CHAPTER > 11

p-Block Elements

KEY NOTES

- In *p*-block elements, the last electron enters in the outermost *p*-orbital.
- There are six groups of *p*-block elements in the periodic table numbering from 13 to 18. Their valence shell **electronic configuration is ns^2np^{1-6}** (except for He).
- Differences in the **inner core** of their electronic configuration greatly influence their physical and chemical properties.
- The maximum oxidation state shown by a *p*-block element is equal to the total number of valence electrons.
- The number of possible oxidation states increases towards the right of the periodic table.
- In addition to this so called group oxidation state, *p*-block elements may show other oxidation states as well.
- The occurrence of oxidation states two units less than the group oxidation states is called **inert pair effect**.
- The combined effect of size and availability of *d*-orbitals considerably influences the ability of these elements to form π -bonds.
- Non-metals have higher ionisation enthalpies and electronegativities than metals.
- Non-metal oxides are acidic or neutral whereas metal oxides are basic in nature.

Group 13 Elements : The Boron Family

- Group-13 contains six elements, *viz*, B, Al, Ga, In, Tl, Nh and is collectively called **boron family.**
- Nh has been prepared in small amounts and its half-life of most stable isotope is 20 seconds. Due to these reasons, its chemistry has not been established yet.
- Aluminium is the most abundant metal and third most abundant element in earth's crust, after oxygen and silicon.

Electronic Configuration

Their electronic configuration is [inert gas] ns^2np^1.

Physical Properties

Atomic Radii

- It increases on moving down the group from B to Tl.
- However, the atomic radius of Ga is less than that of Al.
- The presence of additional 10*d*-electrons offer only poor screening effect for the outer electrons from the increased nuclear charge in gallium (Ga).

Ionisation Enthalpy

- It follows the trend given below :
  $In < Al < Ga < Tl < B$.
- The discontinuity in the ionisation enthalpy values between Al and Ga and that between In and Tl are due to inability of *d*-and *f*-electrons, having low screening effect to compensate the increased nuclear charge.

Electronegativity

It first decreases from B to Al and then increases marginally.

Note ***Boron*** *is non-metallic, extremely hard and has high melting point. Rest of the members are soft metals with low melting point.*

Density

Density of the elements increases down the group from boron to thallium.

Chemical Properties

Oxidation State Due to **inert pair effect**, on moving down the group, stability of lower oxidation state increases.
The trend is as follows :

$$B^+ < Al^+ < Ga^+ < In^+ < Tl^+$$

Chemical Reactions

Important reactions of group 13 are given below :

Reactions	Properties
Reaction with oxygen $4E(s)+3O_2(g) \xrightarrow{\Delta} 2E_2O_3(s)$ For thallium, $4Tl(s) + O_2(g) \longrightarrow 2\,Tl_2O(s)$	• Crystalline boron is unreactive. • Tl forms thallium (I) oxide, Tl_2O more stable than Tl_2O_3. • B_2O_3 is acidic, Al and Ga oxide are amphoteric and those of In and Tl are basic.
Reaction with nitrogen $2E(s)+N_2(g) \xrightarrow{\Delta} 2EN(s)$	• All elements readily form nitrides at high temperature.
Reaction with water • No reaction occurs between boron and water • Aluminium is very reactive even at lower temperature. $2Al(s) + 3H_2O(l) \longrightarrow Al_2O_3 + 3H_2(g)\uparrow$	• Ga, In and Tl are less reactive. • They get attacked by the combination of both water and oxygen. • Individual reaction with water and oxygen do not take place.
Reaction with acids $\underset{\text{(Exception boron)}}{2M(s)} + 6HCl(aq) \longrightarrow 2M^{3+}(aq) + 6Cl^-(aq) + 3H_2\uparrow(g)$	• B does not react with acids at moderate temperature. • Conc. HNO_3 renders Ga and Al passive by forming a protective oxide layer on surface.
Reaction with alkalies $\underset{\text{(Exception In and Tl)}}{2M(s)} + 2NaOH(aq) + 2H_2O(l) \longrightarrow 2NaMO_2(aq) + 3H_2(g)$	• Al reacts with both mineral acids and aqueous alkalies and thus shows amphoteric character.
Reaction with halogen $\underset{\text{(Exception TlI}_3\text{)}}{2E(s)} + 3X_2(g) \longrightarrow 2EX_3(s) \qquad (X = \text{F, Cl, Br I})$	• The covalent trihalides, e.g. BF_3 being **electron deficient** are strong Lewis acids and the tendency to behave as Lewis acids decreases with increase in size down the group.

Anomalous Properties and Important Compounds of Boron

B due to its **small size**, high charge density and **non-availability** of *d*-electrons, shows anomalous behaviour, i.e. it has high melting and boiling points, forms covalent compounds, shows allotropism and behaves as a typical non-metal.

Some Important Compounds of Boron

Borax ($Na_2[B_4O_5(OH)_4]\cdot 8H_2O$)

Physical Property

It is a white crystalline solid and generally represented as $Na_2B_4O_7\cdot 10H_2O$.

Chemical Properties

- **Reaction with water** It dissolves in water to give an alkaline solution.

$$Na_2B_4O_7 + 7H_2O \longrightarrow 2NaOH + \underset{\text{Orthoboric acid}}{4H_3BO_3}$$

- **Borax bead test** The metaborates of many transition metals have characteristic colours and thus, **borax bead test** can be used to identify them.

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

Orthoboric Acid (H_3BO_3)

It is a white crystalline solid with soapy touch. It is sparingly soluble in water, but highly soluble is hot water.

Preparation

It can be prepared as follows :

$$Na_2B_4O_7 + 2HCl + 5H_2O \longrightarrow 2NaCl + 4B(OH)_3$$

Chemical Properties

- It is a weak monobasic acid and acts as a Lewis acid by accepting electrons from a hydroxyl ion.

$$B(OH)_3 + 2HOH \longrightarrow [B(OH)_4]^- + H_3O^+$$

- On heating orthoboric acid forms metaboric acid (HBO_2) which on further heating forms B_2O_3.

