Chapter: The p-block Elements

Exercise

11.1. Discuss the pattern of variation in the oxidation states of

(i) B to Tl and (ii) C to Pb.

Answer:

(i) B to Tl

The electric configuration of elements in group 13 is ns^2np^1. As a result, their most common oxidation state should be +3. However, only boron and aluminum practically exhibit the +3 oxidation state. The remaining elements, Ga, In, and Tl, exhibit both +1 and +3 oxidation states. The +1 state becomes more stable as one moves down the group. Tl (+1), for example, is more stable than Tl (+3). The inert pair effect is to blame for this. The nucleus is strongly attracted to the two electrons in the s-shell, and they do not participate in bonding. As one moves down the group, the inert pair effect becomes more pronounced. As a result, Ga (+1) is unstable, In (+1) is moderately stable, and Tl (+1) is extremely stable.

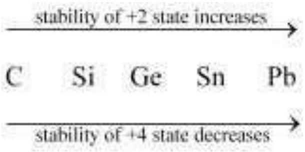
Group 13 element	Oxidation State
B	+3
Al	+3
Ga, In, Tl	+1, +3

As one moves down the group, the stability of the +3 oxidation state decreases.

(ii) C to Pb

Group 14 elements have the electronic configuration ns^2np^2. As a result, their most common oxidation state should be +4. However, as one moves down the group, the +2 oxidation state becomes more common. C and Si are mostly in the +4 state. The higher oxidation state becomes less stable as one moves down the group. The inert pair effect is to blame for this. As a result, while Ge, Sn, and Pb exhibit both the +2 and +4 states, the stability of the lower oxidation state increases while the stability of the higher oxidation state decreases as one moves down the group.

Group 14 element	Oxidation State
C	+3
Si	+4
Ge, Sn, Pb	+2, +4

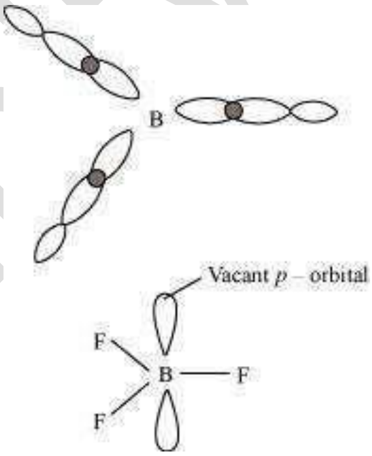


11.2. How can you explain higher stability of BCl_3 as compared to $TlCl_3$?

Answer: Boron and thallium are elements in Periodic Table Group 13. The +1 oxidation state becomes more stable as one moves down the group in this group. Because the +3 oxidation state of B is more stable than the +3 oxidation state of Tl, BCl_3 is more stable than $TlCl_3$. The +3 state in Tl is highly oxidising, and it reverts to the more stable +1 state.

11.3. Why does boron trifluoride behave as a Lewis acid?

Answer: Boron's electric configuration is ns^2np^1. Its valence shell contains three electrons. As a result, it can only form three covalent bonds. This means that boron has only six electrons surrounding it, and its octet is incomplete. When one boron atom combines with three fluorine atoms, the resulting octet is incomplete. As a result, boron trifluoride retains its electron deficiency and acts as a Lewis acid.



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

Answer: BCl_3 is easily hydrolyzed because it is a Lewis acid. As a result, boric acid is formed.

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

CCl_4 is completely resistant to hydrolysis. Carbon has no unoccupied orbitals. As a result, it cannot accept electrons from water in order to form an intermediate. When CCl_4 and water are mixed, separate layers form.

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

11.5. Is boric acid a protic acid? Explain.

Answer: Boric acid does not belong to the family of protic acids. It is a weak monobasic acid that behaves like a Lewis acid.

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

It behaves like an acid by accepting two electrons from the hydroxide ion.

11.6. Explain what happens when boric acid is heated.

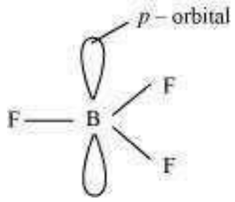
Answer: When orthoboric acid (H_3BO_3) is heated to 370 K or higher, it transforms into metaboric acid (HBO_2). Further heating results in the formation of boric oxide (B_2O_3).

$$H_3BO_3 \xrightarrow[370\ K]{\Delta} HBO_2 \xrightarrow[\text{red hot}]{\Delta} B_2O_3$$

11.7. Describe the shapes of BF_3 and BH_4^-. Assign the hybridisation of boron in these species.

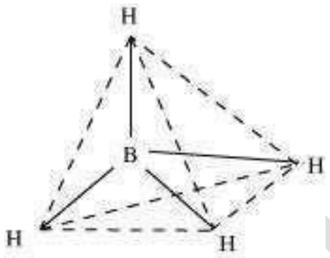
Answer: (i) BF_3:

Boron tends to form monomeric covalent halides due to its small size and high electronegativity. The geometry of these halides is planar triangular. This triangular shape is formed by the overlap of three boron sp^2 hybridized orbitals with three halogen sp orbitals. Boron undergoes sp^2 hybridization in BF_3.



