The p-Block Elements

11

Chapter

EXERCISE

1. Discuss the pattern of variation in the oxidation states of:
(i) B to Tl

Ans: There are $ns^2\ np^1$ elements in group 13. This means that they should show the +3 oxidation state more often. There are two elements that practically exhibit +3 oxidation state: Boron and aluminium. Only Ga, In, and Tl have both +1 and +3 oxidation states. The +1 condition gets more stable as you move along the group. Examples include the fact that Tl (+1) has a higher stability than Tl (+3). Inert pair effect is to blame.

Due to high nuclear attraction, there is no interaction between the two electrons in the s-shell. When this happens, it's called the "inert pair effect". Moving down the group, the inert pair effect becomes more pronounced. As a result, Ga (+1) is unstable, In (+1) is reasonably stable, and Tl (+1) is quite stable. This is given below in the table.

Group 13 elements	Oxidation state
B	+3
Al	+3
Ga, In, Tl	+1, +3

Therefore, we can see that the stability of +3 oxidation state decreases down the group.

(ii) C to Pb

Ans: Elements in group 14 have the electrical configuration of $ns^2\ np^2$. This means their preferred oxidation state should be +4. The +2 oxidation state, on the other hand, gets more and more frequent as the group is descended. When it comes to C and Si, they tend to display the +4 state. The higher oxidation state becomes less stable as you move down the group. Inert pair effect is to blame. In other words, whereas Ge, Sn and Pb have both +2 and+4 states, the lower oxidation state becomes more stable and the higher oxidation state less stable as you move down the group of elements. This is given below in the table.

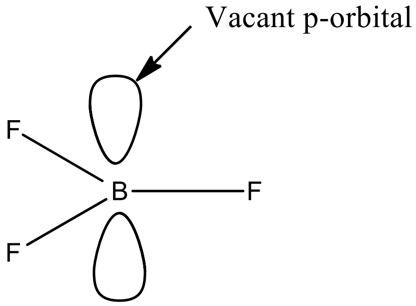
Group 14 elements	Oxidation state
C	+4
Si	+4
Ge, Sn, Pb	+2, +4

2. **How can you explain higher stability of BCl_3 as compared to $TlCl_3$?**

Ans: In the periodic table, group 13 includes elements such as boron and thulium. +1 oxidation state gets more stable as you move down the group in this group. Due to the fact that B's +3 oxidation state is more stable than Tl's, BCl_3 is more stable than $TlCl_3$. This is because Tl's +3 state is highly oxidizing and it quickly reverts back to its more stable +1 form.

3. **Why does boron trifluoride behave as a Lewis acid?**

Ans: Boron has the electronic configuration $2s^2\ 2p^1$. In its valence shell, it possesses three electrons. As a result, it is limited to forming three covalent connections. Boron has just six electrons surrounding it and its octet is incomplete as a result (sextet is available). Sextet is formed when one boron atom is combined with three fluorine molecules. Bifurofluoride, on the other hand, is always electron-deficient and functions as a Lewis acid. The structure of BF_3 is given below:



4. Consider the compounds, BCl_3 and CCl_4. How will they behave with water? Justify.

Ans: As a Lewis acid, BCl_3 is easily hydrolyzed.. As a result, boric acid is produced. The reaction is given below:

$$BCl_3 + 3H_2O \rightarrow 3HCl + B(OH)_3$$

Hydrolysis is impossible with CCl_4. Carbon has no unoccupied orbital in its atomic structure. In order to produce an intermediate, it must take electrons from water in order to do so. In the presence of water, CCl_4 and water forms distinct layers.

$$CCl_4 + H_2O \rightarrow \text{No reaction}$$

5. Is boric acid a protic acid? Explain.

Ans: No, it's an acid, but it's not one of the protic ones. As a Lewis acid, it's a weak monobasic acid with a low pH.

$$B(OH)_3 + 2H_2O \rightarrow [B(OH)_4]^- + H_3O^+$$

Because it accepts two electrons from the OH^- ion, it behaves like an acid.

6. Explain what happens when boric acid is heated.

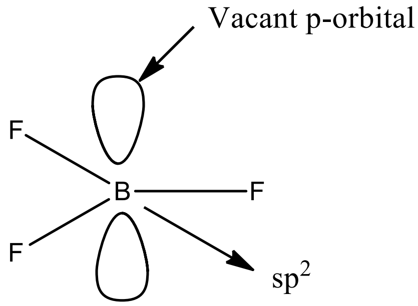
Ans: At 370 K or above, the orthoboric acid (H3BO3) transforms into metaboric acid (HBO2). On additional heating, boric oxide B2O3 is formed. The reaction is given below:

$$H_3BO_3 \xrightarrow[370K]{\Delta} \underset{\text{Metaboric acid}}{HBO_2} \xrightarrow[\text{red hot}]{\Delta} \underset{\text{Boric oxide}}{B_2O_3}$$

7. Describe the shapes of BF_3 and BH_4^-. Assign the hybridization of boron in these species.

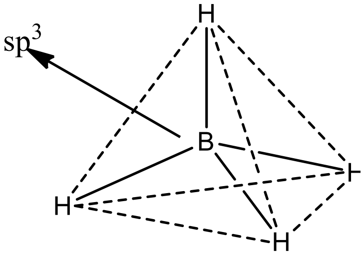
Ans: Let us first understand the BF_3 first.

Boron prefers to produce monomeric covalent halides due to its small size and strong electronegativity. There is a flat triangular geometry to these halides In order to achieve this triangle shape, boron sp^2 hybridized orbitals overlap with p-orbitals of three other elements. It is sp^2 hybridized with Boron in BF_3. The shape of boron trifluoride is given below:



Now, let us discuss about BH_4^-.