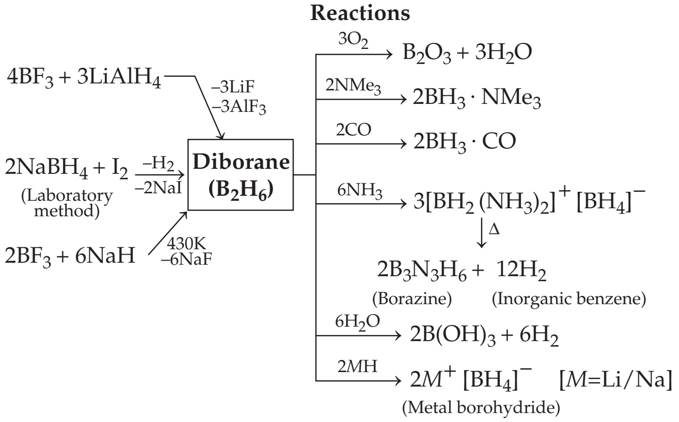
$$H_3BO_3 \xrightarrow{\Delta} HBO_2 \xrightarrow{\Delta} B_2O_3$$

Diborane (B_2H_6)

- The simplest boron hydride known is diborane.
- It is colourless, highly toxic gas with b.p. of 180 K.

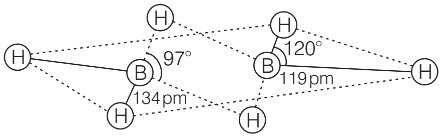
Preparation

It's preparation and reactions are as follows :



Structure

It has non-planar structure in which four terminal B—H bonds (2C—2*e*) lie in same plane while the two bridge B—H—B bonds (3C—2*e*) lie above and below the plane of 4 B—H bonds as shown below :



Borohydrides

Boron forms a series of hydridoborates and amongst these most important is $[BH_4]^-$, which is tetrahedral.

$$2MH + B_2H_6 \longrightarrow 2M^+[BH_4]^- \quad [M = \text{Li or Na}]$$

Uses of B and Al

- Boron being extremely hard refractory solid of high m.p, low density and very low electrical conductivity finds many applications.
- Boron fibres are used to make bullet proof vest and materials for aircraft.
- Borax and boric acid are used in the manufacture of heat resistant glass, glass wool and fibre glass.
- Aluminium is a bright silvery white metal with high tensile strength, high electrical and thermal conductivity. It is used extensively in industry and everyday life.
- Al is used to make pipes, rods, wires, foils, air craft parts etc.

Group 14 Elements : The Carbon Family

- Group-14 includes C, Si, Ge, Sn, Pb, Fl.
- Flerovium (Fl) has been prepared in small amount and its half-life is short, thus its chemistry has not been established.
- The general electronic configuration of these elements is ns^2np^2.

Physical and Chemical Properties

Covalent Radius

It increases considerably from C to Si thereafter from Si to Pb a small increase in radius is observed.

Ionisation Enthalpy

- It decreases down the group. However, there is small decrease in $\Delta_1 H$ from Si to Ge to Sn and slight increase in $\Delta_1 H$ from Sn to Pb is observed.
- The trend is, C > Si > Ge > Sn < Pb

Electronegativity

- The electronegativity values for elements from Si to Pb are almost the same.
- Carbon and silicon are non-metals, germanium is a metalloid whereas tin and lead are soft metals with low melting points.

Oxidation State

- Carbon and silicon mostly show +4 oxidation state while other elements show both +2 and +4 oxidation states.
- Stability of +2 oxidation state increases down the group due to inert pair effect.

Chemical Reactions

Important reactions of group 14 are given below :

Reactions	Properties
Reaction with oxygen $M(s) + \frac{1}{2}O_2(g) \longrightarrow MO$ (Limited supply) $M(s) + O_2(g) \longrightarrow MO_2$ (Excess)	• Forms two types of oxides, i.e. monoxide and dioxide. • Nature of monoxide is CO-neutral, GeO-acidic, SnO and PbO-amphoteric • Nature of dioxides is $\underbrace{CO_2, SiO_2, GeO_2}_{\text{Acidic}}, \underbrace{SnO_2, \text{and } PbO_2}_{\text{Amphoteric}}$

Reactions	Properties
Reaction with water $M(s) + 2H_2O(l) \xrightarrow{\Delta} MO_2 + 2H_2(g)$ (Exception-Pb)	• C, Si, Ge are not affected by water. • Sn decomposes steam to form dioxide and H_2 gas. • Pb is unaffected by H_2O due to the formation of oxide film.
Reaction with halogen $M + X_2 \longrightarrow MX_2$ $M + 2X_2 \longrightarrow MX_4$ (Exception-PbI_4 (does not exist))	• MX_4 are covalent in nature (exception SnF_4 and PbF_4). • Stability of dihalides increases down the group. • The order of thermal stability of halides is $CX_4 > SiX_4 > GeX_4 > SnX_4 > PbX_4$ • Except CCl_4, other tetrachlorides are easily hydrolysed by water.

Anomalous Properties and Allotropes of Carbon

- **Carbon** is a typical non-metal forming covalent bonds employing all its four valence electrons.
- It shows the property of catenation.
  The order of catenation power is
  $$C >> Si > Ge \approx Sn$$

The important allotropes of carbon are described as follows :

Diamond

- It has crystalline lattice.
- It has rigid 3-D network of sp^3-hybridised C-atoms.
- It is the hardest substance known.
- It is an insulator of electricity, but a conductor of heat.
- C-C bond length is 154 pm.

Graphite

- It is soft having layered structure.
- Each layer has sp^2-hybridised carbon atoms in hexagonal ring and adjacent layers are held together by van der Waals' forces, thus graphite shows lubricating properties.
- It is a good conductor of electricity, so used in making electrodes.