(ii) BH_4^-

Boron-hydride ion (BH_4^-) is formed by boron orbital sp^3 hybridisation. As a result, it has a tetrahedral structure.



11.8. Write reactions to justify amphoteric nature of aluminium.

Answer: If a substance exhibits both acidic and basic properties, it is said to be amphoteric. Aluminium is amphoteric, meaning it dissolves in both acids and bases.

$$(i)\,2Al + 6HCl \rightarrow 2Al^{3+} + 6Cl^{-} + 3H_2$$

$$(ii)\,2Al + 2NaOH + 6H_2O \rightarrow 2Na^{+}\left[Al(OH)_4\right]^{-} + 3H_2$$

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

Answer: The octet of electrons in an electron-deficient compound is not complete, i.e., the central metal atom has an incomplete octet. As a result, it requires electrons to complete its octet.

(i) BCl_3

An example of an electron-deficient compound is BCl_3. B possesses three valence electrons. The number of electrons surrounding it increases to six after forming three covalent bonds with chlorine. It is, however, still missing two electrons to complete its octet.

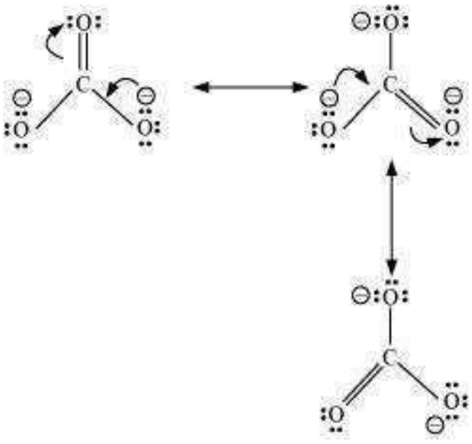
(ii) $SiCl_4$

Silicon's electronic configuration is ns^2np^2. This means it has four valence electrons. Its electron count rises to eight after forming four covalent bonds with four chlorine atoms. $SiCl_4$ is thus not an electron-deficient compound.

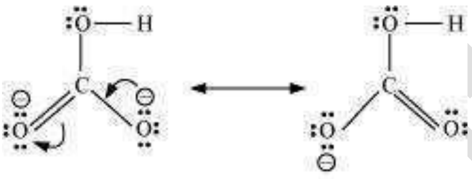
11.10. Write the resonance structures of CO_3^{2-} and HCO_3^-.

Answer:

(a) CO_3^{2-}



(b) HCO_3^-



(A) (B)

There are only two resonating structures for the bicarbonate ion.

11.11. What is the state of hybridisation of carbon in (a) CO_3^{2-} (b) diamond (c) graphite?

Answer: The state of hybridisation of carbon in:

(a) CO_3^{2-}

The hybridization of carbon in CO_3^{2-} is sp^2 and is it is bonded to three oxygen atoms.

(b) Diamond

In diamond, each carbon is sp^3 hybridised and is bonded to four other carbon atoms.

(c) Graphite

In graphite, each carbon atom is sp^2 hybridised and is bonded to three other carbon atoms.

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

Answer:

Diamond	Graphite
1. It has a crystalline lattice structure.	1. Its structure is layered.
2. Each carbon atom in diamond is sp^3 hybridized and is bonded to four other carbon atoms via a bond.	2. Each carbon atom in graphite is sp^2 hybridised and bonded to three other carbon atoms via a bond. A bond is formed by the fourth electron.
3. It has a tetrahedral structure.	3. It has a planar geometry.
4. Diamond has a $C-C$ bond length of 154 pm.	4. Graphite has a $C-C$ bond length of 141.5 pm.
5. It has a strong covalent bond network that is difficult to break.	5. It is quite soft, and its layers are easily separated.
6. It acts as an insulator between two conductors.	6. It is a good conductor of electricity.

11.13. Rationalise the given statements and give chemical reactions:

- Lead (II) chloride reacts with Cl2 to give $PbCl_4$.
- Lead (IV) chloride is highly unstable towards heat.
- Lead is known not to form an iodide, PbI4.

