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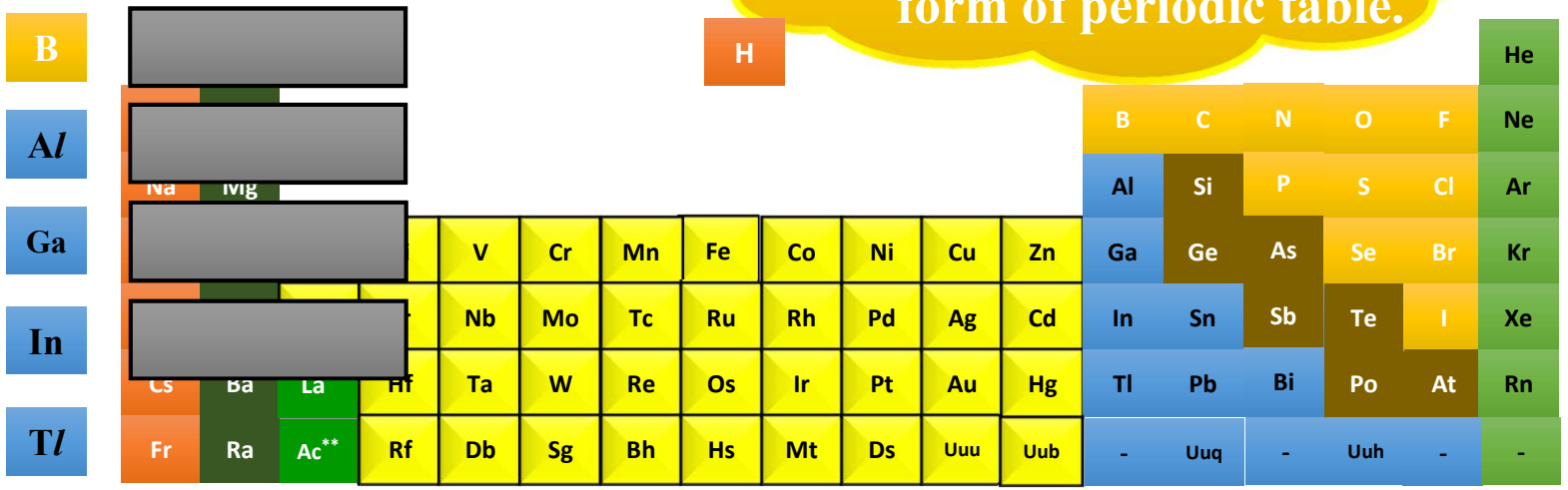
An Initiative by अमर उजाला

GROUP 13 ELEMENTS

13th GROUP ELEMENTS

These elements are placed in 13th (IIIA) group in the long form of periodic table.



* Lanthanoids	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
** Actinoids	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Electronic configuration of IIIA group elements

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

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

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

Electronic configuration of IIIA group elements

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

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

Element	Atomic No.	Electronic configuration
B	5	[He] $2s^2\ 2p^1$
A*l*	13	[Ne] $3s^2\ 3p^1$
Ga	31	[Ar] $3d^{10}\ 4s^2\ 4p^1$
In	49	[Kr] $4d^{10}\ 5s^2\ 5p^1$
T*l*	81	[Xe] $4f^{14}\ 5d^{10}\ 6s^2\ 6p^1$

Their general outer most electronic configuration is $ns^2\ np^1$

In the penultimate shell, Boron contains $2e^-$, Aluminium contains $8e^-$, and other elements contain $18e^-$.

MCQs

1) General electronic configuration of IIIA group elements is…

a) ns^2np^2

b) ns^1np^2

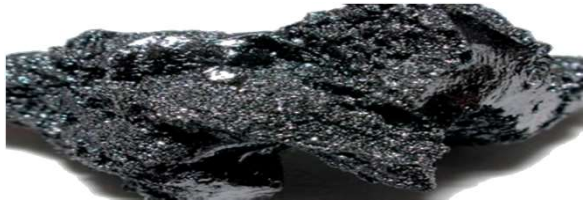
c) ns^2np^1 ✓

d) ns^2np^3

ABUNDANCE OF GROUP 13 ELEMENTS

Abundance of IIIA group elements:

- Boron is a rare element, mainly it occurs in *combined state*. It has two isotopic forms of ^{10}B (19%) and ^{11}B (81%).



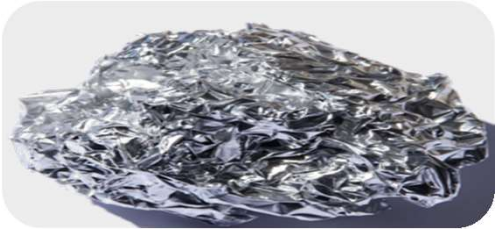
Boron

Important minerals of boron:

Borax	:	$Na_2B_4O_7.10H_2O$
Kernite (Razorite)	:	$Na_2B_4O_7.4H_2O$
Orthoboric acid	:	H_3BO_3
Colemanite	:	$Ca_2B_6O_{11}.5H_2O$

Abundance of IIIA group elements:

- '**A*l***' is the most abundant metal and *third* most abundant element in the earth's crust.



Aluminium

Important minerals :

Corundum	:	Al_2O_3
Diaspore	:	$Al_2O_3 . H_2O$
Bauxite	:	$Al_2O_3 . 2H_2O$
Gibbsite	:	$Al_2O_3 . 3H_2O$
Cryolite	:	$Na_3 Al F_6$
Feldspar	:	$K Al Si_3 O_8$

Abundance of IIIA group elements:

Ga, In, Tl → **Less abundant**

↓

Highly toxic

:: Decreasing Order of Abundance ::

Aluminium

Gallium

Boran

Thallium

Indium

Al > **Ga** > **B** > **Tl** > **In**

Al: % abundance 8.2% (82,000ppm)

Ga: % abundance 0.0018% (18ppm)

B: % abundance 0.0001% (10ppm)

Tl: % abundance 0.00006% (0.6ppm)

In: % abundance 0.000005% (0.05ppm)

MCQs

1) Number of water molecules in Borax…

a) 6

b) 8

c) 9

d) 10

2) Formula of corundum is…

a) $Al_2O_3.H_2O$

b) $Al_2O_3.2H_2O$

c) Al_2O_3 ✓

d) $Al_2O_3.3H_2O$

3) Formula of cryolite is

a) Na_3AlF_6

b) $3NaF.AlF_3$

c) Both a & b ✓

d) Na_2AlF_4

PHYSICAL PROPERTIES OF GROUP 13 ELEMENTS

Physical Properties

1) Atomic Mass

B < A*l* <Ga < In < T*l*

Physical Properties

2) Atomic Radius:

Elements	B	A*l*	Ga	In	T*l*
At. Radii (pm)	88	143	135	167	170

B < Ga < A*l* < In < T*l*

The sharp increase of atomic radius of 'A*l*' is due to greater screening effect of electrons of

What is screening effect?

Decrease in the force attraction of nucleus over the valence shell electrons due to inner core electrons shielding is called screening effect. i.e., greater the screening effect, easier the removal of electron.

Physical Properties

3) Ionic Radius (M^{+3}) :

$$B^{+3} < Al^{+3} < Ga^{+3} < In^{+3} < Tl^{+3}$$

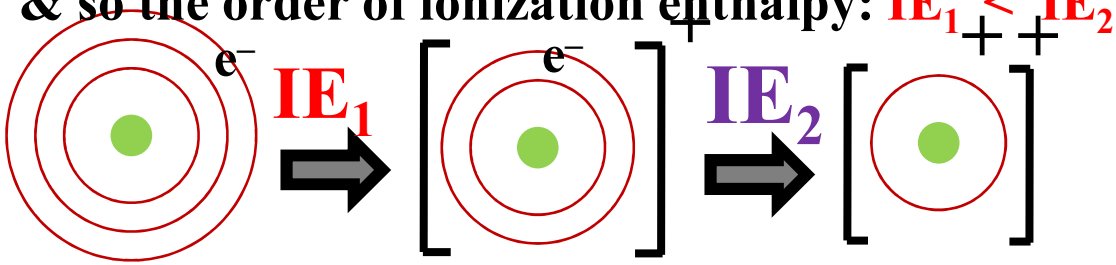
Physical Properties

4) Ionisation Enthalpy :

Ionization enthalpy values ↓(decrease) with ↑(increase) in atomic radii.

Since, the outer electrons become more loosely held down the group.

& so the order of ionization enthalpy: $IE_1 < IE_2 < IE_3$ ….



Atom *Monovalent Cation* *Divalent Cation*

Physical Properties

4) Ionisation Enthalpy :

- **Ionisation enthalpy ↓ from 'B' to 'A*l*' but**

  from A*l* → T*l* increases marginally.

The observed discontinuity in the ionisation enthalpy between 'Al' and 'Ga' and between 'In' and 'Tl' are due to lower screening effect of d and f orbitals

Elements	B	Al	Ga	In	Tl
I.E. values kJ/mol	801	577	579	558	589

B > Tl > Ga > Al > In

∴ 'B' has highest I.E. in IIIA group.

Physical Properties

5) Electronegativity :

Elements	B	Al	Ga	In	Tl
E.N. values	2.0	1.5	1.6	1.7	1.8

Elec
but i

The tendency of an atom to attract the shared pair of electrons towards itself is known as electro negativity.

B > T*l* > In > Ga > Al

∴ 'B' is the most E.N. element in IIIA group.

Physical Properties

6) Melting point :

M.pts (K)

B	Al	Ga	In	Tl
2453	933	303	430	576

- Boran is extremely hard and coloured solid.
- The M.P. & B.P. of boran are very high.
- The order of melting point of IIIA group elements is as follows

B > Al > Tl > In > Ga

Due to very strong crystal lattice, boron has high melting point.