By hybridizing boron orbitals in sp^3, boron-hydride (BH_4^-) is produced. Because of this, it is tetrahedral. The shape of boron-hydride ion is given below:



8. Write reactions to justify the amphoteric nature of aluminium.

Ans: Amphoteric substances exhibit both acidic and basic properties. In both acids and bases, aluminium dissolves and exhibits amphoteric behaviour. The reaction is given when the aluminium reacts with hydrochloric acid.

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

The reaction is given when the aluminium reacts with sodium hydroxide.

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

9. What are electron deficient compounds? Are BCl_3 and $SiCl_4$ electron deficient species? Explain.

Ans: When electrons are lacking in a compound, an incomplete octet of electrons is present in the central metal atom. Electrons are therefore required to complete its octet.

(i) BCl_3

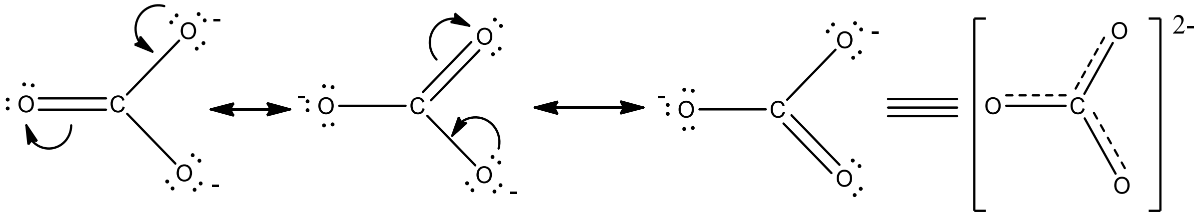
When it comes to electron-deficient compounds, BCl_3 is an excellent example. B contains three electrons in its valence state. Chlorine has six electrons surrounding it after three covalent bonds are formed with it. Two electrons are required to complete the octet.

(ii) $SiCl_4$

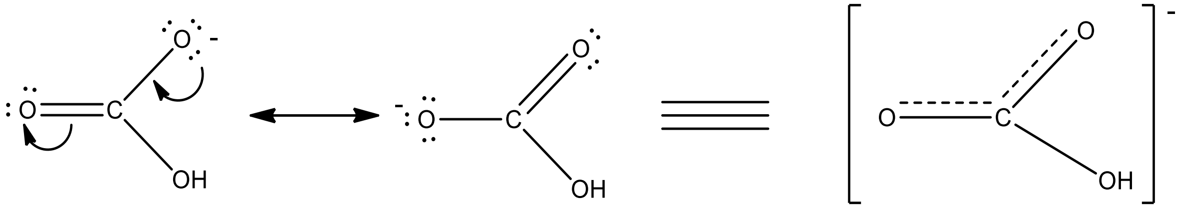
Silicon's electronic configuration is $ns^2\ np^2$. These four valence electrons imply that it contains four electrons. Its electron count climbs to eight when it establishes four covalent connections with four chlorine atoms. Due to its lack of electron deficiency, $SiCl_4$ is not an electron-deficient substance.

10. Write the resonance structures of CO_3^{2-} and HCO_3^{-}.

Ans: The resonating structures of carbonate ion (CO_3^{2-}) is given below:



The resonating structures of bicarbonate ion (HCO_3^{-}) is given below:



11. What is the state of hybridization of carbon in

(a) CO_3^{2-}

Ans: As the carbon atom in carbonate ion (CO_3^{2-}) is bonded to three oxygen atoms so, the hybridization is sp^2.

(b) Diamond

Ans: The hybridization of carbon atom in diamond is sp^3 because each carbon atom is attached with four different carbon atoms.

(c) Graphite

Ans: The hybridization of carbon atom in graphite is sp^2 because each carbon atom is attached with three different carbon atoms.

12. Explain the difference in properties of diamond and graphite on the basis of their structures.

Ans: The different properties of diamond and graphite are listed below in the table.

Diamond	Graphite
There are crystal lattices in the molecule.	It's layered.
The hybridization of carbon atom in diamond is sp^3 because each carbon atom is attached with four different carbon atoms.	The hybridization of carbon atom in graphite is sp^2 because each carbon atom is attached with three different carbon atoms.

There are tetrahedral units	The geometry of the graphite is planar
The length between the C-C bond is 154pm	The length between the C-C bond is 141.5pm
Covalent bonds are extremely stiff, making it difficult to break the bonds of the material.	You can easily separate its layers because it's fairly squishy. Because of this, it has a lubricating effect.
In addition, it functions as an insulator for electronic devices.	It has good electrical conductivity.

13. Rationalize the given statements and give chemical reactions:

(a) Lead (II) chloride reacts with Cl_2 to give $PbCl_4$.

Ans: In the periodic table, lead is in group 14. This group's oxidation states are +2 and +4. The +2 oxidation state gets more stable as one move down the group, whereas the +4 oxidation state becomes less stable. The inert pair effect is responsible for this. Consequently, $PbCl_4$ has a lower stability than $PbCl_2$. When chlorine gas is bubbled through a saturated solution of $PbCl_2$, $PbCl_4$ is formed. The reaction is given below:

$$PbCl_{2(s)} + Cl_{2(g)} \rightarrow PbCl_{4(l)}$$

(b) Lead (IV) chloride is highly unstable towards heat.