Answer:

(a) Lead is in Periodic Group 14 of the periodic table. This group exhibits two oxidation states: +2 and +4. The +2 oxidation state becomes more stable as one moves down the group, while the +4 oxidation state becomes less stable. The inert pair effect is to blame for this. As a result, $PbCl_4$ is far less stable than $PbCl_2$. When chlorine gas is bubbled through a saturated Answer of $PbCl_2$, however, $PbCl_4$ is formed.

$$PbCl_2 + Cl_2 \rightarrow PbCl_4$$

(b) Because of the inert pair effect, the higher oxidation state becomes unstable as one moves down group IV. Pb(IV) is a highly unstable element that, when heated, degrades to Pb (II).

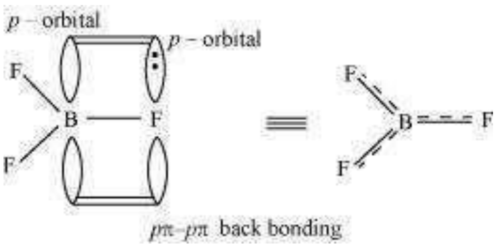
$$PbCl_4 \xrightarrow{\Delta} PbCl_2 + Cl_2$$

(c) It is known that lead does not form PbI_4. In nature, Pb (+4) is oxidizing and I- is reducing. The reaction of Pb(IV) and iodide ion is unstable. In nature, the iodide ion is a strong reducer. Pb(IV) oxidizes I^- to I_2 before being reduced to Pb (II).

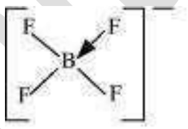
$$PbI_4 \rightarrow PbI_2 + I_2$$

11.14. Suggest reasons why the B–F bond lengths in $BF_3\,(130\text{ pm})$ and $BF_4^-\,(143\text{ pm})$ differ.

Answer: The length of the B–F bond in BF_3 is shorter than the length of the B–F bond in BF_4^-. BF_3 is an electron-poor species. To compensate for a vacant p-orbital on boron, the fluorine and boron atoms undergo p–p back-bonding. This gives the B–F bond a double bond character.



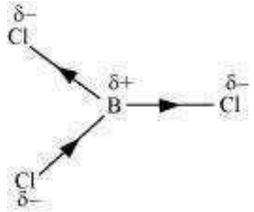
This double-bond character causes the bond length to shorten in BF3 (130 pm). However,when BF3 coordinates with the fluoride ion, a change in hybridization from sp^2 (in BF3) tosp^3 (in BF_4^-) occurs. Boron now forms 4σ bonds and the double-bond character is lost. Thisaccounts for a B–F bond length of 143 pm in BF_4^- ion.



Tetrahedral structure

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

Answer: The B–Cl bond is polar in nature due to the difference in electronegativities of B and Cl. The BCl_3 molecule, on the other hand, is non-polar. This is due to the fact that BCl_3 has a trigonal planar shape. It's a molecule with two halves. As a result, the respective dipole moments of the B–Cl bond cancel each other out, resulting in a zero-dipole moment.



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

Answer: Hydrogen fluoride (HF) is a covalent compound with extremely strong intermolecular hydrogen bonds. As a result, it does not provide ions and does not dissolve aluminum fluoride (AlF). Sodium fluoride (NaF) is an ionic compound that dissolves AlF when added to the mixture.

This is due to the abundance of free F^-. The process involves a reaction:

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

Aluminium fluoride precipitates out of the Answer when boron trifluoride (BF_3) is added to it. This occurs because boron has a much higher proclivity to form complexes than aluminum. As a result, when BF_3 is added to the Answer, B replaces Al from the complexes in the following way:

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

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

Answer: Because of its ability to form a complex with haemoglobin, carbon monoxide is extremely poisonous. The $CO\text{–}H_b$ complex has a higher stability than the $O_2\text{–}H_b$ complex. The former prevents Hb from forming a bond with oxygen. As a result of not receiving oxygen, a person dies from suffocation. It has been discovered that the $CO\text{–}H_b$ complex is approximately 300 times more stable than the $O_2\text{–}H_b$ complex.

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

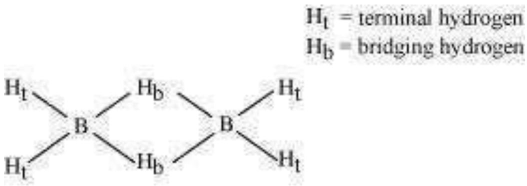
Answer: Carbon dioxide is an extremely important gas for our survival. An increase in CO_2 levels in the atmosphere, on the other hand, poses a serious threat. Carbon dioxide levels have risen due to increased combustion of fossil fuels, decomposition of limestone, and a decrease in the number of trees. Carbon dioxide has the ability to trap the heat emitted by sunrays. The more carbon dioxide there is, the more heat is trapped. As a result, the atmospheric temperature rises, contributing to global warming.

