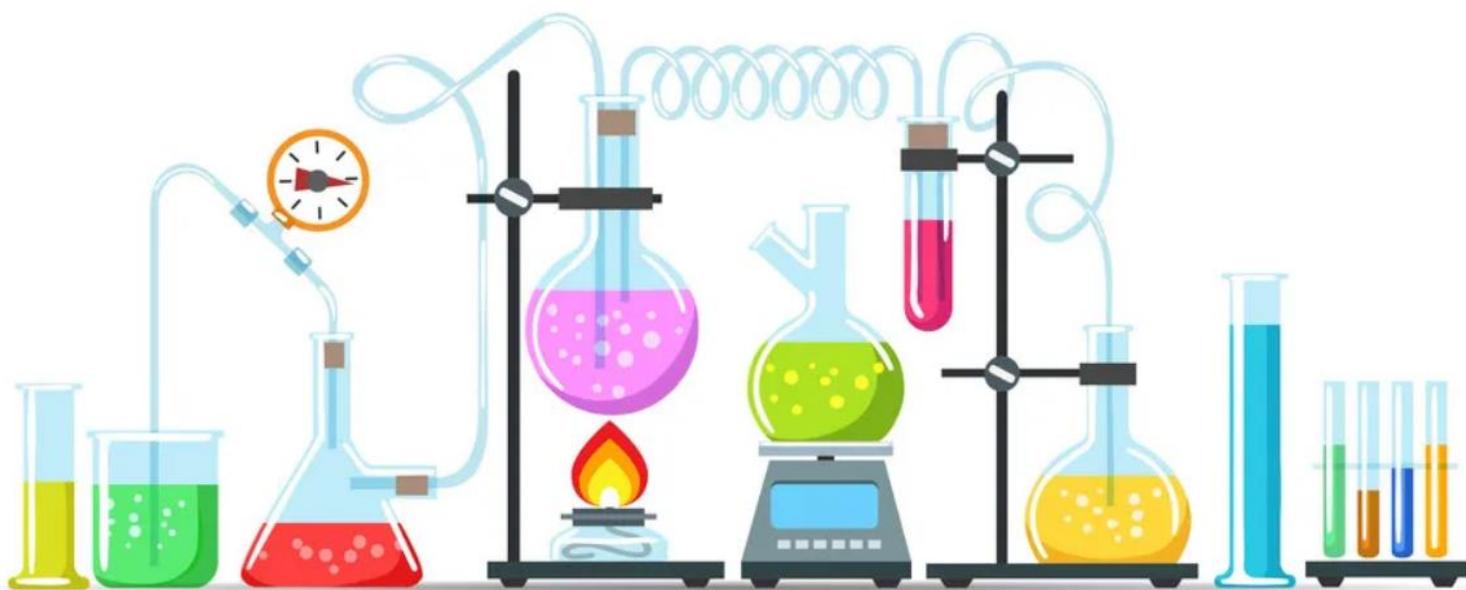


# CHEMISTRY

## CHAPTER 11: THE P-BLOCK ELEMENTS



# THE P-BLOCK ELEMENTS

## Introduction

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The elements in which last electron enters into p-subshell are called as p-block elements. The number of p-orbitals is three and, therefore, the maximum number of electrons that can be accommodated in a set of p-orbitals is six, hence p-block contains six groups.

## Boron Family

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**Group III A contains six elements:** Boron, aluminium, gallium, indium, thallium and ununtrium. The penultimate shell (next to the outermost) contains  $1s^2$  in boron,  $2s^2 2p^6$  (8 electrons) in aluminium and  $(n-1)s^2(n-1)p^6(n-1)d^{10}$  (18 electrons) in other elements.

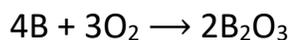
Boron is a non-metal and always form covalent bonds. Boron family is known as most heterogeneous family as there is no regular trend in all properties, as it comes after d-block, lanthanoid contraction, poor shielding of d-orbital, they have large deviation in properties.

### 1. Physical Properties

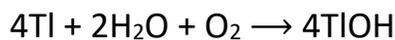
The atomic radius, ionic radius and density increases when one moves from top to bottom in a group in periodic table. While melting point decreases from B to Ga and then increases from (Ga to In). Ionisation energy decreases from B to Al, but shows a reverse trend in going from Al to Ga.

### 2. Chemical Properties

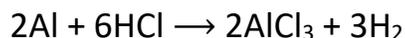
i. **Reaction with air:** Impure boron in air forms oxide while pure boron is less reactive.



ii. **Reaction with water:** Boron is not affected by water or steam under ordinary conditions. However, Aluminium reacts with cold water if oxide layer is not present on its surface.

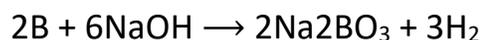


iii. **Reaction with acids:** Boron is not affected by non-oxidising acids like HCl and dilute  $H_2SO_4$  while other elements dissolve and liberate  $H_2$  gas.



iv. **Reaction with alkalis:** Boron, Aluminium, Gallium react with alkali solutions whereas

Indium and Thallium are not affected by alkalis.



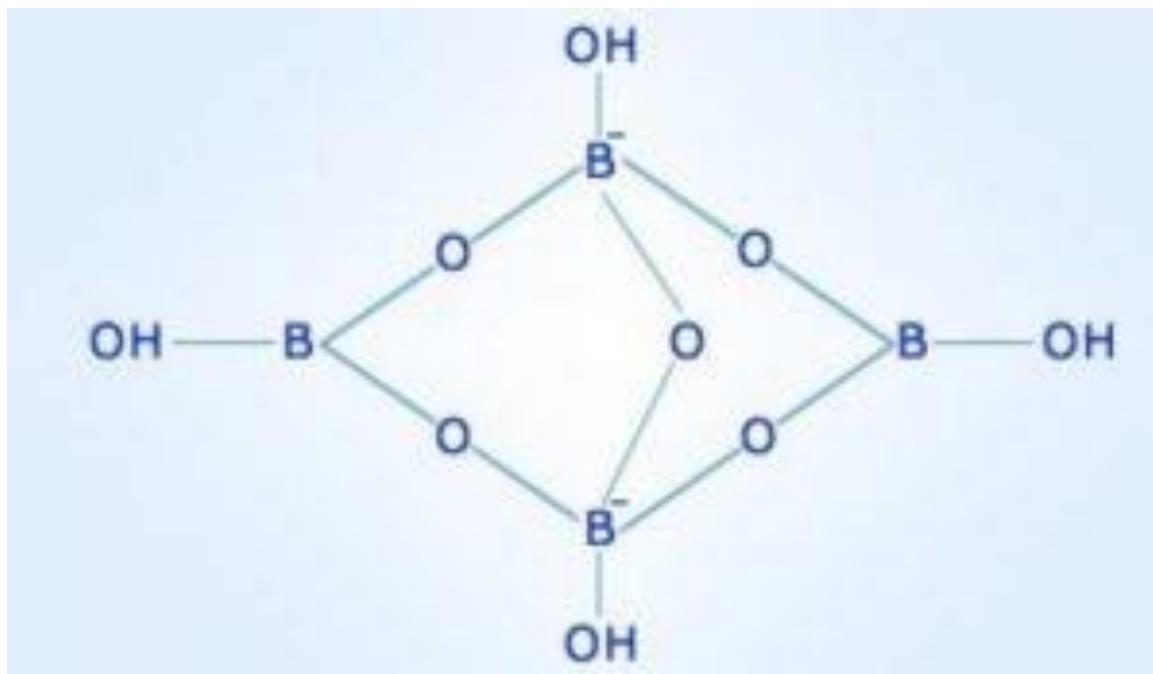
## Anomalous Properties of Boron

Boron, the first member of group 13 elements, shows anomalous behaviour and differ from rest of the members of its family. The main reason for this difference are:

- Exceptionally small atomic and ionic size.
- High ionization enthalpy.
- Absence of d orbital in its valence shell.
- It has higher melting and boiling point than those of the other members of its group.

## Borax

It Borax contains the tetranuclear unit i.e.  $[\text{B}_4\text{O}_5(\text{OH})_4]^{2-}$ . The correct formula is  $\text{Na}_2[\text{B}_4\text{O}_5(\text{OH})_4] \cdot 8\text{H}_2\text{O}$ .



### 1) From Tincal

Naturally occurring borax is called tincal or suhaga. Tincal obtained from dried up lakes contains 50% borax. It is boiled with water and filtered to remove insoluble impurities of clay, sand. The filtrate is concentrated when crystals of borax separate out.

