such a way that the double bond no longer involved protons, rather it involved two similar 'three centre bonds'.

sp^3-Hybridization And Structure Of B_2H_6:

It is supposed that boron atoms undergo sp^3 hybridisation. Each boron then utilizes two such orbitals containing one electron each for bonding with terminal hydrogens. There are now two sp^3 hybrid orbitals and one electron left with each boron atom. Also there are two 1s orbitals containing one electron each belonging to two hydrogen atoms not yet bonded. Thus, in all, there are six atomic orbitals and four electrons available which can **form two three centre bonds known as the hydrogen bridges** between the boron atoms as shown in Fig. (6.3)

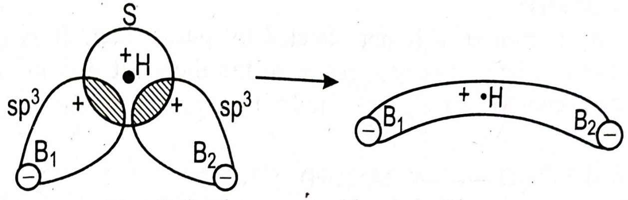
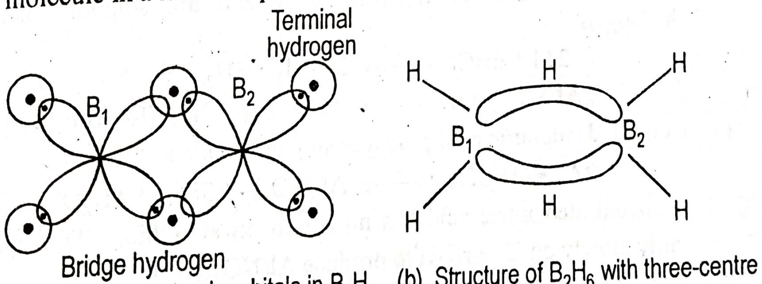


Fig. (6.3) Three-centred bonds in diborane.

The molecule of diborane contains two such bonds. **Due to repulsion between the two hydrogen nuclei, the delocalised orbitals or bridges are bent away from each other in the middle** (یہ بانڈز درمیان سے جھکے ہوتے ہیں). This is why the hydrogen bridge orbitals is shifted upwards in the middle. The other bridge orbital will be shifted downwards. This is the reason that these three atom orbitals are frequently referred to as **banana bonds**.

The molecule in a more simple form may be represented as in Fig. (6.4).



(a) Overlapping of atomic orbitals in B_2H_6 (b) Structure of B_2H_6 with three-centre bond or banana bond

Fig. (6.4) Representation of structure of diborane.

6.5 Aluminium:

Occurrence Of Aluminium:

Aluminium does not occur free in nature. It is a constituent (حصہ) of clay, slate and many types of silicate rocks. It **forms 7.28% of the earth crust.** It occurs: as oxides, fluorides, silicates and sulphates. Its metallurgy is discussed in the chapter of industries.

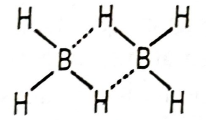
6.5.1 Physical Properties Of Aluminium:

(i) It is a light metal (density 2.7 g cm^3).

(ii) Aluminium shows a bluish white lustre (چمک) which is destroyed on long exposure to air due to the formation of a layer of oxide on it.

(i) Normal Hydrogen Bond Concept:

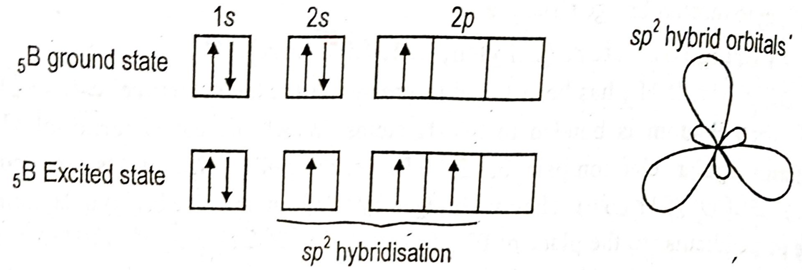
This concept was proposed by Buraway that the bridge between the boron atoms involves normal hydrogen bonds as shown below:



However, this concept is not acceptable due to a very small difference in the electronegativity values of B (1.00) and H (2.1) atoms.