Fullerenes

- It contains 60 carbon atoms with sp^2-hybridisation.
- C_{60} molecule has a shape, like soccer balls are called **Buckminster fullerene.**
- It contains 20 six-membered and 12 five-membered rings.
- Other forms of elemental carbon like carbon black, coke and charcoal are all impure forms of graphite or fullerenes.

Uses

Graphite fibres embedded in plastic material form high strength, lightweight composites. Being a good conductor, graphite is used for electrodes in batteries and industrial electrolysis.

Some Important Compounds of Carbon and Silicon

Carbon Monoxide (CO)

Preparation

It can be prepared as follows:

$$2C(s) + O_2(g) \xrightarrow{\Delta} 2CO(g)$$

$$HCOOH \xrightarrow[\text{Conc. } H_2SO_4]{373K} H_2O + CO$$

[Small scale preparation]

Important reactions

- $C(s) + H_2O(g) \xrightarrow{473-1273K} \underbrace{CO(g) + H_2(g)}_{\text{Water gas or synthesis gas}}$

  [Commercial scale]
- $2C(s) + O_2(g) + 4N_2(g) \xrightarrow{1273K} \underbrace{2CO(g) + 4N_2(g)}_{\text{Producer gas}}$
- $HCOOH \xrightarrow[\text{conc. } H_2SO_4]{373\ K} H_2O + CO$

Properties and Uses

- It is a colourless, odourless and almost water insoluble gas.
- It is a powerful reducing agent.
- CO molecule acts as a donor and reacts with certain metals on heating to form **metal carbonyls**.
- The highly poisonous nature of CO arises because of its ability to form a **complex with haemoglobin** which is more stable than oxygen-haemoglobin complex. This complex reduce the oxygen carrying capacity of human body.
- CO is a component of water gas, producer gas and coal gas.

Carbon Dioxide (CO_2)

Preparation

It can be prepared as follows :

$$C(s) + O_2(g) \xrightarrow{\Delta} CO_2(g)$$

$$CH_4(g) + 2O_2(g) \xrightarrow{\Delta} CO_2(g) + 2H_2O(g)$$

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

[Laboratory preparation]

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

[Commercial scale]

Properties and Uses

- It is colourless, odourless gas.
- With water, it form carbonic acid (H_2CO_3) which is a weak dibasic acid.
- CO_2 which is normally present to the extent of 0.03% by volume in the atmosphere is removed from it by the process known as **photosynthesis**.

- It is not poisonous but in excess may lead to increase in **greenhouse effect**.
- Solid CO_2 is called **dry ice** and is used as a refrigerant for ice-cream and frozen food.

Silicon Dioxide (SiO_2)

Properties

- It is also called **silica** and found in the form of quartz, cristobalite and tridymite.
- It is covalent and has three-dimensional network solid structure.
- Silica in its normal form is almost non-reactive, because of very high Si—O bond enthalpy. However, it is attacked by HF and NaOH as follows :

$$SiO_2 + 2NaOH \longrightarrow Na_2SiO_3 + H_2O$$
$$SiO_2 + 4HF \longrightarrow SiF_4 + 2H_2O.$$

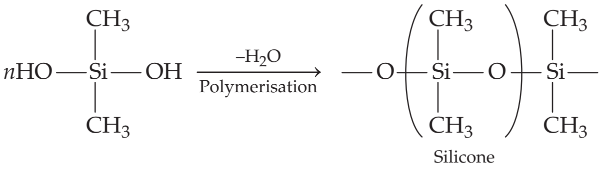
Silicones

They are the organosilicon polymers having $—R_2SiO—$ monomer and —O— Si —O— linkage.

Preparation

The starting material for the manufacture of silicones are alkyl or aryl substituted silicon chloride, R_nSiCl_{4-n}.

$$2CH_3Cl + Si \xrightarrow[570\ K]{\text{Cu powder}} (CH_3)_2SiCl_2 \xrightarrow[-2HCl]{+2H_2O} (CH_3)_2\ Si(OH)_2$$



$$n\mathrm{HO}-\underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{Si}}}-\mathrm{OH} \xrightarrow[\text{Polymerisation}]{-H_2O} -\mathrm{O}-\left(\underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{Si}}}-\mathrm{O}\right)-\underset{\mathrm{CH_3}}{\overset{\mathrm{CH_3}}{\mathrm{Si}}}-$$

Silicone

Uses

Silicones are chemically inert and possess insulating properties.

Silicates

- They are the minerals of silicon having SiO_4^{4-} as the basic repeating unit.
- Main types of silicates are orthosilicates, pyrosilicates, sheet and 3-dimensional silicates.
- The two important man-made silicates are glass and cement.

Zeolites

- They are prepared by substituting Si-atoms in 3-dimensional network of SiO_2 by Al.
- ZSM-5, a type of zeolite, is used to convert alcohols directly into gasoline.
- Hydrate zeolite is used as an ion exchanger in softening of ''hard water''.
- Zeolites are widely used as a catalyst in petrochemical industries.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Introduction*

1 The characteristic valence shell configurations of group-13 and 14 elements are respectively

(a) ns^2np^1 and ns^2np^2
(b) ns^2np^2 and ns^2np^3
(c) ns^2np^3 and ns^2np^4
(d) ns^2np^4 and ns^2np^5

2 The number of possible oxidation states of *p*-block elements

(a) decreases towards the right of the periodic table
(b) increases towards the right of the periodic table
(c) first increases then decreases down the group
(d) first decreases then increases down the group

3 In boron and carbon families, the group oxidation state is most stable for

(a) heavier elements in the group
(b) lighter elements in the group
(c) middle element in the group
(d) last element in the group

4 The compounds formed by the highly reactive non-metals with highly reactive metals and the non-metals are respectively

(a) covalent and ionic
(b) ionic and covalent
(c) metallic and ionic
(d) metallic and covalent