Ans: This occurs due to the inert pair effect as you move along group IV. Because Pb(IV) is very unstable, it can be reduced to Pb when heated (II). The reaction is given below:

$$PbCl_{4(l)} \xrightarrow{\Delta} PbCl_{2(s)} + Cl_{2(g)}$$

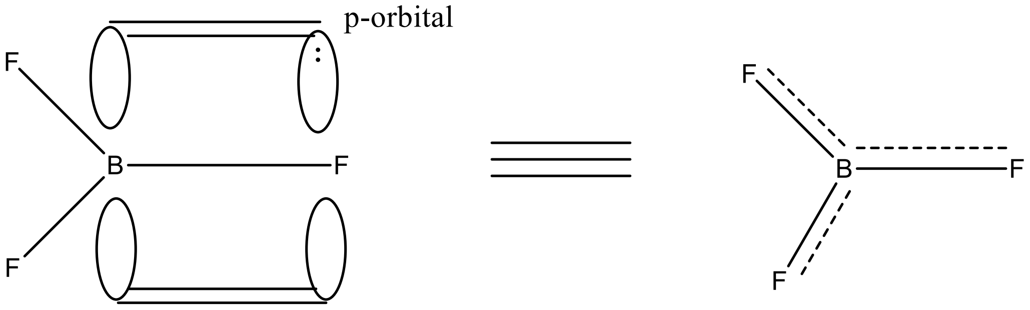
(c) Lead is known not to form an iodide, PbI_4.

Ans: As far as we know, lead does not produce PbI_4. The oxidation of Pb (+4) occurs in nature, while the reduction of I^- takes place in nature. Combining Pb(IV) with iodide ion does not result in stability. The iodide ion is a powerful reducing agent in the environment. I^- is oxidised to I2 by Pb(IV), which is then reduced to Pb (II). The reaction is given below:

$$PbI_4 \rightarrow PbI_2 + I_2$$

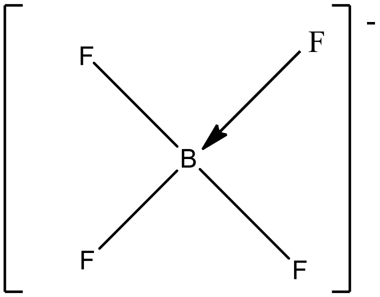
14. Suggest reasons why the B–F bond lengths in BF_3 (130 pm) and BF_4^- (143 pm) differ.

Ans: This is due to the lower B –F bond length in BF_3 as compared to BF_4^-. Emission of BF_3 is limited due to its low electron density. This deficit is remedied by the fluorine and boron nuclei back-bonding each other. As a result, the B–F bond takes on a double bond nature.



p pi - p pi back-bonding

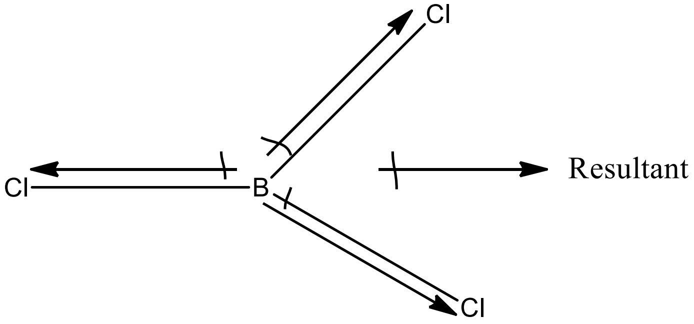
These characters cause the bond length in BF_3 to shrink because of the double bond (130 pm). In contrast, when the BF_3 ion interacts with the fluoride ion, the hybridisation changes from sp^2 (in BF_3) to sp^3. Boron now has four sigma-bonds, and the double-bond feature has been lost as a result of this change. B–F bond length in BF_4^- ion is 143 pm as a result of the above calculation.



Tetrahedral structure

15. If B–Cl bond has a dipole moment, explain why BCl_3 molecule has zero dipole moment.

Ans: The B–Cl bond is polar due to the difference in electronegativities between B and Cl. But the molecule BCl_3 isn't polar. Due to its trigonal planar form, BCl_3 exhibits this property. As the name suggests, it is composed of a pair of symmetrical molecules. Because of this, the B–Cl bond's dipole moments cancel each other out, resulting in a zero dipole moment. The structure showing zero dipole moment of BCl_3 is given below:



Dipole moment = 0

16. Aluminium trifluoride is insoluble in anhydrous HF but dissolves in addition to NaF. Aluminium trifluoride precipitates out of the resulting solution when gaseous BF3 is bubbled through. Give reasons

Ans: Hydrogen fluoride (HF) is a very strong intermolecular hydrogen-bonding covalent molecule. Because of this, it does not contain ions and does not dissolve aluminium trifluoride. Aluminium trifluoride dissolves when sodium fluoride (NaF) is added to the mixture. Due to the availability of free Fluoride anion, this is the case. The reaction which defines this process is given below:

$$AlF_3 + 3NaF \rightarrow \underset{\text{Sodium hexafluoroaluminate(III)}}{Na_3[AlF_6]}$$

Boron trifluoride precipitates from the solution when it is added to it. This is due to the fact that boron has a greater inclination to form complexes than aluminium. So when Boron trifluoride is introduced, B replaces Al in the complex molecules as a result of BF3. The reaction for this is given below:

$$Na_3[AlF_6] + 3BF_3 \rightarrow 3Na[BF_4] + AlF_3$$

17. Suggest a reason as to why CO is poisonous.

Ans: Since carbon monoxide is able to form a compound with haemoglobin, it is extremely toxic. The CO–Hb combination is more stable than the O_2-Hb complex because it contains more hydrogen atoms (CO). As a result of the former, Hb does not bond with oxygen. People die from suffocation when they don't get enough oxygen. About 300 times more stable than O_2, the CO–Hb combination has been discovered.