(ii) Protonated Double Bond Concept:

R. S. Pitzer (1945) suggested the concept of a double bond between the two boron atoms. Each boron atom undergoes sp^2 hybridization as follows:



Now, we are bond to think that one of the sp^2 hybrid orbitals of each boron atoms overlaps to form one B-B σ bond. There is one unhybridized empty *p* orbital associated with each boron atom which lies in a plane perpendicular to the sp^2 hybrid orbitals. Sideways overlapping of these *p* orbitals gives a π bond between the two boron atoms. Hence there is a π bond between the two boron atoms. The two, so called different hydrogen atoms, provide electrons to this π bond. They are, consequently, converted into protons which lie in the electron charge cloud of the π bond. In this way, the four hydrogen atoms will be coplanar with the two boron atoms, while the other two will lie above and below this plane.

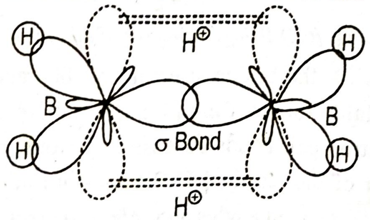


Fig. (6.2) Structure of diborane.

This structure is consistent with the results of infrared and electron diffraction studies and also explains hindered rotation around B-B axis.

Draw Back Of This Structure:

This structure envisages (خیال میں لاتا) acidic properties which are, however, not given by the compound.

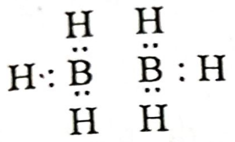
(iii) Three-centre Bond Concept:

This concept, was proposed by **Longuet-Higgins** and **Professor William N. Lipscomb**. It is a sort of molecular orbital concept. These people modified Pitzer's concept in

6.4.1 Structure Of Diborane (B_2H_6): (Electron Deficient Molecule)

This is an electron deficient compound. Its structure presents an interesting case since there are not enough valence electrons to form the expected number of covalent bonds.

Boron atom has three electrons in the outermost orbit in the excited state. Therefore, it can link itself with three hydrogen atoms. Each of the boron atoms in diborane can link itself to three hydrogen atoms, there are no electrons left to form a bond between the two boron atoms.



$$\begin{array}{ccccc} & \mathrm{H} & & \mathrm{H} & \\ \mathrm{H}\cdot\!: & \underset{\cdot\cdot}{\ddot{\mathrm{B}}} & & \underset{\cdot\cdot}{\ddot{\mathrm{B}}} & :\mathrm{H} \\ & \mathrm{H} & & \mathrm{H} & \end{array}$$

This is a sort of anomaly. Various structures for diborane have been proposed. But we are going to discuss bridge structure.

Hydrogen Bridge Structure (Ethylene-type Structure):

Dibornace, B_2H_6, has been found to prossess a **bridge structure** (پل نما ساخت). In this structure each B atom is bonded to two H atoms. Which are called **terminal H atoms.** They form regular electron-pair bonds. The resulting BH_2 **fragments are co-planar** (دونوں BH_2 یونٹس ایک پلین میں ہوتے ہیں). They are bridged by two H atoms. The bridging H atoms are in a plane perpendicular to the plane of BH_2 fragments (پل پر موجود H ایٹمز کا پلین باقی مالیکیول کے عموداً ہے). One H-atom lies above and other H-atom below the plane to the rest of the molecule. It prevents rotation between the two boron atoms (دونوں B ایٹمز کی باہمی روٹیشن ممکن نہیں ہے). The various bond distances and angles are shown in Fig. (6.1).