11.19. Explain structures of diborane and boric acid.

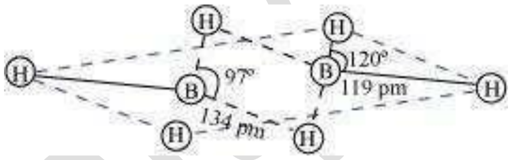
Answer:

(a) Diborane

B_2H_6 is an electron-poor compound. B_2H_6 has only 12 electrons in which 6 electrons from 6 H atoms and 3 electrons from each of the two B atoms. As a result of combining with three H atoms, none of the boron atoms have any electrons left. Diborane's structure has been determined through X-ray diffraction studies to be as follows:



Two boron atoms and four terminal hydrogen atoms (H_t) are located in one plane, while the other two bridging hydrogen atoms (H_b) are located in a plane perpendicular to the plane of boron atoms. Again, one of the two bridging hydrogen atoms is above the plane and the other is below it. The terminal bonds are two-centre two-electron (2c – 2e–) bonds, whereas the two bridging (B–H–B) bonds are three-centre two-electron (3c – 2e–) bonds.



(b) Boric acid

Boric acid is a layered substance. Each planar BO_3 unit is connected to the others via H atoms. The H atoms form a covalent bond with a BO_3 unit, while another BO_3 unit forms a hydrogen bond. The dotted lines in the diagram represent hydrogen bonds.

11.20. What happens when

(a) Borax is heated strongly,

(b) Boric acid is added to water,
(c) Aluminium is treated with dilute NaOH,
(d) BF_3 is reacted with ammonia?

Answer:

(a) When heated, borax undergoes a number of transformations. It first swells and loses water molecules. Then it solidifies into a glass-like material known as borax bead after becoming a transparent liquid.

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

(b) When boric acid is mixed with water, electrons from the hydrocide ion are accepted.

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

(c) When Al reacts with dilute NaOH, sodium tetrahydroxoaluminate is formed (III). During the process, hydrogen gas is liberated.

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

(d) An adduct is formed when BF_3 (a Lewis acid) reacts with NH_3 (a Lewis base). In BF_3, this results in a complete octet around B.

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

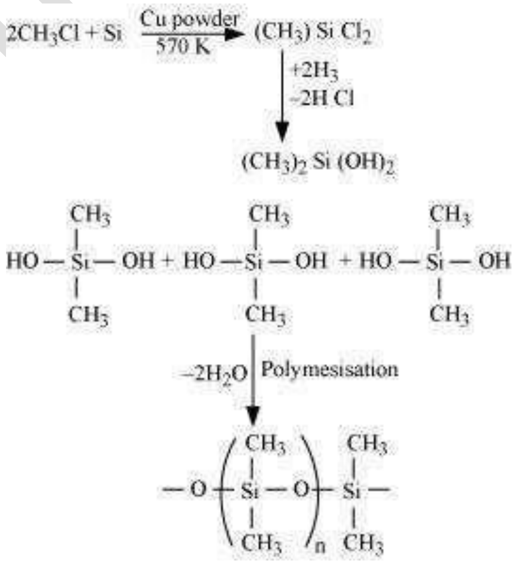
11.21. Explain the following reactions:

(a) Silicon is heated with methyl chloride at high temperature in the presence of copper;
(b) Silicon dioxide is treated with hydrogen fluoride;

(c) CO is heated with ZnO;
(d) Hydrated alumina is treated with aqueous NaOH Answer.

Answer:

(a) When silicon reacts with methyl chloride in the presence of copper (catalyst) at 537 K, a class of organosilicon polymers known as methylsubstituted chlorosilanes $(MeSiCl_3, Me_2SiCl_2, Me_3SiCl, \text{and } Me_4Si)$ are formed.



(b) When silicon dioxide $\left(SiO_2\right)$ is heated with hydrogen fluoride (HF), silicon tetrafluoride is formed $\left(SiF_4\right)$. The Si–O bond is typically a strong bond that is resistant to attack by halogens and most acids, even at high temperatures. HF, on the other hand, attacks it.

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

The SiF_4 produced in this reaction can be further reacted with HF to produce hydrofluorosilicic acid.

$$SiF_4 + 2HF \rightarrow H_2SiF_6$$

(c) When CO reacts with ZnO, ZnO is reduced to Zn. CO is a reducing agent.

$$ZnO + CO \xrightarrow{\Delta} Zn + CO_2$$

(d) When hydrated alumina is mixed with sodium hydroxide, the former dissolves in the latter as sodium meta-aluminate is formed.