18. How is excessive content of CO_2 responsible for global warming?

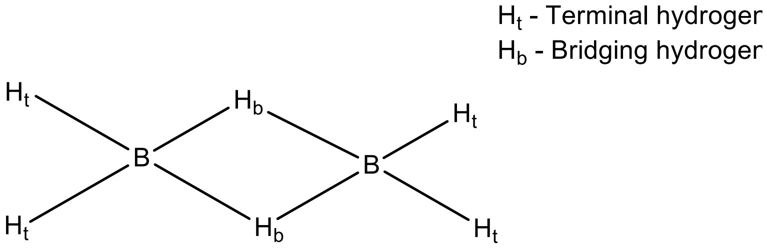
Ans: We cannot survive without carbon dioxide. Increased atmospheric CO_2 levels, on the other hand, are extremely dangerous. Carbon dioxide levels have risen due to an increase in the use of fossil fuels, the breakdown of limestone, and a decrease in the number of trees. Carbon dioxide has the ability to trap solar heat.

The more carbon dioxide in the atmosphere, the more heat is trapped. Global warming is the outcome of a rise in atmospheric temperature.

19. Explain structures of diborane and boric acid.

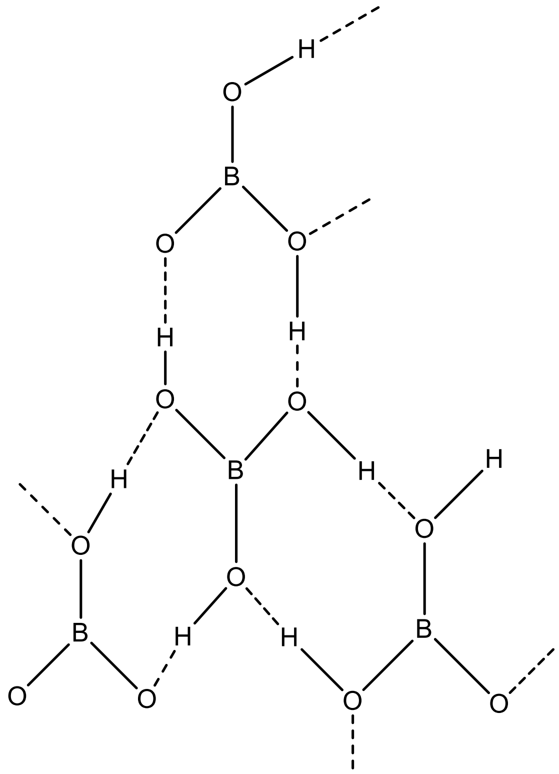
Ans: Diborane

B_2H_6 is a chemical with a low electron density. 6 of the 6-H atoms have electrons, while the two B atoms each have three electrons. Since the boron nuclei have lost all their electrons after merging with three hydrogen nuclei, none of them remain. X-ray studies have shown the structure of the diborane as given below:



As seen in the diagram, two boron molecules and four terminal hydrogen atoms (H_t) are in one plane, while the two remaining bridged hydrogen atoms (H_b) are in an orthogonal plane. In this case, one of the hydrogen atoms is above the plane while the other is below it. Both of the terminal bonds (2c – 2e) and the two bridge bonds (B-H-B) are typical three-centre, two-electron (3c – 2e) bonds.

Boric acid has a multi-layered structure that makes it difficult to dissolve. Planar BO_3^{2-} units are connected by H atoms. Two BO_3^{2-} units are joined together by hydrogen bonds, and the H atoms are joined by covalent bonds with another BO_3^{2-} unit. Those dotted lines indicate hydrogen bonding in the provided figure.



20. What happens when

(a) Borax is heated strongly

Ans: When heated, borax undergoes a number of chemical changes. After losing water molecules, it expands. That transforms into an opaque liquid, which then solidifies into a glass-like substance called borax bead. The reaction is given below:

$$\underset{\text{Borax}}{Na_2B_4O_7.10H_2O} \xrightarrow{\Delta} \underset{\text{Sodium metaborate}}{Na_2B_4O_7} \xrightarrow{\Delta} 2NaBO_2 + \underset{\text{Boric anhydride}}{B_2O_3}$$

(b) Boric acid is added to water

Ans: In water, boric acid absorbs electrons from OH^- ions. The reaction is given below:

$$B(OH)_3 + 2H_2O \rightarrow [B(OH)_4]^- + H_3O^+$$

(c) Aluminium is treated with dilute NaOH

Ans: NaOH and Al react to produce sodium tetrahydroxoaluminate (III). In the process, hydrogen gas is released. The reaction is given below:

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

(d) BF_3 is reacted with ammonia

Ans: Adduct is formed via the chemical reaction between BF_3 (a Lewis acid) and NH_3 (a Lewis base). BF_3 has an octet centred on B. The reaction is given below:

$$F_3B + :NH_3 \rightarrow F_3B \leftarrow :NH_3$$

21. Explain the following reactions

(a) Silicon is heated with methyl chloride at high temperature in the presence of copper;

Ans: At 537 K, silicon combines with methyl chloride in the presence of copper (catalyst) to create methyl substituted chlorosilanes ($MeSiCl_3$, Me_2SiCl_2, Me_3SiCl and Me_4Si), a family of organosilicon polymers. The reaction is given below:

$$\underset{\text{Methyl chloride}}{2CH_3Cl} + Si \longrightarrow CH_3SiCl_3 + (CH_3)_2SiCl_2 + (CH_3)_3SiCl + (CH_3)_4Si$$

(b) Silicon dioxide is treated with hydrogen fluoride;

Ans: If you heat silicon dioxide with hydrogen fluoride, you get silicon tetrafluoride(SiF_4). Even at high temperatures the Si–O bond is usually a strong bond that is resistant to assault by halogens and most acids. HF, on the other hand, is a serious threat to its survival.

$$SiO_2 + 4HF \rightarrow SiF_4 + 2H_2O$$

Hydrofluorosilicic acid may be produced by reacting SiF_4 with HF. The reaction is given below:

$$SiF_4 + 2HF \rightarrow H_2SiF_6$$

(c) CO is heated with ZnO;

Ans: CO reduces ZnO to Zn when it interacts with ZnO. CO acts as a reducing agent. The reaction is given below:

$$ZnO_{(s)} + CO_{(g)} \xrightarrow{\Delta} Zn_{(s)} + CO_{2(g)}$$

(d) Hydrated alumina is treated with aqueous NaOH solution.