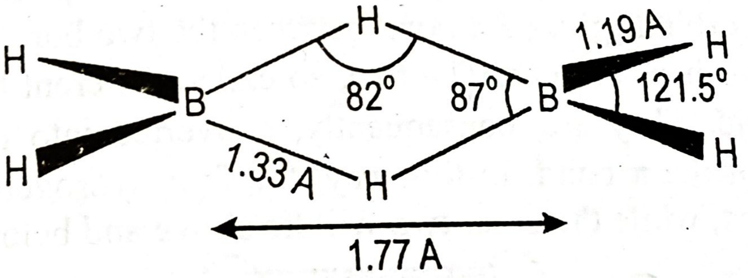


Fig. (6.1) Bridge structure of diborane.

When we keep in view the bridge structure of diborane. It **has 8 bonds.** Actually there are **12 electrons available for bonding** (3 per B and 1 per H), hence, all the bonds in the molecule cannot be electron-pair bonds because they would required **16 electrons** for the structure of Fig. (6.1) Four of the terminal H-B bonds are normal single bonds. This gets support as evidenced (گواہی دینا) by bond angles and **infrared stretching frequencies.** The other two hydrogen atoms and four electrons are in a different environment.

The **bond lengths** between boron and hydrogen at the bridges is **133 pm** while that of terminal positions is **119 pm.** The terminal B-H distances are the same as the bond lengths measured in **non-electron deficient compounds.** It means that the electron deficiency is associated with the bridge groups.

Theories Of Bridging H-atoms:

A number of bonding theories have been proposed to account for the nature of the bridge in

Properties Of Diborane (B_2H_6):

(i) **Combustion:**

It bums in air or oxygen producing large amount of heat.

ایندھن کے طور پر، استعمال کیا جاتا ہے۔)

$$B_2H_6 + 3O_2 \longrightarrow B_2O_3 + 3H_2O; \quad \Delta H = -201.7\ kJ\ mol^{-1}$$

For this reason, it is used as a fuel in internal combustion energies.

(ii) **Action Of Alkalies:**

Diborane undergoes hydrolysis in the presence of water or alkalies.

$$B_2H_6 + 2KOH + 2H_2O \longrightarrow \underset{\text{Pot. metaborate}}{2KBO_2} + 6H_2$$

(iii) With excess NH_3, it gives BN, boron nitride.

$$B_2H_6 \xrightarrow[\text{High temp.}]{\text{Excess } NH_3} BN$$

(iv) One of H can be replaced by Cl atom.

$$B_2H_6 \xrightarrow{HCl} B_2H_5Cl$$

$$B_2H_6 \xrightarrow{BCl_3} B_2H_5Cl$$

(v) BCl_3 can be obtained by treatment with Cl_2 at 25°C.

$$B_2H_6 \xrightarrow[298\ K]{Cl_2} BCl_3$$

(vi) Hydrolysis with H_2O gives H_3BO_3. (Boric acid)

$$B_2H_6 \xrightarrow{H_2O} B(OH)_3 + H_2$$

(vii) With CO, we get $COBH_3$.

$$B_2H_6 \xrightarrow{CO} COBH_3$$

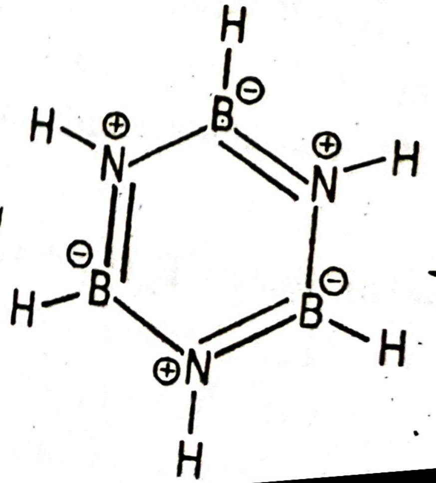
(viii) Preparation of higher hydrides.

$$B_2H_6 \xrightarrow[373-523\ K]{H_2} \text{Higher hydrides}$$

(ix) With NH_3 it gives borazole.

$$B_2H_6 \xrightarrow[473\ K]{NH_3} \text{Borazole or Borazine } (B_3N_3H_6)$$

اس کی ساخت بنزین کی طرح ہے۔



Borazole کو Inorganic benzene بھی کہتے ہیں۔

(viii) For the preparation of metaborates like $NaBO_2$, $Ba(BO_2)_2$, $Cu(BO_2)_2$, $Co(BO_2)_2$ etc.