- 'Ga' has low melting point since it exists as simple Ga_2 molecule.

Physical Properties

7) Boiling point :

The order of boiling point of IIIA group elements is as follows…

B.pts (K)

B	Al	Ga	In	Tl
392 3	2740	2676	2353	173 0

B > Al > Ga > In > Tl

Make a Note

Due to large difference in temperature (2373K) between m.p and b.p ‘Ga’ is used as a pyro metric liquid.
(i.e. filled in high temperature measuring liquid thermometers)

Physical Properties

8) Density :

Density of the IIIA group elements increases down the group.

Elements	B	Al	Ga	In	Tl
Solid state(gm/cc)	2.34	2.69	5.09	7.31	11.5
liquidstate(gm/cc)	2.36	2.37	6.09	7.01	11.2

Physical Properties

9) Electropositive character or Metallic nature :

Electropositive character order of IIIA group elements is as given below :

B < Al > Ga > In > Tl

Or

Al >B > Ga > In > Tl

MCQs

1) Which IIIA group element has lowest melting point?

a) B

b) Ga ✓

c) Al

d) Tl

2) The order of electropositive character of IIIA group elements is …

a) B > Al > Ga > In > Tl

b) B < Al < Ga < In < Tl

c) B < Al > Ga > In > Tl ✓

d) B < Al < Ga > In > Tl

CHEMICAL PROPERTIES OF GROUP 13 ELEMENTS

Chemical Properties :

1. Oxidation State :

What is inert pair effect?

- The +1 oxidation state becomes more stable due to **inert pair effect.**

The non-participation of s electron pair in bonding or the reluctance of s electron pair in bonding is called inert pair effect

Chemical Properties :

1. Oxidation State :

- **The common oxidation number of group 13 elements is +3.**
- **Due to small size of boron, the sum of its first three ionization enthalpies is very high. This prevents it to form +3 oxidation state.**
- **Boron exhibits -3 oxidation state with highly electropositive metals**

Ex: Mg_3B_2

Chemical Properties :

1. Oxidation State :

- **Along with +3 other elements Ga, In and T*l* shows +1 oxidation state**
- **The stability of +1 increases from Ga to T*l* due to inert pair effect**
- **The inert pair effect increases from Ga to T*l***

EX: T*l*C*l* more stable than T*l*C*l*$_3$

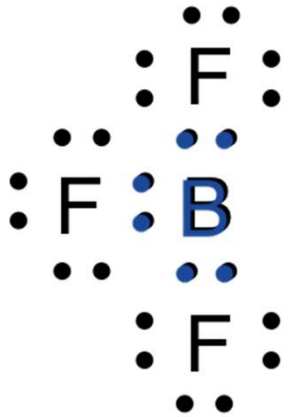
Chemical Properties :

Valency :

Valency means combining capacity of an element

- **In general, these are Trivalent compounds as they possess three electrons in their valence shell.**
- **In Trivalent state the number of electrons around the central atom will be only 6 in the bonded molecule so, it act as a Lewis acid.**
- **Have tendency to accept a pair of electrons to achieve stable electronic configuration.**

Example : **BF_3**

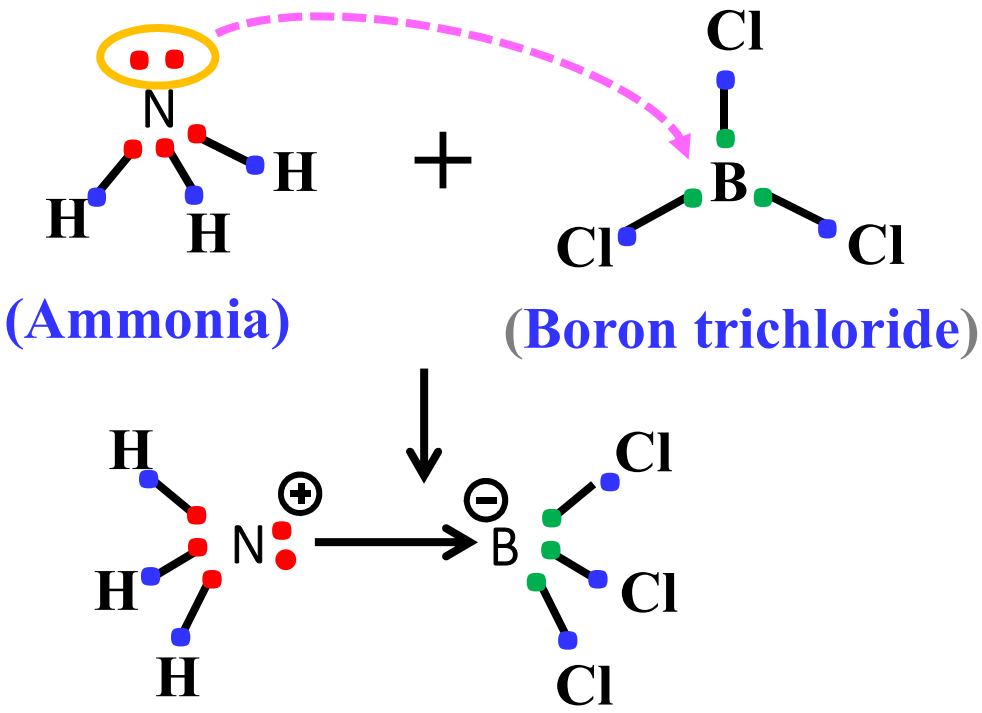


Chemical Properties :

- ***The tendency to behave as a Lewis acid decreases with increase in the atomic size down the group.***

For example :

- ***BCl_3 easily accepts a lone pair of electron from ammonia to form $H_3N \rightarrow BCl_3$ where as $AlCl_3$ achieves stability by forming a dimer.***



Ammonium boron trichloride

Nature of compounds of IIIA group elements:

- **IIIA group elements mostly form *covalent compounds* because of their high ionization energy.**

- **Compounds of boron are always covalent but some compounds of other elements like $AlCl_3$, $GaCl_3$ are covalent only in an anhydrous state.**

Question:

Why cannot boron form B^{+3} ion?

Answer:

The element with highest sum of ionisation energies $I.E_1$, $I.E_2$ and $I.E_3$ is boron.

Hence, it cannot form B^{+3} ion.

Question:

Why is the maximum covalency of boran only four whereas that of aluminium is six?

Answer:

‘A*l*’ has vacant ‘d’-orbitals hence it can expand its octet.

In boron, there are no d-orbitals at all.

Hence, it cannot expand its octet.

Question:

Write the correct order of reducing nature of group 13 elements in +3 oxidation state.

Answer:

Reducing nature

A*l* > B > Ga > In > T*l*

MCQs

1) More stable and more common Oxidation state of 'T*l*' is…

a) +1

b) +2

c) +3

d) +5

2) $AlCl_3$ exists as…

a) Monomer

b) Dimer ✓

c) trimer

d) tetramer

REACTIVITY TOWARDS AIR & ORDER OF ACIDIC NATURE OF OXIDES OF GROUP 13 ELEMENTS

1) Reactivity towards air

- **Boron is unreactive in crystalline form, But in Amorphous form on heating in air forms B_2O_3**

- **Aluminum will form a very thin oxide layer on the surface of it by heating in the atmosphere of O_2 .**

- **At high temperature, they form nitrides**

1) Reactivity towards air

Air has mainly two constituents, *oxygen & nitrogen*.

The common reactions of IIIA group elements towards oxygen and nitrogen is to form trioxides and nitrides.

First two members form compounds more readily than others are as follows…

$$4\ B(s) + 3\ O_2(g) \xrightarrow{(\Delta)} 2\ B_2O_3(s)$$

$$2\ Al(s) + N_2(g) \xrightarrow{(\Delta)} 2\ AlN(s)$$

1) Reactivity towards air

- **Boron exists in *two forms*. They are…**
  - **a) Crystalline**
  - **b) Amorphous**
- **Boron is *unreactive towards air in crystalline state.***
- ***Amorphous boron* on *heating* in air forms boron trioxide.**

$$4B + 3O_2 \rightarrow 2B_2O_3$$

1) Reactivity towards air

- ***At high temperature*, boron also *combines with nitrogen* to form boron nitride.**

$$2B + N_2 \xrightarrow{high\ temperature} 2BN$$

1) Reactivity towards air

- **'A*l*' is not affected by dry air. However, a *thin oxide layer* is formed on the surface of 'A*l*' metal *in moist air*.**

$$4Al + 3O_2 \xrightarrow{moisture/heat} 2Al_2O_3$$

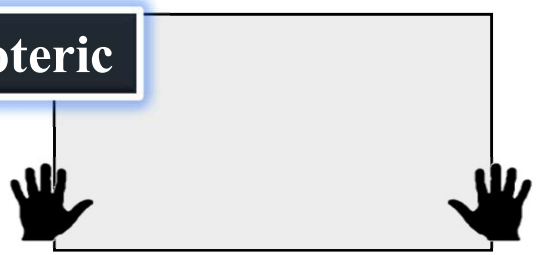
- **At high temperature, A*l* also forms nitride with nitrogen.**

$$2Al + N_2 \xrightarrow{high\ temperature} 2AlN$$

2) Order of Acidic Nature :

B_2O_3 > Al_2O_3 > Ga_2O_3 > In_2O_3 > Tl_2O_3

Acidic | Amphoteric | Basic



MCQs

1) Which is more acidic oxide ?

a) Tl_2O_3

b) Ga_2O_3

c) Al_2O_3

d) B_2O_3 ✓

2) Which of the following is an amphoteric oxide?