5 The second period elements of *p*-block starting from boron, are restricted to a maximum covalency of

(a) four (using 1*s*, 2*s* and two 2*p* orbitals)
(b) six (using 1*s* and 2*s* -orbitals)
(c) four (using one 2*s* and three 2*p* orbitals)
(d) six (using 1*s* and three 2*p* orbitals)

6 The third period elements of *p*-block with the electronic configuration $3s^2 3p^n$ have the vacant 3*d* orbitals lying between the

(a) 3*p* and 4*s* levels of energy
(b) 3*s* and 3*p* levels of energy
(c) 3*s* and 4*s* levels of energy
(d) 2*p* and 3*s* levels of energy

7 Which orbitals are used by third period of *p*-block elements in order to expand their covalency beyond four?
(a) $3d$ (b) $4s$ (c) $3p$ (d) $4d$

8 Boron forms only $[BF_4]^-$ which one of the following is formed by aluminium?
(a) $[AlF_4]^-$ (b) $[AlF_6]^{3-}$ (c) $[AlF_4]^{3-}$ (d) $[AlF_6]^-$

9 The element that shows greater ability to form $p\pi$-$p\pi$ multiple bonds, is ***JEE Main 2019***
(a) Ge
(b) Si
(c) Sn
(d) C

TOPIC 2 ~ *Group-13 Elements : The Boron Family*

(Important Trends and Anomalous Properties of Boron)

10 Boron is not found in the form of
(a) borax (b) kernite
(c) carnallite (d) orthoboric

11 Which of the following element is the most abundant metal and the third most abundant element in the earth's crust?
(a) Al (b) B
(c) Ga (d) In

12 The correct order of atomic radii in group 13 elements is ***NEET 2018***
(a) B < Ga < Al < Tl < In
(b) B < Al < Ga < In < Tl
(c) B < Al < In < Ga < Tl
(d) B < Ga < Al < In < Tl

13 Between which of the following elements is the discontinuity in the ionisation enthalpy values observed?
(a) Al and Ga (b) In and Tl
(c) B and Al (d) Both (a) and (b)

14 The electronegativity of aluminium is similar to ***JEE Main 2019***
(a) lithium (b) carbon
(c) beryllium (d) boron

15 Among the elements of group-13, boron possesses a high melting point due to
(a) very high electronegativity
(b) very high ionisation energy
(c) small size
(d) strong bonding between individual atoms in the solid state

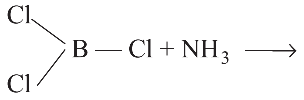
16 Which of the following properties is possessed by the members of group 13, except B?
(a) are soft metals
(b) have low melting point
(c) have high electrical conductivity
(d) All of the above

17 Which of the following oxidation state(s) is shown by Ga, In and Tl?
(a) Only +1 (b) Only +3
(c) +3 as well as +1 (d) Only +2

18 The relative stability of +1 oxidation state of group 13 elements follows the order ***JEE Main 2019***
(a) Al < Ga < Tl < In (b) Al < Ga < In < Tl
(c) Tl < In < Ga < Al (d) Ga < Al < In < Tl

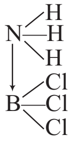
19 In trivalent state, the number of electrons around the central atom in a molecule of the compounds of group 13 elements will be
(a) four (b) six (c) eight (d) five

20 Consider the following reaction.

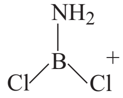


The product will be

(a) $N\overset{+}{H}_3Cl$ and $\overset{-}{\ddot{B}}Cl_2$ (b)

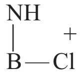


(c)



+ HCl

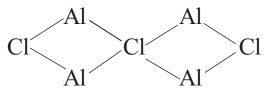
(d)



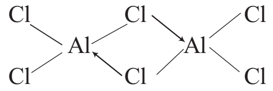
+ 2HCl

21 $AlCl_3$ achieves stability by forming a dimer. Structure of this dimer is

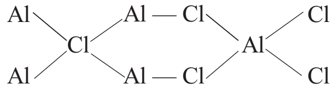
(a)



(b)



(c)



(d) None of the above

22 Consider the following reactions.

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

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

Here, I and II are

(a) $I \rightarrow B_2O_3(s)$, $II \rightarrow AlN(g)$

(b) $I \rightarrow B_2O_3(g)$, $II \rightarrow AlN(s)$

(c) $I \rightarrow B_2O_3(g)$, $II \rightarrow AlN(g)$

(d) $I \rightarrow B_2O_3(s)$, $II \rightarrow AlN(s)$

23 Boron trioxide is acidic and reacts with metal oxides form to

(a) metal borates (b) metal boroxides

(c) metal hydroxide (d) None of these

24 $p\ Al(s) + q\ HCl(aq) \longrightarrow r Al^{3+}(aq) + s\ Cl^-(aq) + t\ H_2(g)$

The stoichiometric coefficients (*p, q, r, s , t*) used in balancing the above reaction are respectively

(a) 3, 6, 2, 6, 2 (b) 6, 3, 6, 2, 2

(c) 2, 6, 2, 6, 3 (d) 4, 6, 4, 6, 6

25 $2Al(s) + 2NaOH(aq) + 6H_2O(l) \longrightarrow 2A + 3H_2(g)$

Here, A is

(a) $Na^+[Al(OH)_4]^-\ (aq)$ Sodium tetrahydroxoaluminate (III)

(b) $Na_2[Al(OH)_4]^-\ (aq)$ Sodium tetrahydroxoaluminate (III)

(c) $Na^+[Al(OH)_6]^-\ (aq)$ Sodium hexahydroxoaluminate (II)

(d) $Na[Al(OH)_6]^-\ (aq)$ Sodium hexahydroxoaluminate (III)

26 The similarities among the trichlorides, tribromides and triiodides of all group-13 elements is/are that they are

(a) covalent in nature (b) hydrolysed in water

(c) Both (a) and (b) (d) None of these

27 Which of the following elements does not exist in aqueous medium, as species like tetrahedral $[M(OH)_4]^-$ and octahedral $[M(H_2O)_6]^{3+}$?