Hydrides Of Boron, (Boranes) Electron Deficient Molecules

Hydrides of boron are electron deficient molecules like $AlCl_3$ etc.

paration:

Some common methods of preparation of hydride are given as under.

By Pyrolysis Of Diborane:

Normally diborane required for the purpose is made by treating sodium borohydride, H_4, with concentrated H_2SO_4.

$$\underset{\text{Sodium borohydride}}{2NaBH_4 + H_2SO_4} \longrightarrow Na_2SO_4 + \underset{\text{Diborane}}{B_2H_6}$$

Diborane is a source for obtaining the higher hydrides mainly B_4H_{10}, B_5H_{11}, B_5H_9 $B_{10}H_{14}$.

$$\underset{\text{Diborane}}{B_2H_6} \xrightarrow{373\ K} \underset{\text{Tetraborane}}{B_4H_{10}}$$

$$\underset{\text{Diborane}}{B_2H_6} \xrightarrow{393\ K} \underset{\text{(Pentaborane-11)}}{B_5H_{11}}$$

$$B_2H_6 \xrightarrow{453\ K} \underset{\text{(Pentaborane-9)}}{B_5H_9} + B_{10}H_{14}$$

By Reduction Of Boron Halide:

$LiAlH_4$ is best reducing agent.

$$4BF_3 + 3LiAlH_4 \longrightarrow 2B_2H_6 + 3AlF_3 + 3LiF$$

Diborane can also be obtained by action of hydrogen on boric oxide.

$$\underset{\text{Boron oxide}}{B_2O_3} + 6H_2 \xrightarrow[Al_2Cl_6]{\text{Al or}} B_2H_6 + 3H_2O$$

By passing electric discharge either on lower boranes.

$$\underset{\text{(Pentaborane-9)}}{2B_5H_9} \xrightarrow{\text{Discharge}} \underset{\text{(Pentaborane-8)}}{2B_5H_8} + H_2$$

By Hydrolysis Of Magnesium Boride:

Magnesium boride on dissolving in aqueous acids yields mainly B_4H_{10}, B_5H_9 and H_{10}.

$$\underset{\text{Magnesium boride}}{2\,Mg_3B_2} + 12HCl \longrightarrow 6MgCl_2 + \underset{\text{Tetraborane}}{B_4H_{10}} + H_2$$

$$BCl_3 + 3H_2O \xrightarrow{\text{Hydrolysis}} \underset{\text{Boric acid}}{H_3BO_3} + 3HCl$$

$$SiCl_4 + 4H_2O \xrightarrow{\text{Hydrolysis}} \underset{\text{Orthosilicic acid}}{H_4SiO_4} + 4HCl$$

(v) Nature Of Hydrides:

Hydrides of boron and silicon known as boranes and silanes, respectively are covalent in nature and have similar methods of preparation.

$$\underset{\text{Magnesium bromide}}{Mg_3B_2} + 6HCl \longrightarrow 3MgCl_2 + \underset{\text{Borane}}{B_2H_6}$$

$$\underset{\text{Magnesium silicide}}{Mg_2Si} + 4HCl \longrightarrow 2MgCl_2 + \underset{\text{Silane}}{SiH_4}$$

(vi) Reaction Of Nitrides With Water:

The nitrides of both boron and silicon decompose **steam** and liberate **ammonia.**

$$\underset{\text{Boron nitride}}{BN} + \underset{\text{Steam}}{3H_2O} \longrightarrow H_3BO_3 + NH_3$$

$$\underset{\text{Silicon nitride}}{Si_3N_4} + \underset{\text{Steam}}{12H_2O} \longrightarrow 3H_4SiO_4 + 4NH_3$$

