is converted into solid which is known as dry ice.



CO_2 turns blue litmus paper red so it is acidic in nature. It is sparingly soluble in water but when dissolved in water, carbonic acid (Soda water, H_2CO_3) can be obtained.



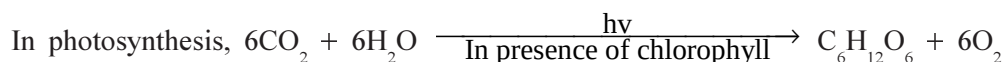
Lime water turns it milky.



Lime water Calcium carbonate



Calcium hydrogen carbonate



Uses : Act as a coolant in cold storage. In preparation of soft drinks and soda water. In preparation of washing soda (solvay's process). As a fire extinguisher. In curing of local burns and in hospital for surgical operation of sores. During artificial respiration for the victims of CO poisoning it is used in form of carbogen (95 %O₂ + 5 % CO₂ mixture known as carbogen.) For the purification of cane sugar juice in manufacturing of sugar. In photosynthesis by green plants. To control the pH (7.26 to 7.42) of blood CO₂ gas is used in carbonic acid buffer system (H₂CO₃ + HCO₃⁻). In production of fertiliser like urea.

36. Difference in distance between two carbon-carbon atoms in diamond and graphite is
 (A) 154 pm (B) 141.5 pm (C) 12.5 pm (D) 20 pm
37. Fullerene contains rings having six carbon atoms and rings having five carbon atoms.
 (A) 20, 12 (B) 6, 8 (C) 7, 14 (D) 12, 20
38. Which coloured solutions obtained by C₆₀ and C₇₀ Fullerene dissolve in toluene solvent ?
 (A) Purple, orange-red (B) blue, purple (C) red, blue (D) Yellow, orange
39. $12\text{C} + 9\text{H}_2\text{SO}_4 \rightarrow \boxed{\text{X}} + 6\text{H}_2\text{O} + 9\text{SO}_2$ what is X in the reaction ?
 (A) Malatic acid (B) Sulphurous acid (C) Formic acid (D) Acetic acid
40. What is used as medicine for hookworm in intestine ?
 (A) CO₂ (B) CCl₄ (C) CF₂Cl₂ (D) CHCl₃
41. In which of the following presence fruits are quickly rippen ?
 (A) Na₂SO₄ (B) NaCl (C) CaC₂ (D) CaCl₂
42. What is used as a shield against radioactive radiation ?
 (A) WC (B) CaC₂ (C) SiC (D) Be₄C
43. What is proportion of mixture known as carbogen during artificial respiration for the victims of CO passing it ?
 (A) 95 %O₂ + 5 %CO₂ (B) 5 %O₂ + 95 %CO₂ (C) 95 %O₂ + 5 %N₂ (D) 5 %O₂ + 95 %N₂

Answers : 36. (C), 37. (A), 38. (A), 39. (A), 40. (B), 41. (C), 42. (D), 43. (A)

● Important Compounds of Silicon

(1) Silicon hydrides : Si_n H_{2n+2} where n = 1 to 8

The value of bond enthalpy for silicon-silicon is 297 KJmole⁻¹, hence catenation character is observed in it so it forms limited hydride compounds Si_n H_{2n+2} where n = 1 to 8. This compound is also known as silane. The stability of silanes are less compared to hydrides of carbon, hence they have more reduction power.

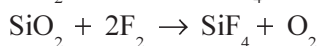
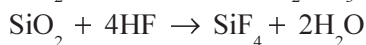
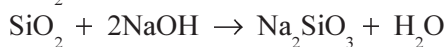
(2) Silicon dioxide : (Silica) (SiO₂) :

SiO₂ does not exist as a single molecule but the arrangement of number of atoms form a giant crystal. More than 22 allotropic structures are known crystalline.

crystal like → quartz, tridimite, crystobelite

Amorphous like → silica gel and kieselgur

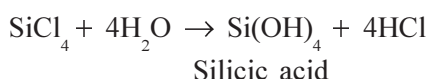
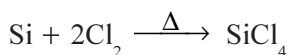
SiO₂ are acidic, hence it dissolves in liquid alkali or alkali carbonate to form silicate compounds.



● Uses of Silica

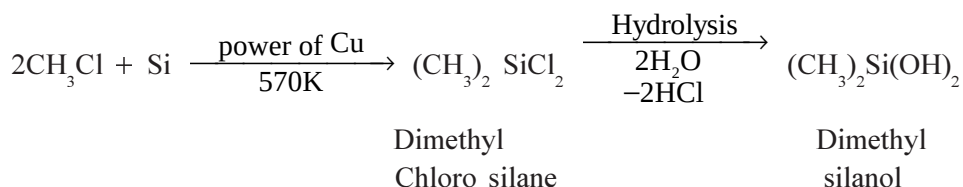
- As a piezoelectrical crystal, crystal oscillators, transducer.
- Laboratory glassware and preparation of optical components such as lens and prisms.
- In sample cell for U.V. spectrophotometers.
- As a drying agent in form of silica gel and also in material for adsorption in chromatography.
- As catalyst. In water filtration plants in form of kieselgur.

(3) Silicon tetrachloride (SiCl₄) : In silicon tetrachloride silicon has sp³ hybridisation and so it is tetrahedral in shape.

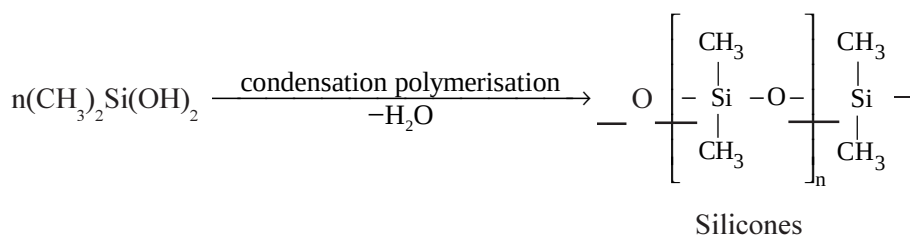


Silicones : Silicones are synthetic materials containing Si–O–Si bond linkage. These compounds are polymeric substances containing R₂SiO repeating unit. They have general formula (R₂SiO)_n where R is alkyl or aryl group. Its empirical formula R₂SiO is similar to that of ketone of organic compound so they are called silicones.

● Preparation



The length of this polymer chain can be controlled by (CH₃)₃SiCl.



● Properties : (i) Chain Type (Form)

- (1) short → Oily, liquid
- (2) Medium → viscous oil jellies, greases
- (3) long → rubbery elastomers and resins

(ii) Silicones resist the organic reagent, oxidation and thermal decomposition. Hence, they are chemically inert.

(iii) Silicones are heat resistant and electric insulator substances; more over possess the character of water repellent.

● **Uses :** For making water-proof paper, wool, textiles, wood, etc. they are coated with a thin film of silicones. Silicones are used as sealants and electrical insulators. As lubricant at high and low temperatures. Surgical implants. Antifoaming agents in cosmetics.

● **Structure of Silicates :** Approximately 95 % of the earth crust consists of silicates and silica. Silicate compounds contain independent $[\text{SiO}_4]^{4-}$ or such type of ions joined to form combined silicate ions and their charges are being balanced by cations such as Na^+ , K^+ , Mg^{2+} , Ca^{2+} . The basic structural building block in silicates is the $[\text{SiO}_4]^{4-}$ having tetrahedral structure.

In the structure of silicates depending upon the number of corner (0, 1, 2, 3, 4) of the $[\text{SiO}_4]^{4-}$ tetrahedron shared with other tetrahedrons and based on that they are classified. In a three dimensional structure of SiO_2 , Si^{4+} is partially substituted by Al^{3+} which gives aluminosilicate called feldspar. In aluminosilicate, the SiO_4^{4-} and AlO_4^{5-} tetrahedrons join with each other in a simple way to form three dimensional networks known as zeolites.

Classification of Silicates :

No. of Corner of SiO_4^{4-}	Type	Anion unit	Examples
0	Orthosilicate	SiO_4^{4-}	Zircon (ZrSiO_4), Forsterite (Mg_2SiO_4)
1	Pyrosilicate	$\text{Si}_2\text{O}_7^{6-}$	Thort veitite ($\text{Sc}_2\text{Si}_2\text{O}_7$)) Hemimorphite $\text{Zn}_2\text{Si}_2\text{O}_7 \cdot \text{Zn}(\text{OH})_2 \cdot \text{H}_2\text{O}$
2	Cyclic silicate Ring silicate Chain silicate (A) Linear silicate (B) Cross link	$\text{Si}_3\text{O}_9^{6-}$ $\text{Si}_6\text{O}_{18}^{12-}$ $(\text{SiO}_3^{2-})_n$ OR $(\text{SiO}_3)_n^{2n-}$ $(\text{Si}_4\text{O}_{11})_n^{6-}$	Wollastonite $\text{Ca}_2\text{Si}_3\text{O}_9$ Beryl $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$ Spodumene $\text{LiAl}(\text{SiO}_3)_2$ Diopside $\text{CaMg}(\text{SiO}_3)_2$ Tri-molyte $\text{Ca}_2\text{Mg}_5(\text{Si}_8\text{O}_{22})(\text{OH})_2$ Aesbestos
3	Sheet silicate	$(\text{Si}_2\text{O}_5)_n^{2n-}$ Or $(\text{Si}_2\text{O}_5)_n^{2n-}$	Stearite $\text{Mg}_3(\text{Si}_4\text{O}_{10})(\text{OH})_2$ Muscovite $\text{KAl}_2(\text{Si}_3\text{AlO}_{10})(\text{OH})_2$
4	Three dimensional	SiO_2	Feldspar, Zeolite, Calumino silicate different types of silica (quartz, trydimite, cristobalite)

● **Uses of zeolite**

Zeolite has a network of cavities linked by channels. Zeolite is used as a catalyst. One important catalyst of zeolite is ZSM 5. It is used in petrochemicals. It converts alcohol directly into gasoline (petrol) by dehydration and the mixture of hydrocarbon is formed.

44. What is obtained by hydrolysis silicon tetrachloride ?

- (A) $\text{Si}(\text{OH})_4$ (B) $(\text{CH}_3)_2\text{Si}(\text{OH})_2$ (C) $\text{Si}(\text{OH})_2\text{Cl}_2$ (D) None.

45. Which is common formula of silicones ?

- (A) SiO_4^{4-} (B) $\text{Si}_2\text{O}_7^{6-}$ (C) $(\text{R}_2\text{SiO})_n$ (D) $(\text{SiO}_3)_n^{2n-}$

46. Match correct pair :

Glass	Components
(P) Potash glass	(T) CeO_2
(Q) Flint glass	(U) $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2$
(R) Pyrex glass	(V) $\text{K}_2\text{O} \cdot \text{PbO} \cdot 6\text{SiO}_2$
(S) Fruck glass	(W) $\text{K}_2\text{SiO}_3 \cdot \text{CaSiO}_3 \cdot 4\text{SiO}_2$

(A) (P)-(W), (Q)-(V), (R)-(U), (S)-(T)

(B) (P)-(T), (Q)-(W), (R)-(V), (S)-(U)

(C) (P)-(U), (Q)-(T), (R)-(W), (S)-(V)

(D) (P)-(V), (Q)-(U), (R)-(T), (S)-(W)

47. Which of the following is known as 'glass eater' ?

- (A) HBr (B) HI (C) HCl (D) HF

48. Which negative ion unit in beryll ?

- (A) $\text{Si}_2\text{O}_7^{6-}$ (B) $\text{Si}_3\text{O}_9^{6-}$ (C) $\text{Si}_6\text{O}_{18}^{12-}$ (D) $(\text{Si}_4\text{O}_{11})_n^{6-}$

49. What is negative ion unit in porcelain clay ?

- (A) $(\text{Si}_2\text{O}_5^{2-})_n$ (B) $\text{Si}_2\text{O}_7^{6-}$ (C) $\text{Si}_6\text{O}_{18}^{12-}$ (D) $\text{Si}_3\text{O}_9^{6-}$

50. Which of the following is known as 'butter of tin' ?

- (A) $\text{SnCl}_2 \cdot 5\text{H}_2\text{O}$ (B) $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ (C) $\text{SnCl}_4 \cdot 4\text{H}_2\text{O}$ (D) $\text{SnCl}_4 \cdot 5\text{H}_2\text{O}$

Answers : 44. (A), 45. (C), 46. (A), 47. (D), 48. (C), 49. (A), 50. (D)

● Nitrogen Group

● Elements of group-15, their minerals, occurrence

No.	Name of Element	symbol	Atomic no.	electron configuration	Minerals and occurrence
1.	Nitrogen (Non-metal)	N	7	$1s^2 2s^2 2p^3$ or $[\text{He}] 2s^2 2p^3$	● 78 % in air ● 17% in animals and plants proteins ● Form of nitrate salt in earth's layer ● NaNO_3 : Chile salt petre ● KNO_3 : Indian salt petre ● Potassium nitrate
2.	Phosphorous (Non-metal)	P	15	$1s^2 2s^2 2p^2 3s^2 3p^3$ or $[\text{Ne}] 3s^2 3p^3$	● Form apatite mineral common Formula ↓ $\text{Ca}_5(\text{PO}_4)_3 \cdot \text{CaX}_2$ (X = F, Cl, OH) Flourapatite $\text{Ca}_5(\text{PO}_4)_3 \cdot \text{CaF}_2$

					$[3\text{Ca}_3(\text{PO}_4)_2 \cdot \text{CaF}_2]$ Chlorapatite $\text{Ca}_9(\text{PO}_4)_6 \cdot \text{CaCl}_2$ $[3\text{Ca}_3(\text{PO}_4)_2 \cdot \text{CaCl}_2]$ Hydroxyapatite- $\text{Ca}_9(\text{PO}_4)_6 \cdot \text{Ca}(\text{OH})_2$ or $[3\text{Ca}_3(\text{PO}_4)_2 \cdot \text{Ca}(\text{OH})_2]$ 60% Ca and P in bones and teeth. $\text{Ca}_3(\text{PO}_4)_2$ Phosphoprotein in eggs and milk
3.	Arsenic (Semimetal)	As	33	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$ or $[\text{Ar}] 3d^{10} 4s^2 4p^3$	As_4S_4 Rielger (volcano regions) As_2S_3 orpiment FeAsS - Arsenopyrites
4.	Antimony (Semimetal)	Sb	51	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^3$ or $[\text{Kr}] 4d^{10} 5s^2 5p^3$	Sb_2S_3 -stibine, Sb_2O_4 - Antimony ore
5.	Bismuth (Metal)	Bi	83	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^3$ or $[\text{Xe}] 4f^{14} 5d^{10} 6s^2 6p^3$	Bi_2S_3 Bismuthine Bi_2O_3 Bismite $(\text{BiO})_2\text{CO}_3$ Bismuthspar

Electronic configuration of valence shell of group-15 elements is $ns^2 np^3$. In which s-orbital is completely filled and p-orbitals are incompletely filled, so elements are specially stable.

● Oxidation State

- The common oxidation states of elements of group 15 are -3 , $+3$ and $+5$.
- The tendency to show -3 oxidation state decreases as we go down the group because of increase in the atomic size and metallic properties.

Similarly the stability of $+5$ oxidation state also **decreases**.

Imp $\Rightarrow$ when N element reacts with O element, it shows

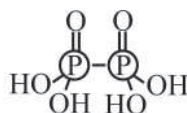
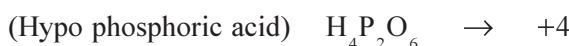
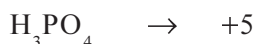
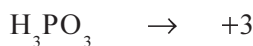
$+1$ to $+5$ oxidation states.

Examples :

NH_3	$\text{NH}_2\cdot\text{NH}_2$	NH_2OH	N_2	N_2O	NO	N_2O_3	NO_2 OR N_2O_4	N_2O_5
-3	-2	-1	0	+1	+2	+3	+4	+5

- P elements and its oxo acid show +1, +3, +4, +5 oxidation state.