## 2) From Colemanite

The mineral colemanite is finely powdered and is boiled with sodium carbonate solution.



The precipitate of calcium carbonate thus formed is removed by filtration. The filtrate is concentrated and cooled when crystals of borax separate out. Sodium metaborate present in the mother liquor can be converted into borax by passing a current of carbon dioxide through it.

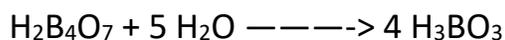
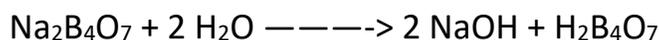
## 3) From Boric Acid

Borax can also be prepared in small amounts by neutralising boric acid with sodium carbonate.

On cooling crystal of borax i.e.  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$  separate out.

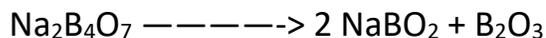
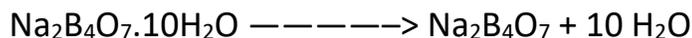
### Properties of Borax

- 1) It is a white crystalline solid, less soluble in cold water but more soluble in hot water.
- 2) The aqueous solution of borax is alkaline due to hydrolysis. Borax is therefore, used as a water softener and cleaning agent.

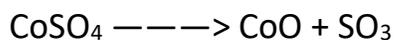


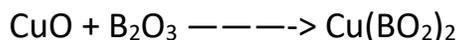
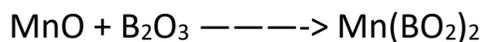
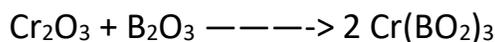
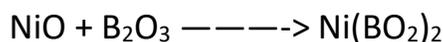
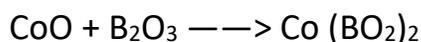
### Action of heat- borax Bead Test

Borax loses its water of crystallisation and swells up to form a puffy mass. On further heating, it melts into a clear liquid which solidifies to a transparent glass like bead which consists of sodium metaborate ( $\text{NaBO}_2$ ) and boric anhydride ( $\text{B}_2\text{O}_3$ )



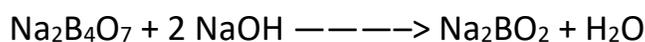
The glassy bead is commonly known as borax bead and is employed in qualitative analysis for the detection of certain coloured basic radicals such as  $\text{Ni}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Cu}^{2+}$ ,  $\text{Mn}^{2+}$ . Whenever a coloured salt containing these cations is heated with borax bead on a platinum wire, the salt decomposes to form the corresponding metal oxide which then combines with  $\text{B}_2\text{O}_3$  present in the glassy bead to form coloured metaborates. This test is called borax bead test.





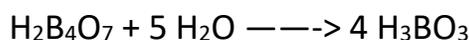
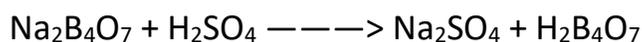
### Action of Sodium Hydroxide

On adding a calculated quantity of sodium hydroxide to borax, sodium metaborate is formed.



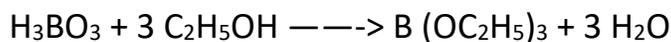
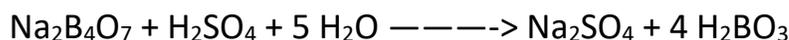
### Action of Sulphuric Acid

On adding a calculated quantity of concentrated sulphuric acid to a hot concentrated solution of borax, boric acid is produced.



### Action of Ethyl Alcohol and Sulphuric Acid

On heating borax with ethyl alcohol and concentrated sulphuric acid, vapours of triethylborates are produced. When ignited these vapours burn with a green edged flame.



### Uses of Borax

Borax is used in:

- 1) in the manufacture of enamels and glazes for earthen ware. The glazed surface is resistant to heat, stains and scratches.
- 2) as a flux in soldering
- 3) in the preparation of medicinal soaps due to its antiseptic properties.
- 4) in the manufacture of heat resistant Borosilicate glass.

- 5) to make peroxoborate- an important cleansing and bleaching agent present in washing powder.
- 6) as a stiffening agent for candle wicks.
- 7) to produce a good finish in laboratory.
- 8) in the laboratory for borax bead test.
- 9) in softening of water.

## Boron Hydrides

The binary compounds of boron with hydrogen are called Boron hydrides.

These hydrides of boron are called boranes. These hydrides can be divided into several series:

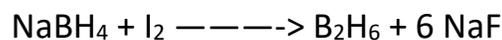
- 1)  $B_nH_{n+4}$  (called nido borane) such as  $B_2H_6$  (diborane),  $B_5H_9$  (pentaborane),  $B_6H_{10}$  (hexaborane),  $B_8H_{12}$  (octaborane),  $B_{10}H_{14}$  (decaborane).
- 2)  $B_nH_{n+6}$  (called arachno borane) such as  $B_4H_{10}$  (tetraborane),  $B_5H_9$  (pentaborane),  $B_6H_{10}$  (hexaborane),  $B_8H_{14}$  ( octaborane),  $B_9H_{15}$  ( nonaborane).

### Preparation

- 1) By reduction of boron trifluoride etherate with Lithium aluminium hydride in diethyl ether.



- 2) Diborane is prepared in the laboratory by the oxidation of sodium borohydride with iodine in diglyme as solvent.



- 3) On the industrial scale, diborane is obtained by the reduction of  $\text{BF}_3$  with sodium hydride.



### Preparation of higher boranes

Higher boranes are obtained when  $\text{B}_2\text{H}_6$  is heated at 373-523 K.

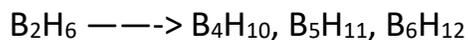
### Properties

#### 1) Physical state

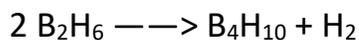
Diborane is a colourless, highly toxic gas, b.p. 180 K.

## 2) Stability

Diborane is stable only at low temperature. When diborane is heated in a sealed tube, between 373- 533 K, a complex reaction occurs and various higher boranes are formed.

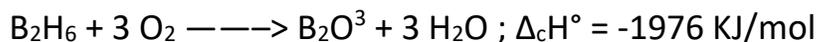


By careful control of temperature ,pressure and reaction time , different individual boranes can be obtained.



## 3) Combustibility

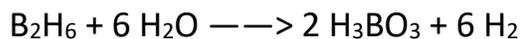
It catches fire spontaneously upon exposure to air. It burns in oxygen evolving an enormous amount of heat.



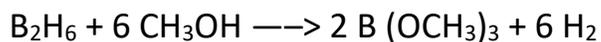
Like diboranes, higher boranes spontaneously burn in air.

## 4) Hydrolysis

Boranes are readily hydrolysed by water to form boric acid.

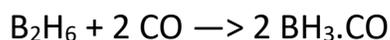
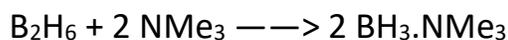


With methanol ,trimethylborate is formed.