Dissimilarities In Boron (B) And Silicon (Si):

(vii) Boron does not decompose water or **steam**.	(vii) Al **decomposes steam** to form hydrogen. $2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2$
(viii) Boron forms **covalent compounds** only.	(viii) Al forms both **covalent** and **electrovalent** compounds.
(ix) Boron reacts with hydrogen to form a number of hydrides like B_2H_6, B_5H_9 etc.	(ix) Al does not form any stable hydride.
(x) $B(OH)_3$, *i.e.*, H_3BO_3 is **weakly acidic.**	(x) $Al(OH)_3$ is **amphoteric.**
(xi) BCl_3 is a **fuming liquid.**	(xi) $AlCl_3$ is **amphoteric.**
(xii) Boron combines with metals to form **borides.** $3Mg + 2B \rightarrow Mg_3B_2$	(xii) Al combines with metals to form **alloys.**
(xiii) Boron has maximum **covalency** as **four.**	(xiii) Al has maximum **covalency as six.**
(xiv) Boron is **oxidised** by **conc. HNO_3** to form boric acid. $B + 3HNO_3 \rightarrow H_3BO_3 + 2NO_2$	(xiv) Al **becomes passive** with conc. HNO_3.
(xv) Boron dissolves in **fused alkalies** to form **hydrogen.** $2B + 6NaOH \rightarrow 2Na_3BO_3 + 3H_2$	(xv) Al dissolves in hot alkalies to form hydrogen. $2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$
(xvi) Borates are very stable.	(xvi) Aluminates are less stable.

6.2.1 Diagonal Relationship (وتری تعلق) Between Boron ($_5B$) And Silicon ($_{14}Si$):

Boron, the first member of group III-A (13), differs from other members in certain respects and resembles silicon, the second member of group IV A (14), to which it is diagonally related.

Similarities In Boron (B) And Silicon (Si)

(i) **Conductivity:**

Both boron and silicon are **semiconductors** in their crystalline form and possess high melting points.

(ii) **Nature Of Oxides:**

Both boron and silicon form oxides such as B_2O_3 and SiO_2 respectively which are acidic in nature. They dissolve in alkalies to form **borates** and **silicates.**

$$B_2O_3 + 2\,NaOH \longrightarrow \underset{\text{Sodium metaborate}}{2NaBO_2} + H_2O$$

$$SiO_2 + 2NaOH \longrightarrow \underset{\text{Sodium metasilicate}}{Na_2SiO_3} + H_2O$$

(iii) **Nature Of Hydroxide:**

Boron and silicon form hydroxides which are **weak acids** with no basic properties.

(iv) **Hydrolysis Of Halides:**

Boron and silicon halides (except BF_3) readily hydrolyse to give their corresponding acids.

Tl are ionic. However, the other halide of these elements are covalent when anhydrous. For example, anhydrous $AlCl_3$ is covalent but in water it get hydrolyzed to give Al^{3+} (aq) ions. This change is mainly due to high hydration energy of Al^{3+} ions. Some members of the group also form complex halides e.g., $[AlF_6]^{3-}$ $[GaCl_6]^{3-}$ etc.

(xiii) Formation Of Oxides And Hydroxides:

All the elements of this group form oxides and hydroxides. As we move from boron to thallium, the oxides and hydroxides of these elements change from acidic through amphoteric to basic. **Thus oxides and hydroxides of boron are acidic, those of Al and Ga are amphoteric while those of In and Tl are basic.**

(xiv) Flame Test:

Boron gives a **green-edged flame**. Aluminium does not give any colour. **Gallium gives violet (بنفشی) colour, indium a dark blue (گہرا نیلا), and thallium a green coloured flame on heating.**

Anomalous (خلافِ معمول) Properties Of Borom In Group III-A:

Boron differs in many properties from the other elements of its own subgroup. The main points of difference are.