a) Tl_2O_3

b) In_2O_3

c) Al_2O_3 ✓

d) B_2O_3

3) Which is more basic oxide ?

a) Tl_2O_3

b) Ga_2O_3

c) Al_2O_3

d) B_2O_3

REACTIVITY TOWARDS ACIDS, ALKALIES & HALOGENS OF GROUP 13 ELEMENTS

3) Reactivity towards water :

- **Boron does not react with either cold or hot water.**
- **When steam is passed over red hot boron, hydrogen gas is liberated.**

$$2B + 3H_2O \rightarrow B_2O_3 + 3H_2 \uparrow$$

- ***Only aluminium reacts with boiling water .***

$$2\,Al + 6\,H_2O \xrightarrow{(\Delta)} 2\,Al(OH)_3 + 3\,H_2 \uparrow$$

3) Reactivity towards water :

- **'Ga' and 'In' do not react with cold or hot water.**
- **T*l* reacts with water and forms T*l*OH in moist air.**

$$4Tl + 2H_2O + O_2 \rightarrow 4TlOH$$

3) Reactivity towards acids and alkalies :

- **Boron does not react with acids and alkalies even at moderate temperature**
- **Al shows amphoteric character**
- **Al dissolves in dilute HCl and liberates dihydrogen**

$$2\,Al_{(s)} + 6\,HCl_{(aq)} \longrightarrow 2\,Al^{+3}_{(aq)} + 6Cl^{-}_{(aq)} + 3H_{2(g)}$$

- **Aluminum also reacts with alkali and liberates dihydrogen.**

$$2Al_{(s)} + 2NaOH_{(aq)} + 6\,H_2O_{(l)} \rightarrow 2Na[Al(OH)_4]_{(aq)} + 3H_{2(g)}$$

Halides of IIIA group elements

Properties

- **Boron trihalides such as BF_3, BCl_3, BBr_3, BI_3 are covalent due to *high polarising power of B^{+3} ion*.**
- **These compounds behave as Lewis acids.**
- **The order of Lewis acidic strength is …**

$$BI_3 > BBr_3 > BCl_3 > BF_3$$

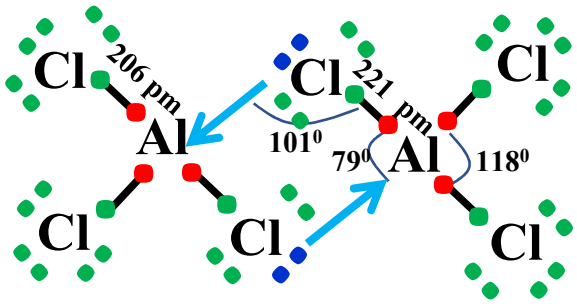
- **BF_3 is weak Lewis acid due to *back bonding.***

Q)White fumes appear around the bottle of anhydrous aluminium chloride. Give reason.

Anhydrous aluminium chloride is partially hydrolysed with atmospheric moisture to liberate HCl gas. Moist HCl appears white in colour.

5) Reactivity towards halogens :

- $AlCl_3$ is represented as Al_2Cl_6 upto 400^0C and above 800^0C, it exists as monomer.
- $AlCl_3$ is a Lewis acid.
- The dimeric aluminium chloride is denoted with *six covalent bonds and two dative bonds.*



Al_2Cl_6 is called auto complex.

5) Reactivity towards halogens :

- **In trivalent state, most of the compounds being covalent are *hydrolysed in water* to form *tetrahedral* $[M(OH_4)]^-$ species.**

- **$AlCl_3$ in *acidified aqueous solution* forms *octahedral* $[Al(H_2O)_6]^{3+}$ ion.**

MCQs

1) Boron reacts with...

a) cold water

b) hot water

c) ice

d) steam

2) Red hot Boron on reaction with steam liberates…

a) O_2

b) N_2

 H_2

d) both A&C

3) 'T*l* ' on reaction with water forms…….. Compound.

a) $Tl(OH)_3$

b) T*l*OH

c) $Tl(OH)_3$

d) $[Tl(OH)_4]$

4) Which is weak Lewis acid?

a) BCl_3

b) BF_3

c) BI_3

d) BBr_3

5) The no.of covalent and dative bonds present in dimeric $AlCl_3$…

✓ **a) 6,2**

b) 2,6

c) 3,3

d) 3,0

6) On hydrolysis $AlCl_3$ forms------- ion.

a) tetrahedral

b) square planar

✔ octahedral

d) trigonal bi pyramidal

7) Back bonding is present in

a) BF_3

b) BCl_3

c) BBr_3

d) BI_3

ANOMALOUS PROPERTIES OF BORON

Anomalous properties of boron

Boron shows anomalous behaviour due to…

a) small size

b) high ionization potential

c) high electronegativity

d) non-availability of vacant d-orbitals

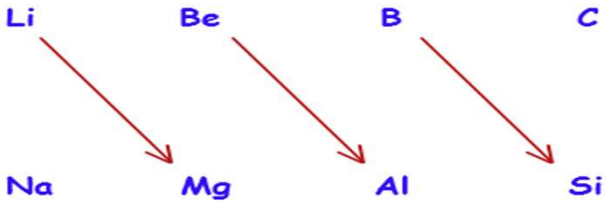
e) presence of two electrons in the penultimate shell

Anomalous properties of boron

- **Boron is a *non metal*, whereas A*l*, Ga, In and T*l* are *metals*.**

- **Boron *always forms covalent compounds* whereas other elements can form ionic compounds also apart from covalent compounds.**

Anomalous properties of boron



- **Boron shows *diagonal relationship* with Silicon.**
- **Boron *does not displace hydrogen* from acids whereas other elements can liberate hydrogen.**
- **B_2O_3 is an acidic oxide, whereas Al_2O_3 is amphoteric oxide, Tl_2O_3 is a strong base.**

Anomalous properties of boron

- **$B(OH)_3$ or H_3BO_3 is an acid. The hydroxides of *other elements are either amphoteric or basic in nature.***

- **Simple *borates and silicates can polymerize readily forming polyacids* whereas *others do not form polyacids.***

Anomalous properties of boron

- **Boron has *maximum* covalency *of 4.***
- ***Other elements of IIIA or group 13* exhibit a maximum covalency of *6.***
- **Boron *does not form BF_6^{3-} ion* due to non- availability of d-orbitals.**
- **Aluminium is able to form AlF_6^{-3} ion due to the availability of vacant d-orbitals.**
- **B forms BF_4^- ion.**
- ***Boron forms covalent hydrides which are stable.***

Anomalous properties of boron

- **Boron *never appears as a cation* and does not form B^{+3} ion.**
- **The halides of B except BF_3 *hydrolyse readily and vigorously in water* whereas the other metal halides undergo either partial hydrolysis or no hydrolysis with water.**
- **Boron forms *borides with metals* while others almost do not react.**
- **Boron forms *oxide and nitride* (B_2O_3 , BN) when burnt in air.**

MCQs

1) Anomalous behaviour of Boron is due to…

a) Small size, Non-availability of vacant d-orbitals

b) High EN , High IE

c) Presence of 2 electrons in penultimate shell

d) All the above

2) Boron shows diagonal relationship with-----element.

a) Si

b) Al

c) Mg

d) Na

3) Maximum covalency of B & Al are respectively…

a) 6, 4

b) 4, 6 

c) 6, 6

d) 4, 4

4) Which of the following does not undergo hydrolysis?

a) BCl_3

b) BBr_3

c) BF_3

d) $AlCl_3$

SOME IMPORTANT COMPOUNDS OF BORON

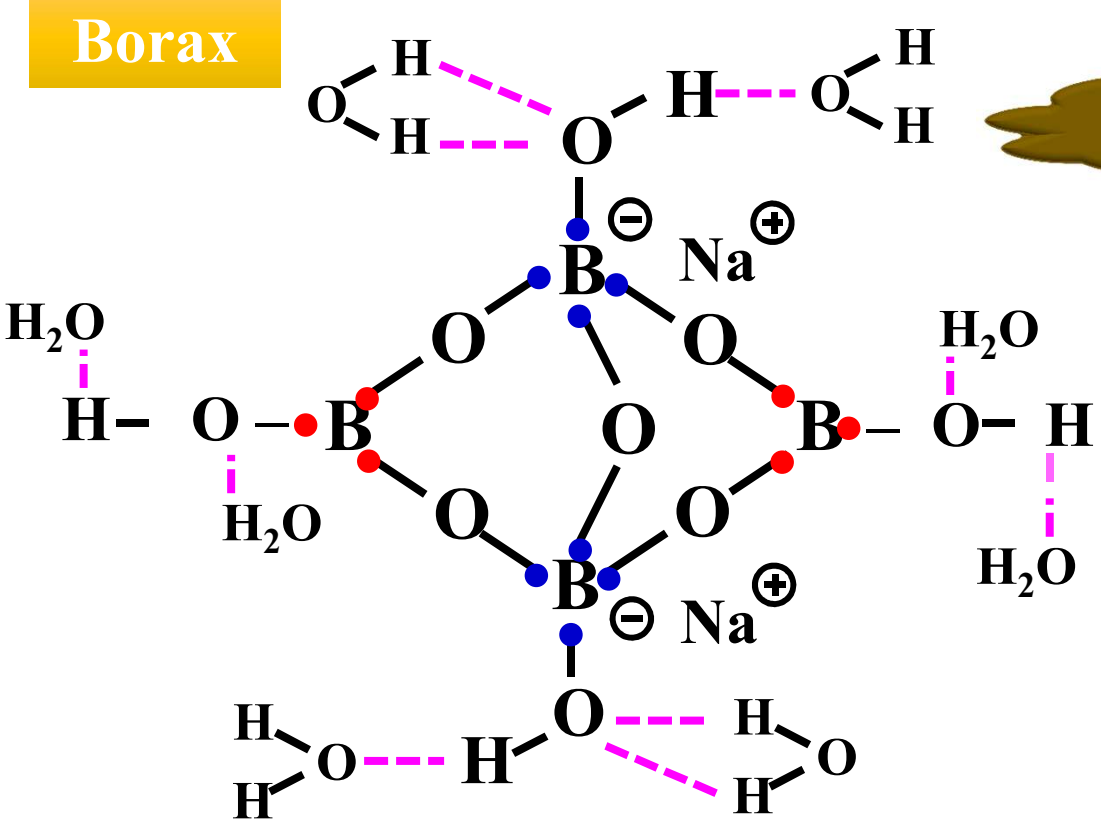
Some important compounds of boron:

- Borax
- Orthoboric acid
- Diborane

Borax

It is white crystalline solid of formula $Na_2B_4O_7.10H_2O$ or $Na_2[B_4O_5(OH)_4].8H_2O$

Borax



Structure of borax

Borax

Borax exists in three crystalline forms.

i) Prismatic borax = $Na_2B_4O_7\ 10H_2O$

ii) Octahedral form = $Na_2B_4O_7\ 5H_2O$

iii) Borax glass = $Na_2B_4O_7$

Preparation of borax

1) From Tincal

Tincal is impure form of borax

Tincal obtained from dried lakes contains about 50% borax.

- **It is *boiled with water* and filtered to remove insoluble impurities.**
- **The *filtrate is concentrated* and finally borax is obtained.**

Preparation of borax

2) From colemanite ($Ca_2B_6O_{11}$) :

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

On cooling of sodium tetraborate, crystals of borax separate out.

$$Ca_2B_6O_{11} + 2Na_2CO_3 \xrightarrow{(\Delta)} Na_2B_4O_7 + 2NaBO_2 + 2CaCO_3$$

(Colemanite) (aq. Sodium carbonate) (Sodium tetraborate) (Sodium meta borate) (Calcium carbonate)

Preparation of borax

3) From Boric acid (H_3BO_3) :

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

$$4\,H_3BO_3 + Na_2CO_3$$

(Boric acid) | (aq. Sodium carbonate)

$$\downarrow$$

$$Na_2B_4O_7 + 6H_2O + CO_{2\,(g)}$$

(Sodium tetraborate)

2) Formula of Colemanite is…

a) $Ca_2B_4O_7.10H_2O$

b) $Ca_2B_6O_7.8H_2O$

c) $Ca_2B_6O_{11}.5H_20$ ✓

d) $Ca_2B_4O_7.5H_2O$

3) The number of moles of borax obtained from Colemanite is --- (from the stoichiometry of the reaction)

a) 1

b) 2

c) 3

d) 4

4) Borax contains

a) Four triangular units

b) Four tetrahedral units

✓c) Two tetrahedral units & Two triangular units

d) Three tetrahedral units & Three triangular units

PROPERTIES OF BORAX

Properties of borax

i) It is *less soluble in cold water but more soluble in hot water.*

ii) Borax dissolves in water to give an alkaline solution

$$Na_2B_4O_7 + 7H_2O \longrightarrow 2NaOH + 4H_3BO_3$$

Properties of borax

iii) Action of heat – Borax bead test.

This test is useful in the identification of basic radicals in qualitative analysis.

On heating, borax loses its water of crystallisation and swells up to form a puffy mass.

On further heating, it breaks into sodium metaborate and boric anhydride which on solidification appears as a transparent glass like bead.

Properties of borax

iii) Action of heat – Borax bead test.

(BORAX powder)

$Na_2B_4O_7.10H_2O$

Borax(Tincal)

(Platinum loop)

$\xrightarrow{(\Delta)}$

$- 10\ H_2O$

$Na_2B_4O_7$

(Borax)

$\xrightarrow{(\Delta)}$

(BORAX bead)

$2\ NaBO_2 + B_2O_3$

(Sodium meta borate)

(Boric anhydride)

Properties of borax

iii) Action of heat – Borax bead test.

The glassy bead is commonly known as borax bead.

- It is used as a qualitative analysis for the detection of certain coloured basic radicals such as

Ni^{2+}, Co^{2+}, Cr^{3+}, Cu^{2+}, Mn^{2+} etc.

Properties of borax

iii) Action of heat – Borax bead test.

Example:

$$CoO + B_2O_3 \xrightarrow{(\Delta)} Co(BO_2)_2$$

(Cobalt oxide) *(Borax bead)* (Cobalt meta borate)

(Blue coloured bead)

$$NiO + B_2O_3 \xrightarrow{(\Delta)} Ni(BO_2)_2$$

(Nickel oxide) *(Borax bead)* (Nickel meta borate)

(Violet coloured bead)

Some other

S.No	Basic Radical	Metal metaborate formed	Colour of the bead
1	Cu^{2+}	$Cu(BO_2)_2$	Green
2	Fe^{2+}	$Fe(BO_2)_2$	Greenish
3	Cr^{3+}	$Cr(BO_2)_3$	Yellow
4	Mn^{2+}	$Mn(BO_2)_2$	Violet

the colours in table

l test

MCQs

1) Formula of borax bead is…

a) $Na_2B_4O_7.10H_2O$

b) B_2O_3 ✓

c) $Na_2B_4O_7$

d) H_3BO_3

2) Borax is alkaline due to …….. hydrolysis

✔ **a) cation**

b) anion

c) Both a & b

d) None of above

3) Colour of $Co(BO_2)_2$ is

a) Green

b) Yellow

c) Violet

d) Blue

USES OF BORAX
&
ORTHO BORIC ACID

MCQs

1) Formula of borax s…

a) ✔ $Na_2B_4O_7.10H_2O$

b) $Na_2B_4O_7.8H_2O$

c) $Na_2B_4O_7$

d) $Na_2B_4O_7.5H_2O$

Uses of borax

Borax is used..

a) in the manufacture of *optical and hard glasses.*

b) in making enamels and paints for *earthen pots.*

c) as a mild antiseptic in the preparation of medicinal soaps.

Uses of borax

Borax is used..

d) also used as a food preservative.

e) as a flux in soldering & welding.

f) in the BORAX BEAD TEST.

2) Ortho boric acid (Boric acid):

H_3BO_3 is a white crystalline solid, with soapy touch.

It is sparingly soluble in cold water but highly soluble in hot water.

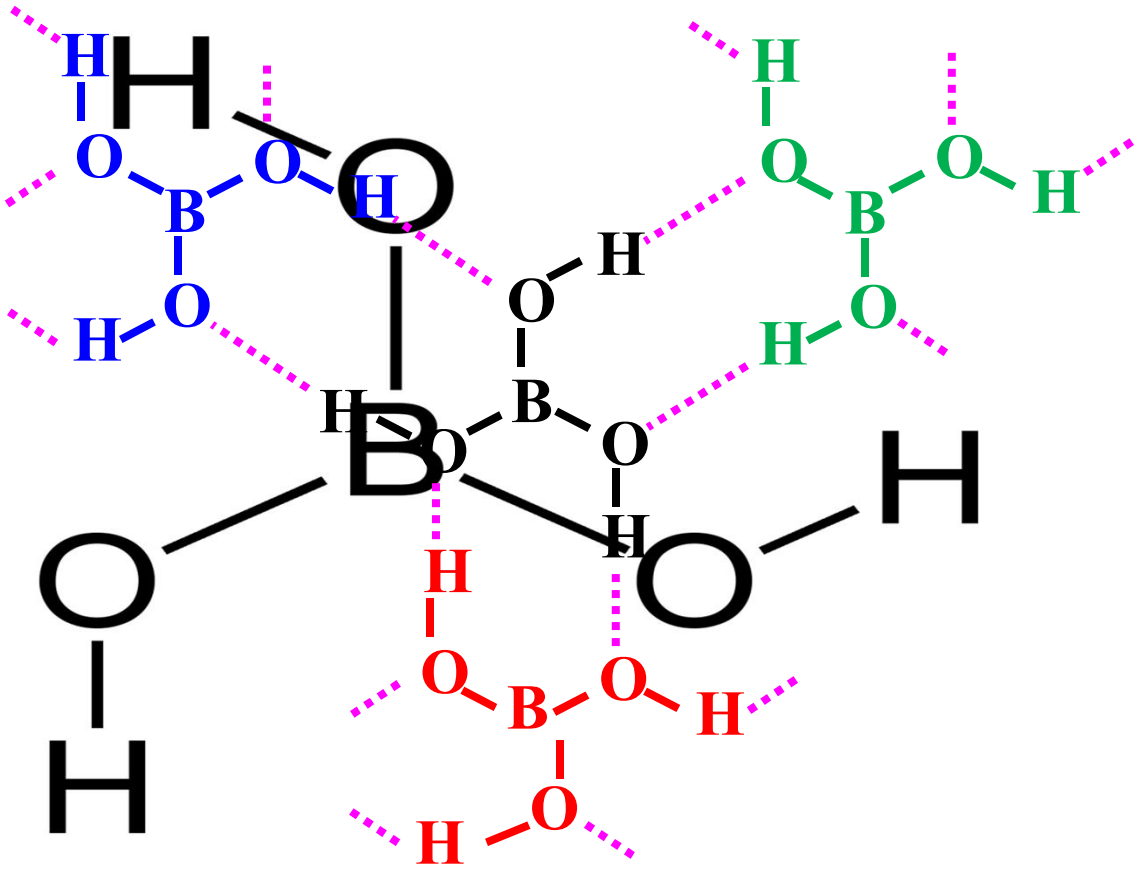
2) Ortho boric acid (Boric acid):