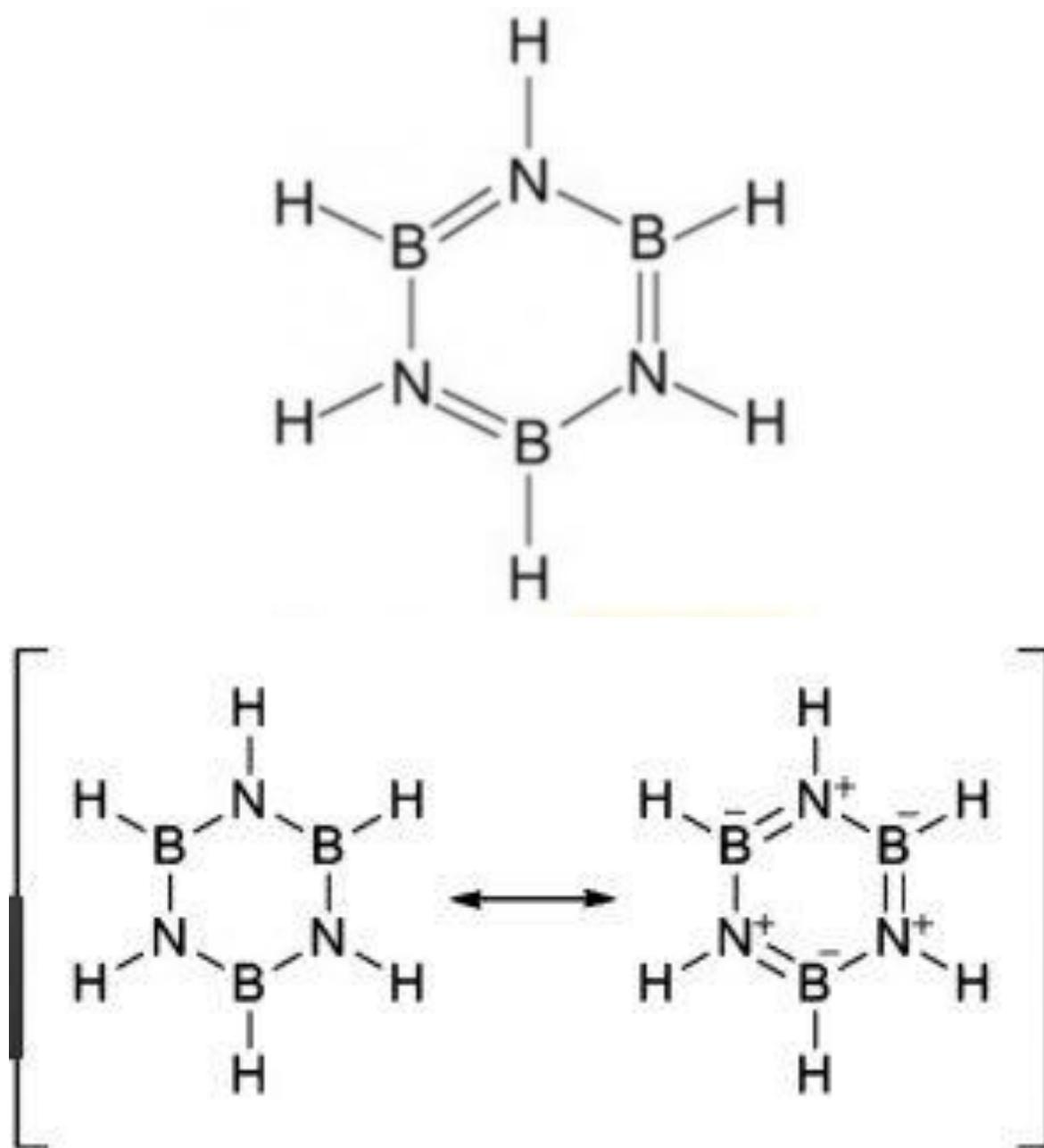


## 5) Reaction with Lewis bases – cleavage reaction

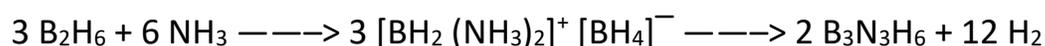
Diborane on treatment with Lewis bases first undergoes cleavage to form borane which then reacts with Lewis bases to form adducts.



## 6) Reaction with Ammonia



Diborane combines with ammonia to form an addition product,  $B_2H_6 \cdot 2NH_3$  formulated as  $[BH_2(NH_3)_2]^+ [BH_4]^-$ , which when heated to 473 K decompose to give a volatile compound called borazine or borazole.

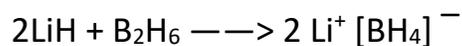
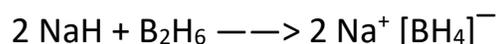


Borazine is isoelectronic and isosteric with benzene and its structure is similar to that of benzene except that in benzene the  $\pi$ -electrons are completely delocalised but in borazine, they are only partially delocalized.

Because of its similarity with benzene, borazine is also called inorganic benzene.

### 7) Formation of complex borohydride

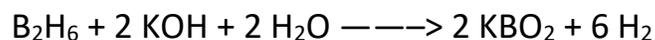
Several metal hydrides react with diborane to form tetrahydridoborates known as borohydride. All these contain the tetrahedral  $[\text{BH}_4]^-$  ion.



Both sodium borohydride and lithium borohydride are used as reducing agent in organic synthesis. They also serve as starting material for many other borohydrides.

### 8) Reaction with alkalis

Diborane dissolves in strong alkali to produce metaborates and dihydrogen gas.

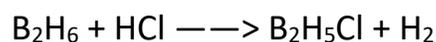
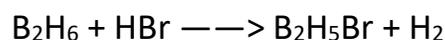


### 9) Action of halogen acids

Diborane reacts with halogen acids to give halodiboranes evolving  $\text{H}_2$  gas.

The reactivity of halogen acids follow the order:  $\text{HI} > \text{HBr} > \text{HCl}$

Thus HI react at about 323 K in absence of catalyst while HBr and HCl reacts in presence of their aluminium halide as catalyst.

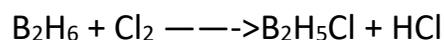


### 10) Action of halogens

Halogens also react with diborane to form the corresponding halodiboranes.

The reactivity decreases in the order:  $\text{Cl}_2 > \text{Br}_2 > \text{I}_2$ .

Thus  $\text{Cl}_2$  reacts explosively at room temperature,  $\text{Br}_2$  reacts rapidly at 373 K while  $\text{I}_2$  reacts slowly at still higher temperature.



### Uses of Boron Hydrides

- 1) Diborane is used for preparing a number of boron hydrides such as  $\text{LiBH}_4$ ,  $\text{NaBH}_4$ .
- 2) It is used as a reducing agent in organic reactions.

3) It is used as a fuel for supersonic rockets.

### Structure of Diborane

1) In diborane, each boron atom has 3 Valence electrons for sharing. If we assume that each boron forms 3 covalent bonds with 3 hydrogen atoms, then there are no electrons left with boron atom for sharing with other boron atoms. Therefore the two boron atoms cannot be linked.

There are two types of hydrogen atom :

1) The four hydrogen atoms (two on left and two on right shown by thick lines) are called terminal hydrogens.

These four terminal hydrogens and the two boron atoms lie in the same plane while the remaining two hydrogen atoms- one lying above and one lying below this plane form bridges and hence are called which bridged hydrogen.

There are two types of bonds in  $B_2H_6$  molecules.

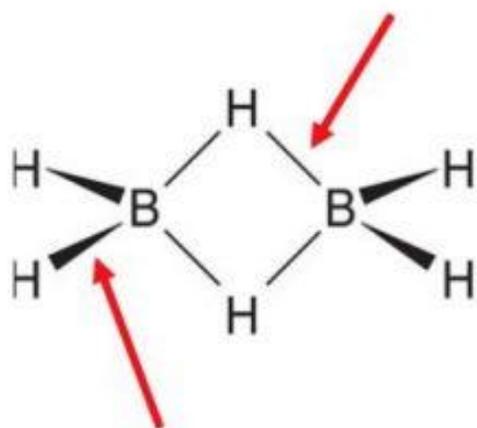
1) The four terminal B-H bonds are normal covalent bonds and hence are quite strong. Each bond is formed by sharing a pair of electron between B and H and hence are also called two centre electron pair bonds or two centre two electron bond ( $2c - 2e$ )

2) The two bridge bonds i.e.  $B-H-B$  are quite different from normal covalent bonds. Each bridge hydrogen is bonded to two boron atoms by a pair of of electrons. These are three centre electron pair bonds or three centre 2 electron bonds and hence are quite weak.

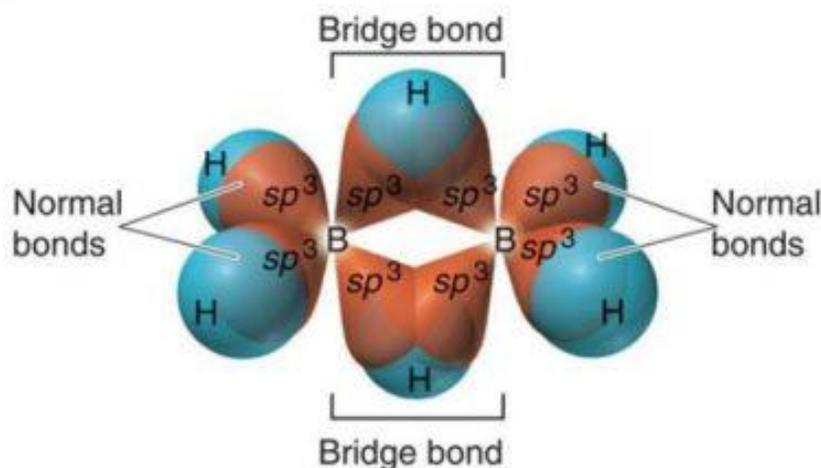
Because of their semblance to a banana, these three centre electron pair bonds are also called banana Bond.