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

11.22. Give reasons:

(i) Conc. HNO_3 can be transported in aluminium container.
(ii) A mixture of dilute NaOH and aluminium pieces is used to open drain.
(iii) Graphite is used as lubricant.
(iv) Diamond is used as an abrasive.
(v) Aluminium alloys are used to make aircraft body.
(vi) Aluminium utensils should not be kept in water overnight.
(vii) Aluminium wire is used to make transmission cables.

Answer: (i) Because concentrated HNO_3 reacts with aluminum to form a thin protective oxide layer on the aluminum surface, it can be stored and transported in aluminum containers. Aluminium is rendered inactive by this oxide layer.

(ii) Sodium tetrahydroxoaluminate(III) and hydrogen gas are formed when sodium hydroxide and aluminum react. The pressure generated by the hydrogen gas is used to open clogged drains.

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

(iii) Graphite has a layered structure, and different layers are held together by weak van der Waals forces. These layers can be stacked on top of one another. Graphite is a soft and slick material. Graphite can thus be used as a lubricant.

(iv) Carbon is sp^3 hybridised in diamond. Each carbon atom is held together by four other carbon atoms via strong covalent bonds. These covalent bonds run throughout the surface, giving it a very rigid three-dimensional structure. Because it is extremely difficult to break this extended covalent bonding, diamond is the hardest substance known. As a result, it is used as an abrasive and in cutting tools.

(v) Aluminium has a high tensile strength and a low weight. It can also be alloyed with metals like Cu, Mn, Mg, Si, and Zn. It has a high degree of malleability and ductility. As a result, it is used to construct aircraft bodies.

(vi) Water's oxygen reacts with aluminium to form a thin layer of aluminium oxide. This layer prevents the aluminum from reacting further. overnight. However, if water is kept in an aluminum vessel for an extended period of time, some aluminium oxide may dissolve in the water. Water should not be stored in aluminum vessels overnight due to the dangers of aluminum ions.

(vii) Silver, copper, and aluminum are among the best electrical conductors. Silver is a costly metal, and silver wires are even more so. Copper is a very expensive and heavy metal. Aluminium is a pliable metal. As a result, aluminum is used to make wires for electrical conduction.

11.23. Explain why is there a phenomenal decrease in ionisation enthalpy from carbon tosilicon?

Answer:

Carbon (the first element in group 14) has a very high ionisation enthalpy (1086 kJ/mol). Because of its small size, this is to be expected. However, as one moves down the group to silicon, the enthalpy drops dramatically (786 kJ). This is due to an increase in the atomic sizes of elements as they move down the group.

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

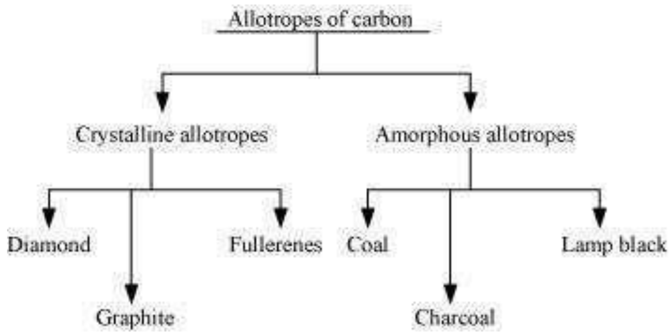
Answer:

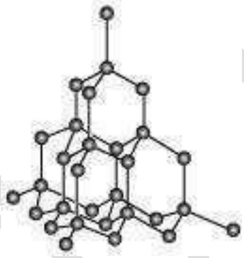
Element	Atomic radius (in pm)
Aluminum	143
Gallium	135

Although Ga has one more shell than Al, it is smaller in size. This is due to the 3d-electrons' poor shielding effect. The shielding effect of d-electrons is very poor, and the effective nuclear charge experienced by gallium valence electrons is much higher than in Al.

11.25. 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?

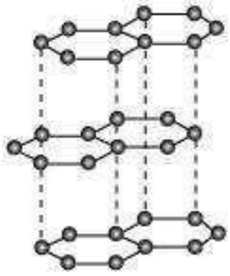
Answer: Allotropy refers to the existence of an element in multiple forms, each with the same chemical properties but distinct physical properties. Allotropes are the various forms of an element.





Diamond:

Diamond is a very hard substance due to its rigid 3-D structure. Diamond is, in fact, one of the hardest naturally occurring substances. It is used as an abrasive and in the manufacture of cutting tools.



Graphite:

It is made up of layers of sp^2 hybridised carbon. These layers are held together by van der Walls forces that are weak. Because these layers can slide over each other, graphite becomes soft and slippery. As a result, it is used as a lubricant.

11.26. (a) Classify following oxides as neutral, acidic, basic or amphoteric:
$CO, B_2O_3, SiO_2, CO_2, Al_2O_3, PbO_2, Tl_2O_3$
Write suitable chemical equations to show their nature.