Example :



Oxidation state of group-15 elements :

N	-3 to +5 (-3, -2, -1, 0, +1, +2, +3, +4, +5)
P, As	-3, +3, +5
Sb	+3, +5
Bi	+3

● Periodicity in physical properties

With the increase in atomic number,

- increase in atomic size
- decrease in ionisation enthalpy
- Decrease in electronegativity
- Increase in metallic property.

Metallic property increases with atomic number

Atomic and Ionic Radii	Ionisation Enthalpy	Electronegativity
• increases • There is remarkable increase in the atomic radii while moving from N to P, but there is slight increase in atomic radii while going from As to Bi. The reason for this is that the elements d-or/and f-orbitals are present.	• decreases. • $\Delta_1\text{H}_1$ $\Delta_1\text{H}_2$ $\Delta_1\text{H}_3$ • As the p-orbitals in elements of group 15 are half filled and so they possess characteristic stability. Hence electron is not removed easily from these elements	• decreases atomic size with atomic number while going down the group. Hence electronegativity decreases • The difference in electronegativity decreases is found to be less. Element of this group are polyatomic. e.g. (N_2, P_4, As_4, Sb_4)

● Allotrop

- There are allotropes of all elements of this group except nitrogen and bismuth.
- P (Phosphorous) contains three allotrops. (White, Red, Black)
- Arseric (As) and antimony (sb) contain two allotropes. (Yellow and Grey)

● **Periodicity in chemical properties**

(1) Reaction with hydrogen element : All the elements of group 15 form hydrides of the type MH_3 (where $M = N, P, As, Sb$ or Bi) by combining with hydrogen.

NH_3	PH_3	AsH_3	SbH_3	BiH_3
Amonia	Phosphine	Arsina	Stibaina	Bismuthaina
Bond angle (107.8°)	(93.6°)	(91.8°)	(91.3°)	(90°)

The stability of the hydride compounds decreases as we go from NH_3 to BiH_3 in the group.

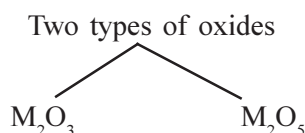


Reaction with oxygen element



Specific hydride of N is N_3H (Hydrazoic acid)

(2) Reaction with oxygen element



Acidic property decreases as we go down the group.

Oxide of element containing higher oxidation state is more acidic than lower oxidation state.

Example : $N_2O < NO < N_2O_3 < N_2O_4 < N_2O_5$ (very most acidic)
 (+1) (+2) (+3) (+4) (+5)

M_2O_3 oxides,

$[N]$ and $[P]$ oxides $\rightarrow$ acidic

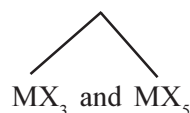
$[As]$ and $[Sb]$ oxides $\rightarrow$ amphoteric

$[Bi]$ oxides $\rightarrow$ basic

Note : Oxide of non-metal - acidic, oxide of metal - basic, oxide of semimetal - amphoteric

Order of acidity for trioxide : $N_2O_3 > P_4O_6 > As_4O_6 > Sb_4O_6$. Same order for pentoxide.

(3) Reaction with halogen elements



Halide compounds of the type.

* As there are **no d-orbitals in valence** shell of nitrogen atom, it is **not able** to form pentahalide.

* **Pentahalides** are more **covalent** than **trihalides**.

* All the **trihalides** except the nitrogen element are **stable**.

↓

While only the one trihalide of nitrogen element. $[NF_3]$ is stable. ($\because$ N(75 pm) and F(72 pm) equal size, N – F bond becomes strong)

* Trihalide compounds except BiF_3 are covalent compounds.



(Ionic)

(4) Reaction with metal elements

Form binary compounds like

- $\text{Ca}_3\text{N}_2 \rightarrow$ Calcium nitride
- $\text{Ca}_3\text{P}_2 \rightarrow$ Calcium Phosphide
- $\text{Na}_3\text{As} \rightarrow$ Sodium arsenide
- $\text{Zn}_3\text{Sb}_2 \rightarrow$ Zinc antimonide
- $\text{Mg}_3\text{Bi}_2 \rightarrow$ Magnesium bismuthide

In these the oxidation state of N, P, As, Sb, and Bi is -3 .

51. Which oxidation state show when 'N' element reacts with 'O' element ?
(A) $+3$ to $+5$ (B) -3 to $+3$ (C) $+1$ to $+5$ (D) $-3, +3, +5$
52. Which order is correct for basicity of group-15 element's hydride ?
(A) $\text{SbH}_3 > \text{PH}_3 > \text{AsH}_3 > \text{NH}_3$ (B) $\text{NH}_3 > \text{SbH}_3 > \text{PH}_3 > \text{AsH}_3$
(C) $\text{NH}_3 > \text{PH}_3 > \text{AsH}_3 > \text{SbH}_3$ (D) $\text{SbH}_3 > \text{AsH}_3 > \text{PH}_3 > \text{NH}_3$
53. Which oxide of nitrogen is the most acidic ?
(A) N_2O_5 (B) N_2O_3 (C) N_2O_4 (D) NO
54. Which is correct order of acidity of oxide ?
(A) $\text{NO} < \text{N}_2\text{O} < \text{N}_2\text{O}_3 < \text{NO}_2 < \text{N}_2\text{O}_5$ (B) $\text{N}_2\text{O} < \text{NO} < \text{N}_2\text{O}_3 < \text{NO}_2 < \text{N}_2\text{O}_5$
(C) $\text{N}_2\text{O}_5 < \text{NO}_2 < \text{N}_2\text{O}_3 < \text{NO} < \text{N}_2\text{O}$ (D) $\text{N}_2\text{O}_5 < \text{N}_2\text{O}_3 < \text{NO}_2 < \text{NO} < \text{N}_2\text{O}$

Answers : 51. (C), 52. (C), 53. (A), 54. (B)

● Nitrogen

Preparation, properties and uses of dinitrogen gas (N_2) :

Preparation :

(1) Dinitrogen is prepared by liquefaction and fractional distillation of air.

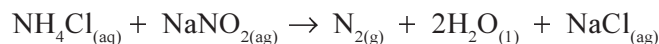
As the boiling point of dinitrogen is 77.2 K

it is first obtained during distillation.

while the boiling point of dioxygen O_2 is 90 K

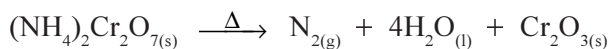
(2) In the laboratory :

Nitrogen can be prepared by the reaction of aqueous ammonium chloride (NH_4Cl) with aqueous sodium nitrite (NaNO_2)



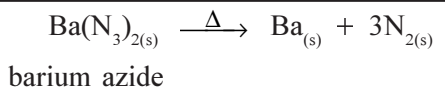
Drawback : During this reaction, NO and HNO₃ are found. To remove them, the gas produced during the reaction is passed through the mixture potassium dichromate of and aqueous sulphuric acid.

(3) Thermal decomposition of ammonium dichromate

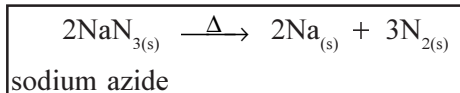


(4) Very pure dinitrogen gas :

Very pure dinitrogen gas can be obtained by thermal decomposition of **sodium azide** or **barium azide**.



OR



Physical Properties

N₂ gas

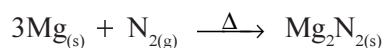
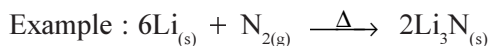
Colourless
Two stable isotopes
Sparingly
Inert at

Tasteless
¹⁴N, ¹⁵N
soluble in water
room temperature

Non poisonous

● Chemical Properties

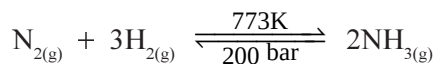
- At high temperature, it combines with certain metals and forms ionic nitrides.



- With non-metals it forms covalent nitrides.

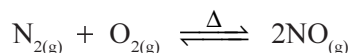


- It reacts with dihydrogen (Haber process) :



FeO catalyst, K₂O + Al₂O₃ is added as promoters

- It reacts with dihydrogen and dioxygen and forms ammonia gas nitric oxide gas respectively



Uses

- | | | |
|---|---|---|
| <ul style="list-style-type: none"> In the production of NH₃ Preparation of HNO₃ | <ul style="list-style-type: none"> Reactivity of O₂ in the air is decreased Metallurgical process to maintain inert atmosphere | <ul style="list-style-type: none"> In electric bulbs, preparation of HNO₃ As coolant in preservation of biological substance and food materials. |
|---|---|---|

● Anomalous Behaviour

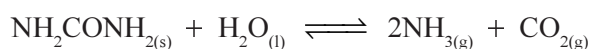
- Nitrogen is in gaseous form as dinitrogen (N_2), while other elements are in solid state in the form of M_4 molecule (except Bi)
- Nitrogen element does not possess allotropes but other elements possess allotropes.
- Nitrogen trioxide (N_2O_3) and Nitrogen pentoxide (N_2O_5) are **monomolecular** (monomers); while the trioxides and pentoxides of other elements are bimolecular (dimers) (eg. P_4O_6 , P_4O_{10} , As_4O_6 , As_4O_{10})
- As N_2 is non-metal, its oxide compounds possess acidic property.
- The halides of nitrogen except NF_3 are explosive, while the halides of other elements are stable.
- NH_3 non-poisonous while, PH_3 , AsH_3 is poisonous.
- Because of smaller size and higher electronegativity of nitrogen element, there is characteristic property of forming $p\pi - p\pi$ bond in it. While this property is not possessed by the other elements of this group.
- There are no d-orbitals available in the orbits of nitrogen elements its maximum bonding capacity is 4. As a result it cannot form $d\pi - d\pi$ bond. The other elements of this group are able to form this type of bonds.

● Compounds of Nitrogen Elements

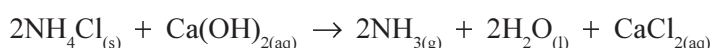
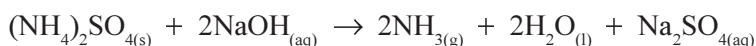
(i) Ammonia (NH_3) :

Preparation

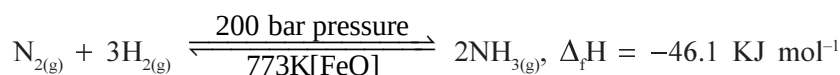
(1) Decay of nitrogen containing organic compounds like **urea**.



(2) By reaction of ammonium salt with $NaOH$ or $Ca(OH)_2$ ammonia gas can be obtained.

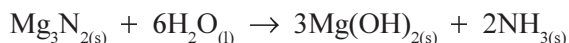


(3) Haber's process (Industrial production) :



$[FeO]$ as catalyst are used alongwith $K_2O + Al_2O_3$ in less proportions as promoters.

(4) Hydrolysis of magnesium nitride, ammonia gas is obtained.

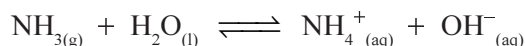


Physical Properties

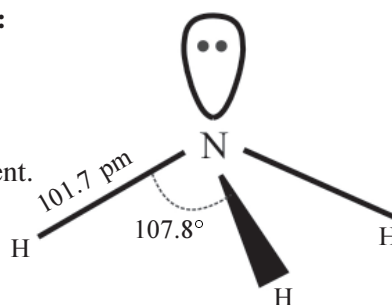
- Colourless gas with pungent smell.
- Trigonal pyramidal structure.
- Three bonding and one non-bonding electron pairs are present.

Chemical Properties

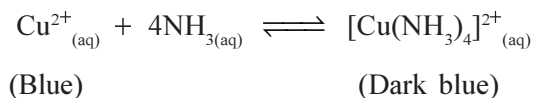
(1) Ammonia gas dissolves in water and forms NH_4OH .



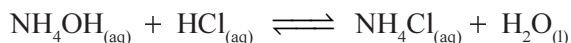
Structure :



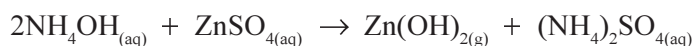
(2) As nitrogen atom in ammonia molecule has got non-bonding pair of electron, it acts as a Lewis base. It forms co-ordinate covalent bond with metal ion and forms complex ions.



(3) Aqueous solution of ammonia with acid gives ammonium salt.



With aqueous solution of
metal salt give metal hydroxide



Uses :

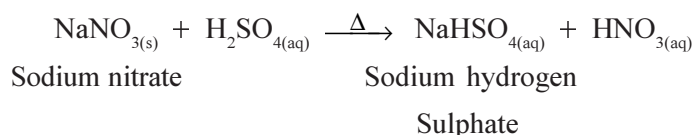
- ammonium nitrate
- urea
- ammonium phosphate
- ammonium sulphate
- Preparation of HNO_3
- Liquid NH_3 is used as refrigerant.

} Formation of fertilisers

(2) Nitric acid (HNO_3)

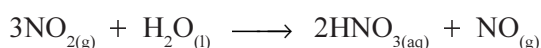
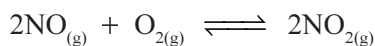
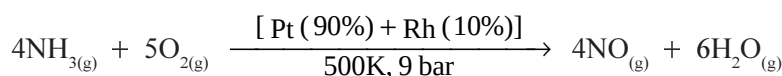
Preparation

(1) **In laboratory :** Sodium nitrate or potassium nitrate is heated with concentrated H_2SO_4 in a glass retort.

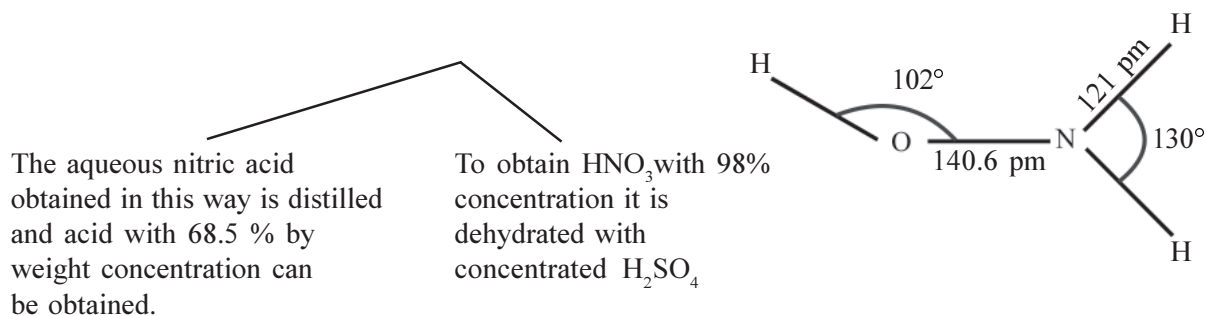


Anhydrous nitric acid is obtained by distilling concentrated aqueous solution of HNO_3 in presence of P_4O_{10} .

(2) Ostwald's method : (Industrial production)



Structure :

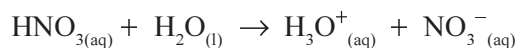


- **Physical Properties**

- Colourless liquid.
- Planar structure in gaseous state.