### Structure of diborane on the basis of hybridization

Hydride *bridge bond* , or three-center, two-electron bond.



Normal covalent bond formed by overlap of  $sp^3$  hybrid orbital from B with s orbital from H.



The boron atom in the excited state is  $1s^2 2s^1 2p_x^1 2p_y^1 2p_z^0$ .

It undergoes  $sp^3$  hybridisation

The two half filled hybrid orbitals of each boron atom overlap with the half filled orbitals of hydrogen atom forming normal covalent bonds whereas the third half filled hybrid orbital of one boron atom and the vacant hybrid orbital of the second boron atoms overlap simultaneously with the half filled orbitals of hydrogen atom. The electron cloud contains only two electrons but spreads over 3 atoms. That is why this bond is called three centre electron pair bond.

Because of the shape of the electron cloud formed, it is called banana bond. Molecules like  $B_2H_6$  which do not have sufficient number of electrons to form normal covalent bonds are called electron deficient molecules.

## Compounds of Boron

### 1. Borax/ Sodium Tetraborate ( $Na_2B_4O_7 \cdot 10H_2O$ )

It is the most important compound of boron. It is a white crystalline solid. Borax dissolves in water to give an alkaline solution.

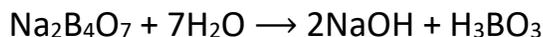
**Preparation:**

**From Boric acid:** Boric acid is neutralised with sodium carbonate and the resulting solution is cooled to get crystals of borax.

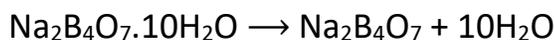


### Properties:

- i. It gets hydrolysed with water to form an alkaline solution



- ii. **Borax bead test:** On heating borax first swells up due to elimination of water molecules. On further heating it melts to a liquid which then solidifies to a transparent glassy mass.



- iii. It is a useful primary standard for titration against acids.



## 2. Diborane: $\text{B}_2\text{H}_6$

The simplest boron hydride known, is diborane. It is prepared by treating boron trifluoride with  $\text{LiAlH}_4$  in diethyl ether.

### Preparation



### Properties

- Stable at low temperature only, colourless and highly toxic.
- $\text{B}_2\text{H}_6 + 6\text{H}_2\text{O} \rightarrow 2\text{H}_3\text{BO}_3 + 6\text{H}_2$
- $\text{B}_2\text{H}_6 + 6\text{Cl}_2 \rightarrow 2\text{BCl}_3 + 6\text{HCl}$
- $\text{B}_3\text{H}_6 + 2\text{Me}_3\text{N} \rightarrow 2[\text{Me}_3\text{N} \cdot \text{BH}_3]$

## Uses of Boron and Aluminium and Their Compounds

### Boron Compounds

Boron is a hard solid having high melting point low density and very low electrical conductivity. Some important boron compounds are:

- Boron fibers:** It is mixed with plastic to form a material which is lighter than aluminium but tougher and stiffer than steel hence it is used in body armour, missiles and aircrafts.
- Boron-10 ( $^{10}\text{B}$ ) isotope:** Boron carbide rods or boron steel are used to control nuclear reactions as neutron absorbers.  

$${}_5\text{B}^{10} + {}_0\text{n}^1 \longrightarrow {}_5\text{B}^{11}$$
- Borax:** It is used in manufacture of enamels and glazes for pottery and tiles. It is also used in making optical glasses and also borosilicate glasses which is very resistant to heat and shock. It is used as an antiseptic.
- Boric acid:** It is used in glass industry, in food industry as preservative. It is also used as an antiseptic and eye wash under the name 'boric lotion'. It is also used in manufacture of enamels and glazes for pottery.
- Boron carbide:** Hardest boron compound.

### Aluminium Compounds

Aluminium and its alloy are used in packing industry, utensil industry, aeroplane and transportation industry etc.

- Alumina ( $\text{Al}_2\text{O}_3$ ):**
  - Used in chromatography.
  - Used in making bauxite bricks which are used for lining furnaces.
- Aluminium chloride ( $\text{AlCl}_3$ ):** Used in manufacture of dyes, drugs and perfumes and also in manufacture of gasoline. It is also used as catalyst in Friedel Craft reaction.
- Potash Alum. [ $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24 \text{H}_2\text{O}$ ]:** Used in purification of water, leather tanning, as antiseptic and as a mordant.

## Group 14 Elements : The Carbon Family

Group IV A contains six elements: carbon, silicon, germanium, tin, lead and ununquadium. The penultimate shell (prior to outermost) contains  $1s^2$  -grouping in carbon,  $2s^2 2p^6$  (8 electrons) in silicon and  $(n-1)s^2(n-1)p^6(n-1)d^{10}$  (18 electrons) in other elements. This shows why carbon differs from silicon in some respects and these two differ from rest of the members of this group. General electronic configuration is  $ns^2 np^2$ .

### 1. Atomic and Physical Properties

The important properties of carbon family are discussed below:

- Atomic Radii:** The atomic radii of group 14 elements are less than the corresponding elements of group 13. However, the atomic radii increases down the family.

ii. **Ionisation Energies:** The higher ionisation energies than group 13 are due to the higher nuclear charge and smaller size of atoms of group 14 elements. While moving down the group, the ionisation energies decreases till Sn.



iii. **Oxidation state and valency:** The elements of group 14 show tetravalency by sharing four of its valence electrons. Therefore, they have oxidation state of +4. In addition, Ge, Sn and Pb also show +2 oxidation state.

iv. **Catenation:** Catenation is ability of like atoms to link with one another through covalent bonds. Tendency decreases from C to Pb. It is due to the decreasing M-M single bond energy. Thus, the tendency for catenation decreases as:



v. **Allotropy:** All the elements of the carbon family with the exception of lead exhibit allotropy. Carbon exists as two important allotropic forms diamond and graphite.

## 2. Chemical Properties

- i. **Reactivity towards air:** All members of this group form monoxide of the general formula MO such as CO, SiO, SnO and PbO. All members of this group form dioxides of molecular formula MO<sub>2</sub> such as CO<sub>2</sub>, SiO<sub>2</sub>, GeO<sub>2</sub>, SnO<sub>2</sub> and PbO<sub>2</sub>.
- ii. **Reactivity towards water:** In this family three members i.e., carbon, silicon and germanium are affected by water while lead is not affected by water due to formation of protective oxide film, but tin decomposes with steam into tin dioxide and hydrogen gas.
- iii. **Reactivity towards halogen:** These elements form two types of halides - MX<sub>2</sub> and MX<sub>4</sub>. Most of the MX<sub>4</sub> are covalent. SnF<sub>4</sub> and PbF<sub>4</sub> are ionic in nature.

### Anomalous Behaviour of Carbon

Carbon shows anomalous behaviour due to its smaller size, higher electronegativity, higher ionization enthalpy and unavailability of d orbitals. Carbon atom forms double or triple bonds involving pπ-pπ bonding. Carbon has also the property to form closed chain compounds with O, S and N atoms as well as forming pπ-pπ multiple bonds with other elements particularly N, S and O. When we move down the group size increases and electronegativity decreases hence catenation tendency decreases. Order is:



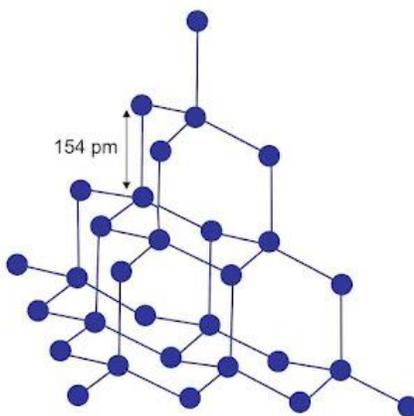
### Allotropes of Carbon

Carbon shows allotropism due to catenation and  $p\pi-p\pi$  bond formation. Carbon exists in two allotropic forms – crystalline and amorphous. The crystalline forms are diamond and graphite while the amorphous forms are coal, charcoal and lamp-black. The third form is fullerenes discovered by Kroto, Smalley and Curl.