Ans: Due to the formation of sodium meta-aluminate, hydrated alumina and sodium hydroxide dissolve one another. The reaction is given below:

$$Al_2O_3.2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$$

22. Give reasons:

(i) Conc. HNO_3 can be transported in aluminium containers.

Ans: Because it interacts with aluminium to create a thin protective oxide layer on the metal surface, concentrated HNO_3 may be kept and carried in containers made of aluminium. It's because of this oxide layer that aluminium is rendered inert.

(ii) A mixture of dilute NaOH and aluminium pieces is used to open the drain

Ans: After reacting with aluminium, sodium tetrahydroxoaluminate(III) and hydrogen gas are produced. Drains can be unlocked using the pressure of the hydrogen gas that is generated. The reaction is given below:

$$2Al + 2NaOH + 6H_2O \rightarrow 2Na^+[Al(OH)_4]^- + 3H_2$$

(iii)Graphite is used as lubricant.

Ans: Graphite has a layered structure, with weak van der Waals forces holding the layers together. Each of these levels may be stacked on top of one another. Graphite is a smooth, slick material that is easy to work with. Graphite can therefore be used as a lubricant.

(iv)Diamond is used as an abrasive.

Ans: Carbon is sp^3 hybridised in diamonds. Each carbon atom is covalently linked to four other carbon atoms. As a result of the presence of covalent connections on the surface, it has a highly rigid 3-D structure This prolonged covalent connection is extremely difficult to break, which is why diamond is the hardest material known.

Thus, it is used as an abrasive and for cutting tools.

(v) Aluminium alloys are used to make aircraft bodies.

Ans: High tensile strength and low weight are two of the advantages of aluminium. Metals like Cu, Mn, Mg, Si and Zn can be alloyed with it. Because of its flexibility and ductility, it can be shaped into almost any shape.

As a result, it is utilised in the construction of aeroplanes.

(vi) Aluminium utensils should not be kept in water overnight.

Ans: The oxygen in water interacts with aluminium to create a thin coating of aluminium oxide, which can be seen in the photo. Essentially, this layer stops aluminium from reacting further. Aluminium oxide may dissolve into the liquid if it is stored in an aluminium vessel for a long time. Since aluminium ions are toxic, water should not be kept overnight in metal containers due to the harmful ions.

(vii) Aluminium wire is used to make transmission cables.

Ans: Among the greatest conductors of electricity are silver, copper, and aluminium. As a result, silver is a highly costly metal, as are silver wires. Because copper is so costly and so heavy, it's a difficult metal to work with. It's an extremely malleable metal. Wires for electrical conduction are made from aluminium.

23. Explain why there is a phenomenal decrease in ionisation enthalpy from carbon to silicon?

Ans: Carbon's ionisation enthalpy (1086 kJ/mol) is quite high. In light of its modest size, this is not surprising at all. The enthalpy of silicon, on the other hand, plummets dramatically (786 kJ). This is due to the fact that the atomic size of elements increases as you move down the group.

24. How would you explain the lower atomic radius of Ga as compared to Al?

Ans:

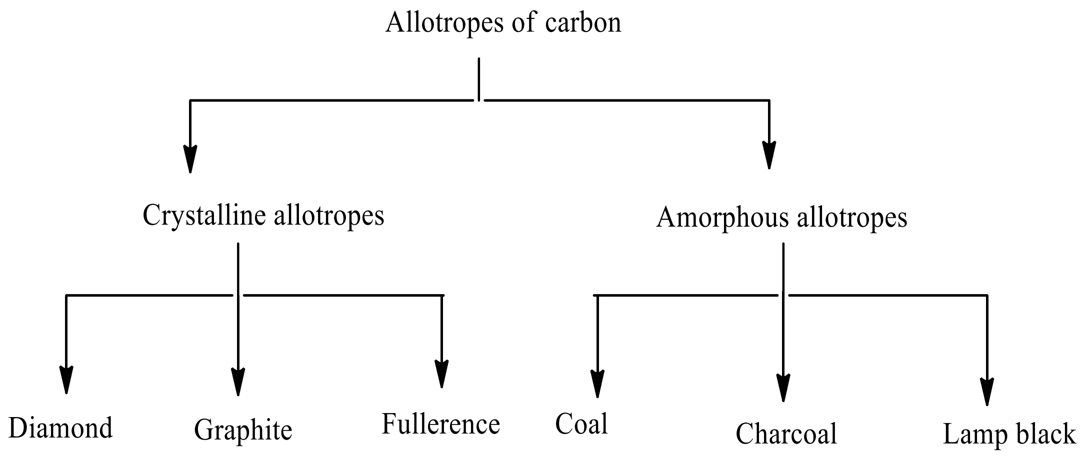
Atomic radius (in pm)	
Aluminium	143
Gallium	135

Ga has one extra shell than Al, although it's smaller. 3d-electrons have a weak shielding effect, which is why this occurs. When it comes to gallium, the valence electrons' effective nuclear charge is significantly higher than when it comes to aluminium.

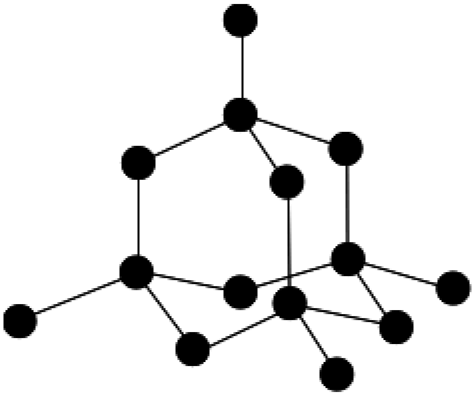
25. What are allotropes? Sketch the structure of two allotropes of carbon namely diamond and graphite. What is the impact of structure on physical properties of two allotropes?