- **It can be prepared by acidifying an aqeuous solution of borax.**

$$\underbrace{Na_2B_4O_7 + 5H_2O}_{\text{(aq. Borax solution)}} + 2HCl \xrightarrow{(\Delta)} 4H_3BO_3 + 2NaCl$$

Ortho boric acid

- **It has a layered structure in which planar BO_3 units are joined by hydrogen bonds.**



Structure

Ortho boric acid

$(H_3BO_3)_n$

MCQs

1) The formula of Boric acid is …

a) H_3BO_3

b) HBO_2

c) H_2BO_3

d) H_3BO_4

2) In the layered structure of boric acid, the planar units of BO_3 are joined by…

✔ **a) Hydrogen bonds**

b) Metallic bonds

c) Coordinate covalent bonds

d) Weak van der waal's forces of attraction

3) Which of the following are the uses of Borax?

a) As a food preservative

b) Reagent in borax bead test

c) As a mild antiseptic in medicinal soaps

d) All of these

PROPERTIES
&
USES OF BORIC ACID

Properties of boric acid

Acidic nature:

- **Boric acid is a weak monobasic acid.**

- **It is not a protonic acid but acts as a Lewis acid by accepting a pair of electrons from a hydroxyl ion of water.**

Properties of boric acid

Action of heat

- On heating orthoboric acid above 370k we get metaboric acid, HBO_2 which on further heating gives boric oxide (B_2O_3).

$$H_3BO_3 \xrightarrow{375k} HBO_2 \xrightarrow{\Delta} B_2O_3$$

Ortho boric acid — Metaboric acid — Boric anhydride or Boron trioxide

$$4\,H_3BO_3 \xrightarrow{435k} H_2B_4O_7 \xrightarrow{\Delta} B_2O_3$$

tetraboric acid

Uses of Boric acid :

Boric acid is used…

- **In manufacturing heat resistant glasses.**
- **In the manufacture of enamels & glazes in pottery.**
- **Also used as a food preservative.**
- **As a mild antiseptic for eye wash under the name boric lotion.**

Question:

Why is Boric acid considered as a weak acid?

Solution:

- **Because it is not able to release H^+ ions on its own.**

It accepts OH^- ions from water molecule to complete its octet and in turn releases H^+ ions.

$$B(OH)_3 + HOH \longrightarrow [B(OH)_4]^- + H^+$$

MCQs

1) Boric acid is a …….. weak acid.

a) tribasic

b) dibasic

✓ monobasic

d) tetrabasic

2) H_3BO_3 is…

a) a Bronsted acid

b) an Arrhenius acid

c) a Lewis base

d) a Lewis acid

3) Carom board powder is made of …

a) Boric acid

b) Lactic acid

c) Fructose

d) Thallous acid

BORON HYDRIDES

Boron Hydrides :

The binary compounds of boron with hydrogen are called boron hydrides or boranes

These hydrides can be divided into two series.

I) $B_n H_{n+4}$ (nido-boranes)

II) $B_n H_{n+6}$ (arachno-boranes)

Latin *nidus* = "nest"

arachno = "spider's web"

Boron Hydrides :

These hydrides can be divided into two series.

$B_n H_{n+4}$	$B_n H_{n+6}$
e.g.	e.g.
$B_2 H_6$ (Di borane)	$B_4 H_{10}$ (tetra borane - 10)
$B_5 H_9$ (penta borane -9)	$B_5 H_{11}$ (penta borane - 11)
$B_6 H_{10}$ (hexa borane - 10)	$B_6 H_{12}$ (hexa borane - 12)
$B_8 H_{12}$ (octa borane - 12)	$B_8 H_{14}$ (octa borane - 14)
$B_{10} H_{14}$ (deca borane - 14)	$B_9 H_{15}$ (nona borane - 15)

:: Make a note ::

- **Boranes have gained importance as potential high energy fuels, in view of their high heat of combustion.**
- **These are better fuels than the hydrocarbons.**
- **Heat of combustion of diborane is much higher than that of ethane.**

Diborane:

- **The simplest Boron hydride is diborane.**
- **It is prepared by treating borontrifluoride with $LiAlH_4$ in the presence of diethyl ether**

$$4BF_3 + 3LiAlH_4 \xrightarrow{diethyl\ ether} 3B_2H_6 + 3LiF + 3AlF_3$$

Preparation of diborane

1) Laboratory Method:

- **Oxidation of sodium borohydride with Iodine.**

$$2NaBH_4 + I_2 \rightarrow B_2H_6 + 2NaI + H_2$$

Preparation of diborane

2) Industrial method:

- **Diborane is produced on an industrial scale by the reaction of BF_3 with sodium hydride.**

$$6\,NaH + 2\,BF_3 \xrightarrow{450\ K} B_2H_6 + 6\,NaF$$

(Sodium hydride) (Boron tri fluoride) Di borane

MCQs

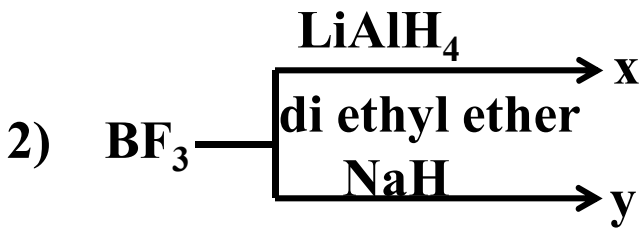
1) B_2H_6 is…

a) closo borane

b) nido borane

c) arachno borane

d) clado borane

2) 

Products x, y are…

a) B_2H_6 , B_2H_6

b) B_2H_6 , B_5H_9

c) B_5H_9 , B_4H_{10}

d) B_2H_6 , B_4H_{10}

3) B_2H_6 is…

a) an electron rich compound

b) an electron deficient compound

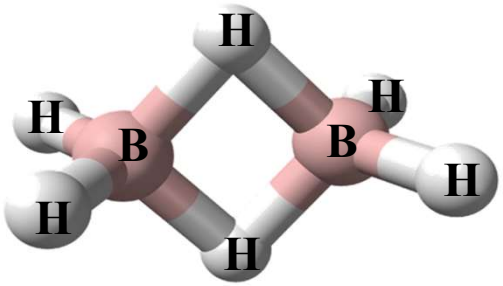
c) an electron surplus compound

d) a super electron rich compound

PROPERTIES OF DIBORANE

Properties of Diborane :

1) Diborane is a colourless gas with foul smell.



2) It is stable at low temperatures in the absence of grease and moisture.

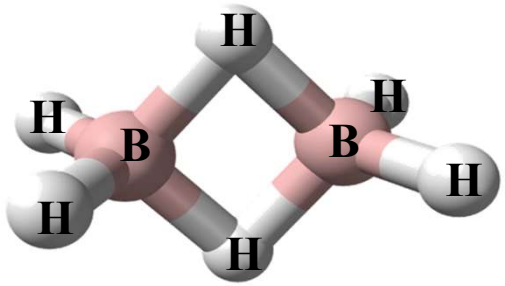
3) At high temperature, it decomposes to give other hydrides of boron.

4) It is dimer of BH_3 which does not exist as a monomer.

5) It readily reacts with water giving boric acid and hydrogen gas.

$$B_2H_6 + 6H_2O \rightarrow 2H_3BO_3 + 6H_2$$

Properties of Diborane :



1) Physical state:

It is a colorless, highly toxic gas with a boiling point of 180K.

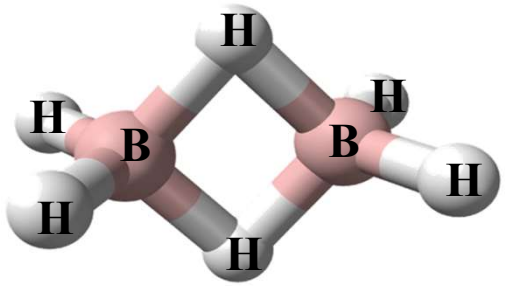
2) Combustibility:

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

$$B_2H_6 + 3O_2 \rightarrow B_2O_3 + 3H_2O;\ \Delta_C H^0 = -1976\ kJmol^{-1}$$

Properties of Diborane :

3) Hydrolysis:

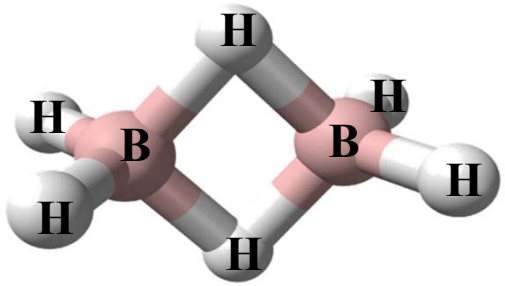


Diborane is readily hydrolyzed by water to form boric acid.

$$B_2H_6\,(g) + 6H_2O\,(l) \rightarrow 2H_3BO_3\ \ (aq) + 6H_2\,(g)$$

Properties of Diborane :

4) Reaction with Lewis bases:



Diborane undergoes cleavage reactions with Lewis bases (L) to give borane adducts ($BH_3.L$).

$$B_2H_6 + 2\,N(CH_3)_3 \longrightarrow 2\,H_3B \leftarrow N(CH_3)_3$$

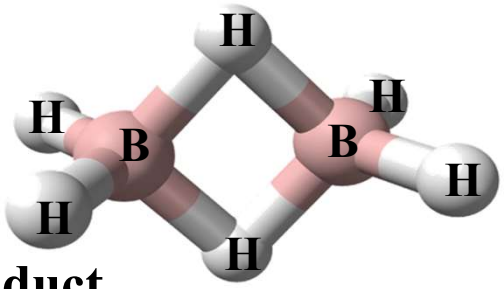
(Diborane) (Tri methyl amine) (Adduct)

$$B_2H_6 + 2\,CO \longrightarrow 2\,H_3B \leftarrow CO$$

(Diborane) (Carbon monoxide) (Adduct)

Properties of Diborane :

5) Reaction with ammonia:



It combines with ammonia to form an addition product.