**Note:** Tin has maximum number of allotropes.

### Diamond

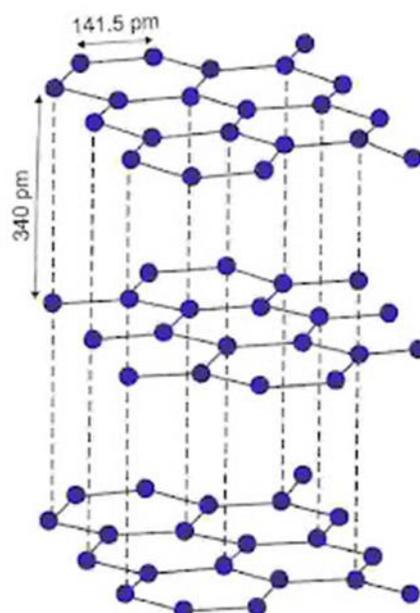
In diamond each carbon is joined to other four carbon tetrahedrally and carbon-carbon bond length is  $1.54\text{\AA}$  and bond angle is  $109^{\circ}28'$  having  $sp^3$  hybridisation on each carbon. All four electrons in carbon are involved in bonding hence, it is bad conductor of electricity. Diamond is an excellent thermal conductor.



It is hardest natural substance known. It is transparent and has a specific gravity 3.52 and its refractive index is high (2.45). Difficult to break due to extended covalent bonding. Diamond is used for making cutters. Blades of diamond are used in eye surgery and as an abrasive for sharpening hard tools. Impure diamonds (black) are used in knives for cutting glass.

### Graphite

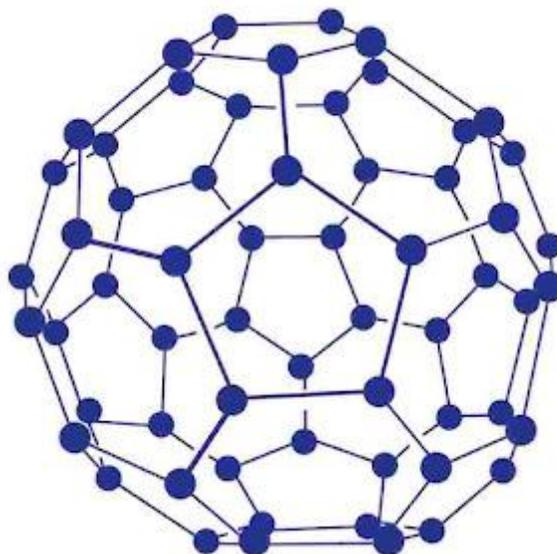
Each carbon is  $sp^2$  hybridised. It has layered structure. These layers are attracted by van der Waals force. Each carbon has one free electron in  $p$ -orbital, so it is a good conductor of electricity. All electrons get delocalized in one layer and form  $\pi$ -bond. Electron jumps from one orbital to another hence it is a good conductor of heat and electricity. In graphite carbon-carbon bond length is  $141.5\text{ pm}$  and distance between adjacent graphite layer is  $340\text{ pm}$ .



Graphite is used as a lubricant at high temperature. Oil gets burn or denatured at high temperature but graphite does not get denatured even at high temperature so, preferred over oil and grease.

### Fullerene

It was made as a result of action of a laser beam or strong heating of a sample of graphite in presence of inert atmosphere. The sooty material mainly contains  $C_{60}$  with  $C_{70}$  (small amount). Most common fullerene is  $C_{60}$  called Buckminsterfullerene which has football-like structure. It contains 20 six-membered ring and 12 five-membered ring. It is used to make ball bearings.



### Coal

It is the crude form of carbon. It has been formed in nature as a result of slow decomposition of vegetable matter under the influence of heat, pressure and limited supply of air. The successive

stages of transformation are peat, lignite, bituminous, steam coal and anthracite. Bituminous is hard stone, burns with smoky flame. The superior quality is anthracite which burns with non-smoky flame.

### Uses of carbon

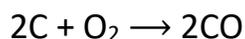
- **Graphite:** In making lead pencils, electrodes of electric furnances, as a moderator in nuclear reactor, as a lubricant in machinery.
- **Charcoal:** In removing offensive odour from air, in removing fused oil from crude spirit, in decolourising sugar syrup, in gas masks etc.
- **Carbon black:** For making printing inks, black paints, Indian inks, boot polishes and ribbons of typewriters.
- **Coal:** For the manufacture of coal gas, coal tar, coke, and synthetic petrol.

## Allotropes of Carbon

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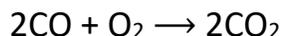
### 1. Carbon Monoxide (CO)

**Preparation:** Carbon monoxide is majorly prepared by



**Properties:**

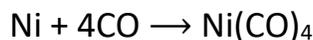
i. Burns with blue flame



ii.  $\text{CO} + \text{Cl}_2 \rightarrow \text{COCl}_2$  (Phosgene)

iii.  $\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$

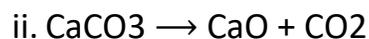
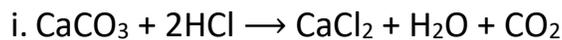
iv. Many of the transition metals form metal carbonyls



### 2. Carbon Dioxide (CO<sub>2</sub>)

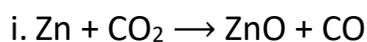
**Preparation:**

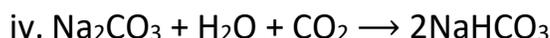
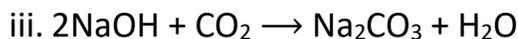
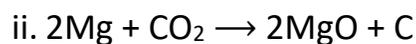
Carbon dioxide is mostly prepared by decomposition of carbonates and bicarbonates:



**Properties:**

Carbon dioxide is an acidic, colourless gas. The important properties are:





## Silicones

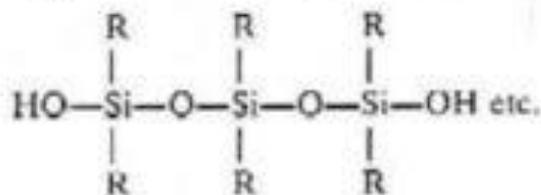
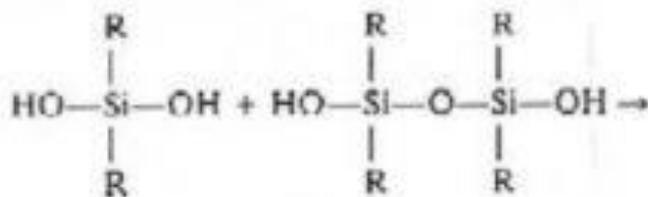
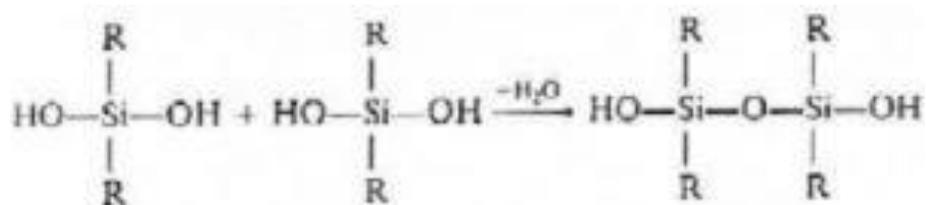
Silicones are synthetic organosilicon polymers containing repeated  $\text{R}_2\text{SiO}$  units held by Si-O-Si linkages.

These compounds have general formula  $(\text{R}_2\text{SiO})_n$  where R = methyl or aryl group.

### Preparation

When methyl chloride reacts with silicon in the presence of copper as a catalyst at 570 K, various types of methyl substituted chlorosilanes of formula  $\text{CH}_3\text{SiCl}_3$ ,  $(\text{CH}_3)_2\text{SiCl}_2$ ,  $(\text{CH}_3)_3\text{SiCl}$  along with small amount of  $(\text{CH}_3)_4\text{Si}$  are formed.

Hydrolysis of dichlorodimethylsilanes followed by polymerization yields chain polymers.



### Properties

1) Silicones made up of short chain molecules are oily liquid, silicones with medium chains behave as viscous oils, jellies and greases, those with very long chains behave as rubbery elastomers and resins.

2) They are chemically inert i.e. resistant to oxidation, thermal decomposition or to attack by organic reagents.

- 3) Silicones being surrounded by non-polar alkyl group are water repelling in nature.
- 4) They are heat resistant and have high dielectric strength i.e. have good electrical insulating properties.

### Uses

- 1) For making water proof papers , wool , textile , wood by coating them with a thin film of silicone.
- 2) As sealants and electrical insulators.
- 3) As lubricant at high as well as low temperature since there is little change in their viscosities with temperature.
- 4) Being biocompatible, they are used in surgical and cosmetic implants.