Ans: When an element exists in more than one form, with the same chemical characteristics but distinct physical qualities, it is said to be allotropy. Allotropes are the different forms of an element.

The classification is given below:

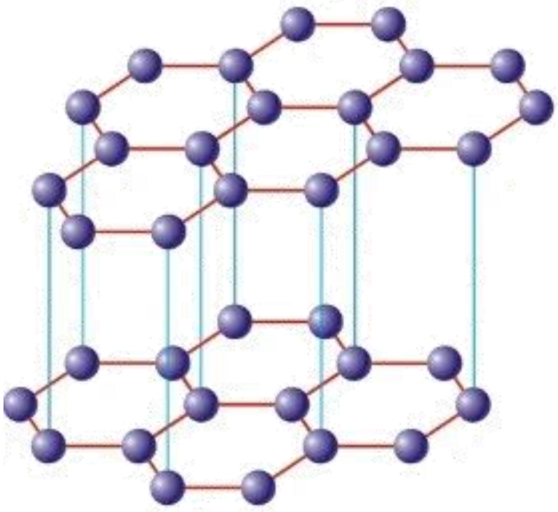


The structure of diamond is given below:



As a result of its rigid 3-D structure, diamond is an extremely hard material. Diamond is one of nature's toughest substances. For abrasive and cutting instruments, it is used.

The structure of graphite is given below:



Hybridized carbon sp^2 is stacked in layers. Weak Van der waals forces hold these layers together. Layers of graphite may slide over one another, making it supple and slick As a result, it's utilized as a lubricant in machinery.

26. (a) Classify following oxides as neutral, acidic, basic or amphoteric:
CO, B_2O_3, SiO_2, CO_2, Al_2O_3, PbO_2, Tl_2O_3

Ans: CO (carbon monoxide) is a neutral compound.

B_2O_3 is an acidic compound as it is acidic in nature it will react with base to form salt. When it reacts with NaOH it forms sodium metaborate.

$B_2O_3 + 2NaOH \rightarrow 2NaBO_2 + H_2O$

SiO_2 is an acidic compound as it is acidic in nature it will react with base to form salt. When it reacts with NaOH it forms sodium silicate.

$SiO_2 + 2NaOH \rightarrow 2Na_2SiO_3 + H_2O$

CO_2 is an acidic compound as it is acidic in nature it will react with base to form salt. When it reacts with NaOH it forms sodium carbonate.

$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$

Al_2O_3 is an amphoteric compound because it can react with both acids and bases. The reaction with sodium hydroxide and sulfuric acid is given below:

$Al_2O_3 + 2NaOH \rightarrow NaAlO_2$

$Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

PbO_2 is an amphoteric compound because it can react with both acids and bases. The reaction with sodium hydroxide and sulfuric acid is given below:

$PbO_2 + 2NaOH \rightarrow Na_2PbO_3 + H_2O$

$2PbO_2 + 2H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O + O_2$

Tl_2O_3 is basic compound because it can react with acid to form salt. It can react with hydrochloric acid to form thallium chloride. The reaction is given below:

$Tl_2O_3 + 6HCl \rightarrow 2TlCl_3 + 3H_2O$

27. In some of the reactions thallium resembles aluminium, whereas in others it resembles with group I metals. Support this statement by giving some evidence.

Ans: Thallium is a member of group 13 of the periodic table. +3 is the most common oxidation state for this group. However, heavier members of this group also exhibit +1 oxidation. This is caused by the inert pair effect. Aluminium has a +3 oxidation state, whereas alkali metals have a +1 oxidation state. Thallium has both oxidation states. As a result, it resembles both aluminium and alkali metals.

Like aluminium, thallium produces compounds such as $TlCl_3$ and Tl_2O_3. In the combinations TlO_2 and TlCl, it is similar to alkali metals.

28. When metal X is treated with sodium hydroxide, a white precipitate (A) is obtained, which is soluble in excess of NaOH to give a soluble complex (B). Compound (A) is soluble in dilute HCl to form compound (C). The compound (A) when heated strongly gives (D), which is used to extract metal. Identify (X), (A), (B), (C) and (D). Write suitable equations to support their identities.

Ans: In the presence of sodium hydroxide, the supplied metal X forms a white precipitate, which dissolves in excess of sodium hydroxide Because of this, X must be made of aluminium.

Alkali hydroxide (compound A) is the white precipitate that forms. Compound (B) is sodium tetrahydroxoaluminate (III), which is produced when an excess of the base is added.

$$\underset{\text{Aluminium (X)}}{2\ \mathrm{Al}} + \underset{\text{Sodium hydroxide}}{3\ \mathrm{NaOH}} \longrightarrow \underset{\text{White ppt. (A)}}{\mathrm{Al\,(OH)_3}} + 3\ \mathrm{Na^+}$$

$$\underset{\text{(A)}}{\mathrm{Al\,(OH)_3}} + \mathrm{NaOH} \longrightarrow \underset{\substack{\text{Sodium tetrahydroxyaluminate (III)}\\ \text{(Soluble complex B)}}}{\mathrm{Na^+[Al(OH)_4]^-}}$$

Adding diluted hydrochloric acid to aluminium hydroxide results in the formation of aluminium chloride (compound C).

$$\underset{\text{(A)}}{\mathrm{Al(OH)_3}} + 3\mathrm{HCl} \rightarrow \underset{\text{(C)}}{\mathrm{AlCl_3}} + 3\mathrm{H_2O}$$

In addition, when compound A is heated to a high temperature, compound (D) is formed. It is used to remove metal (X) from a solution. Alumina is used to produce aluminium metal, which is then refined into aluminium alloy. As a result, compound (D) must be alumina.

$$\underset{\text{(A)}}{2\mathrm{Al(OH)_3}} \xrightarrow{\Delta} \underset{\text{(D)}}{\mathrm{Al_2O_3}} + 3\mathrm{H_2O}$$

29. What do you understand by

(a) inert pair effect

Ans: The likelihood of s-block electrons to engage in chemical bonding diminishes as one travels down the group. Inert pair effect is the name given to this phenomenon. $ns^2\ np^1$ are the electronic configurations of group 13 elements and +3 is the valency. The +1 oxidation state, on the other hand, becomes more stable as one moves down the group. Due to the ns^2 electrons' inadequate shielding by the d- and f- electrons, this phenomenon occurs. ns^2 electrons cannot participate in chemical bonding because of inadequate shielding.