Answer:

(1) CO = Neutral

(2) B_2O_3 = Acidic

Because it is acidic, it combines with bases to form salts. When it reacts with NaOH, it produces sodium metaborate.

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

(3) SiO_2 = Acidic

Because it is acidic, it combines with bases to form salts. It forms sodium silicate when it reacts with NaOH.

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

(4) CO_2 = Acidic

Because it is acidic, it combines with bases to form salts. When it reacts with NaOH, it produces sodium metacarborate.

$$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$$

(5) Al_2O_3 = Amphoteric

Both acids and bases react with amphoteric substances. Both NaOH and H_2SO_4 react with Al_2O_3.

$$Al_2O_3 + 2NaOH \rightarrow NaAlO_2$$

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

(6) PbO_2 = Amphoteric

Both acids and bases react with amphoteric substances. Both NaOH and H_2SO_4 react with PbO_2.

$$PbO_2 + 2NaOH \rightarrow Na_2PbO_3 + H_2O$$

$$2PbO_2 + 3H_2SO_4 \rightarrow 2PbSO_4 + 2H_2O + O_2$$

(7) Tl_2O_3 = Basic

Since it is basic, it combines with acids to form salts. When it reacts with HCl, it produces thallium chloride.

$$Tl_2O_3 + 6HCl \rightarrow 2TiCl_3 + 3H_2O$$

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

Answer: Thallium is a member of Periodic Table Group 13. This group's most common oxidation state is +3. However, heavier members of this group exhibit the +1 oxidation state as well. This is due to the inert pair effect. Aluminium has a +3 oxidation state, while alkali metals have a +1 oxidation state. Thallium exhibits both oxidation states. As a result, it is similar to both aluminum and alkali metals.

Thallium, like aluminum, can be converted into compounds such as $TlCl_3$ and Tl_2O_3. It is similar to alkali metals in the compounds Tl_2O and TlCl.

11.28. When metal X is treated with sodium hydroxide, a white precipitate (A) is obtained, whichis soluble in excess of NaOH to give soluble complex (B). Compound (A) is soluble in diluteHCl 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

Answer:

With sodium hydroxide, the given metal X forms a white precipitate, and the precipitate dissolves in excess of sodium hydroxide. As a result, X must be made of aluminum.

Aluminium hydroxide is obtained as a white precipitate (compound A). When an excess of the base is added, the compound B formed is sodium tetrahydroxoaluminate (III).

When dilute hydrochloric acid is added to aluminium hydroxide, it produces aluminium chloride (compound C).

$$\underset{\text{Aluminium}(X)}{2Al} + 3NaOH \rightarrow \underset{\text{white ppt}(A)}{Al(OH)_3} \downarrow + 3Na$$

$$\underset{\text{white ppt}(A)}{Al(OH)_3} + NaOH \rightarrow Na^+ \underset{\substack{\text{sodium tetrahydroxoaluminate (III)} \\ \text{(soluble complex B)}}}{\left[Al(OH)_4\right]^-}$$

In addition, when compound A is heated to a high temperature, compound D is formed. This compound is employed in the extraction of metal X. Alumina is used to extract aluminum metal. As a result, compound D must be alumina.

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

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

11.29. What do you understand by (a) inert pair effect (b) allotropy and (c) catenation?

Answer:

(a) Inert pair effect

The tendency of s-block electrons to participate in chemical bonding decreases as one moves down the group. This is known as the inert pair effect. The electronic configuration of group 13 elements is ns^2np^1, and their group valency is +3. Moving down the group, however, makes the +1 oxidation state more stable. This is due to the d- and f- electrons' poor shielding of the ns^2 electrons. Because of the poor shielding, the ns^2 electrons are tightly held by the nucleus and thus cannot participate in chemical bonding.

(b) Allotropy

Allotropy refers to the existence of an element in multiple forms, each with the same chemical properties but distinct physical properties. Allotropes are the various forms of an element. Carbon, for example, has three allotropic forms: diamond, graphite, and fullerenes.

(c) Catenation

Some elements' atoms (such as carbon) can form long chains or branches by forming strong covalent bonds with one another. This is referred to as catenation. It is most prevalent in carbon and has a significant presence in Si and S.

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

(i) Its aqueous Answer is alkaline to litmus.
(ii) It swells up to a glassy material Y on strong heating.
(iii) When conc. H_2SO_4 is added to a hot Answer of X, white crystal of an acid Z separatesout.