### Summary-

1. **Allotropes:** Those compounds which have different physical properties but similar chemical properties are called allotropes e.g., diamond and graphite.
2. **Catenation:** Tendency of carbon atom to link with itself to form long chain is called catenation.
3. **Inert pair effect:** Decrease in tendency of  $ns^2$  electron pair to participate in bond formation with increase in atomic number is called inert pair effect.
4. **Silicones:** It is organosilicon compound containing repeated  $R_2SiO$  units.
5. **Silicates:** Compounds in which anions are either discrete  $SiO_4^{-4}$  units or a number of such units combine together through corners.
6. **Alums:** All double sulphates having one monovalent basic radical and one trivalent basic radical.
7. **Boranes:** Hydrides of boron are called as boranes.

Class : 11th Chemistry  
Chapter- 11: p - Block Elements

[B, Al, Ga, In, Tl]

**Electronic configuration:**  $ns^2np^1$

**Atomic Radii:** Atomic radius of Ga is less than Al.

**I.E.:** Decrease from B to Al is associated with increase in size.  $\Delta_1H_1 < \Delta_1H_2 < \Delta_1H_3$

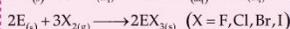
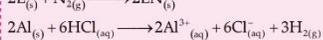
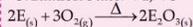
**Electronegativity:** Down the group, decreases from B to Al and then increases marginally.

**Physical Properties:**

- Non-metallic, hard and black coloured solid.
- Exists in many allotropic forms.
- B has high m.p. while others have low m.p.
- Density increases down the group.

**Chemical Properties:**

• Oxidation State: +1, +3

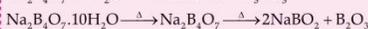
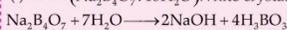


**Trends and Anomalous Properties of Boron:**

- Except in boron,  $[M(OH)_n]$  and  $[M(H_2O)_n]^{+1}$  exist in aqueous medium.
- Boron trifluoride reacts with Lewis bases.
- Maximum covalence of B is 4.

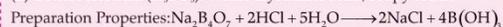
**Important Compounds of Boron:**

(i) Borax ( $Na_2B_4O_7 \cdot 10H_2O$ ) White crystalline solid

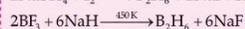
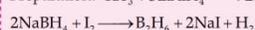
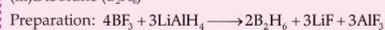


Borax bead test is used for identification.

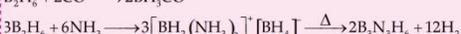
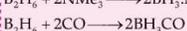
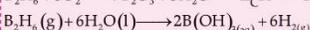
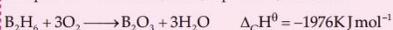
(ii) Orthoboric acid ( $H_3BO_3$ ): White crystalline solid, soapy touch



(iii) Diborane ( $B_2H_6$ )



Properties: Colourless, toxic, b.p.: 180K, catches fire



**Uses of Boron and Aluminium and their Compounds:**

- Boron fibers are used in making bullet-proof vest and light material for aircraft.
- Borax is used in manufacturing heat resistant glasses.
- Al is used in packing, utensil making, construction and transportation industry.

[C, Si, Ge, Sn, Pb]

**Electronic configuration:**  $ns^2 np^2$

**Covalent Radius:** Increase from C to Si and from Si to Pb a small increase is observed.

**I.E.:** Decreases down the group.

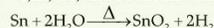
**Electro negativity:** More than group 13 elements. From Si to Pb same.

**Physical Properties:**

- Solid.
- C and Si are non-metals, Ge metalloid, Sn and Pb are soft metals.
- M.p. and b.p. higher than group 13 elements.

**Chemical Properties:**

- Oxidation State: +4, +2
- Forms oxides on heating in oxygen.
- C, Si, Ge, and Pb are not affected by water.



• Form halides of formula  $MX_2$  and  $MX_4$

**Important Trends and Anomalous Behavior of Carbon:**

• C differs from rest due to smaller size, higher electronegativity, high ionisation enthalpy and unavailability of d orbitals.

• C forms  $p\pi-p\pi$  multiple bonds

• Shows Catenation

**Allotropes of Carbon:**

- Diamond
- Carbon
- Fullerenes

**Uses of Carbon:**

- Graphite composites are used in tennis rackets, fishing rods, aircrafts and canoes.
- Graphite is used for electrodes in batteries and industrial electrolysis.
- C black is used in black ink and as filter in automobile tyres.
- Diamond is used in jewelry.

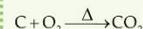
**Important Compounds of C and Si**  
**Zeolites:** used as catalyst in petrochemical industries.

**Silicon Dioxide:** Si is covalently bonded to 4 oxygen atoms.

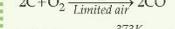
**Silicates Structural 4- unit is:**  $SiO_4^{4-}$

**Silicones:** Group of organosilicon polymers ( $B_2SiO$ ) with replanting unit.

**Carbon Dioxide:**



**Carbon monoxide:**



**Electronic configuration:**

$ns^2 np^{1-2}$  (except He)

**Producer Gas:** Mixture of  $CO + N_2$

**Water Gas: or Synthesis Gas:**  
Mixture of  $CO + H_2$

Group 14  
Elements

Group 13  
Elements

p - Block  
Elements

## Important Questions

### Multiple Choice questions-

Question 1. Consider the following statement about Ozone I. O<sub>3</sub> is formed by the interaction of fluorine. II. It turns tetramethyl base paper as violet. III. It turns benzidine paper as brown. The correct set of true statement is

- (a) I and II
- (b) I, II and III
- (c) I and III
- (d) II and III

Question 2. In the compound of type ECl<sub>3</sub>, where E = B, P, As, or Bi, the angle Cl – E – Cl for different E are in the order:

- (a) B = P = As = Bi
- (b) B > P > As > Bi
- (c) B < P = As = Bi
- (d) B < P < As < Bi

Question 3. In white phosphorous(P<sub>4</sub>) molecule, which one is not correct:

- (a) 6P-P single bonds are present
- (b) 4P-P single bonds are present
- (c) 4 lone pair of electrons is present
- (d) P-P-P bond angle is 60°

Question 4. All the elements of oxygen family are

- (a) Non metals
- (b) Metalloids
- (c) Radioactive
- (d) Polymorphic

Question 5. Which of the following will not produce hydrogen gas?

- (a) Reaction between Fe and dil. HCl
- (b) Reaction between Zn and NaOH
- (c) Reaction between Zn and conc. H<sub>2</sub>SO<sub>4</sub>
- (d) Electrolysis of NaCl in Nelsons cell

Question 6. Amorphous form of Silica is

- (a) Tridymite
- (b) Kieselguhr
- (c) Cristobalite
- (d) Quartz

Question 7. Graphite is a soft solid lubricant extremely difficult to melt. The reason for this anomalous behavior is that graphite.

- (a) Has carbon atoms arranged in large plates of rings of strongly bound carbon atoms with weak interplate bonds
- (b) Is a non – crystalline substance
- (c) Is an allotropic form of carbon
- (d) Has molecules of variable molecular masses like polymers.

Question 8. Borax is used as a cleansing agent because on dissolving in water, it gives

- (a) Alkaline solution
- (b) Acidic solution
- (c) Bleaching solution
- (d) Amphoteric solution.

Question 9. Among the C-X bond (where, X = Cl, Br, I) the correct decreasing order of bond energy is

- (a) C-I > C-Cl > C-Br
- (b) C-I > C-Br > C-Cl
- (c) C-Cl > C-Br > C-I
- (d) C-Br > C-Cl > C-I

Question 10. On heating boron with caustic potash, the pair of products formed are

- (a) Potassium Borate + Dihydrogen
- (b) Potassium Borate + Water
- (c) Potassium Borate + H<sub>2</sub>
- (d) Borax + Dihydrogen.

Question 11. Which of the following statements regarding ozone is not correct?

- (a) The oxygen-oxygen bond length in ozone is identical with that of molecular oxygen
- (b) The ozone is resonance hybrid of two structures
- (c) The ozone molecule is angular in shape
- (d) Ozone is used as a germicide and disinfectant for the purification of air.

Question 12. There is no S-S bond in

- (a) S<sub>2</sub>O<sup>2-</sup>4
- (b) S<sub>2</sub>O<sup>2-</sup>5
- (c) S<sub>2</sub>O<sup>2-</sup>3
- (d) S<sub>2</sub>O<sup>2-</sup>7

Question 13. Which is strongest Lewis acid?