$3\ B_2H_6 + 6\ NH_3 \longrightarrow B_2H_6.2NH_3$ or Diammonate diborane

(Diborane) (ammonia)

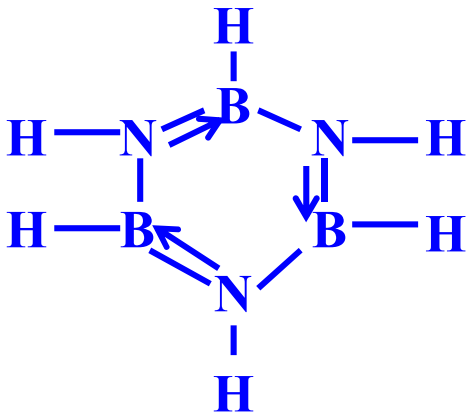
$3\ [BH_2(NH_3)_2]^{\oplus}[BH_4]^{\ominus}$

(Adduct)

$\xrightarrow{(\Delta)\ /\ 473\ K}\ 2\ B_3N_3H_6 + 12\ H_2$

(Borazole) (Di hydrogen)

The structure of borazole ($B_3N_3H_6$) is similar to that of benzene and hence it is called Inorganic benzene.

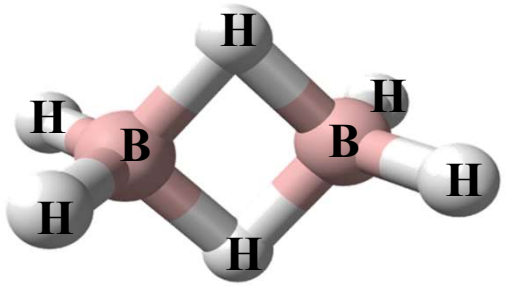


Borazole

NOTE : Borazole is i) iso structural ii) iso electronic with benzene

Properties of Diborane :

6) Reaction with metal hydride:



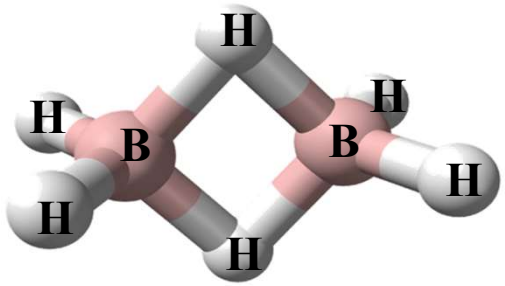
- Several metal hydrides react with diborane to form *tetrahydridoborates or borohydrides*.

$$2\,M^{\oplus}H^{\ominus} + B_2H_6 \xrightarrow[\text{ether}]{\text{Di ethyl}} 2\,M^{\oplus}[BH_4]^{\ominus}$$

(Metal hydride) (Diborane) (Metal borohydride)

Properties of Diborane :

6) Reaction with metal hydride:



Example:

$$2\,LiH + B_2H_6 \xrightarrow[\text{ether}]{\text{Di ethyl}} 2\,Li[BH_4]$$

(Lithium hydride) (Diborane) (Lithium borohydride)

$$2\,NaH + B_2H_6 \xrightarrow[\text{ether}]{\text{Di ethyl}} 2\,Na[BH_4]$$

(Sodium hydride) (Diborane) (Sodium borohydride)

Diborane gives H_2 with

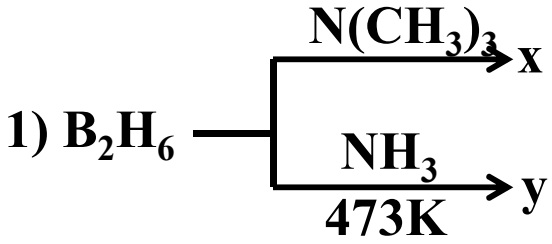
i) H_2O ii) HCl in $AlCl_3$ iii) KOH_{aq} iv) NH_3

$$B_2H_6 + 6H_2O \rightarrow 2H_3BO_3 + 6H_2$$

$$B_2H_6 + 2KOH + 2H_2O \rightarrow 2KBO_2 + 6H_2$$

$$3B_2H_6 + 6NH_3 \xrightarrow{200^0C} 2B_3N_3H_6 + 12H_2$$

MCQs



x,y are respectively…

Answer

a) $H_3B \leftarrow N(CH_3)_3$ only

b) $B_3N_3H_6$, $H_3B \leftarrow N(CH_3)_3$

c) ✓ $H_3B \leftarrow N(CH_3)_3$, $B_3N_3H_6$

d) $B_3N_3H_6$, $B_3N_3H_6$

2) The LiH acts as

a) reducing agent

b) oxidizing agent

c) complexing agent

d) dehydrating agent

3) In LiH, the negatively charged species is

a) Li

b) H

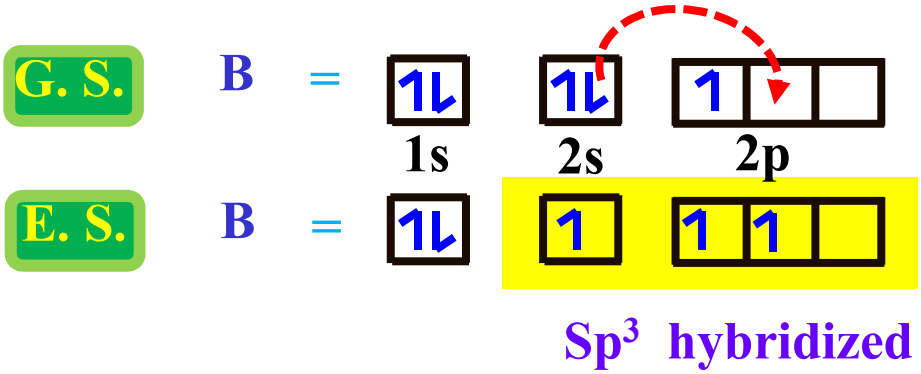
c) Li^+

d) H^- ✓

STRUCTURE AND USES OF DIBORANE

Structure of Diborane :

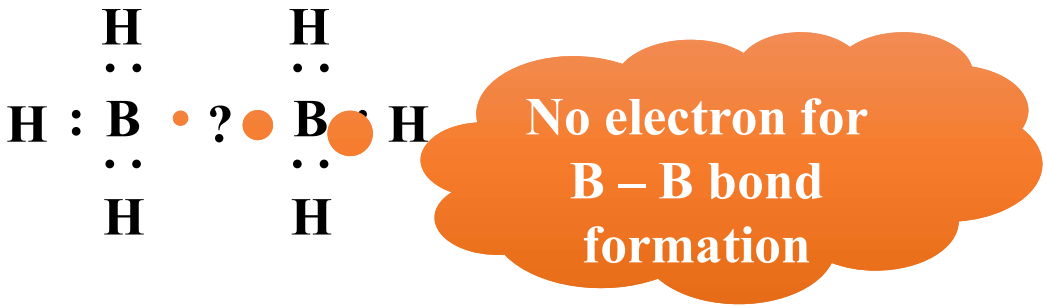
- **The structure of diborane is very interesting. In diborane, each boron atom has 3 valance electrons for sharing.**



Sp^3 hybridized

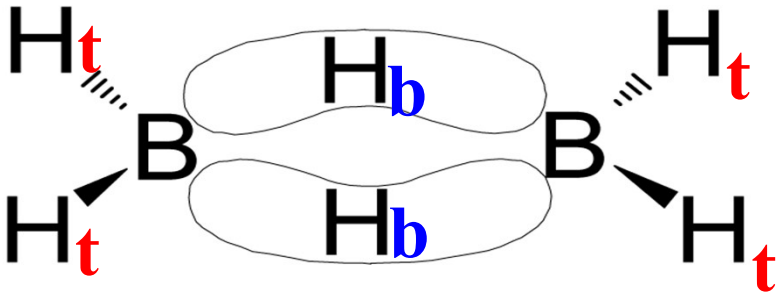
Structure of Diborane :

- If we assume that each boron atom forms 3 covalent bonds with 3 hydrogen atoms then there will be no electrons left with boron atom for sharing with other boron atom.