- **Chemical Properties**

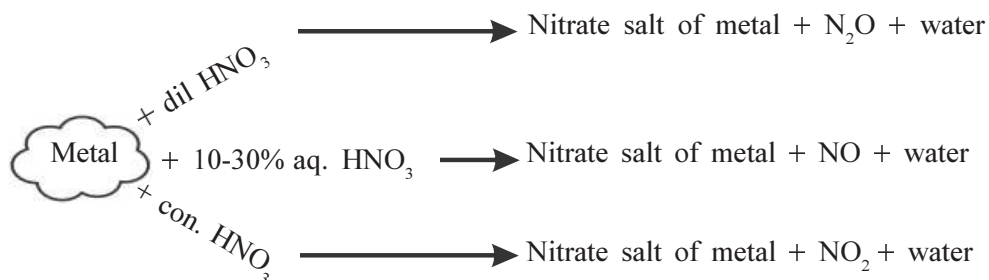
Aqueous solution of HNO_3 as a strong acid



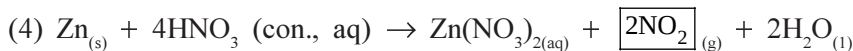
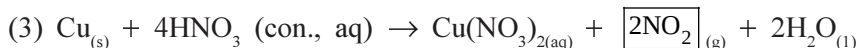
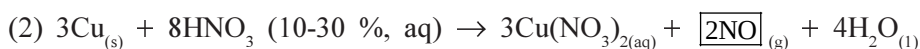
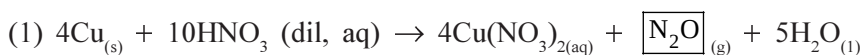
Concentrated nitric acid is a strong reducing agent. (Reaction with metal)

Certain metals like Cr, Al do not dissolve in concentrated nitric acid. (because inert oxide layer is formed on these metals)

Metals like Au, Pt do not react.



Examples :

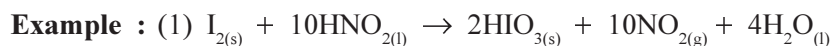


- **(Reaction with non-metal)**

The non-metals and their compounds are oxidised by concentrated HNO_3

Remember :

- Oxidation of $\text{I}_2 \rightarrow \text{HIO}_3$ (Iodic acid)
- Oxidation of $\text{C} \rightarrow \text{CO}_2$ (Carbon dioxide)
- Oxidation of $\text{S}_8 \rightarrow \text{H}_2\text{SO}_4$ (Sulphuric acid)
- Oxidation of $\text{P}_4 \rightarrow \text{H}_3\text{PO}_4$ (Phosphoric acid)



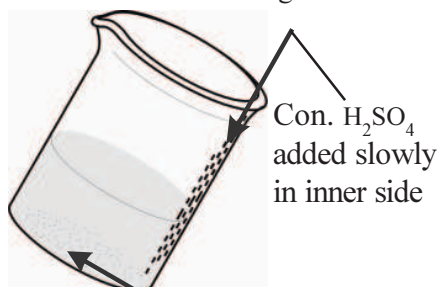
Aqueous solution of HNO_3 gives ring test.

This ring test is given by NO_3^- ion in aqueous solution. (Qualitative analysis of inorganic substance)

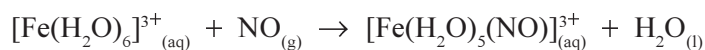
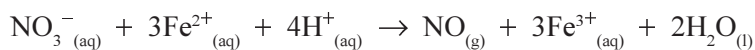
So nitric acid also give this test.

● Ring test

Brown coloured ring is observed near the surface where concentrated sulphuric acid and mixed solution meet. This ring is due to formations of nitroso complex.



Aqueous solution of NO_3^- ion + Freshly prepared FeSO_4 solution



(Brown colour)

IUPAC Name : Penta aquanitrosonium iron (II) ion.



IUPAC Name : Penta aquanitrosonium iron (I) ion.

Uses of HNO_3 : Fertilisers like ammonium nitrate and explosive substances like TNT and nitroglycerine.

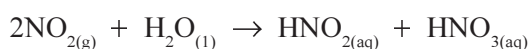
Used as oxidising agents in rocket fuels.

● Oxides of nitrogen :

Name of oxide of nitrogen	Molecular Formula	Oxidation state of N element	Common methods of preparation	Physical appearance and chemical nature
Dinitrogen oxide (Nitrogen (I) oxide)	N_2O	+1	$\text{NH}_4\text{NO}_3 \xrightarrow{\Delta} \text{N}_2\text{O} + 2\text{H}_2\text{O}$	Colourless gas neutral
Nitrogen monoxide (Nitrogen (II) oxide)	NO	+2	-	Colourless gas, neutral, Paramagnetism
Dinitrogen trioxide (Nitrogen (III) oxide)	N_2O_3	+3	$2\text{NO} + \text{N}_2\text{O}_4 \xrightarrow{250\text{K}} 2\text{N}_2\text{O}_3$	blue solid acidic
Nitrogen dioxide (Nitrogen (IV) oxide)	NO_2	+4	$2\text{Pb}(\text{NO}_3)_2 \xrightarrow{673\text{K}} 4\text{NO}_2 + 2\text{PbO} + \text{O}_2$	brown gas acidic Paramagnetism
Dinitrogen tetroxide (Nitrogen (IV) oxide)	N_2O_4	+4	$2\text{NO}_2 \xrightleftharpoons[\text{heat}]{\text{cool}} \text{N}_2\text{O}_4$	Colourless solid/ liquid, acidic
Dinitrogen pentoxide (Nitrogen (V) oxide)	N_2O_5	+5	$4\text{HNO}_3 + \text{P}_4\text{O}_{10} \rightarrow 4\text{HPO}_3 + 2\text{N}_2\text{O}_5$	colourless solid, acidic

Nitric oxides (NO) partially polymerises in liquid state because of presence of one unpaired electron.

Oxides of nitrogen : Oxides of nitrogen react with water and forms oxoacid compounds of nitrogen.



N_2O_3 is anhydride of nitrous acid (HNO_2)

N_2O_5 is anhydride of nitric acid (HNO_3)

55. Which of the following is co-valent nitride ?
 (A) Li_3N (B) Mg_3N_2 (C) Ca_3N_2 (D) BN
56. What is added as promoters in haber process for production of NH_3 ?
 (A) $\text{K}_2\text{O} + \text{Al}_2\text{O}_3$ (B) $\text{CaO} + \text{NaOH}$ (C) $(\text{NH}_4)_2\text{CO}_3$ (D) K_2CO_3
57. $(\text{NH}_4)_2\text{Cr}_2\text{O}_7 \xrightarrow{\Delta} \text{x} + \text{y} + 4\text{H}_2\text{O}_{(l)}$ Identify X and Y.
 (A) N_2 , Cr_2O_3 (B) NO , Cr_2O_3 (C) N_2O , CrO_2 (D) NO , Cr_2O_3
58. Which oxide is anhydride of nitric acid ?
 (A) N_2O (B) N_2O_3 (C) N_2O_4 (D) N_2O_5
59. Which catalyst is used in preparation of HNO_3 in Ostwald method ?
 (A) $\text{Pt}(90\%) + \text{Rh}(10\%)$ (B) $\text{Pt}(10\%) + \text{Ag}(90\%)$
 (C) $\text{Pu}(90\%) + \text{Re}(10\%)$ (D) $\text{Pr}(90\%) + \text{Rh}(10\%)$
60. Which of the following reacts with Cu-metal to produce N_2O gas ?
 (A) dil HNO_3 (B) 10-30 % aqueous HNO_3 (C) concentration HNO_3 (D) All above
61. What is obtained when I, S, P and C reacts with HNO_3 ?
 (A) HIO_3 , H_2SO_4 , H_3PO_4 , CO_2 (C) I_2O_5 , H_2SO_4 , H_3PO_4 , CO
 (B) HIO_3 , H_2SO_4 , H_3PO_3 , CO_2 (D) I_2O_5 , SO_2 , P_4O_{10} , CO_2
62. Which of the reaction reacts with FeSO_4 gives brown coloured ring ?
 (A) NO_2 (B) N_2O_3 (C) N_2O_5 (D) NO
63. What is used as oxidizing agent in rocket fuel ?
 (A) HNO_3 (B) H_2SO_4 (C) NO_2 (D) NaOH

Answers : 55. (D), 56. (A), 57. (A), 58. (D), 59. (A), 60. (A), 61. (A), 62. (D), 63. (A)

Phosphorous Allotropes

White (yellow)	Red	Black
- Poisonous and wax like white substance. - discrete tetrahedral P_4 molecules. - Insoluble in water, soluble CS_2 - Glow in the dark 317 K melting point	Preparation : White phosphorous is heated at 573 K in absence of air. - less soluble in CS_2 and less reactive - does not burn in contact of air. - melting point 873 K	- Two forms (1) α- black : - Heating red phosphorous in closed tube at 803 K temperature. (2) β-black :

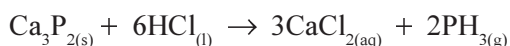
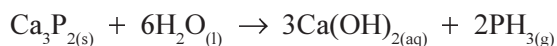
• Highly reactive • Burns when kept open in air. Stored in water. • If white phosphorous is heated at 573K in absence of air, it is changed to stable red form. • More reactivity is due to its abnormal structure. • Strain in P_4 molecule • Bond angle is 60° • P-P bond is bent. • This bond is weak and reactive. • In inert atmosphere, P undergoes redox reaction with boiling NaOH form PH_3 (phosphine). White phosphorous	Red phosphorous	• white phosphorous is heated under high pressure at 473K
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● Compounds of Phosphorus

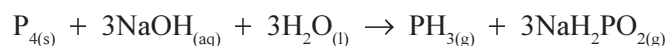
(1) Phosphine (PH_3) :

Preparation :

(1) Phosphine is obtained by reacting calcium phosphide with water or dilute hydrochloric acid.



(2) In laboratory, phosphine is prepared by reacting white phosphorous with concentrated NaOH in inert atmosphere.



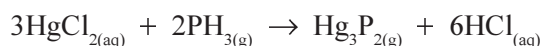
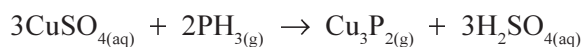
Sodium hypophosphite

● Physical Properties

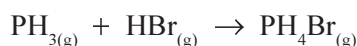
- Phosphine is a colourless gas having smell like rotten fish and is very poisonous gas.
- It is sparingly soluble in water.

● Chemical Properties

Phosphine : If phosphine is absorbed in aqueous solution of CuSO_4 (copper sulphate) or mercuric chloride (HgCl_2) corresponding phosphide is formed.



Phosphine explodes when it comes in contact with oxidising agents like HNO_3 , Cl_2 , Br_2 . Phosphine is a weak base. It gives phosphonium bromide by reaction with HBr .



Uses :

Because of spontaneous combustion property of phosphine, it is used in Holme's signals.

By making a hole in the vessel containing calcium carbide and calcium phosphide is thrown into the sea and so the gas produced burns which works as signal.

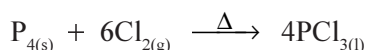
It is used in preparation of smoke screen.

Calcium phosphide reacts with water to produce PH_3 , which burns with air to produce cloud of P_4O_{10} . It acts as smoke screen.

(2) Phosphorous trichloride (PCl_3) :

(i) Preparation :

(1) Phosphorous trichloride is obtained by passing dry chlorine gas on white phosphorous at high temperature.



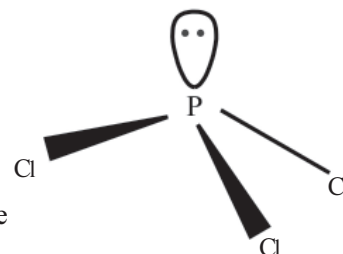
(2) Phosphorous trichloride is obtained by reaction of white phosphorous with thionyl chloride (SOCl_2)



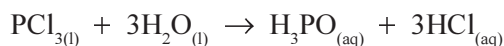
(ii) Properties :

Physical properties :

- Colourless fuming liquid.
- Soluble in solvents like benzene, chloroform, ether, carbon disulphate
- Its shape is pyramidal.

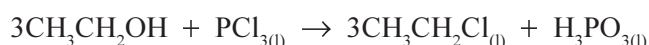
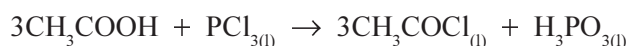


Chemical Properties : Phosphorous trichloride forms fumes when it comes in contact with air or water because the P-Cl bond present in PCl_3 is decomposed and is converted into the resulting product phosphorous acid (H_3PO_3).



It reacts with organic compounds having OH group, viz.

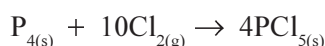
CH_3COOH and $\text{C}_2\text{H}_5\text{OH}$:



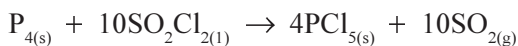
(3) Phosphorous pentachloride (PCl_5)

Preparation :

By reaction of white phosphorous with excess amount of dry chlorine gas.....



By reaction of white phosphorous with sulphuryl chloride (SO₂Cl₂)....



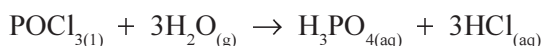
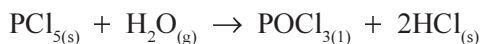
Physical Properties :

Yellowish white coloured solid substance.

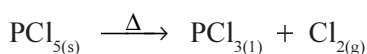
Possesses trigonal bipyramidal shape in liquid and gaseous states.

Chemical properties :

- (1) By hydrolysis by moisture of air and finally phosphoric acid is formed.



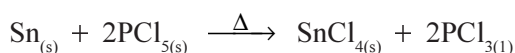
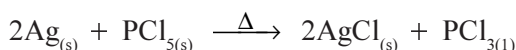
- (2) Phosphorous pentachloride sublimes on heating but decomposes when heated more.



- (3) By reaction with organic compounds having –OH group.



- (4) On heating PCl₅ with metal piece, it forms corresponding metal chlorides.



(4) Oxo acids of phosphorus :

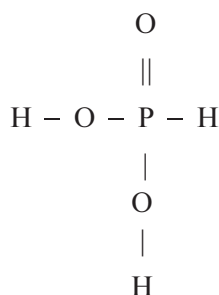
Different oxoacids of phosphorous are obtained of phosphorous oxides with water.



H₃PO₃

Oxidation number of P = +3

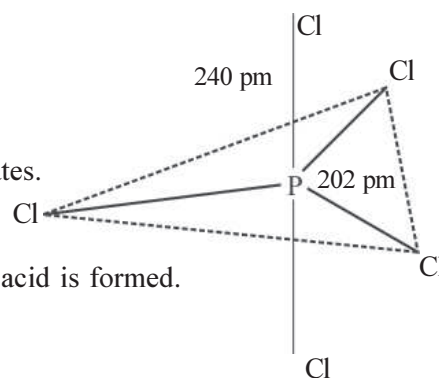
It is weak diprotic acid.



Hydrogen atom directly combined with phosphorous is not acidic because, the electronegativities of both P and H are same and so P – H bond is non-planar.

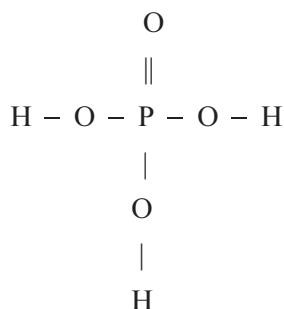
Orthophorus acid (H₃PO₃)

$$\text{Ka}_1 = 1.0 \times 10^{-2}, \text{Ka}_2 = 2.6 \times 10^{-7}$$



● **H₃PO₄ (Orthophosphoric acid)**

Oxidation number of P = +5



[Weak triprotic acid]

$$K_{a_1} = 7.5 \times 10^{-3}, K_{a_2} = 6.2 \times 10^{-8}, K_{a_3} = 4.8 \times 10^{-13}$$

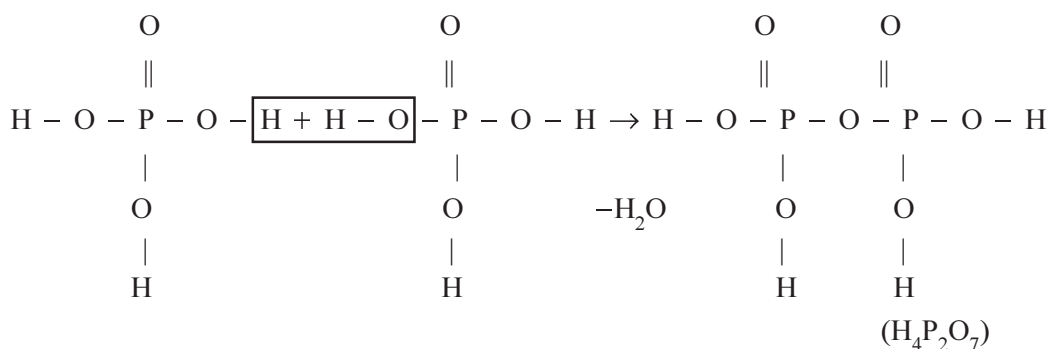
● **H₄P₂O₇**

● Pyro phosphoric acid

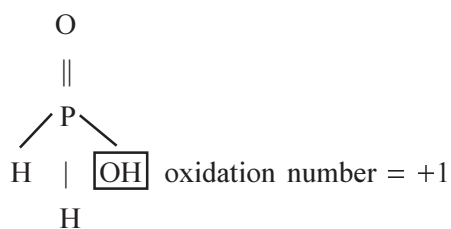
● Oxidation state P = +5

● Tetra basic

Preparation : Diphosphoric acid (H₄P₂O₇) is also called pyrophosphoric acid which is obtained by removal of one molecule of water when two molecules of H₃PO₄ combine.