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

Answer:

To litmus, the given salt is alkaline. X is thus a salt of a strong base and a weak acid. Furthermore, when X is heated to a high temperature, it swells to form substance Y. As a result, X must be borax. When heated, borax loses water and expands to form sodium metaborate. When heated further, it solidifies to form the glassy material Y. As a result, Y must be a combination of sodium metaborate and boric anhydride.

$$\underset{\text{Borax}}{Na_2B_4O_7.7H_2O} \xrightarrow{\Delta} \underset{\text{sodium hydroxide}}{2NaOH} + \underset{\text{Orthoboric acid}}{4H_3BO_3}$$

$$\underset{\text{Borax}}{Na_2B_4O_7.10H_2O} \xrightarrow{\Delta} Na_2B_4O_7 \xrightarrow{\Delta} \underset{\text{sodium metaborate}}{2NaBO_2} + \underset{\text{Boric anhydride (Glassy material)}}{B_2O_3}$$

When concentrated acid is added to borax, white orthoboric acid (Z) crystals form.

$$\underset{\text{Borax}(X)}{Na_2B_4O_7.10H_2O} + H_2SO_4 \xrightarrow{\Delta} 2Na_2SO_4 + \underset{\text{Orthoboric acid }(Z)}{4H_3BO_3} + 5H_2O$$

11.31. Write balanced equations for:

$(i) BF_3 + LiH \rightarrow$

$(ii) B_2H_6 + H_2O \rightarrow$

$(iii) NaH + B_2H_6 \rightarrow$

$(iv) H_3BO_3$

$(v) Al + NaOH \rightarrow$

$(vi) B_2H_6 + NH_3 \rightarrow$

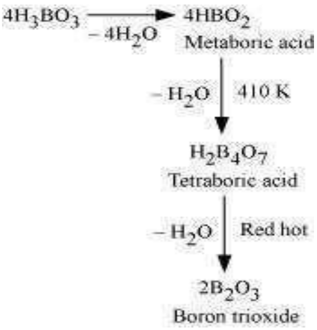
Answer:

$(i) 2BF_3 + 6LiH \rightarrow B_2H_6 + 6LiF$

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

$(iii) NaH + B_2H_6 \rightarrow 2NaBH_4$

(iv)



$(v) 2Al + NaOH + 6H_2O \rightarrow 2Na^+\left[Al(OH)4\right]^- + 3H_2$

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

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

Answer:

Caron dioxide

CO_2 can be produced in the laboratory by the action of dilute hydrochloric acid on calcium carbonate. The following is the reaction:

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

CO_2 is produced commercially by heating limestone. The following is the reaction:

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \uparrow$$

Caron monoxide

CO is produced in the laboratory by dehydrating formic acid with conc. H_2SO_4 at 373 K. The following is the reaction:

$$HCOOH \xrightarrow[\text{conc. } H_2SO_4]{373\text{ K}} H_2O + CO_2 \uparrow$$

Commercially, CO is produced by passing steam over hot coke. The following is the reaction:

$$C + H_2O \xrightarrow{473\text{–}1273\text{ K}} \underbrace{CO + H_2}_{\text{water gas}}$$

11.33. An aqueous Answer of borax is

(a) neutral	(b) amphoteric
(c) basic	(d) acidic

Answer: (c)

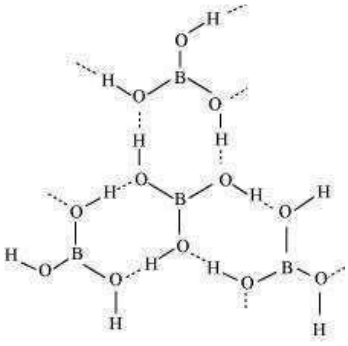
Borax is a salt of a strong base (NaOH) and a weak acid $\left(H_3BO_3\right)$. As a result, it is fundamental in nature.

11.34. Boric acid is polymeric due to

(a) its acidic nature	(b) the presence of hydrogen bonds
(c) its monobasic nature	(d) its geometry

Answer:

(b) Because of the presence of hydrogen bonds, boric acid is polymeric. The dotted lines in the diagram represent hydrogen bonds.



11.35. The type of hybridisation of boron in diborane is

(a) sp

(b) sp^2

(c) sp^3

(d) dsp^2

Answer:

(c) In diborane, the hybridization of boron is sp^3.

11.36. Thermodynamically the most stable form of carbon is

(a) diamond	(b) graphite
(c) fullerenes	(d) coal

Answer: (b)

Graphite is the most thermodynamically stable form of carbon.

11.37. 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

Answer: (b)

Group 14 elements have four valence electrons. As a result, the group's oxidation state is +4. However, due to the inert pair effect, the lower oxidation state becomes increasingly stable, while the higher oxidation state becomes less stable.

As a result, this group has +4 and +2 oxidation states.