(i) B has a very small atomic radius.

(ii) The hypothetical (قیاسی) B^{3+} ion has very small size, high charge and hence high charge density. This value is so high that B^{3+} ion does not exist.

(iii) All the compounds of boron are covalent.

(iv) Boron has less than four valence-electrons and this gives it a great electron accepting power. Its compounds behave as strong Lewis acids and hence forms a large number of complex compounds.

(v) Boron shows a maximum covalency of four and does not exhibit inert pair effect.

2 Comparison Of Boron And Silicon

ints Of Dissimilarity Between Boron (B) And Aluminium (Al)

Boron ($_5B$)		Aluminium ($_{13}Al$)
Boron is a **non-metal** and is a bad **conductor of heat and electricity.**	(i)	Aluminium is a **metal** and is a **good conductor of heat and electricity.**
It has high **melting point (2300°C).**	(ii)	It has low **melting point (660°C).**
There are **two electrons** in the penultimate shell (2, 3).	(iii)	There are **eight electrons** in the penultimate shell (2, 8, 3).
Its crystalline form is very **hard.**	(iv)	It is sufficiently **soft.**
Boron **shows allotropy** and is found in two forms *viz.* crystalline and amorphous.	(v)	It does not show **allotropy.**
Boron does not react with **dil. acids.**	(vi)	Al **reacts with dil. acids** to form hydrogen. $2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2\uparrow$

hence do not form $M^{\oplus}$ cations. Since the inert pair effect increases from Ga to Tl, the stability of +3 oxidation state decreases while that of +1 state increases down the group. Thus Ga(+1) compounds are unstable, In(+1) compounds are moderately stable whereas those of Tl(+1) are the most stable. The relative stability order of $M^{\textcircled{3+}}$ and $M^{\oplus}$ cations is shown below.

$$B^{\textcircled{3+}} > Al^{\textcircled{3+}} > Ga^{\textcircled{3+}} > In^{\textcircled{3+}} > Tl^{\textcircled{3+}}$$

and

$$B^{\oplus} < Al^{\oplus} < Ga^{\oplus} < In^{\oplus} < Tl^{\oplus}$$

(vii) **Nature Of Bond Formed:**

The nature of the compounds of $M^{\textcircled{3+}}$ ions is decided by Fajan's rule. It states that the smaller the cation, the greater is its tendency to form covalent compounds. Thus with the increase of the size of $M^{\textcircled{3+}}$ ions from $B^{\textcircled{3+}}$ to $Tl^{\textcircled{3+}}$, their tendency to form covalent compounds decreases.

(viii) **Ionization Energies:**

First ionization energies of these elements correspond to the removal of np^1 electron from ns^2p^1 configuration. The second and third ionization energies correspond to the removal of ns^2 electrons in succession. Because of the increase in size of Al, the ionization energy decreases from B to Al.

But in going from Al to Ga the value of ionization energy increases. **The increase in the case of gallium is due to the fact that the intervening d-electrons in Ga are not able to shield the nuclear charge effectively and hence the valence electrons in Ga are more firmly held to the nucleus and its ionization energy increases.**

(ix) **Electropositive Or Metallic Character:**

Electropositive character of the elements increases as we move from B to Tl. Thus B is a semi-metal i.e., it is closer to non-metals than to metals in its properties, while other members are metallic in nature. Al, Ga, In and Tl have almost equal electropositive character as is evident from their almost equal ionization energy values.

(x) **Reactivity Of Elements:**

Pure boron is almost unreactive at ordinary temperature. It reacts with air only when heated. Boron does not react with water. It is attacked only by hot concentrated acids and alkalies.

Aluminium decomposes water and reacts readily in air at ordinary temperature to form a protective layer (ایسی تہہ جو حفاظت کرے) of its oxide. This layer protects it from further action. Gallium and indium are not affected by air even when heated. However, thallium is a little more reactive and forms an oxide on its surface.