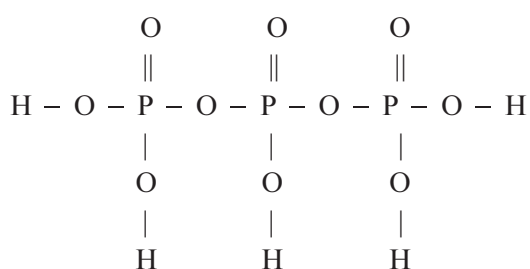
H₃PO₂ (pyrophosphonic acid) (hypophosphorous acid)



● **H₅P₃O₁₀**

In it HPO₃ unit is repeated three times.

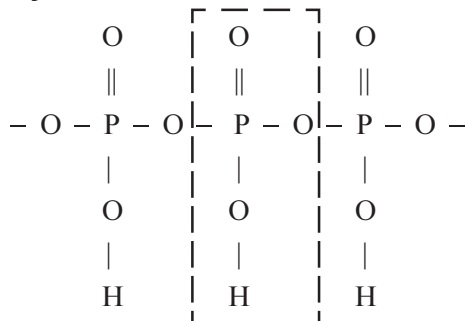
Structural formula :



● **(HPO_n)**

Polymetaphosphoric acid : (HPO₃)_n

HPO₃ unit is repeated. Oxidation number = +5

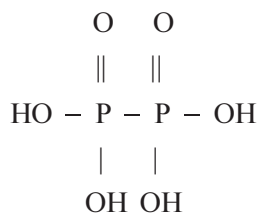


Hypo phosphorous acid (H₄P₂O₆)

Tetra basic

oxidation number of P = +4

Structural formula :

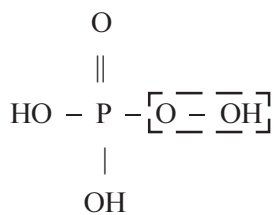


(2) Peroxo monophosphoric acid (H₃PO₅)

Tri basic

Oxidation number of P = +5

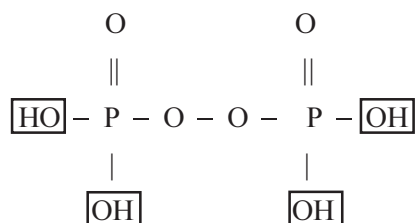
Structural formula :



(3) Peroxo diphosphoric acid (H₄P₂O₈)

Tetrabasic

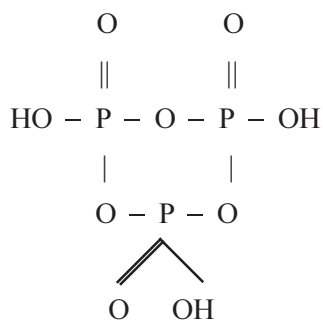
Oxidation number of P = +5



(4) Cyclo trimeta phosphoric acid (HPO₃)₃

Tribasic (HPO₃)₃

Oxidation number of P = +5



Oxoacids of phosphorous

No.	Name	Molecular formula	Oxidation number of P	Bond type and No. of Bonds	Basicity
(1)	Hypo phosphorous acid (phosphonic acid)	H_3PO_2	+1	$\text{P} - \text{OH} \rightarrow 1$ $\text{P} - \text{H} \rightarrow 2$ $\text{P} = \text{O} \rightarrow 1$	Mono
(2)	Orthophosphorous acid (phosphonic acid)	H_3PO_3	+3	$\text{P} - \text{OH} \rightarrow 2$ $\text{P} - \text{H} \rightarrow 1$ $\text{P} = \text{O} \rightarrow 1$	Di
(3)	Pyrophosphorous acid	$\text{H}_4\text{P}_2\text{O}_5$	+3	$\text{P} - \text{OH} \rightarrow 2$ $\text{P} - \text{H} \rightarrow 2$ $\text{P} = \text{O} \rightarrow 2$ $\text{P} - \text{O} - \text{P} \rightarrow 1$	Di
(4)	Hypo phosphoric acid	$\text{H}_4\text{P}_2\text{O}_6$	+4	$\text{P} - \text{OH} \rightarrow 4$ $\text{P} = \text{O} \rightarrow 2$ $\text{P} - \text{P} \rightarrow 1$	Tetra
(5)	Ortho phosphoric acid	H_3PO_4	+5	$\text{P} - \text{OH} \rightarrow 3$ $\text{P} = \text{O} \rightarrow 1$	Tri
(6)	Meta phosphoric acid • cyclo tri metaphosphoric acid • linear trimetel phosphoric acid	HPO_3 $(\text{HPO}_3)_3$ $(\text{HPO}_3)_n$	+5 +5 +5	$\text{P} - \text{OH} \rightarrow 3$ $\text{P} = \text{O} \rightarrow 3$ $\text{P} - \text{O} - \text{P} \rightarrow 3$ $\text{P} = \text{O} \rightarrow 1$ $\text{P} - \text{OH} \rightarrow 1$ $\text{P} - \text{O} - \text{P} \rightarrow 1$	Tri Mono
(7)	Pyrophosphoric acid	$\text{H}_4\text{P}_2\text{O}_7$	+5	$\text{P} - \text{OH} \rightarrow 4$ $\text{P} = \text{O} \rightarrow 2$ $\text{P} - \text{O} - \text{P} \rightarrow 1$	Tetra
(8)	Peroxomono phosphoric acid	H_3PO_5	+5	$\text{P} - \text{O} - \text{O} - \text{H} \rightarrow 1$ $\text{O} - \text{H} \rightarrow 2$ $\text{P} = \text{O} \rightarrow 1$	Tri
(9)	Peroxo diphosphoric acid	$\text{H}_4\text{P}_2\text{O}_8$	+5	$\text{O} - \text{H} \rightarrow 4$ $\text{P} = \text{O} \rightarrow 2$ $\text{P} - \text{O} - \text{O} - \text{P} \rightarrow 1$	Tetra

● **Phosphorous and its compounds :**

64. Which of the following mixture heated in kiln to produce phosphorous ?
 (A) $\text{Ca}_3(\text{PO}_4)_2 + \text{SiO}_2$ (B) $\text{SiO}_2 + \text{C}$ (C) $\text{Ca}_3(\text{PO}_4)_2 + \text{C}$ (D) $\text{Ca}_3(\text{PO}_4)_2 + \text{SiO}_2 + \text{C}$
65. $\text{P}_{4(\text{s})} + 3\text{NaOH}_{(\text{aq})} + 3\text{H}_2\text{O}_{(\text{l})} \rightarrow \text{PH}_{3(\text{g})} + \boxed{\text{X}}$. Identify X in given reaction.
 (A) Na_3PO_4 (B) Na_2HPO_4 (C) NaH_2PO_4 (D) NaH_2PO_2
66. Which of the following comes in contact with PH_3 to explode ?
 (A) HNO_3 (B) Cl_2 (C) Br_2 (D) All above
67. Which compound of phosphorous is useful in Holmes signal ?
 (A) PH_3 (B) P_2O_5 (C) Ca_3P_2 (D) P_2O_3
68. In which of the following reaction does not produce phosphine ?
 (A) white P heated with NaOH (B) red P heated with NaOH
 (C) Ca_3P_2 reacting with water (D) P_4O_6 reacts with water
69. How many number of 'O' atoms attach to every 'P' in P_4O_6 and no. of bonds of P – O in P_4O_6 ?
 (A) 1.5, 2 (B) 2, 1 (C) 3, 4 (D) 4, 3
70. $\text{P}_{4(\text{s})} + 8\text{SOCl}_{2(\text{l})} \rightarrow 4\boxed{\text{X}} + 4\boxed{\text{Y}} + 2\boxed{\text{Z}}$ what are X, Y and Z respectively ?
 (A) PCl_5 , SO_2 , S_2Cl_2 (B) POCl_3 , SO_2 , SOCl_2 (C) PCl_3 , SO_3 , S_2Cl_2 (D) PCl_3 , SO_2 , S_2Cl_2
71. What is the shape and hybridisation of PCl_5 molecule ?
 (A) Trigonal bi-pyramidal, sp^3d (B) Pyramidal, dsp^3
 (C) Trigonal bi-pyramidal, sp^3 (D) Planar triangular, sp^3d^2
72. Which of the following coating fixed on both sides of match box ?
 (A) potassium chlorate and red lead (B) potassium chlorate and antimony sulphide
 (C) antimony sulphide and red phosphorous (D) antimony sulphide and red lead
73. What is equivalent weight of phosphoric acid in following reaction ?
 $\text{NaOH} + \text{H}_3\text{PO}_4 \rightarrow \text{NaH}_2\text{PO}_4 + \text{H}_2\text{O}$
 (A) 25 (B) 49 (C) 59 (D) 98
74. How many number of bonds of P–O–P are present in cyclic meta phosphoric acid ?
 (A) 0 (B) 2 (C) 3 (D) 4
75. In which of the following presence of spontaneous combustion property of phosphine ?
 (A) Vapour of P_4 (B) Vapour of P_2H_4 (C) Vapour of P_2H_6 (D) moisture

76. In which of the following P–O–P bond does not exist ?
 (A) Iso hypo phosphoric acid (B) Diphosphorous acid
 (C) Di phosphoric acid (D) Hypo phosphoric acid
77. Which of the following is tribasic acid ?
 (A) H_4PO_2 (B) H_3PO_4 (C) $\text{H}_4\text{P}_2\text{O}_7$ (D) H_3PO_3
78. Which of the following part of repeating unit in poly meta phosphoric acid ?
 (A) HPO_3 (B) H_3PO_2 (C) H_3PO_3 (D) HPO_2
79. Indetify incorrect pair
 (A) Orthophosphorous acid – dibasic – oxidation number of P = +3
 (B) Diphosphoric acid – tetrabasic – Oxidation number of P = +5
 (C) Hypophosphoric acid – tetrabasic – Oxidation number of P = +4
 (D) Phosphonic acid – dibasic – Oxidation number of P = +1
80. Which of the following oxoacid in phosphorous is strong reducing agent ?
 (A) Hypo phosphorous acid (B) phosphorous acid
 (C) Hypo phosphoric acid (D) pyro phosphorous acid

Answers : 64. (D), 65. (D), 66. (D), 67. (C), 68. (B), 69. (C), 70. (D), 71. (A), 72. (C), 73. (D), 74. (C), 75. (B), 76. (D), 77. (B), 78. (A), 79. (D), 80. (A)

● Elements of Group 16 :

General information, e^- configuration, occurance, oxidation state, physical and chemical properties :

- Oxygen, sulphur, selenium, tellurium and polonium elements are included in group 16.
- These elements are known as oxygen group elements or as chalcogens.
- **Electronic Configuration :** The electronic configuration of valence shell of elements of group 16 is ns^2np^4 .

● Occurence :

- Oxygen element is the most abundant element available in highest proportion on the earth.
- Oxygen element possesses about 46.6% mass of earth's crust. In dry air, oxygen is 20.9461 % by volume.
- Sulphur present on the earth is about 0.03-0.1 % by mass of earth's crust.
- It is available in combined forms

Sulphate compounds like $\rightarrow$ gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

$\rightarrow$ Epsom salt ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$)

$\rightarrow$ Baryte (BaSO_4) and

Sulphide compounds like → Galena (PbS)

→ Zinc blende (ZnS)

→ Copper pyrites (CuFeS₂)

● **Oxidation states :**

Elements	O	S	Se	Te	Po
Oxidation state	-2, -1, +1, +2	-2, +2, +4, +6	-2, +2, +4, +6	-2, +2, +4, +6	+2, +4

- The stability of (-2) oxidation states of these compounds decreases as we go down the group.
- Polonium does not show (-2) oxidation state.
- In OF₂, oxidation state of oxygen is (+2).
- As we go down in the group, the stability of +6 oxidation state decreases and stability of +4 oxidation state increases.

● **Periodicity in Physical and Chemical properties**

Periodicity in Physical properties :

- The atomic and ionic radii with increase in number of orbits in the elements, increases when we go down the group.
- The value of ionization enthalpy decreases with increase in atomic number as we go down the group.
- As we go down the group, electronegativity decreases.

Chemical properties :

- All the elements of group 16 form hydrides of the type H₂M (where M = S, Se, Te, Po). The acidic property of the hydride compounds increase on going from H₂O to H₂Te.
- All the elements of group 16 form oxides of two types MO₂ and MO₃ when react with oxygen element (where M = S, Se, Te, Po).
- The property as reducing agents of these dioxide compounds, decreases as we go down from SO₂ to TeO₂. SO₂ is a reducing agent, while TeO₂ is an oxidising agent. All these oxides possess acidic nature.
- The order of stability of halide compounds is F⁻ > Cl⁻ > Br⁻ > I⁻. Amongst the hexahalide compounds, only hexafluoride are found to be stable.

81. Which of the following element does not possess -2 oxidation state ?

- (A) Te (B) Se (C) Po (D) S

82. Which mineral is sulphate containing barium ?

- (A) Barite (B) Galena (C) Zincite (D) Gypsum

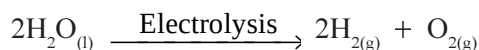
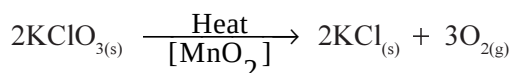
83. As we move from top to bottom in group 16 bond angle in hydride compounds decrease, because...
- (A) Repulsion between bonding e^- pair-bonding e^- pair increases.
 (B) Repulsion between bonding e^- pair-bonding e^- pair decreases.
 (C) Electronegativity of central atom decreases.
 (D) Electronegativity of central atom increases.
84. Which of the following has maximum magnetic dipole moment ?
- (A) H_2O (B) H_2S (C) H_2Se (D) H_2Te

Answers : 81. (C), 82. (A), 83. (C), 84. (D)

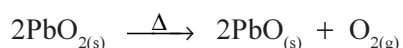
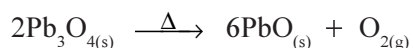
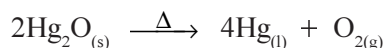
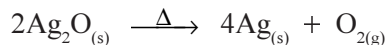
● Oxygen

● Preparation of Dioxygen gas :

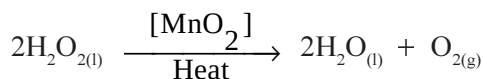
- (i) By thermal decomposition of oxygen containing elements like $KClO_3$ and $KMnO_4$ or by electrolysis of acidic water.



- (ii) Dioxygen gas is obtained by thermal decomposition of oxides of certain metals.



- (iii) Dioxygen gas is obtained by decomposition of H_2O_2 in the presence of manganese dioxide.