(a) Boron (b) Thallium

(c) Gallium (d) Indium

28 BF_3 easily reacts with a Lewis base such as NH_3 to complete octet around boron. This can be expressed as

(a) $F_3B + :NH_3 \longrightarrow F_3B \leftarrow NH_3$

(b) $F_3B + :NH_3 \longrightarrow F_3B \rightarrow NH_3$

(c) $:BF_3 + NH_3 \longrightarrow BF_3 \rightarrow NH_3$

(d) $:BF_3 + NH_3 \longrightarrow BF_3 \leftarrow NH_3$

29 The group 13 elements react with halogens to form trihalides except

(a) BCl_3 (b) TlI_3

(c) $AlCl_3$ (d) GaI_3

30 Which one of the following elements is unable to form MF_6^{3-} ion? ***NEET 2018***

(a) B (b) Al (c) Ga (d) In

31 Which of the following is not true for boron and aluminium?

(a) Hydrogen gas is evolved when they are dissolved in alkali.

(b) On heating with oxygen, both form oxide of the type M_2O_3.

(c) On heating with nitrogen, both form nitrides of the type MN.

(d) Both form acidic hydroxides

TOPIC 3 ~ *Some Important Compounds of Boron and Aluminium*

32 Complete the following reaction,

$$Na_2B_4O_7 + 7H_2O \longrightarrow 2NaOH + A$$

Here, A is

(a) orthoboric acid (b) boric acid

(c) borax (d) diborane

33 On heating, borax first loses water molecules and swells up. On further heating it turns into a transparent liquid, which solidifies into glass like material known as

(a) borax wax (b) borax bead

(c) borax liquid (d) None of these

34 Borax is heated in a bunsen burner flame with a compound X on a loop of platinum wire. A blue coloured bead of compound Y is formed. Identify X and Y

	X	Y
(a)	$Ca(BO_2)_2 1$	CoO
(b)	CoO	$Co(BO_2)_2$
(c)	CoO_2	$Co(BO_2)_2$
(d)	CoO	$CoBO_2$

35 The reaction given below is used for the preparation of orthoboric acid by acidifying an aqueous solution of borax.

$$Na_2B_4O_7 + X + H_2O \longrightarrow Y + B(OH)_3$$

Choose the suitable X for the above reaction.

(a) HCl (b) NaCl (c) NaF (d) F_2

36 On heating, orthoboric acid above 370 K forms 'X' which on further heating yields 'Y'. 'X' and Y' are respectively

(a) boric oxide, metaboric acid

(b) metaboric acid, boric oxide

(c) paraboric acid, boric oxide

(d) boric oxide, paraboric acid

37 The industrial scale production of diborane involves the reaction of BF_3 with

(a) lithium hydride

(b) sodium hydride

(c) Both (a) and (b)

(d) None of the above

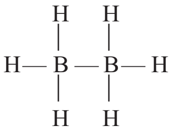
38 Which of the following reactions are shown by diborane?

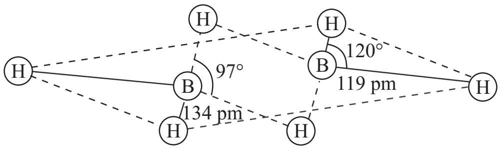
(a) $B_2H_6 + 2NMe_3 \longrightarrow 2BH_3 \cdot NMe_3$
(b) $B_2H_6 + 6H_2O \longrightarrow 2B(OH)_3 + 6H_2$
(c) $B_2H_6 + 2CO \longrightarrow 2BH_3 \cdot CO$
(d) All of the above

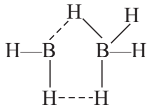
39 Diborane (B_2H_6) reacts independently with O_2 and H_2O to produce, respectively. ***JEE Main 2019***

(a) B_2O_3 and H_3BO_3
(b) B_2O_3 and $[BH_4]^-$
(c) H_3BO_3 and B_2O_3
(d) HBO_2 and H_3BO_3

40 The structure of diborane, B_2H_6 is

(a)


(b)


(c)


(d) None of the above

41 Which of the following tetrahydridoborate(s) is/are known as borohydrides?

(a) Sodium tetrahydridoborate
(b) Lithium tetrahydridoborate
(c) Potassium tetrahydridoborate
(d) Both (a) and (b)

TOPIC 4 ~ *Group-14 Elements : The Carbon Family*
(Important Trends and Anomalous Properties of Carbon)

42 Which of the following isotopes of carbon with half-life 5770 yrs is used for radiocarbon dating?

(a) ${}^{12}_{6}C$
(b) ${}^{13}_{6}C$
(c) ${}^{14}_{6}C$
(d) None of these

43 The elements of group 13 and 14 respectively, which are prepared in small amount and their half-life is short are

(a) flerovium and nihonium
(b) nihonium and flerovium
(c) nihonium and lead
(d) silicon and lead

44 The small increase in the covalent radii from Si to Pb is due to the presence of

(a) half-filled *d*-orbitals in heavier members
(b) completely filled *d* and *f*-orbitals in heavier members
(c) presence of completely filled *d*-orbitals in lighter members
(d) None of the above

45 Which of the following is the correct order of first ionisation enthalpy of group 14 elements?

(a) Si > Ge > Sn > Pb
(b) Si > Ge > Sn < Pb
(c) Si < Ge < Sn < Pb
(d) Si < Ge < Sn > Pb

46 The tendency of Ge, Sn and Pb to show +2 oxidation state increases in the sequence :

(a) Ge = Sn < Pb
(b) Ge < Sn < Pb
(c) Ge > Sn > Pb
(d) Ge > Sn = Pb

47 Which of the following species is not stable? ***NEET (National) 2019***

(a) $[GeCl_6]^{2-}$
(b) $[Sn(OH)_6]^{2-}$
(c) $[SiCl_6]^{2-}$
(d) $[SiF_6]^{2-}$

48 The hybridisation of the central atom in $[SiF_6^{2-}]$, $[GeCl_6]^{2-}$, $[Sn(OH)_6]^{6-}$ is

(a) sp^3d
(b) sp^3d^2
(c) sp^3
(d) sp^3d^3

49 Consider the following oxides

$GeO, CO_2, CO, GeO_2, SiO_2, SnO_2, SnO,$

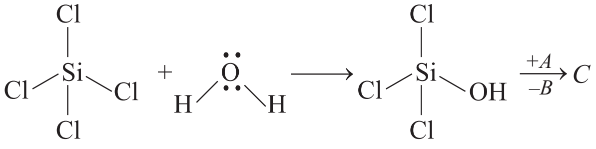
Which of the following option is correct?