- (a) BF<sub>3</sub>
- (b) BCl<sub>3</sub>

- (c)  $\text{BBr}_3$
- (d)  $\text{BI}_3$

Question 14. Fertilizer having the highest nitrogen percentage is:

- (a) Calcium cyanamide
- (b) Urea
- (c) Ammonium nitrate
- (d) Ammonium sulphate

Question 15. In general, the Boron Trihalides act as

- (a) Strong reducing agent
- (b) Lewis Acids
- (c) Lewis Bases
- (d) Dehydrating Agents

### Very Short:

1. Do boron halides form additional compounds with amines?
2. How does boron interact with  $\text{NaOH}$ ?
3. What is the oxidation state of C in
  - (a)  $\text{CO}$
  - (b)  $\text{HCN}$
  - (c)  $\text{H}_2\text{CO}_3$
  - (d)  $\text{CaC}_2$
4. What is the state of hybridization of C in
  - (a)  $\text{CO}_3^{2-}$
  - (b)  $\text{CCl}_4$
  - (c) diamond
  - (d) Graphite?
5. Give two examples of electron-deficient compounds.
6. Arrange the following halides of boron in the increasing order of acidic character
7. What is dry ice? Why is it so-called?
8. Write balanced equations to show hydrolysis reactions of  $\text{CO}_3^{2-}$  and  $\text{HCO}_3^-$ .
9. Why boron does not form  $\text{B}^{3+}$  ion?
10. Which oxide of carbon is an anhydride of carbonic acid?

### Short Questions:

1. Although boric acid  $B(OH)_3$  contains three hydroxyl groups, yet it behaves as a monobasic acid. Explain.
2.  $SiCl_4$  forms  $[SiCl_6]^{2-}$  while  $CCl_4$  does not form  $[CCl_6]^{2-}$ . Explain.
3. Why does not silicon form an analogue of graphite?
4. Why carbon forms covalent compounds whereas lead forms ionic compounds?
5. How is borax prepared from?
6. Mention three important uses of borax.

### Long Questions:

1.  $SiCl_4$  forms  $[SiCl_6]^{2-}$  while  $CCl_4$  does not form  $[CCl_6]^{2-}$ . Explain
2. Borazine is more reactive than benzene. Why?
3. (i) What are the different oxidation states exhibited by the group 14 elements? Discuss the stability of their oxidation states.  
(ii) What type of oxides are formed by group 14 elements? Which of them are acidic, neutral or basic?
4. (a)  $[SiF_6]^{2-}$  is known whereas  $[SiCl_6]^{2-}$  is not known. Give reasons  
(b) Select the member (s) of group 14 that  
(i) forms the most acidic oxide  
(ii) is commonly found in the +2-oxidation state  
(iii) used as a semi-conductor.  
(c) Explain why a diamond that is covalent has a high melting point?  
(d) Discuss the reaction of silica with  
(i) NaOH  
(ii) HF
5. (a) Carbon exhibits catenation, whereas silicon does not. Explain.  
(b) How does boron differ from aluminum.  
(c) Write the similarities between boron and silicon.

### Assertion Reason Questions:

1. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

**Assertion (A):** If Aluminium atoms replace a few silicon atoms in three dimensional network of silicon dioxide, the overall structure acquires a negative charge.

**Reason (R)** : Aluminium is trivalent while silicon is tetravalent.

- (i) Both A and R are correct and R is the correct explanation of A.
- (ii) Both A and R are correct but R is not the correct explanation of A.
- (iii) Both A and R are not correct.
- (iv) A is not correct but R is correct.

2. In the following questions, a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

**Assertion (A)**: Silicon's are water repelling in nature.

**Reason (R)** : Silicon's are organosilicon polymers, which have  $(-R_2SiO-)$  as repeating unit.

- (i) A and R both are correct and R is the correct explanation of A.
- (ii) Both A and R are correct but R is not the correct explanation of A.
- (iii) A and R both are not true.
- (iv) A is not true but R is true.

### Case Study Based Question:

1. The heavier members of 13 and 14 groups besides the group oxidation state also show another oxidation state which is two units less than the group oxidation state. Down the group ( $\downarrow$ ), the stability of higher oxidation state decreases and that of lower oxidation state increases. This concept which is commonly called inert pair effect has been used to explain many physical and chemical properties of the element of these groups.

(1) Heavier members of groups 13 exhibit oxidation state

- (a) +3 only
- (b) +1 only
- (c) +1 and +3 both
- (d) +1, +2, +3

(2) Which among the following is the strongest oxidising agent?

- (a)  $SiO_2$
- (b)  $GeO_2$
- (c)  $SnO_2$
- (d)  $PbO_2$

(3) Which among the following is the strongest reducing agent?

- (a) GaCl
  - (b) InCl
  - (c) BCl<sub>3</sub>
  - (d) TlCl
- (4) The strongest reductant among the following is
- (a) SnCl<sub>2</sub>
  - (b) SnCl<sub>4</sub>
  - (c) PbCl<sub>2</sub>
  - (d) GeCl<sub>2</sub>
- (5) Which of the following statement is wrong?
- (a) Tl(III) salt undergo disproportionation.
  - (b) CO is used as a reducing agent.
  - (c) CO<sub>2</sub> is a greenhouse gas.
  - (d) SiO<sub>2</sub> is a covalent solid.

### Answer Key:

#### MCQ

1. (b) I, II and III
2. (b) B > P > As > Bi
3. (a) 6P-P single bonds are present
4. (d) Polymorphic
5. (c) Reaction between Zn and conc. H<sub>2</sub>SO<sub>4</sub>
6. (c) Cristobalite
7. (a) Has carbon atoms arranged in large plates of rings of strongly bound carbon atoms with weak interplate bonds
8. (a) Alkaline solution
9. (c) C-Cl > C-Br > C-I
- 10.(a) Potassium Borate + Dihydrogen
- 11.(a) The oxygen-oxygen bond length in ozone is identical with that of molecular oxygen
- 12.(d) S<sub>2</sub>O<sub>7</sub><sup>2-</sup>
- 13.(a) BF<sub>3</sub>

14.(b) Urea

15.(b) Lewis Acids

### Very Short Answer:

1. Boron halides are Lewis's acids and hence accept a pair of electrons from amines to form additional compounds.

2.  $2B + 6NaOH \rightarrow 2Na_3BO_3 + 3H_2$ .

3. (a) + 2

(b) +2

(c) +4

(d) -1

4. (a)  $sp^2$

(b)  $sp^3$

(c)  $sp^3$

(d)  $sp^2$

5.  $BF_3$  and  $B_2H_6$ .

6.  $BF_3 < BCl_3 < BBr_3 < BI_3$ .

7. Solid  $CO_2$  is known as dry ice. It does not wet a piece of paper/cloth and sublimes without melting. Therefore, it is called dry ice.

8.  $CO_3^{2-} + H_2O \rightleftharpoons OH^- + HCO_3^-$

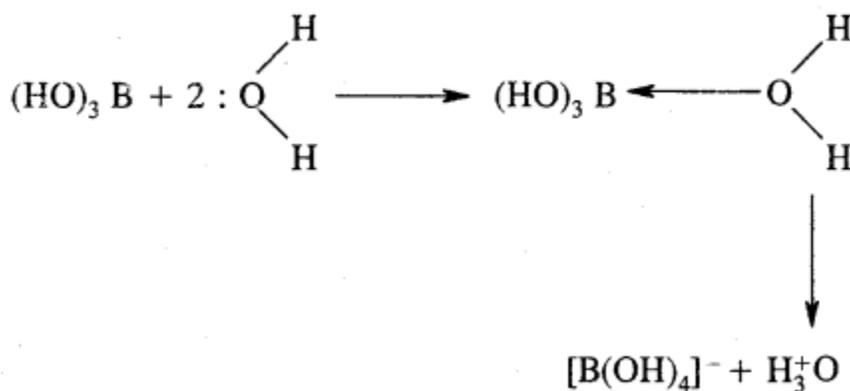
$HCO_3^- + H_2O \rightleftharpoons OH^- + H_2CO_3$ .

9. Boron has a very high sum of the first three ionisation enthalpies. Hence it cannot lose three electrons to form a  $B^{3+}$  ion.

10.  $CO_2$ , because  $H_2CO_3$  acid decomposes to give  $H_2O$  and  $CO_2$ .

### Short Answer:

Ans: 1.

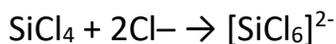


Hydrated species

$\text{B}(\text{OH})_3$  is not a protonic acid.

It behaves as a Lewis acid because it abstracts a pair of electrons from hydroxyl ion.