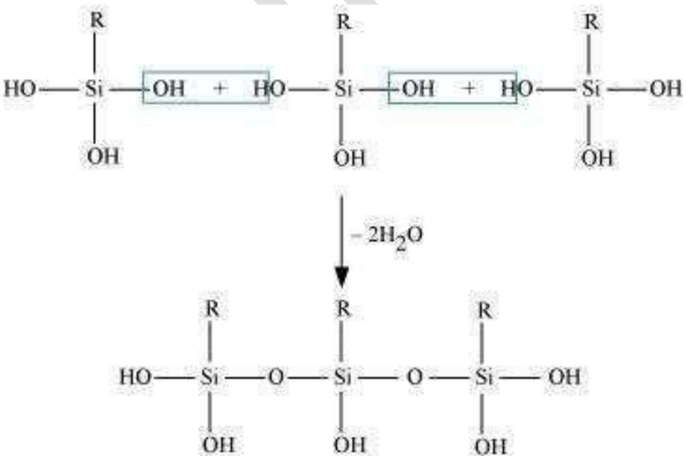
Group 14 element	Oxidation State
C	+3
Si	+4
Ge, Sn, Pb	+2, +4

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

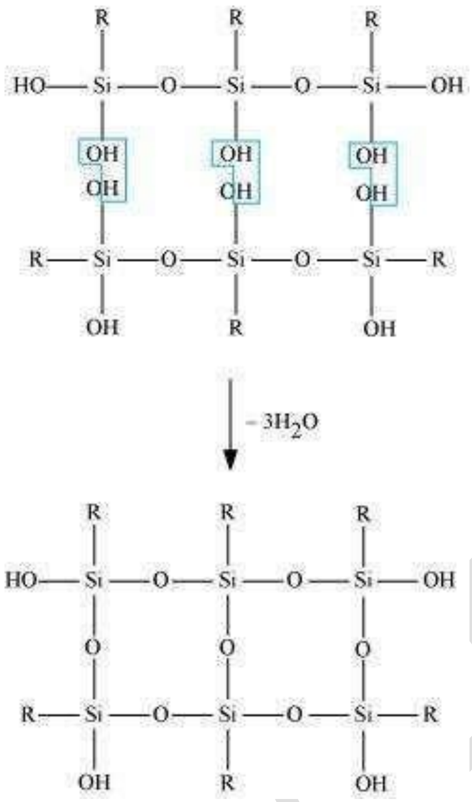
Answer:

(i)

$$RSiCl_3 + 3H_2O \longrightarrow RSi(OH)_3 + 3HCl$$



(ii)



Solved Examples

11.1. Standard electrode potential values, E° for Al^{3+}/Al is –1.66 V and that of Tl^{3+}/Tl is +1.26 V. Predict about the formation of M^{3+} ion in Answer and compare the electropositive character of the two metals.

Answer: Standard electrode potential values for two half cell reactions suggest that aluminium has high tendency to make Al^{3+} (aq) ions, whereas Tl^{3+} is not only unstable in Answer but is a powerful oxidising agent also. Thus Tl+ is more stable in Answer than Tl^{3+}. Aluminium being able to form +3 ions easily, is more electropositive than thallium.

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

Answer: To liberate HCl gas, anhydrous aluminium chloride is partially hydrolyzed with atmospheric moisture. The color of moist HCl is white.

11.3. Boron is unable to form BF_6^{3-} ion. Explain.

Answer: Boron is unable to expand its octet due to a lack of d orbitals. As a result, the maximum boron covalence cannot be greater than 4.

11.4. Why is boric acid considered as a weak acid?

Answer: Because it cannot produce hydrogen ions on its own. It receives hydroxide ions from the water molecule to complete its octet and then emits hydrogen ions.

11.5. Select the member(s) of group 14 that (i) forms the most acidic dioxide,

(ii) is commonly found in +2 oxidation state,

(iii) used as semiconductor.

Answer: (i) carbon

(ii) lead

(iii) silicon and germanium.

11.6. $[\mathrm{SiF_6}]^{2-}$ is known whereas $[\mathrm{SiCl_6}]^{2-}$ not. Give possible reasons.

Answer: The main reasons are:

(i) due to size constraints, six large chloride ions cannot be accommodated around Si^{4+}.

(ii) the interaction between a lone pair of chloride ions and Si^{4+} is weak.

11.7. Diamond is covalent, yet it has high melting point. Why?

Answer: Diamond has a three-dimensional network with strong $\mathrm{C—C}$ bonds that are extremely difficult to break, resulting in a high melting point.

11.8. What are silicones?

Answer: Simple silicones are $\left(-\overset{|}{\underset{|}{\mathrm{Si}}}-\mathrm{O}\right)_n$ chains in which the remaining bonding positions on each silicon are occupied by alkyl or phenyl groups. They are hydrophobic (repellent to water) in nature.