(a) Acidic — GeO_2, CO, SiO_2; Neutral— GeO
Amphoteric— CO_2, SnO, SnO_2
(b) Acidic—SnO_2, GeO_2, CO_2; Neutral— CO, SnO, SiO_2
Amphoteric— GeO
(c) Acidic— CO_2, GeO_2, SiO_2; Neutral— CO
Amphoteric— SnO_2, SnO
(d) Acidic— GeO, SiO_2, SnO; Neutral— CO, CO_2
Amphoteric — SnO_2, GeO_2

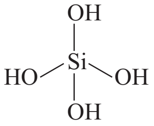
50 Which of the following does not exist?

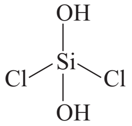
(a) PbI_4
(b) PbF_4
(c) CCl_4
(d) CBr_4

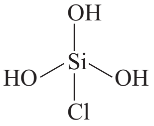
51 Consider the following reaction.



Here, *A, B* and *C* refer to

(a) $A \longrightarrow 3H_2O$; $B \longrightarrow 3HCl$; $C \longrightarrow$ 

(b) $A \longrightarrow 2H_2O$; $B \longrightarrow 2HCl$; $C \longrightarrow$ 

(c) $A \longrightarrow H_2O$; $B \longrightarrow HCl$; $C \longrightarrow$ 

(d) None of the above

52 Carbon differs from the rest of the members of its group due to
(a) its smaller size
(b) non-higher electronegativity and ionisation enthalpy
(c) non-availability of *d*-orbitals in C
(d) All of the above

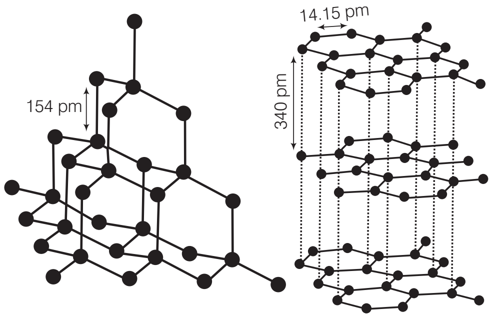
TOPIC 5 ~ *Allotropes of Carbon*

53 Carbon is able to show allotropic forms due to
(a) catenation (b) $p\pi$ - $p\pi$ bond formation
(c) Both (a) and (b) (d) None of these

54 Which of the following is not an allotrope of carbon? ***JIPMER 2019***
(a) Diamond (b) Fullerene
(c) Soot (d) Graphite

55 In which of the following allotropes of carbon, each carbon atom undergoes sp^3-hybridisation and linked to four other carbon atoms by using hybridised orbitals in tetrahedral fashion?
(a) Diamond (b) Graphite (c) Fullerene (d) None of these

56 Following are the figures of two different allotropes of carbon. Identify these allotropes from the following options.



(*A*) (*B*)

(a) $A \rightarrow$ Graphite; $B \rightarrow$ Diamond
(b) $A \rightarrow$ Diamond; $B \rightarrow$ Graphite
(c) $A \rightarrow$ Graphite; $B \rightarrow$ Fullerene
(d) $A \rightarrow$ Diamond; $B \rightarrow$ Fullerene

57 Graphite conducts electricity due to highly
(a) delocalised nature of π-electrons
(b) localised nature of π-electrons
(c) polarised nature of π-electrons
(d) None of the above

58 Graphite cleaves easily between the layers. Thus, it is
(a) soft (b) slippery
(c) Both (a) and (b) (d) None of these

59 '*A*' is an allotrope of carbon made by heating graphite in an electric arc in the presence of inert gases such as helium or argon.

It is the only pure form of carbon because they have smooth structure without having 'dangling' bonds. It is a cage-like molecule. Identify '*A*'.
(a) Diamond (b) Fullerene (c) Graphite (d) None of these

60 C_{60} an allotrope of carbon contains ***JEE Main 2019***
(a) 16 hexagons and 16 pentagons
(b) 20 hexagons and 12 pentagons
(c) 12 hexagons and 20 pentagons
(d) 18 hexagons and 14 pentagons

61 Which of the following is obtained by burning hydrocarbons in a limited supply of air?
(a) Charcoal (b) Carbon black
(c) Coke (d) None of these

TOPIC 6 ~ *Some Important Compounds of Carbon and Silicon*

62 On small scale, pure CO is prepared by dehydration of
(a) stearic acid with HNO_3
(b) benzoic acid with dil. H_2SO_4
(c) lauric acid with HCl
(d) formic acid with conc. H_2SO_4

63 The mixture of CO and H_2 is known as
(a) producer gas
(b) synthesis gas
(c) water gas
(d) Both (b) and (c)

64 A mixture of CO and N_2 is known as

(a) synthesis gas (b) water gas
(c) producer gas (d) All of these

65 Carbon monoxide is used as a reductant. It reduces

(a) only metal oxides of alkali and alkaline earth metals
(b) all metal oxides
(c) all metal oxides except Al_2O_3, alkali metal and alkaline metal oxides
(d) None of the above

66 When carbon monoxide reacts with water, product obtained is

(a) carbonic acid (b) carbon dioxide
(c) hydrogen (d) Both (b) and (c)

67 Main reason of human death by CO poisoning is due to

(a) formation of carbon monoxide-haemoglobin complex
(b) prevention of haemoglobin in red blood corpuscles from carrying oxygen around the body
(c) throat chilling
(d) All of the above