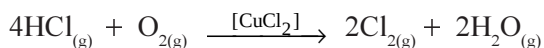
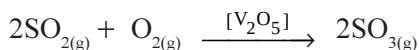
● Properties and uses of dioxygen gas

(i) Physical Properties :

- Dioxygen is a colourless and odourless gas.
- It possesses three stable isotopes ^{16}O , ^{17}O , ^{18}O . It is paramagnetic.
- About 3.08 cm^3 of dioxygen gas dissolve in 100 cm^3 of water at 293 K temperature which is sufficient to sustain life of marine and aquatic living beings.
- It is converted in liquid form at 90K temperature and in solid form by cooling at 55 K temperature.

(ii) Chemical Properties :

Dioxygen gas reacts with most of metal elements except inert and noble gas elements.



● Uses :

- Dioxygen gas is useful in respiration and combustion reaction. In preparation of steel. In oxyacetylene flame. As very high temperature is obtained by this flame in welding work of metals.
- Cylinders of dioxygen gas are useful for treatment of patients in the hospital, mountaineers and divers going deep in the water as well as respiration process.

● Anomalous behaviour

- d-orbitals are not available in valence shells of oxygen atom. Hence, it possesses lower oxidation state (−2, −1, 1, 2). While in other elements, as d-orbitals are available, the expansion of valence orbit in elements is possible. Here, these elements possess higher oxidation states (−2, 2, 4, 6).

● Possess Compounds of Oxygen :

(i) **Simple Oxides** : Oxygen combines with other elements and forms binary compounds called oxides.

- The oxides which give acid by reaction with water are called acidic oxides, eg. SO_2 , Cl_2O_7 , CO_2 , N_2O_5 , HClO_4 , P_4O_{10}
- Generally oxides of non-metals are acidic.

Exception : Oxides of metals are acidic eg. V_2O_5 , Mn_2O_7 , CrO_3

- The oxide compounds which give base by reaction with water are called basic oxides. eg., Na_2O , CaO , BaO , Fe_2O_3 , MgO
- Some oxides possess both the acidic and basic nature. These oxides are called amphoteric oxides. eg. Al_2O_3 .
- Some oxides are such which possess neither of the acidic nor basic nature. These oxides are called neutral oxides eg., CO , NO and N_2O .

(ii) Ozone :

- Ozone is the allotrope of oxygen. Ozone is formed from oxygen in atmosphere in presence of sunlight at the height of 20 kilometer above sea level.

Preparation :

- Ozone gas can be prepared in laboratory by the use of ozonizer of Siemens or Brodie. Ozone is obtained by passing cold and dry oxygen in presence of silent electric charge in Siemen's ozoniser.



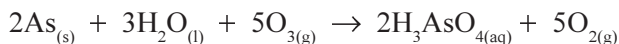
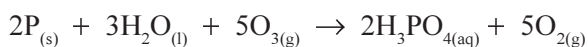
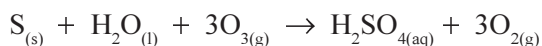
- 8000 to 10000 volt electromotive force is used between rods of aluminium. In electrolysis method, 95 % ozone can be obtained at the anode by electrolysis of acidic water using platinum electrodes and remaining 5% is oxygen gas.

● **Physical properties :**

- Ozone possesses light blue colour in gaseous form, dark blue colour in liquid form and dark violet colour in solid form.
- Ozone possesses characteristic odour.
- Less proportion of ozone is not harmful but if its proportion exceeds 100 ppm, then difficulty develops in respiration. As a result of this there is experience of headache and suffocation.

● **Chemical properties :**

- Strong oxidising agent. Hence ozone gas oxidises lead sulphide to lead sulphate and iodide ion to iodine.
- Nitric oxide coming out from the exhaust of supersonic jet planes, react with ozone and form nitrogen dioxide gas.
- In the same way, it forms oxo acids by reaction with moisture containing sulphur, phosphorus and arsenic.



Uses :

- To sterilise drinking water.
- As bleaching agent for bleaching of different oils, flour and starch.
- As oxidising agent in production of potassium permanganate.

85. Which of the following compound does not give dioxygen when heated ?

- (A) HgO (B) KMnO₄ (C) (NH₄)₂Cr₂O₇ (D) KClO₃

86. Oxygen element possess low oxidation state because...

- (A) d-orbitals are not present in valence shell.
 (B) expansion of valence orbital.
 (C) it is in gaseous form.
 (D) All above.

87. Which oxide is not acidic oxide ?

- (A) SO₂ (B) CrO₃ (C) Cl₂O₇ (D) Fe₂O₃

88. Which of the following is neutral oxide ?

- (A) CO (B) NO (C) NO₂ (D) All are given

89. Which of the following compound does not produce dioxygen when reacts with ozone ?

- (A) PbS (B) H₂S (C) SO₂ (D) Hg

90. By which of the following method is used to prepare ozone in laboratory ?

- (A) UV rays passed in air.
 (B) F₂ reacts with water at low temperature.
 (C) SO₂ reacts with H₂O₂.
 (D) Dry oxygen passed in presence of piece electric charge.

91. Match the correct pair.

Column-I

- (P) ZnO
 (Q) V₂O₅
 (R) Fe₂O₃
 (S) H₂S

Column-II

- (T) Basic
 (U) Amphoteric
 (V) Acidic
 (W) Reductant

- (A) (P)-(U), (Q)-(V), (R)-(T), (S)-(V), (W)
 (B) (P)-(V), (W), (Q)-(Q), (R)-(V), (S)-(T)
 (C) (P)-(T), (Q)-(V), (W), (R)-(U), (S)-(V)
 (D) (P)-(V), (Q)-(T), (R)-(V), (W), (S)-(U)

Answers : 85. (C), 86. (A), 87. (D), 88. (D), 89. (C), 90. (D), 91. (A)

● **Allotropes of Sulphur**

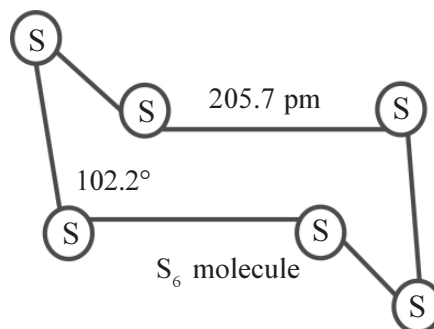
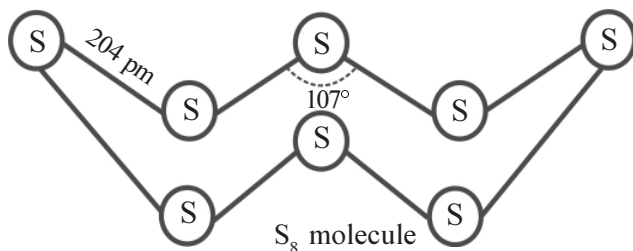
Yellow rhombic sulphur (α-sulphur) and monoclinic sulphur (β-sulphur) are very important.

(i) **Rhombic sulphur (α-sulphur) :**

- Yellow colour.
- Its melting point is 385.8 K.
- On evaporation of solution of sulphur prepared in CS₂, rhombic sulphur is obtained.
- It is insoluble in water but soluble in organic solvents like benzene, alcohol.

(ii) **Monoclinic sulphur (β-sulphur) :**

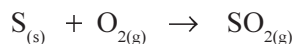
- When sulphur is heated of 369 K it converts into monoclinic sulphur.
- Monoclinic sulphur is soluble in CS₂. Its melting point is 393 K.
- When rhombic sulphur is melted in a dish and then cooled, monoclinic sulphur is obtained.
- Monoclinic sulphur is stable at temperature higher than 369 K and it is chagned to rhombic sulphur at lower temperatures.
- At **369 K** tempreature, both the **allotropes are stable**. This temperature is called the **transition temperature**.
- Both these possess S₈ molecule. S₈ molecule is in the form of a crown.
- The cyclic structure of S₆ molecule is of chair form.



● Compounds of Sulphur

(1) Sulphur dioxide (SO₂) :

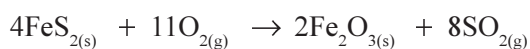
- (i) **Preparation :** When sulphur is combusted in air or oxygen gas, sulphur dioxide (with about 6 to 8% sulphur trioxide) is obtained.



- In laboratory, sulphur dioxide gas is obtained by reaction of hydrochloric acid with sodium sulphite.



- In industries, sulphur dioxide is obtained as a by product during roasting of sulphide mineral.



Sulphur dioxide gas obtained this way is dried and stored in liquid state under pressure in steel cylinder.

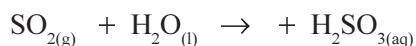
(ii) Properties

Physical Properties :

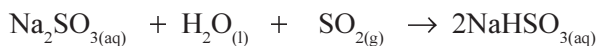
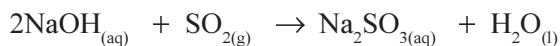
- Colourless gas having intense smell and possessing burning effect.
- Soluble in water in very high proportion.
- It is liquefied at room temperature at 2 bar pressure. Sulphur dioxide molecule is angular.

Chemical Properties :

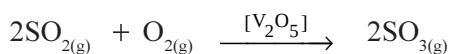
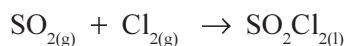
- Solution of sulphurous acid is obtained when sulphur dioxide is passed through water.



- It forms sodium sulphite in first step by reaction with NaOH which reacts with more proportion of sulphur dioxide and form sodium hydrogen sulphate.



- Sulphur dioxide reacts with chlorine gas in presence of catalyst and forms sulphuryl chloride (SO₂Cl₂). Sulphur trioxide is formed by oxidation in presence of vanadium pentoxide catalyst.



- It makes coloured acidic solution of KMnO₄ colourless. Thus it acts as a reducing agent.

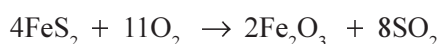
(iii) **Uses :**

- In purification of petroleum and sugar. To bleach wool and silk.
- To dissolve certain organic and inorganic substances liquid sulphur dioxide is used as solvent.
- In industrial production of sulphuric acid, sodium hydrogen sulphite and calcium hydrogen sulphite, sulphur dioxide is used.

(2) **Sulphuric acid (H₂SO₄) :**

(i) **Industrial manufacture :** Mainly the following steps are included in the manufacture of sulphuric acid by contact process.

- (1) To obtain sulphur dioxide gas by combusting sulphur or sulphide mineral in air.

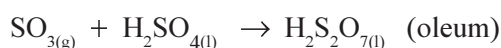


- (2) To convert sulphur dioxide to sulphur trioxide with the help of oxygen in presence of vanadium pentoxide catalyst.

- (3) Sulphur trioxide obtained this way is absorbed in concentrated sulphuric acid and so fuming sulphuric acid or oleum (H₂S₂O₇) is obtained.



Sulphur trioxide gas obtained in this way is absorbed in concentrated sulphuric acid. As a result, fuming sulphuric acid or oleum (H₂S₂O₇) is obtained. Sulphuric acid of required concentration can be obtained by its dilution with water.



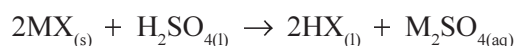
96 to 98 % pure H₂SO₄ can be obtained by contact process.

● **Physical properties :**

- Colourless, dense oily liquid.
- Its specific gravity at 298 K temperature is 1.84.
- Its freezing point is 283 K and boiling point is 611 K.

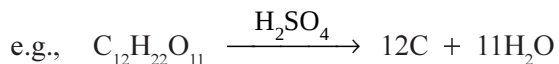
● **Chemical properties :**

- It is used in preparation of other acids due to low volatility.



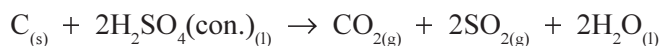
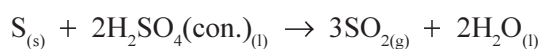
(Where M = metal ion, X = F⁻, Cl⁻, NO₃⁻)

- Concentrated sulphuric acid is a strong dehydrating substance. Gases containing moisture when passed through concentrated H_2SO_4 they become dry. These gases must not be reacting with H_2SO_4 . It removes water from organic compounds.



By this charring reaction sugar becomes black.

- Hot concentrated sulphuric acid acts as oxidising agent. Metals and non-metals are oxidised by concentrated H_2SO_4 and sulphuric acid is reduced and converted to SO_2 .



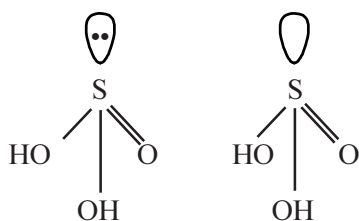
Uses :

- An important industrial chemical. In preparation of most of the chemical substances like fertilizers, dyes, synthetic fibres, soap and detergent, it is called 'King of Chemicals'.
- As a reagent in laboratory.

(3) Oxoacids of sulphur

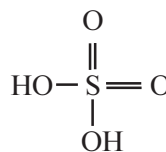
(i) sulphurous acid

- formula : H_2SO_3
- Oxidation no. of S = +4
- structure :



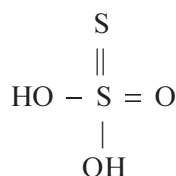
(ii) sulphuric acid

- formula : H_2SO_4
- Oxidation no. of S = +6
- structure :



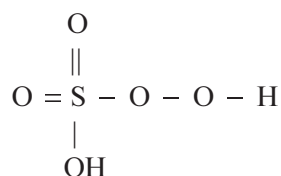
(iii) Thiosulphuric acid

- formula : $\text{H}_2\text{S}_2\text{O}_3$
- Oxidation no. of +6, -2
- structure :



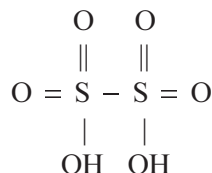
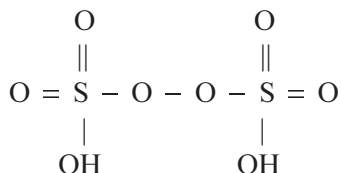
(iv) Peroxomono sulphuric acid (caros acid)

- formula : H_2SO_5
- Oxidation no. of S = +6
- structure :

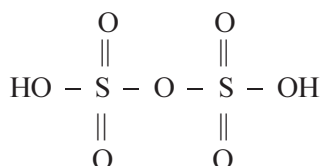


(vi) Dithionic acid

- formula : $\text{H}_2\text{S}_2\text{O}_6$
- Oxidation no. of S = +6
- structure :



- formula : $\text{H}_2\text{S}_2\text{O}_7$
- Oxidation no. of S = +6
- structure :



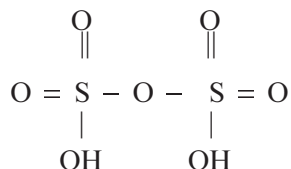
- 393

98. Which aqueous solution of ion reacts with HCl to give intense odour of gas and yellow precipitate when heated ?
 (A) Thiosulphate ion (B) Sulphate ion (C) Sulphide ion (D) Sulphite ion
99. Which of the following is monobasic acid ?
 (A) H_2SO_3 (B) H_2SO_4 (C) H_2SO_5 (D) $\text{H}_2\text{S}_2\text{O}_8$
100. SO_2 gas passed through acidic solution of $\text{K}_2\text{Cr}_2\text{O}_7$
 (A) gives blue coloured solution (B) gives colourless solution
 (C) produce SO_2 (D) gives green coloured substance $\text{Cr}_2(\text{SO}_4)_3$
101. Which oxide of nitrogen is used as catalyst in lead chamber process ?
 (A) NO (B) NO_2 (C) N_2O_3 (D) N_2O_5
102. Which acid possess peroxi bond ?
 (A) sulphurous acid (B) pyrosulphurous acid (C) dithionic acid (D) Caros acid
103. Match correct pair.