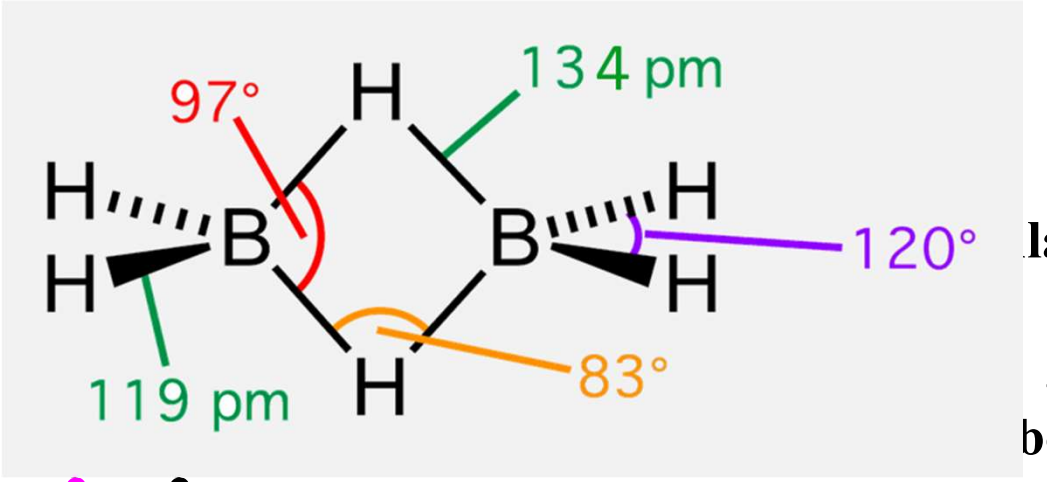


Structure of Diborane :

- Four terminal hydrogen atoms and two boron atoms lie in one plane.
- One hydrogen is above the plane and the other hydrogen is below the plane.
- There are two hydrogens are called *bridge hydrogen atoms.*

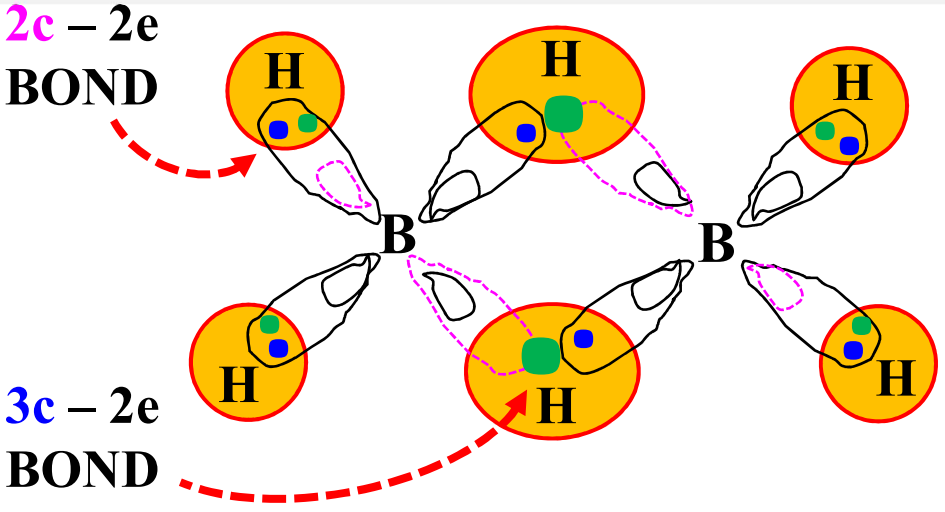


Therefore, by Raman and NMR spectral studies, it is confirmed that four hydrogens of diborane are of one type and the remaining two hydrogen atoms are of another type.



lar two centred – two electron

are different and can be bonds (3C-2e$^-$)



3C– 2e$^-$ bonds also called banana bonds or Tau – bonds ($sp^3 – s – sp^3$)

Methylation of B_2H_6 gives $Me_4B_2H_2$

Uses of Diborane:

- **It is used as a catalyst in polymerisation reactions.**
- **It is used as a reducing agent in organic reactions.**
- **It is used for making high energy fuels and propellants.**
- **It is used for preparing hydrocarbons, alcohols, ketones and acids through hydroboration method.**

MCQs

1) What is the hybridization of boron in diborane?

a) sp^2

b) sp

c) sp^3

d) none

2) Number of 3-centred -2 electron bonds in diborane is…

a) 2

b) 3

c) 4

d) 6

3) The bond angle between boron and bridige hydrogens…

a) 97^0

b) 121^0

c) 135^0

d) 99^0

USES OF BORON AND ALUMINIUM

Uses of Boron :

acture of heat resistant glasses.

ry as control rods.

increasing the

Uses of Aluminium :

- **Aluminium is used for making household utensils, trays, frames, etc.**
- **It is used for making electrical cables, in the form of foils for wrapping cigarettes, chocolates, etc.**
- **It is used for making alloys which are used in making parts of air crafts, automobiles and speed boats.**
- **It is used as a deoxidiser for removing blow holes in metallurgy.**

Uses of Aluminium :

- **It is used in thermit process for the extraction of Fe, Cr, Mn, etc.**
- **It is used in chemical plants and for transporting nitric acid since it is not attacked by nitric acid.**
- **It is used for painting iron surface in the place of tin and zinc.**
- **'Al' powder + NH_4NO_3 is called ammonal.**
- **It is an explosive compound.**

Alloys of Aluminium:

Alloys of aluminium are light, strong and possess high mechanical and tensile strength.

Alloys of Aluminium:

Alloy name	% composition / Uses
Aluminium bronze	Al (10%) + Cu (90%) - Coins, utensils & jewellery.
Magnalium	Al (90%) + Mg (10%) - Balance beams & machinery.
Duralumin	Al(95%) +Mg(1%) +Cu(3%) +Mn(1%) - aeroplanes & automobile parts.
Alnico	Al(20%)+Ni(20%)+Co(10%)+Fe(50%) - permanent magnets.

:: Make a note ::

The use of aluminium and its compounds for domestic purposes is now reduced because of their toxic nature.

MCQs

1) Which is used as a control rod in nuclear industry?

a) B^{11}

b) B^{10}

c) B^{10} and B^{11}

d) B^{12}

2) Al - vessel is used for the transport of …

a) HNO_2

b) H_2SO_4

✓ HNO_3

d) HCl

3) Ammonal is a mixture of …

✔ **a) NH_4NO_3 + Al powder**

b) HNO_3 + Al powder

c) NH_3 + Al powder

d) NH_4Cl + Al powder

4) Alnico contains…

a) Al + Ni

b) Al + Cu

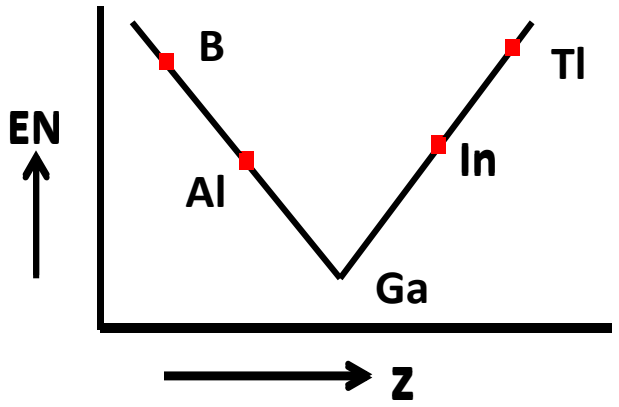
c) Al + Ni + Co

✓ d) Al + Ni + Co + Fe

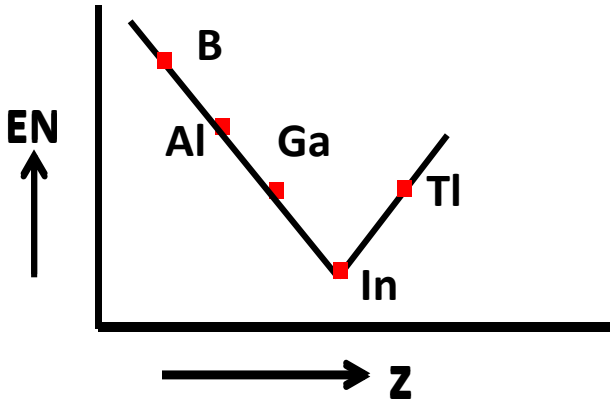
PYQS

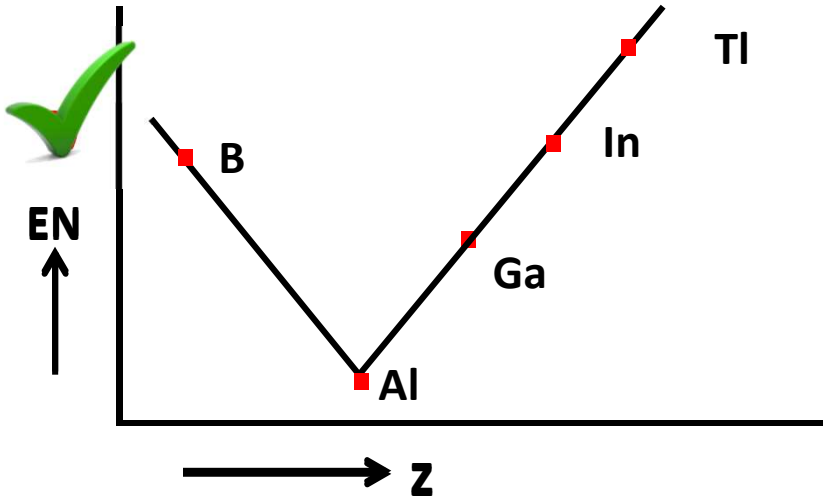
1) **Which one of the following correctly represents the variation of electronegativity(EN) with atomic number (z) of group 13 elements? (E—2014)**

1)

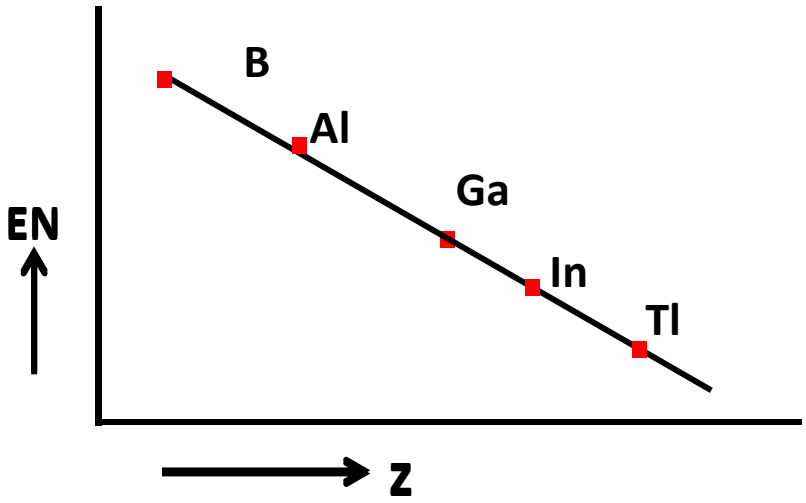


2)