68 In laboratory carbon dioxide is prepared by the reaction of A and B. Here A and B are respectively

(a) $A \rightarrow$ dil. HCl $B \rightarrow$ calcium carbonate
(b) $A \rightarrow$ conc. HCl $B \rightarrow$ calcium carbide
(c) $A \rightarrow$ dil. HCl $B \rightarrow$ calcium carbide
(d) $A \rightarrow$ conc. HCN $B \rightarrow$ magnesium carbonate

69 Which of the following properties of CO_2 makes it of immense biological and geochemical importance?

(a) Non-poisonous nature
(b) Low solubility in water
(c) It forms carbonic acid on reaction with water
(d) None of the above

70 H_2CO_3 / HCO_3^- buffer system helps to maintain the pH of blood between

(a) 7.26 to 7.42 (b) 3.26 to 7.42
(c) 7.26 to 8.00 (d) 7.42 to 7.96

71 0.03% of carbon dioxide present in the atmosphere can be removed by

(a) conversion of CO_2 to glucose
(b) photosynthesis
(c) chemical change of CO_2 to carbohydrate
(d) All of the above

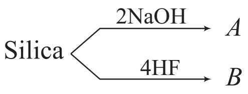
72 What is the hybridisation of C-atom in CO_2 molecule?

(a) sp^2 (b) sp (c) sp^3 (d) None of these

73 95% of earth crust is made up of silica and silicates. Silicon dioxide, commonly known as

(a) silicate (b) silicon
(c) silica (d) All of these

74 Choose the correct option regarding A and B for following reactions.



$$\text{Silica} \xrightarrow{2NaOH} A \qquad \text{Silica} \xrightarrow{4HF} B$$

(a) $A \rightarrow Na_2SiO_3, B \rightarrow SiF_4$ (b) $A \rightarrow NaSiO_2$, $B \rightarrow SiF_4$
(c) $A \rightarrow Na_2SiO_2, B \rightarrow SiF_6$ (d) $A \rightarrow Na_2SiO_3, B \rightarrow SiF_6$

75 The amorphous form of silica is ***JEE Main 2019***

(a) tridymite (b) kieselguhr (c) cristobalite (d) quartz

76 Which of the following is extensively used as piezoelectric material?

(a) Crystobalite (b) Solid CO_2 (c) Dry ice (d) Quartz

77 Silica gel is used as a/an

(a) dehydrating agent (drying agent)
(b) dehydrogenating agent
(c) reducing agent
(d) oxidising agent

78 Which of these is not a monomer for a high molecular mass silicone polymer? ***NEET 2013***

(a) $MeSiCl_3$ (b) Me_2SiCl_2 (c) Me_3SiCl (d) $PhSiCl_3$

79 Hydrolysis of dimethyl dichlorosilane followed by condensation polymerisation lead to the formation of

(a) straight chain polymer (b) sheet polymer
(c) 3-dimensional polymer (d) None of these

80 Which of the following compounds is used in cosmetic surgery? ***NEET (Odisha) 2019***

(a) Silica (b) Silicates (c) Silicones (d) Zeolites

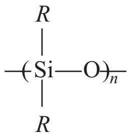
81 The basic structural unit of silicates is ***NEET 2013***

(a) SiO^- (b) SiO_4^{4-} (c) SiO_3^{2-} (d) SiO_4^{2-}

82 The basic structural unit of feldspar, zeolites, mica and asbestos is ***JEE Main 2019***

(a) $(SiO_3)^{2-}$ (b) SiO_2

(c) $(SiO_4)^{4-}$ (d)



$$\left(\underset{R}{\overset{R}{Si}} - O \right)_n$$ (R = Me)

83 Name the type of the structure of silicate in which one oxygen atom of $[SiO_4]^{4-}$ is shared? ***CBSE AIPMT 2011***

(a) Three dimensional (b) Linear chain silicate
(c) Sheet silicate (d) Pyrosilicate

84 Which of the following is used to convert alcohol to petroleum directly?

(a) ZSM-5 (b) Fe_2O_3 (c) Cr_2O_3/Al_2O_3 (d) Feldspar

85 Two elements P and Q react separately with highly electropositive metal to form binary compounds, which upon hydrolysis yield mixture of boranes and silanes? P and Q respectively are

(a) B and Al (b) Si and B (c) B and Si (d) Al and B

SPECIAL TYPES QUESTIONS

I. Statement Based Questions

86 Atomic radius of Ga (135 pm) is less than that of Al (143 pm) because

(a) of the small variation in the inner core of the electronic configuration

(b) the presence of additional $10d$-electrons which offers only poor screening effect for the outer electrons from the increased nuclear charge in gallium

(c) Both (a) and (b) are correct

(d) Neither (a) nor (b) is ccorrect

87 The correct statements regarding the possible reason for the trend of electronegativity in group-13 elements are

(a) similarities in atomic size of the elements

(b) discrepancies in atomic size of the elements

(c) discrepancies in atomic number of the elements

(d) similarities in atomic mass of the elements

88 ''Non-metals have higher ionisation enthalpies and higher electronegativities than metals.''

Following are the conclusions taken from the above statement.

I. Non-metals readily form anions.
II. Metals readily form cations.
III. Metals form both anions and cations.
IV. Non-metals form both anions and cations.

Choose the option that has only correct statements.

(a) Only I
(b) Only III
(c) Both I and II
(d) I, II and IV

89 Consider the following statements for p-block elements.

I. d-orbitals are of higher energy than p-orbitals.
II. d-orbitals contribute less to the overall stability of the molecules.
III. $p\pi$-$p\pi$ bonding of the second row elements contribute more to the overall stability of the molecules.

The correct statement(s) is/are

(a) Both I and II
(b) Both II and III
(c) Only I
(d) I, II and III

90 Consider the given statements regarding the properties of boron.

I. It is a hard refractory solid.
II. It has low melting point and high density.
III. It shows high electrical conductivity.