Column-I	Column-II
(P) $\text{H}_2\text{S}_2\text{O}_2$	(T) S–O–S linkage
(Q) $\text{H}_2\text{S}_2\text{O}_3$	(U) Diprotic
(R) $\text{H}_2\text{S}_2\text{O}_4$	(V) S = S linkage
(S) $\text{H}_2\text{S}_2\text{O}_7$	(W) S – S linkage

- (A) (P)-(U), (W), (Q)-(T),(U), (R)-(U), (V), (S)-(U), (V)
 (B) (P)-(U), (V), (Q)-(U), (V), (R)-(U), (W), (S)-(T), (U)
 (C) (P)-(T), (U), (Q)-(U), (V), (R)-(U), (V), (S)-(U), (W)
 (D) (P)-(U), (W), (Q)-(U), (V), (R)-(T), (U), (S)-(U), (V)

104. Whose structure is this ?



- (A) Peroxo disulphuric acid (B) Pyro sulphuric acid
 (C) Sulphurous acid (D) Caros acid
105. Formic acid reacts with concentrated H_2SO_4 to produce
 (A) CO (B) NO (C) CO_2 (D) NO_2
106. Which is correct order of acidic strength for CO_2 , CuO, CaO, H_2O ?
 (A) $\text{CaO} < \text{CuO} < \text{H}_2\text{O} < \text{CO}_2$ (B) $\text{H}_2\text{O} < \text{CuO} < \text{CaO} < \text{CO}_2$
 (C) $\text{CaO} < \text{H}_2\text{O} < \text{CuO} < \text{CO}_2$ (D) $\text{H}_2\text{O} < \text{CO}_2 < \text{CaO} < \text{CuO}$
107. Hybridisation of S-atom in SF_2 , SF_4 , SF_6 are respectively.
 (A) sp^2 , sp^3 , sp^3d^2 (B) sp^3 , sp^3 , sp^3d^2 (C) sp^3 , sp^3d , sp^3d^2 (D) sp^3 , sp^2 , d^2sp^3

Answers : 92. (B), 93. (A), 94. (B), 95. (C), 96. (B), 97. (C), 98. (A), 99. (C), 100. (A), 101. (A), 102. (C), 103. (B) 104. (B), 105. (A), 106. (A), 107. (C).

● **Elements of group 17 :**

- Fluorine, chlorine, bromine, iodine and astatine are the elements of group 17.
- These elements are collectively known as halogen elements.
- They are reactive non-metallic elements.
- Astatine is a radioactive element.

● **Electronic configuration :**

- The electronic configuration of valence shell of elements of group 17 is ns^2np^5 (where, $n = 2$ to 6). They have one electron less for obtaining electronic configuration like their neighbouring inert elements.
- Order of electronegativity of group-17 elements is $F > Cl > Br > I$.
- Its oxidation state is (-1) in all its compounds. The value of ionisation enthalpy decreases with increase in atomic size. Some oxide and oxoacid of halogen possess $+4$ and $+6$ oxidation state.
- The value of electron gain enthalpy of halogen elements of the period is highest negative.

● **Electronegativity :**

- The electronegativity of halogen elements is more.
 - The electronegativity decreases as we move down in this group.
 - The electronegativity of fluorine element is maximum.
-

108. Number of s and p electrons are respectively

- (A) 15, 18 (B) 12, 17 (C) 8, 17 (D) 4, 19

109. Which of the is the most basic ?

- (A) F (B) Cl (C) Br (D) I

110. Which of the following has less bond dissociation enthalpy ?

- (A) C – Cl (B) C – F (C) C – Br (D) C – I

111. Which order is not proper ?

- (A) Electronegativity : $F_2 > Cl_2 > Br_2 > I_2$
(B) Bond-dissociation enthalpy : $F_2 > Cl_2 > Br_2 > I_2$
(C) Ionization enthalpy : $F_2 > Cl_2 > Br_2 > I_2$
(D) All above.

112. There are two statements are given among this one is statement (A) and other is reason (R). Select correct option to study instructions carefully.

Statement (A) : Reactivity of fluorine is less.

Reason (R) : Bond dissociation enthalpy of $F - F$ is less than other halogen elements.

- (A) Statement (A) and Reason (R) are true. Reason (R) is correct explanation of statement (A).
(B) Statement (A) and Reason (R) are true. Reason (R) is not correct explanation of statement (A).
(C) Both statements (A) and Reason (R) are incorrect.
(D) Statement (A) is wrong while reason (R) is correct.

113. As we move from top to bottomincreases.
 (A) electronegativity (B) volatile Nature (C) oxidizing agent property (D) ionic radius
114. Which compound is partially halide ?
 (A) Cl^- (B) CN^- (C) ICl_2^- (D) ICI
115. Which order of acidic strength is not proper ?
 (A) $\text{HI} > \text{HBr} > \text{HCl}$ (B) $\text{HIO}_4 > \text{HBrO}_4 > \text{HClO}_4$
 (C) $\text{HClO}_4 > \text{HClO}_3 > \text{HClO}_2$ (D) $\text{HF} > \text{H}_2\text{O} > \text{NH}_3$
116. Give ionic trend in metallic halide.
 (A) $\text{MF} < \text{MCl} < \text{MBr} < \text{MI}$ (B) $\text{MF} > \text{MCl} > \text{MBr} > \text{MI}$
 (C) $\text{MF} < \text{MCl} < \text{MBr} < \text{MI}$ (D) $\text{MCl} > \text{MF} > \text{MBr} > \text{MI}$
117. Correct order of standard reduction potential of Halogen group elements.
 (A) $\text{F}_2 > \text{Cl}_2 > \text{I}_2 > \text{Br}_2$ (B) $\text{Cl}_2 > \text{F}_2 > \text{I}_2 > \text{Br}_2$ (C) $\text{I}_2 > \text{Br}_2 > \text{Cl}_2 > \text{F}_2$ (D) $\text{F}_2 > \text{Cl}_2 > \text{Br}_2 > \text{I}_2$
118. Select correct option for true-false statements :
 (A) Order of electronegativity : $\text{I} < \text{Br} < \text{Cl} < \text{F}$.
 (B) Order of electron gain enthalpy : $\text{Cl} > \text{F} > \text{Br} > \text{I}$.
 (C) Cryolite is the main mineral to obtain chlorine.
 (D) More electronegative halogen combine with less electronegative halogen form interhalogen compounds.
 (E) Electron-electron repulsion is more in e^- enter in 3P orbital of chlorine than e^- enter in 2P-orbital of fluorine, so, electron gain enthalpy of fluorine is more than chlorine.
 (F) Last element of halogen group, astatine is a radioactive element.
 (A) TFFFTT (B) TFTFFT (C) TFFFTT (D) TTFFTT
119. High viscosity and high melting point of HF is due to reason.
 (A) low dissociation enthalpy of F_2 molecule (B) nature of H-bond.
 (C) ionic nature of HF (D) high electronegativity of fluorine.
120. Halogen is volatile because
 (A) they all are co-valent property. (B) they possess high boiling point
 (C) they possess low boiling point (D) they are stable at room temperature.

Answers : 108. (C), 109. (D), 110. (D), 111. (B), 112. (D), 113. (D), 114. (B), 115. (B), 116. (B), 117. (D), 118. (D), 119. (B), 120. (C)

● Chemical properties

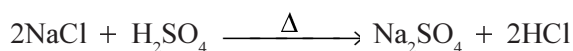
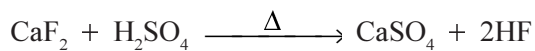
(1) Reactivity :

All halogen elements are chemically active. Reactivity of halogen decreases with increase in atomic number. So fluorine is highly active and iodine is weakly active order of reactivity is $\text{F} > \text{Cl} > \text{Br} > \text{I}$.

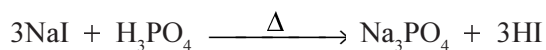
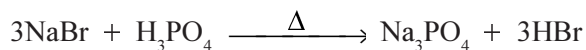
- All halogen elements form halides. Halide ions are used as reducing agents.
- Order of reducing agent : $\text{I} > \text{Br} > \text{Cl} > \text{F}$.

(2) Hydrogen Halide :

- Halogen element attach with hydrogen gives hydrogen halide.
- Preparation of HF and HCl :



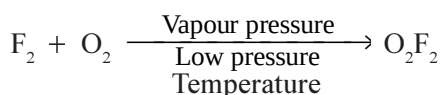
- Preparation of HF and HCl :



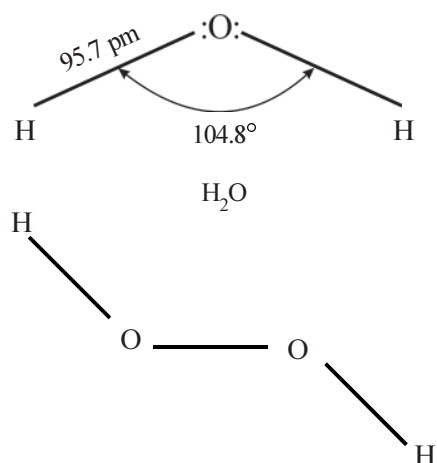
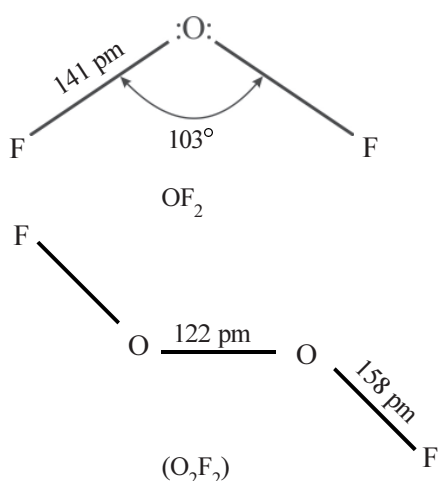
(3) Oxide :

Halogen elements do not combine with oxygen. Compounds of halogen with oxygen obtained indirectly.

- Only two compounds of oxygen with flourine OF_2 and O_2F_2
- While chlorine gives more no. of oxides e.g., Cl_2O , ClO_2 , Cl_2O_6 and Cl_2O_7
- Iodine gives only one oxide e.g., I_2O_5
- Bromine has three oxides e.g., Br_2O , BrO_2 , BrO_3
- All halogen oxides are acts as strong oxidising agent.
- Order of oxidizing agent : $\text{Cl}_2\text{O} > \text{ClO}_2 > \text{Cl}_2\text{O}_6 > \text{Cl}_2\text{O}_7$.
- Reaction of preparation of oxygen fluoride :



- Structure :

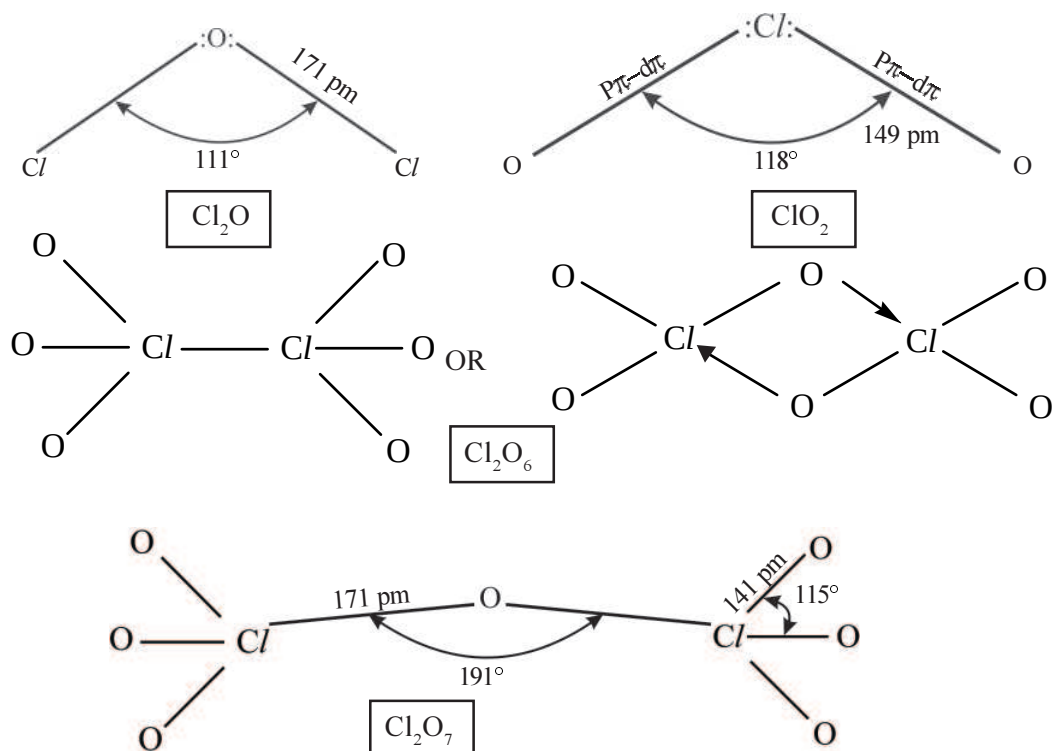


- Uses :

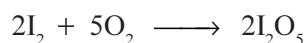
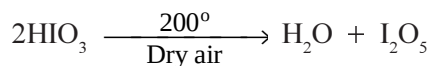
O_2F_2 and OF_2 both are strong fluorinating agent.

O_2F_2 is used in PuF_6 to remove Pu.

● **Structure of oxides of chlorine :**

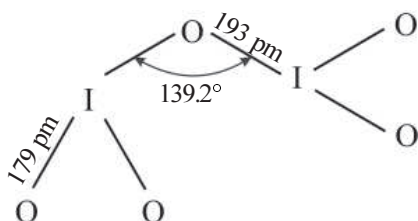


- Structure of bromine oxide is same as chlorine oxide.
- Equation for the preparation of iodine pentoxide.



Uses : I₂O₅ is a good oxidising agent which is used to maintain proportion of CO from air mixture.

Structure :



(4) Oxoacid compounds of Halogen Elements :

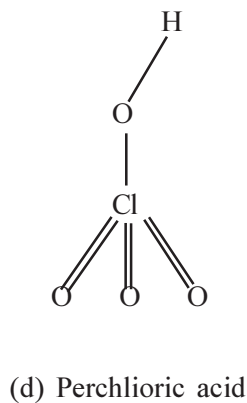
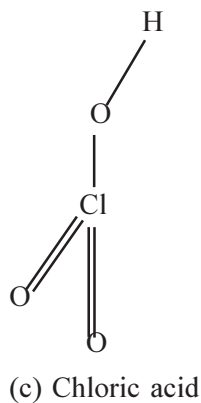
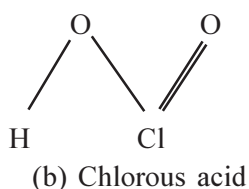
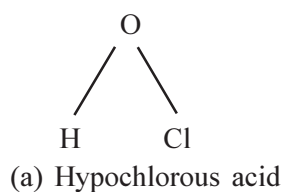
Fluorine forms only one oxoacid because of smaller size and more electronegativity of fluorine element. HOF is called fluoric (I) acid or hypofluorous acid. Other halogen elements form oxoacid compounds in more number.

Most of the compounds cannot be separated in pure form. They are stable as aqueous solutions or in the form of salts. The oxoacid compounds of halogen elements are shown :

Halic (I) acid (Hypohalous acid)	HOX (Hypo- fluorous acid)	HOX (Hypochlorous acid)	HOX (Hypobromous acid)	HOX (Hypoiodous acid)
Halic (II) acid (Halous acid)	-	HOX	-	-
Halic (V) acid (Halous acid)	-	HOX ₂ (chloric acid)	HOX ₂ (Bromic acid)	HOX ₂ (Iodic acid)
Halic (VII) acid (Perhalic acid)	-	HOX ₃ (perchloric acid)	HOX ₃ (perbromic acid)	HOX ₃ (periodic acid)

• The strength of oxoacids of halogens increases with the increase in oxidation state of halogen. e.g., HClO is a very weak acid in which oxidation state of Cl element is (+1).