(xi) **Formation Of Hydrides:**

Boron forms a large number of polymeric hydrides which are called boranes, e.g., B_2H_6, B_4H_{10}, B_5H_9, B_5H_{11} etc. These hydrides are covalent in nature. Aluminium forms only one high molecular weight polymeric hydride, $(AlH_3)_x$. Gallium gives GaH_4 which is called gallane. It is an unstable and volatile liquid. Indium gives polymerised solid hydride, $(InH_3)_x$. The hydrides given by Tl are extremely unstable. The element of this group also form the complex anionic hydrides like $Li^{\oplus}[BH_4]^{\ominus}$, $Li^{\oplus}[AlH_4]^{\ominus}$ etc.

(xii) **Formation Of Trihalides:**

The elements of this group react with halogens to form trihalides (MX_3). The trihalides of boron (BX_3) are covalent and act as Lewis acids. The fluorides of Al, Ga, In and

13	Electronegativity	2.0	1.5	1.6	1.7	1
14	Electron affinity (kJ mol^{-1})	26.8	42.6	29.0	29.0	29
15	Standard reduction potential for $M^{3+}(aq) + 3e^{-} \rightleftharpoons M(s)$ reaction (volts)	−0.87	−1.68	−0.52	−0.34	+0.72
16	Metallic character	Metalloid	← Almost same metallic character →			

6.1.1 Gradation Of The Characteristic Properties Of Group IIIA (1 Elements:

The gradation (کسی سلسلہ کا مرتبہ) in the physical and chemical properties of the elem with the rise of atomic number is as follows:

(i) Electronic Configuration:

$_{5}B = 1s^2\, 2s^2\, 2p_x^1$

$_{13}Al = 1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p_x^1$

$_{31}Ga = 1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p_x^1$

$_{49}In = 1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^6\, 5s^2\, 4d^{10}\, 5p_x^1$

$_{81}Tl = 1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 4s^2\, 3d^{10}\, 4p^6\, 5s^2\, 4d^{10}\, 5p^6\, 6s^2\, 4f^{14}\, 5d^{10}\, 6p_x^1$

(ii) Atomic Volume, Ionic Radius And Density:

Atomic volume and ionic radius of M^{3+} ions go on increasing down the group. Th reason is additional shells.

(iii) Density:

The values of densities in g cm^{-3} go on increasing down the groups.

(iv) Melting Points And Boiling Points:

In the case of melting points, there is sudden fall down from aluminium to gallium followed by a gradual rise again to thallium. The melting point of boron is extremely hig indicating strong bonding between individual atoms. The melting points of other elements especially gallium, indium and thallium, are significantly low indicating that the metalli lattices in them are much more readily ruptured (ٹوٹ جاتا). Boiling points show a continuous decrease with increasing atomic number.

(v) Heat Of Sublimation (عمل تسعید):

The successive (ایک کے بعد دوسرا) decrease in heat of sublimation indicates that the atoms of these elements are held less and less closely, as we move from boron (5) to thallium (81).

(vi) Oxidation States:

M^{3+} cations are obtained when all the three $ns^2\, p^1$ electrons are lost, while M^{+} cations are formed when only one np^1 electron is lost. Boron and aluminium show an oxidation state of +3 while other members show both +1 and +3 oxidation states. In the formation of M^{+} cations the electron pair in ns orbital remains inert. **This is called inert pair effect** (ایسا اثر جو الیکٹران کے جوڑے کا نہ ٹوٹنے کا رجحان سے ہو). B and Al do not show inert pair effect and

13	Electronegativity	2.0	1.5	1.6	1.7	1.8
14	Electron affinity (kJ mol^{-1})	26.8	42.6	29.0	29.0	29.0
15	Standard reduction potential for $M^{3+}(aq) + 3e^{-} \rightleftharpoons M(s)$ reaction (volts)	−0.87	−1.68	−0.52	−0.34	+0.72
16	Metallic character	Metalloid	← Almost same metallic character →			