(b) Allotropy

Ans: When an element exists in more than one form, with the same chemical characteristics but distinct physical qualities due to different bonding, this is called allotropy Allotropes are the different forms of an element. Examples include diamond, graphite and fullerene, which are allotropic forms of carbon.

(c) Catenation

Ans: Some elements (such as carbon) may create lengthy chains or branches by forming strong covalent connections between their atoms. These properties are referred to as "catenation." In carbon, it's the most frequent, while in Si and S it's fairly significant.

30. A certain salt X, gives the following results.

(i) Its aqueous solution is alkaline to litmus.

(ii) It swells up to a glassy material Y on strong heating.

(iii) When conc. H2SO4 is added to a hot solution of X, white crystal of an acid Z separates out.

Write equations for all the above reactions and identify X, Y and Z.

Ans: Using a litmus test, the salt provided is alkali. Because of this, the compound X is salt of a strong acid and a weak base.

A similar phenomenon occurs when the material X is heated to extreme temperatures. As a result, X is borax.

The sodium metaborate is formed when borax is heated and the water evaporates, forming sodium metaborate. Continued heating solidifies it into a glassy substance Y. The combination of sodium metaborate and boric anhydride, is Y.

$$\underset{\text{Borax (X)}}{Na_2B_4O_7.\ 10\ H_2O} \xrightarrow{\text{Water}} \underset{\text{Sodium hydroxide}}{2\ NaOH} + \underset{\text{Orthoboric acid}}{4\ H_3BO_3}$$

$$\underset{\text{Borax (X)}}{Na_2B_4O_7.\ 10\ H_2O} \longrightarrow \underset{\text{Sodium metaborate}}{Na_2B_4O_7} \longrightarrow \underset{\substack{\text{Boric anhydride}\\ \text{(Glassy material)}\\ \text{(Y)}}}{B_2O_3} + 2\ NaBO_2$$

When concentrated acid is added to borax, white crystals of orthoboric acid (Z) are formed.

$$\underset{\text{Borax (X)}}{Na_2B_4O_7.10H_2O} + H_2SO_4 \xrightarrow{\Delta} Na_2SO_4 + \underset{\text{Orthoboric acid (Z)}}{4H_3BO_3} + 5H_2O$$

31. Write balanced equations for:

(i) $BF_3 + LiH \rightarrow$

Ans: When Boron trifluoride is treated with lithium hydride to form Diborane and Lithium fluoride. The reaction is given below:

$$2BF_3 + 6LiH \rightarrow B_2H_6 + 6LiF$$

(ii) $B_2H_6 + 6H_2O \rightarrow 2H_3BO_3 + 6H_2$

Ans: When diborane reacts with water to form orthoboric acid and hydrogen. The reaction is given below:

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

(iii) $B_2H_6 + NaH \rightarrow$

Ans: When Diborane reacts with sodium hydride to form sodium borohydride. The reaction is given below:

$B_2H_6 + 2NaH \rightarrow 2NaBH_4$

(iv) $H_3BO_3 \xrightarrow{\Delta}$

Ans: When orthoboric acid is heated it will form metaboric acid, tetraboric acid and at the last it will form boron trioxide. The reaction is given below:

$$H_3BO_3 \longrightarrow HBO_2 + H_2O$$

$$\underset{\text{metaboric acid}}{4\ HBO_2} \longrightarrow \underset{\text{Tetraboric acid}}{H_2B_4O_7} \longrightarrow \underset{\text{Boron trioxide}}{2\ B_2O_3} + H_2O$$

(v) Al + NaOH →

Ans: When aluminium reacts with sodium hydroxide it will form sodium tetrahydroxoaluminate (III) and hydrogen. The reaction is given below:

$2Al + 2NaOH + 6H_2O \rightarrow 2Na^+[Al(OH)_4]^- + 3H_2$

(vi) $B_2H_6 + NH_3 \rightarrow$

Ans: When diborane reacts with ammonia to form Borazene and hydrogen. The reaction is given below:

$$3B_2H_6 + 6NH_3 \rightarrow 3[BH_2(NH_3)_2]^+[BH_4]^- \rightarrow 2B_3N_3H_6 + 12H_2$$

32. Give one method for industrial preparation and one for laboratory preparation of CO and CO_2 each.

Ans: Carbon dioxide (CO_2)

Industrial: When the carbon is treated with oxygen in excess air, then we get carbon dioxide.

$C(s) + O_2(g) \xrightarrow{\text{Excess air}} CO_2(g)$

Laboratory: In laboratory, when the calcium carbonate is treated with hydrochloric acid we get carbon dioxide along with calcium chloride and water.

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

Carbon monoxide (CO)

Industrial: When the carbon is treated with oxygen in limited air, then we get carbon monoxide.

$$2C(s) + O_2(g) \xrightarrow{\text{Limited air}} 2\,CO(g)$$

Industrial: When formic acid is treated with sulfuric acid carbon monoxide and water are going to form as products.

$$HCOOH \xrightarrow{H_2SO_4} CO + H_2O$$

33. An aqueous solution of borax is

(a) Neutral

(b) Amphoteric

(c) Basic

(d) Acidic

Ans: (c) Borax is a strong base salt (NaOH) and a low acid salt (H_3BO_3). Consequently, it is basic in nature.