**Ans: 2.** Carbon does not have d-orbitals and hence C.  $\text{Cl}_4$  does not combine with  $\text{Cl}^-$  ions to give  $[\text{CCl}_6]^{2-}$ . On the other hand, silicon has vacant 3d-orbitals and thus can expand its covalency from 4 to 6. Therefore,  $\text{SiCl}_4$  combines with  $\text{Cl}^-$  ions to form  $[\text{SiCl}_6]^{2-}$



**Ans: 3.** In graphite, C is  $\text{sp}^2$  hybridised and each C is linked to three other C atoms forming hexagonal rings. Thus, graphite has a two-dimensional sheet-like structure.

Silicon, on the other hand, does not form an analogue of C because of the following two reasons:

1. Silicon has a much lesser tendency for catenation than C as Si-Si bonds are much weaker than C-C bonds.
2. Silicon because of its larger size than C undergoes  $\text{sp}^3$  hybridisation.

**Ans: 4.** Carbon cannot lose electrons to form  $\text{C}^{4+}$  because the sum of four ionisation enthalpies is very high. It cannot gain four electrons to form  $\text{C}^{4-}$  because energetically it is not favorable. Hence C forms only covalent compounds. Down the group 14, ionisation enthalpies decrease, Pb being the last element has so low I.E. that it can lose electrons to form ionic compounds.

**Ans: 5. (I)** Borax is also called sodium tetraborate decahydrate ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ ). It can be prepared as follows:

**From colemanite:** Powdered mineral is boiled with sodium carbonate solution and filtered. The filtrate is concentrated and then cooled when crystals of borax.



The mother-liquor which contains sodium meta-borate is treated with a current of  $\text{CO}_2$ , to convert it into borax which separates out.



(ii) **From Tincal:** Tincal obtained from dried up lakes is boiled with water. The solution is filtered to get rid of insoluble impurities of clay, sand etc. The filtrate is concentrated to get the crystals of borax.

(iii) **From boric acid:** Boric acid is neutralised with sodium carbonate and the resulting solution is concentrated and cooled to get the crystals of borax  $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ .

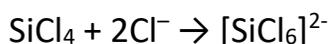


**Ans: 6.** It is used:

- As a flux soldering and welding in industry.
- In the manufacture of borosilicate glass (or pyrex glass).
- In making enamels and glazes.
- In stiffening of candle wicks.
- In softening of water.
- In a qualitative analysis for borax bead test in the laboratory.

### Long Answer:

**Ans: 1.** Carbon does not have d-orbitals, hence  $\text{CCl}_4$  does not combine with  $\text{Cl}^-$  ions to form  $[\text{CCl}_6]^{2-}$ . On the other hand, silicon has vacant 3-d orbitals & thus  $\text{SiCl}_4$  combines with  $\text{Cl}^-$  ions to form  $[\text{SiCl}_6]^{2-}$ .



In other words, carbon shows a fixed covalency of 4 but silicon exhibits varying covalency from 4 to 6.

**Ans: 2.** Both Borazine & Benzene are isoelectronic. In benzene  $\text{C}=\text{C}$  bonds are non-polar while  $\text{N}=\text{B}$  bonds in borazine are polar in nature due to the presence of a co-ordinate bond between N & B atoms. As a result, addition is quite frequent in borazine while it is less in benzene because of delocalization of  $\pi$ -electron charge.

**Ans: 3.** (i) The group 14 elements have four electrons in the outermost shell. The common oxidation states exhibited by these elements are +4 and +2. Since the sum of the first four ionisation enthalpies is very high, compounds in the +4-oxidation state are generally covalent in nature. In heavier members such as Ge, Sn and Pb, the tendency to show +2 oxidation state

increases. It is due to the inability of  $ns^2$  electrons of the valence shell to participate in bonding.

The relative stabilities of these two oxidation states vary down the group. C and Si mostly show a +4 oxidation state. Ge forms stable compounds in the +4 state and only a few compounds in the +2 state. Sn forms compounds in both oxidation states (Sn in +2 state is a reducing agent).

Lead compounds in the +2 state are stable and in the +4 state are strong oxidising agents. In the tetravalent state, the number of electrons around the central atom in a molecule (e.g., carbon in  $CCl_4$ ) is eight. Being electron precise molecules, they are normally not expected to act as an electron acceptor or electron donor.

Although carbon cannot exceed its covalence of more than 4, other elements of the group can do so. It is because of the presence of d-orbital in them. Due to this, their halides undergo hydrolysis and have a tendency to form complexes by accepting electron pairs from donor species. For example, the species like  $SiF_5^-$ ,  $SiF_6^-$ ,  $[GeCl_6]^{2-}$ ,  $[Sn(OH)_6]^{2-}$  exist where the hybridisation of the central atom is  $sp^3d^2$ .

(ii) All members when heated in oxygen form oxides. There are -mainly two types of oxides, i. e., monoxide and dioxide of formula  $MO$  and  $MO_2$  respectively.  $SiO$  only exists at high temperature. Oxides in the higher oxidation state of elements are generally more acidic than those in the lower oxidation state. The dioxides- $CO_2$ ,  $SiO_2$  and  $GeO_2$  are acidic, whereas  $SnO_2$  and  $PbO_2$  are amphoteric in nature. Among monoxides,  $CO$  is neutral,  $GeO$  is distinctly acidic whereas  $SnO$  and  $PbO$  are amphoteric.

**Ans: 4.** (a) (i)  $[SiF_6]^{2-}$  is known whereas  $[SiCl_6]^{2-}$  does not exist.

The main reasons are (i) six large chlorine atoms cannot be accommodated around silicon atom due to the limitation of their size.

(ii) Interactions between lone pairs of a chlorine atom and silicon atom are not very strong

(b) (i) The most acidic dioxide is formed by carbon ( $CO_2$ ).

(ii) Lead is mostly found in the +2 oxidation state in its compounds.

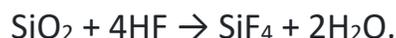
(iii) Silicon and germanium are used as semiconductors.

(c) Though diamond has covalent bonding in it, yet it has a high melting point, because a diamond has a 3-dimensional network involving strong C—C bond, which are very difficult to break and in turn, it has a high melting point.

(d) (i)  $SiO_2$  reacts with HF as follows:



(ii)  $\text{SiO}_2$  reacts with HF as follows:



**Ans: 5.** (a) Carbon shows catenation because of its smaller size, high bond energy of C – C bond, the possibility of  $sp$ ,  $sp^2$ ,  $sp^3$  hybridisation and formation of multiple bonds C-C ( $1\sigma$ ), C = C ( $1\sigma + S1\pi$ ), C ≡ C ( $1\sigma + 2\pi$ ). On the other hand, silicon shows only limited catenation because of its large atomic radius, low bond energy of Si-Si bond and absence of multiple bonds between Si atoms.

(b) Difference between boron and aluminum:

1. Boron is a non-metal but aluminum is a metal.
2. Boron is a semi-conductor while aluminum is a good conductor of electricity.
3. Boron forms a number of hydrides called boranes, but Al forms a polymeric hydride.
4. Halides of boron (except  $\text{BF}_3$ ) are readily hydrolysed by water whereas halides of Al are only partially hydrolysed by water.
5.  $\text{B}_2\text{O}_3$  is acidic, but  $\text{Al}_2\text{O}_3$  is amphoteric.
6. Boron hydroxide  $\text{B}(\text{OH})_3$  is acidic, but  $\text{Al}(\text{OH})_3$  is amphoteric.

(c) Similarities between boron and silicon:

1. Both are non-metals.
2. Both are semi-conductors
3. Boron and silicon form a number of covalent hydrides which have similar properties. For example, they spontaneously catch fire on exposure to air and are readily hydrolysed by water.
4. The halides of boron and silicon are readily hydrolysed by water.
5. Boron trioxide ( $\text{B}_2\text{O}_3$ ) and silicon dioxide ( $\text{SiO}_2$ ) are acidic in nature. These dissolve in alkali solution forming borates and silicates.

### Assertion Reason Answer:

1. (i) Both A and R are correct and R is the correct explanation of A.
2. (ii) Both A and R are correct but R is not the correct explanation of A.

### Case Study Answer:

#### 1. Answer:

- (1) (c) +1 and +3 both
- (2) (d)  $\text{PbO}_2$

(3) (c)  $\text{BCl}_3$

(4) (d)  $\text{GeCl}_2$

(5) (a)  $\text{Tl(III)}$  salt undergo disproportionation.