- HClO₄ is a very strong acid in which oxidation state of a element is (+7).
- Only structure of some oxo acids are given below :

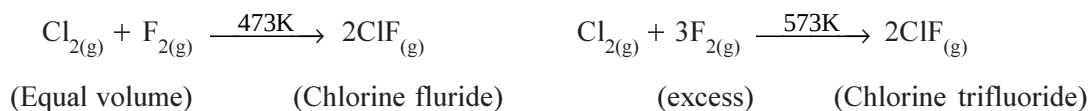


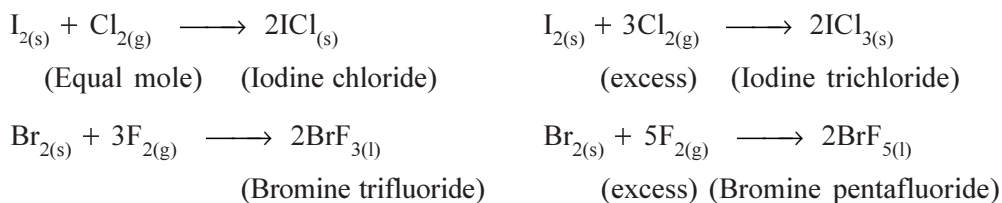
(5) Interhalogen compounds :

When two different halogen elements react with each other and form the compounds, they are called interhalogen compounds. e.g., XX', XX'₃, XX'₅ and XX'₇ compounds, where X = halogen elements with bigger size, X' = halogen elements with smaller size.

(i) Preparation :

Interhalogen compounds are obtained by direct reaction of halogen elements with each other.





(ii) Properties :

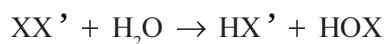
Some properties of Interhalogen compounds :

Type	Formula	Physical state and colour	Structure (Shape)
XX'	ClF	Colourless gas	-
	BrF	Pale brown gas	-
	IF	Detected spectroscopically	-
	BrCl	gas	-
	ICl	Ruby red solid (α -form)	-
	IBr	Red solid (β -form) Black solid	-
XX' ₃	ClF ₃	Colourless gas	Bent T-shaped
	BrF ₃	Yellow green liquid	Bent T-shaped
	IF ₃	Yellow powder	Bent T-shaped
	ICl ₃	Orange solid	Bent T-shaped
XX' ₅	IF ₅	Colourless gas but solid below 77 K	Square pyramidal
	BrF ₅	Colourless liquid	Square pyramidal
	ClF ₅	Colourless liquid	Square pyramidal
XX' ₇	IF ₇	Colourless gas	Pentagonal bipyramidal

(a) Physical properties : Most of the interhalogen compounds are in volatile solid or liquid form. Some compounds are in gaseous form.

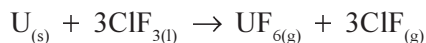
(b) Chemical properties : Generally interhalogen compounds are more reactive than their corresponding halogen elements (Except fluorine) because the X – X' bond in interhalogen compounds is relatively weak in comparison to X – X bond.

By hydrolysis of interhalogen compounds halide ion is formed from smaller size from them and hypohalite (for XX'), halite (for XX'₃), halate (for XX'₅) and perhalate (for XX'₇) ions are formed from bigger size halogen.



(iii) Uses :

- Interhalogen compounds are used as non-aqueous solvent.
- Very good fluorinating reagents.
- ClF_3 and BrF_3 are used to obtain U^{235} for concentration of UF_6 .



121. is used as design of glass, so it can't fill up in glass vessel.

- (A) HI (B) HBr (C) HCl (D) HF

122. Which order is correct according to stability ?

- (A) $\text{HF} > \text{HBr} > \text{HCl} > \text{HI}$ (B) $\text{HI} < \text{HCl} < \text{HBr} < \text{HF}$
(C) $\text{HF} > \text{HCl} > \text{HBr} > \text{HI}$ (D) $\text{HF} > \text{HI} > \text{HCl} > \text{HBr}$

123. Shape of XX_3' type interhalogen compound is

- (A) pentagonal bi pyramidal (B) square pyramidal
(C) angular T-shape (D) octahedral

124. Select correct option for using symbol 'T' and 'F' for the following statements.

- (1) Hypo halite ion = $(\text{OX}_2)^-$ (2) Halite ion = $(\text{XO}_2)^-$
(3) Halate ion = $(\text{XO}_3)^-$ (4) perhalate ion = $(\text{OX}_4)^-$
(A) FTTT (B) TFFT (C) FTTF (D) TTTF

125. Give strong oxidizing agent.

- (A) F_2 (B) Cl_2 (C) Br_2 (D) I_2

126. Which interhalogen possess 'T' shape ?

- (A) ClF_3 (B) ClF (C) ClF_5 (D) IF_7

127. Which of the following element prepare only one stable oxoacid among halogen elements ?

- (A) I (B) F (C) Cl (D) Br

128. Stability order of inter halogen compound is

- (A) $\text{IF}_3 > \text{BrF}_3 > \text{ClF}_3$ (B) $\text{BrF}_3 > \text{IF}_3 > \text{ClF}_3$ (C) $\text{ClF}_3 > \text{BrF}_3 > \text{ZF}_3$ (D) $\text{ClF}_3 > \text{IF}_3 > \text{BrF}_3$

129. Which ions are obtained by hydrolysis of XX_5' and XX_7' compound respectively ?

- (A) XO_3^- , XO_4^- (B) XO_2^- , XO_3^- (C) XO_4^- , XO_5^- (D) XO^- , XO_2^-

130. Which of the following reaction can not be spontaneous ?

- (A) $\text{F}_2 + 2\text{Cl}^- \rightarrow 2\text{F}^- + \text{Cl}_2$ (B) $\text{I}_2 + 2\text{Br}^- \rightarrow 2\text{I}^- + \text{Br}_2$
(C) $\text{Br}_2 + 2\text{I}^- \rightarrow 2\text{Br}^- + \text{I}_2$ (D) $2\text{I}^- + \text{Cl}_2 \rightarrow 2\text{Cl}^- + \text{I}_2$

131. Chlorine atom in ClF_5 possess hybridisation.

- (A) sp^3 (B) sp^3d (C) sp^3d^3 (D) sp^3d^2

132. Chlorine atom in ClO_3^- possess hybridisation.

- (A) sp^2 (B) sp^3 (C) sp^3d (D) sp^3d^2

Answers : 121. (D), 122. (A), 123. (C), 124. (D), 125. (A), 126. (A), 127. (C), 128. (C), 129. (B), 130. (A), 131. (B), 132. (B)

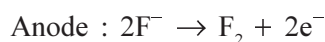
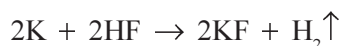
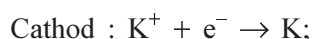
● **Halogen and their compounds :**

(1) Fluorine :

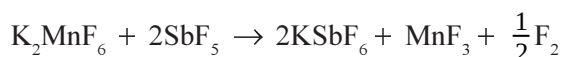
(i) Occurrence : Fluorine does not exist free in nature but it is obtained as fluorite or flourspar (CaF₂), cryolite (Na₃AlF₆) and fluorapatite.

Proportion of fluoride is in sea-water, bones, teeth, blood and in milk.

(ii) Preparation : By electrolysis of aqueous solution, carbon rod act as anode and carbon electrode act as cathode in closed vessel of Ni – Cu or Cu – Fe to get fluorine.



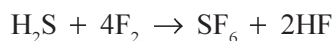
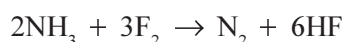
● Other chemical reaction to get fluorine :



(iii) Properties : In all halogen elements it is highly reactive.

● It gives fluoride with metal and non-metal.

● It reacts with NH_3 to produce nitrogen and with H_2S to produce SF_6 .



● Fluorine reacts with cold and dilute NaOH to prepare oxygen difluoride.



● When fluorine reacts with concentrated and hot NaOH gives oxygen.

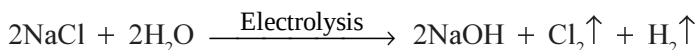


(iv) Uses : In preparation of UF_6 and SF_6 , in CFC, Teflon, Cryolite and HF.

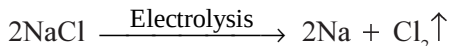
(2) Chlorine :

(i) Occurrence : Chlorine obtained mainly from (NaCl), carnelite (KCl , $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$) and (CaCl_2).

(ii) Preparation : Chlorine is obtained by electrolysis of brine solution.

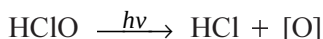
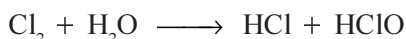


Chlorine is also obtained by electrolysis of molten NaCl.



(iii) Properties : Chlorine reacts with metal and non-metal gives chloride.

- Chlorine gives HCl and HClO by dissociation H_2O of which are unstable.



- Uses of Cl_2 is to remove ink.
- Cl is strong oxidising agent & it converts ferrous into ferric.

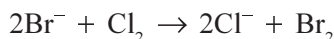
(iv) Uses : In preparation of HCl, NaOCl, bleaching powder, chloride, vinyl chloride and CCl_4 .

(3) Bromine :

(i) Occurrence : Obtained mainly from sea-water, salted water, lake and as NaBr, KBr, and MgBr_2 .

(ii) Preparation : Obtained mainly from sea-water.

- Cl_2 gas pass through sea-water gives Br_2 .

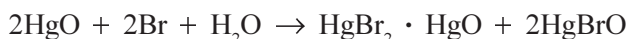


- In laboratory NaBr is heated with MnO_2 and concentrated H_2SO_4 gives Br_2 .



(3) Properties : It is reddish brown coloured heavy liquid.

- Its reactions with water, alkalies, NH_3 , metal and non-metal same as chlorine.
- Bromine water combine with mercury oxide give mercury oxy bromide.



mercury oxide bromide

(4) Uses : In preparation of ethelene bromide.

- In preparation of AgBr, Bromine water. Dyes, Medicines, Benzyl bromide.

(4) Iodine :

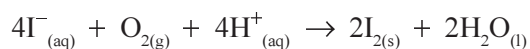
(i) Occurrence : Obtained from leminariya shrubs present in deep ocean, its proportion is 0.5%.

(ii) Preparation : Obtained from brine solution or sea-shrubs.

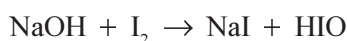
- Its ingredient (which contain 1% I_2) can be obtained by drying marine Weeds and then burning.

(iii) Properties : Partially soluble in water,, its solubility increases with addition of 10% KI solution.

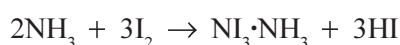
- Reaction of iodine with water is opposite of reaction of fluorine with water.



- In some organic solution it is soluble.
- I_2 reacts with cool and dil NaOH gives hypoiodous acid.



- Reaction of iodine with con and hot NaOH is same as Cl_2 and Br_2 .
- Reaction of iodine with amonia are as follow :

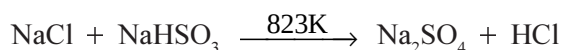
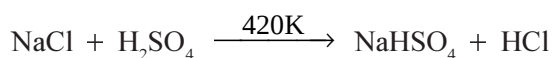


(iv) Uses : In preparation of iodex, iodoform, KI and potassium iodate.

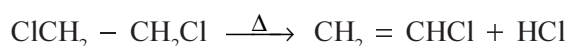
- Due to deficiency of I_2 , probability of goiter disease occurs.

(5) Hydrochloric acid (HCl) : HCl is obtained from passing Hydrogen chloride gas into water.

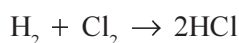
(i) Preparation : HCl is obtained by ‘salt cake’ method.



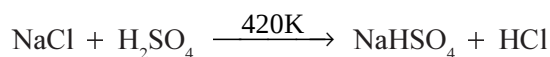
- Excess impure HCl is obtained during conversion of vinyl chloride from 1, 2-dichloro ethane



- Very pure HCl is obtained by direct mixture of H_2 and Cl_2 .



- In laboratory NaCl and concentrated H_2SO_4 are heated gives HCl.



(ii) Properties : It is colourless, spicy smell, easily soluble in colourless solution.

- It is easily soluble in water and it is called hydrochloric acid.
- It produces white fumes with NH_3 .



- Produce H_2 gas with active metal like Zn, Mg, Fe etc.

(iii) **Uses** : In preparation of metal chlorides, chlorine NH_4Cl and glucose.

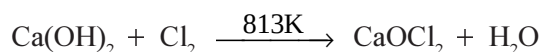
- To remove oxide layer from metal surface.
- In preparation of medicines and in laboratory.

(6) Bleaching powder :

(i) **Occurrence** : It is calcium salt of hypochlorous acid.

- It is mixture of hypochlorite and CaCl_2 .

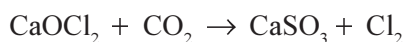
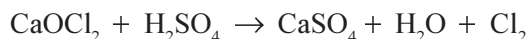
(ii) **Preparation** : Flow of chlorine passed on slaked lime gives bleaching powder.



(iii) **Properties** : In limited amount of bleaching powder react with dilute H_2SO_4 gives oxygen.



- It is oxidising agent and as bleaching agent.
- Excess amount of bleaching powder react with dilute acid or CO_2 to give Cl_2 .



- Good bleaching powder contain 35-38 % part chlorine from total 55.9% chlorine.

(iv) **Uses** : To bleach cotton clothes.

- In preparation of chloroform.
- As antiseptic, germfree water.
- To prevent shrinks in wood.

133. Chlorine reacts with and alkali to give chloride and chlorate respectively.

- (A) cool, dilute (B) hot, dilute (C) hot, concentrate (D) cool, concentrate

134. In which of the following reaction Cl_2 gas is not obtained as product ?

- (A) Oxidation of HCl by MnO_2 (B) Oxidation of HCl by KMnO_4
(C) Oxidation of KClO_3 by KMnO_4 (D) By electrolysis of concentrate NaCl solution

135. Which gas gives reaction with CaO , but not with NaHSO_3 ?

- (A) CO_2 (B) Cl_2 (C) N_2 (D) O_2

136. Salt of chloride heated with $\text{K}_2\text{Cr}_2\text{O}_7$ and concentrate H_2SO_4 give red-blue colour due to

- (A) Cl_2 (B) CrO_2Cl_2 (C) H_2CrO_2 (D) CrO_3

137. reacts with Cl_2 to give bleaching powder ?

- (A) CaCl_2 (B) CaO (C) CaCO_3 (D) Ca(OH)_2

138. When aqueous solution of KBr reacts with to produce bromine gas ?

- (A) I_2 (B) HI (C) Cl_2 (D) SO_2

139. Solution of chlorine in water possess
 (A) only HOCl (B) only HCl (C) HCl and HOCl (D) HCl, HClO and O₂
140. Fluorine does not show different oxidation state, because
 (A) due to its small atomic size (B) due to minimum bond dissociation enthalpy
 (C) d-orbitals are not present (D) due to its high electronegativity
141. What is the main reason for short bond length of B–F bond in BF₃ ?
 (A) Ionic covalent resonance show in BF₃ . (B) Electronegativity of fluorine is more.
 (C) Due to dπ – pπ bond. (D) Due to pπ – pπ bond.
142. Which of the following reacts with KBr solution to produce bromine ?
 (A) solution of I₂ (B) water of chlorine (C) NOCl (D) KI
143. I₂ reacts with hot and concentrated NaOH to give
 (A) NaI + HIO + O₂ (B) NaI + NaIO + O₂ (C) NaI + HIO₃ + H₂O (D) NaI + NaIO₃ + H₂O
144. Which halogen oxidized by HNO₃ ?
 (A) F₂ (B) Cl₂ (C) I₂ (D) Br₂
145. I₂ dissolve in water in presence of
 (A) KI (B) Cl₂ (C) Br₂ (D) KBr
146. Para periodic acid possess ion.
 (A) IO₃[–] (B) IO₆^{–5} (C) IO₅^{–3} (D) IO₄[–]
147. ICl₃ show electro conductivity due to electrolysis of its ionization occurs in
 (A) $2\text{ICl}_3 \rightleftharpoons \text{I}^+ + \text{ICl}_5^-$ (B) $\text{ICl}_3 \rightleftharpoons \text{I}^+ + 3\text{Cl}^-$
 (C) $2\text{ICl}_3 \rightleftharpoons \text{ICl}_2^+ + \text{ICl}_4^-$ (D) $2\text{ICl}_3 \rightleftharpoons \text{ICl}_4^+ + \text{ICl}_2^-$
148. By which reaction gives nitrogen (I) oxide ?
 (A) By thermal decomposition of ammonium nitrate.
 (B) By didecomposition of N₂O₄.
 (C) By thermal decomposition of ammonium nitrite.
 (D) All above.
149. Which of the following gas produce, when CO₂ gas is passed through aqueous solution of bleaching powder ?
 (A) O₂ (B) Cl₂ (C) O₃ (D) Cl₂O
150. $2\text{NaOH} + \text{X} \rightarrow \text{Y} + \text{H}_2\text{O}$
 $\text{Y} + \text{H}_2\text{O} + \text{SO}_2 \rightarrow \text{Z}$. Give formula of X, Y and Z in reactions.
 (A) X = SO₂, Y = Na₂SO₃, Z = Na₂SO₄ (B) X = SO₂, Y = NaHSO₃, Z = Na₂SO₃
 (C) X = SO₃, Y = Na₂SO₃, Z = NaHSO₄ (D) X = SO₂, Y = Na₂SO₃, Z = NaHSO₃

- A purple solid substance X reacts with NH_3 to prepare dilute explosive substance Y and remove purple colour. X reacts with H_2 to give acid Z. Salt reacts with H_3PO_4 to give Z.