6.1.1 Gradation Of The Characteristic Properties Of Group IIIA (I Elements:

The gradation (کسی سلسلہ کا مرتبہ) in the physical and chemical properties of the elemen with the rise of atomic number is as follows:

(i) Electronic Configuration:

$_{5}B = 1s^2\ 2s^2\ 2p_x^1$

$_{13}Al = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^1$

$_{31}Ga = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p_x^1$

$_{49}In = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p_x^1$

$_{81}Tl = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p_x^1$

(ii) Atomic Volume, Ionic Radius And Density:

Atomic volume and ionic radius of M^{3+} ions go on increasing down the group. Th reason is additional shells.

(iii) Density:

The values of densities in g cm^{-3} go on increasing down the groups.

(iv) Melting Points And Boiling Points:

In the case of melting points, there is sudden fall down from aluminium to galliu followed by a gradual rise again to thallium. The melting point of boron is extremely hig indicating strong bonding between individual atoms. The melting points of other element especially gallium, indium and thallium, are significantly low indicating that the metalli lattices in them are much more readily ruptured (ٹوٹ جاتا). Boiling points show a continuou decrease with increasing atomic number.

(v) Heat Of Sublimation (عمل تصعید):

The successive (ایک کے بعد دوسرا) decrease in heat of sublimation indicates that the atoms of these elements are held less and less closely, as we move from boron (5) to thallium (81).

(vi) Oxidation States:

M^{3+} cations are obtained when all the three $ns^2\ p^1$ electrons are lost, while M^{+} cations are formed when only one np^1 electron is lost. Boron and aluminium show an oxidation state of +3 while other members show both +1 and +3 oxidation states. In the formation of M^{+} cations the electron pair in ns orbital remains inert. This is called inert pair effect (اثر جو الیکٹران کے جوڑے کا نہ ٹوٹنے کا رجحان ہے

Introduction

Group III-A (13) consists of five elements. $_5B$ (Boron), $_{13}Al$ (Aluminium), $_{31}Ga$ (Galium), $_{49}In$ (Indium), $_{81}Tl$ (Thalium). B and Al are typical elements (مثالی نمائندگی کرنے والے عناصر) and we will concentrate on their discussion.

6.1 Physical Properties

Some important physical properties are given in the Table (6.1).

Table (6.1): Some Important Physical Properties Of The Elements Of Group IIIA (13)

S. No.	Property	Boron (B_5)	Aluminium (Al_{13})	Gallium (Ga_{31})	Indium (In_{49})	Thallium (Tl_{81})
1	Electronic configuration	$[He]_2\ 2s^2\ 2p^1$ or 2, 3	$[Ne]_{10}\ 3s^2\ 3p^1$ or 2, 8, 3	$[Ar]_{18}\ 4s^2\ 4p^1$ or 2, 8, 3	$[Kr]_{36}\ 5s^2\ 4d^{10}\ 5p^1$ or 2, 8, 18, 18, 3	$[Xe]_{54}\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^1$ or 2, 8, 18, 32, 18, 3
2	Atomic mass (amu)	10.81	26.98	69.72	114.82	204.37
3	Abundance in Earth's crust (ppm)	3	81,300	15	0.1	≈2
4	Single bond covalent radius (pm)	85	143	135	167	170
5	Radius of M^{3+} ion (pm)	20	50	62	81	95
6	Radius of M^{+} ion (pm)	–	–	11.3	132	140
7	Density ($g\ cm^{3-}$)	2.34	2.70	5.91	7.31	11.85
8	Stable oxidation states	+3	+3	+3, +1	+3, +1	+3, +1
9	Heat of sublimation (kJ/ mol)	5.648	324.3	273.2	241.4	179.1
10	Melting point (°C)	2030	659	28.8	156.4	303
11	Boiling point (°C)	2550	2450	2237	2000	1457
12	1st ionisation energy ($kJ\ mol^{-1}$)	798	581	577	556	589