4)



2) In the following sets of reactants which two sets best exhibit the amphoteric character of

SET 1 : $Al_2O_3.xH_2O$ (s) and OH^- (aq)

SET 2 : $Al_2O_3.xH_2O$ (s) and H_2O (aq)

SET 3 : $Al_2O_3.xH_2O$ (s) and H^+ (aq)

SET 4 : $Al_2O_3.xH_2O$ (s) and NH_3 (aq)

1) 1 and 2 2) 1 and 3 3) 2 and 4 4) 3 and 4

Solution : In the presence of base and acid medium $Al_2O_3.xH_2O$ acts as amphoteric

3) Diboran reacts with HCl in the presence of $AlCl_3$ and liberates (E-2013)

1) H_2

2) Cl_2

3) BCl_3

4) Cl_2 & BCl_3

4) Observe the following statements

1) H_3BO_3 is used as antiseptic

2) In B_2H_6 , each boron is sp^2 hybridised

3) Aqueous solution of borax is alkaline in nature (M-2013)

The correct statements are

1) 1 & 2 2) 2 & 3 3) 1, 2 & 3 4) 1 & 3

5) What is Z in the following reactions? (EAMCET-2012)

$$BCl_3 + H_2 \xrightarrow[450^0C]{Cu\text{-}Al} X + HCl$$

$$X \xrightarrow{Methylation} Z$$

1) $(CH_3)BH_2$ 2) $(CH_3)_4B_2H_2$ 3) $(CH_3)_3B_2H_3$ 4) $(CH_3)_6B_2$

Solution :

$X = B_2H_6$ $Z = (CH_3)_4B_2H_2$

6) Electronegativity of group 13 elements follow the order
(EAMCET-2011)

1) B > Ga > Al > Tl > In

2) B> Tl > Ga > Al > In

3) B> Tl > In > Ga > Al

4) B> Al > Tl > In > Ga

7) **Boron cannot form which one of the following anions?**
(A-2011)

1) BO_2^-

2) BF_6^{3-}

3) BH_4^-

4) $B(OH)_4^-$

8) **Diboran reacts with ammonia under different conditions to give a variety of products. which one among the following is not formed in these reactions?**

(E-2010)

1) $B_2H_6.2NH_3$

2) $B_{12}H_{12}$

3) $B_3N_3H_6$

4) $(BN)_n$

9) **Aluminium reacts with NaOH and forms compound 'X'. If the coordination number of aluminium in 'X' is 6, the correct formula of X : (E-2009)**

1) $[Al(H_2O)_4(OH)_2]^-$

2) $[Al(H_2O)_3(OH)_2]$

✔ 3) $[Al(H_2O)_2(OH)_4]^-$

4) $[Al(H_2O)_6](OH)_3$

10) The chemical formula of Feldspar is

1) $KAlSi_3O_8$

2) Na_3AlF_6

3) $NaAlO_5$

4) $K_2SO_4.Al_2(SO_4)_3.4Al(OH)_3$

Solution :

11) The number of sigma and pi(π) bonds present in 'inorganic benzene' respectively are (E-2006)

1) 12 , 6

2) 6 , 6

3) 6 , 12

4) 12 , 3 ✓

12) Heating an aqueous solution of aluminium chloride to dryness will give (A-2005)

1) $AlCl_3$

2) Al_2Cl_6

3) Al_2O_3 ✓

4) $Al(OH)Cl_2$

13) The structure of diborane B_2H_6 contains

1) four 2c-2e bonds & two 3c-2e bonds

2) two 2c-2e bonds & four 3c-2e bonds

3) two 2c-2e bonds & two 3c-2e bonds

4) four 2c-2e bonds & four 3c-2e bonds

14) **Aluminium chloride exists as dimer. Al_2Cl_6 in solid state as well as in solution of non polar solvents such as benzene. When dissolved in water , it gives (AIEEE-2004)**

1) $[Al(OH)_6]^{3-} + 3\ HCl$ 2) $[Al(H_2O)_6]^{3+} + 3\ Cl^-$

3) $Al^{3+} + 3Cl^-$ 4) $Al_2O_3 + 6\ HCl$

Solution : In presence of base and acid medium

$Al_2O_3.xH_2O$ acts as amphoteric

15)The molecular formula of potash alum is

(E - 2004)

1) $KAl_2S_4H_{48}O_{40}$

2) $KAl_2S_4H_{48}O_{39}$

3) $K_2Al_2S_4H_{48}O_{40}$

4) $K_2Al_2S_4H_{48}O_{10}$

16) Thermit is a mixture of X parts of ferric oxide and Y parts of aluminium powder . X and Y respectively are . (E - 2002)

1) 3 : 1 **2) 1 : 3** **3) 3 : 2** **4) 2 : 3**

17) During the electrolytic reducting of alumina, the reaction at cathode is ……. (E - 2004)

1) $2H_2O \rightarrow O_2 + 4H\ e^-$

2) $3F^- \rightarrow 3F + 3e^-$

3) $Al^{3+} + 3e^- \rightarrow Al$ ✓

4) $2H^+ + 2e^- \rightarrow H_2$

18) The ratio of moles of hydrogen produced when two moles of aluminium react with excess HCl and NaOH separately is : (M - 2009)

1) 1 : 1

2) 2 : 1

3) 2 : 1

4) 3 : 2

19) A mixture of boron trichloride and hydrogen is subjected to silent electric discharge to form *A* and *HCl*. *A* is mixed with NH_3 and heated to 200^0C to form *B*. The formula of '*B*' is (M - 2008)

1) H_3BO_3

2) B_2O_3

3) $B_3N_3H_6$ ✓

4) B_2H_6

20) Except B and Al, all other III group elements exhibit +1 oxidation state. This is because (M-2007)

1) They are 'p' block elements

2) Their first ionization energy is less

3) They have low melting point

4) Due to inert pair effect

21) Which of the following is not correct ? **(M-2006)**

1) 'Al' reacts with NaOH and liberate H_2

2) $AlCl_3$ is Lewis acid

3) 'Al' is used in the manufacture of electrical cables

4) NaOH is used during Halls process of purification of bauxite.

22) What are X and Y respectively in the following reaction

$B_2H_6 + 2KOH + 2X \rightarrow 2Y + 6H_2$ **(M-2004)**

1) $K_2O_6.H_2O$

2) H_2, H_3BO_3

3) H_2O, KBO_2

4) H_2O_2, H_3BO_2

23) In the reaction $B_2H_6 + 2KOH + 2X \rightarrow 2Y + 6H_2$ **X and Y are respectively** **(M-2003)**

1) H_2, H_3BO_3

2) HCl, KBO_2

3) H_2O, KBO_3

4) ✓ H_2O , KBO_2

24) Which one of the following elements is a non metal ? (M-2002)

1) B

2) In

3) Na

4) Mg

25) An element M reacts with chlorine to form a compound X, the bond angle X is 120^0. What is M ? (M-2002)

1) Be

2) B

3) Mg

4) N

26) 'Al' reacts with hot conc.H_2SO_4 to liberate (M-2002)

1) SO_2

2) H_2S

3) SO_3

4) S vapour

27)Aluminium reacts with concentrated HCl and concentrated NaOH to liberate the gases …….. respectively. (M-2001)

1) H_2 and O_2

2) O_2 and H_2

3) H_2 and H_2

4) O_2 and O_2

28) What is the formula of diaspore ? **(M-2000)**

1) $Al_2O_3 . 2H_2O$

2) Al_2O_3

3) $Al_2O_3. H_2O$ ✓

4) $AlPO_4$

29) Which of the following is an electron deficient compound? (M-2000)

1) NaCl

2) NaOH

3) B_2H_6

4) KCl

30) Which one of the following elements does not form triiodide on reacting with iodine?

1) B

2) Tl

3) Al

4) Ga

31) identify the reaction which does not liberate hydrogen: (J.M.O.L-2016)

1) Reaction of lithium hybride with B_2H_6

2) Electrolysis of acidified water using Pt electodes.

3) Reaction of zinc with aqueous alkali

4) Allowing a solution of sodium in liquid ammonia to stand

Solution : **Sodium is added to liquid ammonia, producing a solution containing solvated electrons and used as reducing agent.**

$2LiH + B_2H_6 \rightarrow 2Li[BH_4]$ complex and do not liberate H_2

32) Assertion (A): $AlCl_3$ exists as a dimer through halogen bridge bonds.
Reason (R): $AlCl_3$ gets stability by accepting electrons from the bridged halog (Ap E - 2016)

1) Both (A) and (R) are true and (R) is the correct explanation of (A)

2) Both (A) and (R) are true and (R) is not the correct explanation of (A)

3) (A) is true but (R) is false

4) (A) is false but (R) is true

33) Which one of the following forms a basic oxide? **(TS E-2016)**

1) B

2) Tl ✔

3) Al

4) Ga

Solution : $B_2O_3 \rightarrow Acidic\ oxide$

$Al_2O_3 \rightarrow Amphoteric\ oxide$

$Ga_2O_3 \rightarrow Amphoteric\ oxide$

$Tl_2O_3 \rightarrow Basic\ oxide$

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