34. Boric acid is polymeric due to

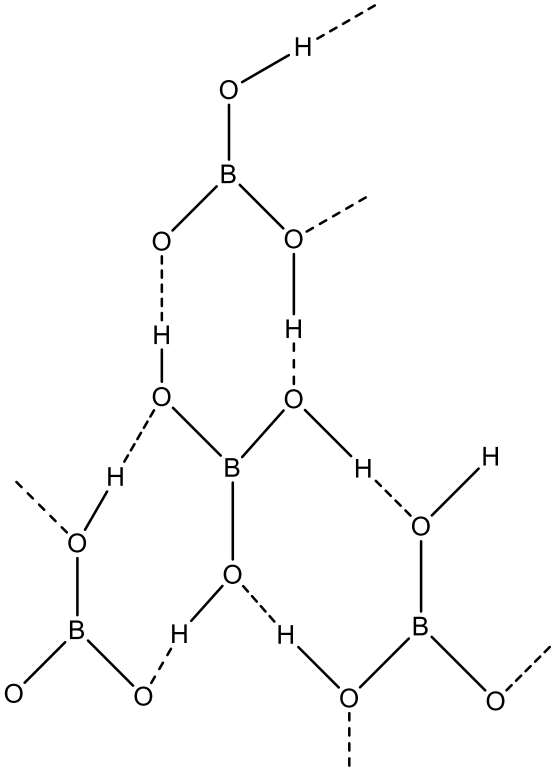
(a) its acidic nature

(b) the presence of hydrogen bonds

(c) its monobasic nature

(d) its geometry

Ans: (b) Due to the existence of hydrogen bonds, boric acid is polymeric. The dotted lines are hydrogen bonding in this image.



35. **The type of hybridization of boron in diborane is**

(a) sp

(b) sp^2

(c) sp^3

(d) dsp^2

Ans: (c) The hybridization of boron in Diborane is sp^3.

36. **Thermodynamically the most stable form of carbon is**

(a) Diamond

(b) Graphite

(c) Fullerenes

(d) Coal

Ans: (b) Thermodynamically the most stable form of carbon atom is Graphite.

37. Elements of group 14

(a) exhibit oxidation state of +4 only

(b) exhibit oxidation state of +2 and +4

(c) form M^{2-} and M^{4+} ion

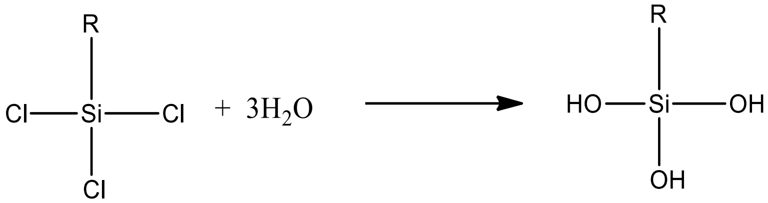
(d) form M^{2+} and M^{4+} ions

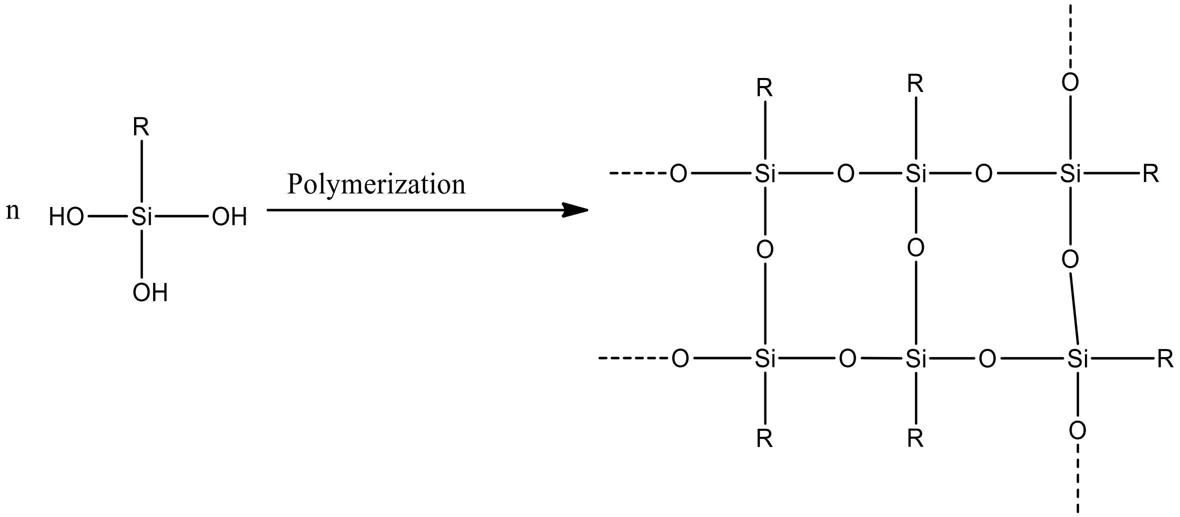
Ans: (b) Group 14 elements contain 4 electrons of valence. Consequently, the group oxidation is +4. However, the inert pair effect results in a more stable lower oxidation status and a less stable higher oxidation level. This group therefore shows +4 and +2 levels of oxidation.

Group 14 elements	Oxidation state
C	+4
Si	+4
Ge, Sn, Pb	+2, +4

38. If the starting material for the manufacture of silicones is $RSiCl_3$, write the structure of the product formed.

Ans: Hydrolysis of alkyl trichlorosilane gives cross-linked silicones. This is given below:





Cross-linked silicone