151. Which is purple coloured solid substance ?

- (A) Cl_2 (B) SO_2 (C) Br_2 (D) I_2

152. Which is dilute explosive substance Y ?

- (A) NI_3 (B) NH_4I (C) HI (D) NI_3, NH_3

153. What is acid Z ?

- (A) HCl (B) HI (C) HBr (D) H_2SO_4

Answers : 133. (C), 134. (B), 135. (D), 136. (B), 137. (B), 138. (D), 139. (C), 140. (B), 141. (C), 142. (A) 143. (B), 144. (C), 145. (A), 146. (A), 147. (B), 148. (B), 149. (A), 150. (D), 151. (B), 152. (D), 153. (D)

Group 18

● Elements of Group 18

- In this group six elements helium, neon, argon, krypton, xenon and radon are present.
- These elements are also known as, 'Inert gases' or 'Noble gases'
- These elements are not considered as metals or non-metals.
- All these elements are in gaseous form at the room temperature and are chemically inert.

Occurrence :

- Helium is obtained most in nature.
- It is available from natural gas.
- Argon possesses 1% by volume in dry air.

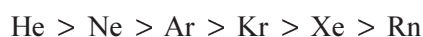
● Uses :

- They are inert, so they are useful to produce inert atmosphere.
- e.g., Ar is used in electric bulb and to prevent from oxygen in welding of metal.
- In liquid state He is used in research to maintain low temperature.
- In liquid state Helium is used in research to maintain low temperature. Its boiling point is very low compared to any substance.

● Periodicity in Physical properties :

- General tendency of increase in the atomic size decrease in ionisation enthalpy with increase in atomic number.

- Order of ionisation enthalpy is,



- Order of melting point : $\text{He} < \text{Ne} < \text{Ar} < \text{Kr} < \text{Xe} < \text{Rn}$
- Order of boiling point : $\text{He} < \text{Ne} < \text{Ar} < \text{Kr} < \text{Xe} < \text{Rn}$
- These gases are very less soluble in water.
- Argon is more soluble than nitrogen and oxygen.
- With increase in size of gas, dipolar attraction force increases.
- So, order of solubility : $\text{He} < \text{Ne} < \text{Ar} < \text{Kr} < \text{Xe}$

154. Match column I with column II.

Column I	Column II	
(A) He	(p) used in beacon light.	(A) (A)-(p); B-(s); (C)-(r); (D)-(q)
(B) Ne	(q) in treatment of cancer.	(B) (A)-(r); B-(p); (C)-(s); (D)-(q)
(C) Ar	(r) fill air in balloon.	(C) (A)-(q); B-(p); (C)-(s); (D)-(r)
(D) Rn	(s) fill in the bulb.	(D) (A)-(r); B-(q); (C)-(p); (D)-(s)

155. First preparation of XePtF_6 compound of inert gas, then after in chemistry new branch of inert gas compound opened prepared this compound.
 (A) Re-leh (B) Birth-Lete (C) Dorn (D) Locvware
156. Inert gases can not react with other elements because
 (A) it is completely filled and possess stable orbit.
 (B) their sizes are very small.
 (C) they do not obtain bulk.
 (D) they are in one dimension.
157. Inert gas possess
 (A) highly chemical reactivity (B) low chemical reactivity
 (C) very low atomic radius (D) more paramagnetic properties
158. Which of the following has highest boiling point ?
 (A) Xe (B) He (C) Ne (D) Ar
159. Inert gases are sparingly soluble in water because
 (A) dipole-dipole interactions. (B) induced dipole-induced dipole interactions.
 (C) dipole-induced dipole interactions. (D) hydrogen bond.
160. Which of the following has the maximum ionization enthalpy ?
 (A) O_2 (B) Ar (C) Be (D) Ce
161. Which colour is produced when electric current is passed in Neon gas at low pressure ?
 (A) Orange-red (B) Blue (C) Green (D) White
162. Correct order of vapour enthalpy of noble gases.
 (A) $\text{He} > \text{Ne} > \text{Ar} > \text{Kr} > \text{Xe} > \text{Rn}$ (B) $\text{He} < \text{Ne} < \text{Ar} < \text{Kr} < \text{Xe} < \text{Rn}$
 (C) $\text{Xe} < \text{Kr} < \text{Ne} < \text{He} < \text{Rn} < \text{Ar}$ (D) $\text{He} < \text{Ne} = \text{Ar} < \text{Kr} < \text{Xe} < \text{Rn}$

163. What is the ratio of $\frac{C_p}{C_v}$ for inert gases ?

- (A) 1.67 (B) 1.33 (C) 1.42 (D) 1.84

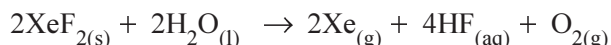
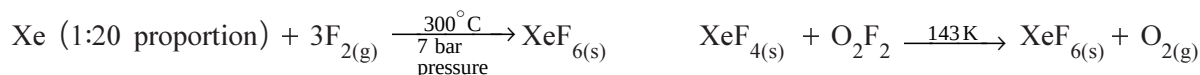
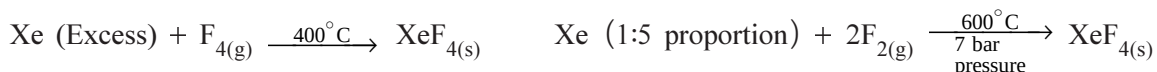
164. Which of the following is not possible ?

- (A) $[\text{KrF}]^+ [\text{S}_6\text{F}_6]^-$ (B) $[\text{KrF}_3^-] [\text{SbF}_4]^+$ (C) $[\text{KrF}^+] [\text{MoOF}_5]^-$ (D) $[\text{KrF}]^+ [\text{WOF}_5]^-$

Answers : 154. (B), 155. (B), 156. (A), 157. (B), 158. (A), 159. (A), 160. (B), 161. (A), 162. (D), 163. (A), 164. (B)

● **Chemical properties :**

- They do not accept electron due to stable electronic configuration of these elements. These elements show more positive electron gain enthalpy.
- He, Ne and Ar do not give chemical reactions, so their compounds are not known.
- Kr and Xe react only with flourine.
- Xe prepare three different fluoride like XeF_2 , XeF_4 and XeF_6 .
- These crystalline solid substances sublime at 25°C temperature. It is strong fluorinating agent.
- It's hydrolysis occurs in very less proportion of water.



• Electronic configuration of its valence shell, very high ionization enthalpy and extraordinary electron affinity are responsible for less reactivity of inert gases.

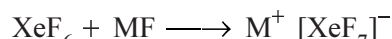
- Order of oxidizing agent : $\text{XeF}_2 < \text{XeF}_4 < \text{XeF}_6$

Xenon fluoride gives positive ion with fluoride ion acceptor and gives negative ion with fluoride ion donor.

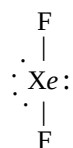
- **Reaction with flourine ion acceptor :**



- **Reaction with flourine ion donor :**

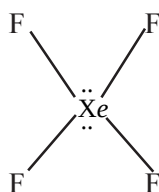


● **Structure of some compounds :**



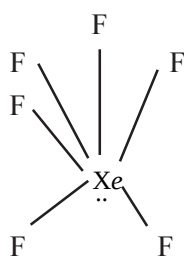
Hybridisation : sp^3d ,
Shape : Linear

(Structure of XeF_2)



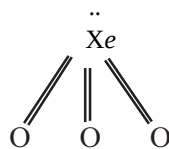
Hybridisation : sp^3d^2 ,
Shape : Square planar

(Structure of XeF_4)



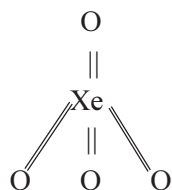
Hybridisation : sp^3d^3 ,
Shape : Distorted octahedral

(Structure of XeF_6)



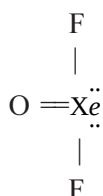
Hybridisation : sp^3 ,
Shape : Triangular Pyramidal

(Structure of XeO_3)



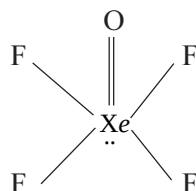
Hybridisation : sp^3 ,
Shape : Tetrahedral

(Structure of XeO_4)



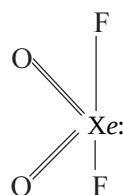
Hybridisation : sp^3d ,
Shape : T-shape

(Structure of $XeOF_2$)



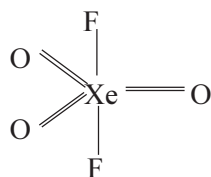
Hybridisation : sp^3d ,
Shape : Square pyramidal

(Structure of $XeOF_4$)



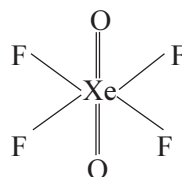
Hybridisation : sp^3d ,
Shape : Distorted trigonal bipyramid

(Structure of XeO_2F_2)



Hybridisation : sp^3d ,
Shape : Trigonal bipyramide

(Structure of XeO_3F_2)



Hybridisation : sp^3d^2 ,
Shape : Octahedral

(Structure of XeO_2F_4)

165. Select correct option for the statements are either true (T) or False (F).

- (A) Xenon possess +2, +4, +6 or +8 oxidation state in their compounds.
- (B) Oxyfluoride compounds like $XeOF_4$ and XeO_2F_2 are obtained by partial hydrolysis of XeF_6 .
- (C) XeO_3 is obtained by hydrolysis of XeF_4 .
- (D) XeO_3 is colourless explosive white substance. It possess trigonal pyramidal structure.

- (E) XeOF_4 is colourless explosive white substance. It possess trigonal pyramidal structure.
- (F) To get XeF_4 between reaction mixture of Xe and F_2 temperature is 573 K and pressure 60 – 70 bar should be maintained.
- (A) TFTTFF (B) FTTTFF (C) TFTFTF (D) TFFTTF
166. What is obtained when proportion of Xe and F_2 is 1 : 5 at 873 K temperature and 7 bar pressure ?
 (A) XeF_4 (B) XeF_6 (C) XeF_2 (D) All above
167. Which compound of Xe reacts with O_2F_2 at 143 K temperature ?
 (A) XeF_6 (B) XeF_4 (C) XeF_2 (D) XeF
168. What is the shape of XeF_4 molecule and hybridisation of Xe ?
 (A) square, dsp^2 (B) tetrahedral, sp^2 (C) square, sp^3d^2 (D) octahedral, d^2sp^3
169. How is the structure of XeOF_4 ?
 (A) Triagonal pyramidal (B) Square pyramidal (C) Distorted octahedral (D) Linear
170. Which is improper in oxyfluoride compounds of Xe ?
 (A) XeOF_4 (B) XeO_3F (C) XeOF_2 (D) Both B and C
171. Number of non-bonding e-pair on Xe in XeF_2 , XeF_4 and XeF_6 respectively
 (A) 2, 3, 1 (B) 1, 2, 3 (C) 4, 1, 2 (D) 3, 2, 1
172. Shape of XeF_4 is
 (A) planar square (B) tetrahedral (C) planar triangular (D) pyramidal
173. Partial hydrolysis of XeF_4 at low temperature gives product.
 (A) XeF_3 (B) XeOF_2 (C) XeOF_4 (D) XeF_2
174. Which compound of xenon and its reaction is not possible ?
 (A) $\text{XeO}_3 + 6\text{HF} \longrightarrow \text{XeF}_6 + 3\text{H}_2\text{O}$
 (B) $3\text{XeO}_3 + 6\text{H}_2\text{O} \longrightarrow 2\text{Xe} + \text{XeO}_3 + 12\text{HF} + 1.5 \text{ O}_2$
 (C) $2\text{XeF}_6 + \text{RbF} \longrightarrow \text{Rb} [\text{XeF}_7]$
 (D) None
175. In which of the following molecule of Xe, non-bonding e^- pairs are equal ?
 (i) XeO_3 (ii) XeOF_4 (iii) XeF_6
 (A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (i), (ii), (iii)
176. XeOF_4 react with SF_4 to give product is
 (A) XeOF_4 and SO_2 (B) Xe and SF_6 (C) XeF_2 and SF_6 (D) SF_6 and XeO_3
177. Shape of XeO_2F_2 is
 (A) Trigonal pyramidal (B) planar square (C) Tetrahedral (D) see-saw

178. Correct order of Xe-F bond length in XeF_2 , XeF_4 and XeF_6 compounds.

- (A) $\text{XeF}_2 > \text{XeF}_4 > \text{XeF}_6$ (B) $\text{XeF}_4 > \text{XeF}_6 > \text{XeF}_2$
 (C) $\text{XeF}_6 > \text{XeF}_4 > \text{XeF}_2$ (D) $\text{XeF}_2 > \text{XeF}_6 > \text{XeF}_4$

179. Match the correct pair of column I and column II

column-I

column-II

- | | | |
|--------------------|--------------------------|--|
| (A) XeF_4 | (p) distorted octahedral | (A) (A)-(r), (B)-(p), (C)-(s), (D)-(q) |
| (B) XeF_6 | (q) tetrahedral | (B) (A)-(s), (B)-(q), (C)-(p), (D)-(r) |
| (C) XeO_3 | (r) planar square | (C) (A)-(p), (B)-(r), (C)-(q), (D)-(s) |
| (D) XeO_4 | (s) trigonal pyramid | (D) (A)-(q), (B)-(s), (C)-(r), (D)-(p) |

180. Match the correct pair of column I and column II

column-I

column-II

- | | | |
|--------------------|-------------------------------|---|
| (A) XeF_2 | (p) Gas at room temperature | (A) (A)-(q), (s) (B)-(p), (C)-(q), (r) (D)-(q), (r) |
| (B) XeO_4 | (q) Solid at room temperature | (B) (A)-(p), (s) (B)-(q), (C)-(p), (s) (D)-(q), (s) |
| (C) XeO_3 | (r) Lone pair = 1 | (C) (A)-(s) (B)-(r), (C)-(p) (D)-(q) |
| (D) XeF_6 | (s) Lone pair = 3 | (D) (A)-(s) (B)-(q), (C)-(p) (D)-(r) |

Answers : 165. (A), 166. (A), 167. (B), 168. (C), 169. (B), 170. (D), 171. (D), 172. (A), 173. (B), 174. (A) 175. (D), 176. (B), 177. (D), 178. (A), 179. (A), 180. (A).