Choose the correct statement(s).

(a) Only I
(b) I and III
(c) Both II and III
(d) All are correct

91 Which of the following statements is/are correct regarding gallium?

I. It has unusually low melting point (303 K).
II. It exists in liquid state during summer.
III. It has a high boiling point (2676 K).

The correct option is

(a) Both I and II
(b) Both I and III
(c) Both II and III
(d) All statements are correct

92 Which of the following statements is correct regarding group 13 elements?

(a) Density increases down the group from B to Ga and then decreases upto Tl

(b) Boiling point of gallium is very high (2676 K)

(c) Boron is a soft non-metal

(d) Melting point of gallium is very high (3030 K)

93 Which of the following statement is incorrect?

(a) The trichlorides of group-13 elements, on hydrolysis form $[M(\mathrm{OH})_4]^-$

(b) $\mathrm{AlCl_3}$ in acidified aqueous solution forms $[\mathrm{Al(H_2O)_6}]^{3+}$

(c) Boron is unreactive in crystalline form

(d) Boron forms a very thin hydroxide layer on its surface

94 Which of the following is correct statement? ***JIPMER 2019***

(a) Aluminium dissolves in dilute mineral acids but is made passive by concentrated nitric acid

(b) Aluminium vessel can be used to storage of NaOH

(c) Aluminium chloride does not dissociate in water

(d) $\mathrm{AlF_3}$ is soluble in anhydrous HF

95 Which of the following statements is correct for the compound $\mathrm{Al_2Cl_6}$?

I. Six Al — Cl bonds are of same length.
II. The angle Al — Cl—Al is 101°.
III. Four Al — Cl bonds are of same length and two of different length.
IV. The angle Cl—Al—Cl is 79° and 118°.

Choose the correct option.

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

96 Consider the following statements :

I. In thallium, +1 oxidation state is predominant.

II. In thallium, +3 oxidation state is oxidising in nature.

III. Compounds of group 13 elements in +1 oxidation state are less ionic than those in +3 oxidation state.

The incorrect statement(s) is/are

(a) Only I (b) Both II and III

(c) Both I and II (d) Only III

97 Standard electrode potential values, E^{S} for Al^{3+}/Al is –1.66 V and that of Tl^{3+}/Tl is +1.26 V. Which of the following is incorrect regarding the given information?

(a) Tl^{3+} is a powerful reducing agent.

(b) Tl^{3+} is not only unstable in aqueous solution, but also a powerful oxidising agent. Tl^{+} is more stable in solution than Tl^{3+}

(c) Al is more electropositive than thallium

(d) Al is able to form +3 ion easily

98 Which of the following statements is/are correct for borax?

(a) It is the compound of boron

(b) It is a white crystalline solid

(c) Its chemical formula is $Na_2B_4O_7 \cdot 10H_2O$

(d) All of the above

99 Which of the following statement is correct regarding diborane?

(a) The two bridged hydrogen atoms and the one boron atoms lie in one plane

(b) Out of six B—H bonds, two bonds can be described in terms of 2-centre-2-electron bonds

(c) Out of six B—H bonds, four B—H bonds can be described in terms of 3-centre-2-electron bonds

(d) The four terminal B—H bonds are 2-centre-2-electron regular bonds

100 Consider the following statements.

I. $LiBH_4$ is used as an oxidising agent in organic synthesis.

II. $NaBH_4$ is used as a reducing agent in organic synthesis.

The correct statement(s) is/are

(a) I is correct

(b) II is correct

(c) I and II are correct

(d) I and II are incorrect

101 Which of the following is the application of borax?

I. It is used in the manufacture of pyrex glasses, fibre glass and glass wool.

II. It is used as a flux for soldering metals.

III. It is used as a constituent of medicinal soaps.

The correct option is

(a) Both I and II (b) Both II and III

(c) Both I and III (d) I, II and III

102 Consider the following statements :

I. BBr_3 is stronger Lewis acid than BF_3.

II. $p\pi$ - $p\pi$ back bonding occurs in the halides of boron, but not in the halides of aluminium.

III. Borazine is less reactive than boron.

IV. Al is unstable in air and water.

The set of incorrect statements is

(a) Both I and II (b) Both II and III

(c) Both III and IV (b) None of these

103 Which of the following statement is incorrect?

(a) All members of group 14 are solids.

(b) Carbon and silicon are non-metals whereas germanium, tin and lead are metals

(c) Melting and boiling points of group 14 elements are higher than those of corresponding elements of group 13

(d) None of the above

104 Consider the following statements regarding group-14 elements. The incorrect statement is

(a) these can form halides of formula MX_2 and MX_4

(b) except carbon, all other members can react directly with halogen under suitable conditions

(c) most of the tetrahalides are ionic in nature

(d) SnF_4 and PbF_4 are ionic in nature

105 Consider the following statements.

I. Sn in +2 oxidation state is an oxidising agent.

II. Pb compounds are stable in +2 state.

III. Pb compounds act as reducing agent in +4 state.

The correct statement(s) is/are

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

106 Consider the following statements.

I. $GeCl_4$ in HCl forms $H_2[GeCl_6]$.

II. Trisilyl amine is pyramidal.

III. $SnCl_4$ is more stable than $SnCl_2$.

IV. $Ge(OH)_2$ is amphoteric.

The correct statement(s) is/are

(a) Both I and IV (b) Both II and III

(c) Both I and II (d) Both III and IV

107 Which of the following statement is correct for isotope of carbon? ***JIPMER 2019***

(a) Graphite is a conductor of electricity

(b) The carbon atoms of diamond are sp^3-hybridised

(c) Graphite is more stable thermodynamically than diamond

(d) All are correct

108 The major difference between diamond and graphite is due to the

(a) crystal structure of diamond which is different from that of graphite

(b) combination of graphite with oxygen to form CO_2 but not with diamond

(c) different masses of atoms

(d) All of the above

109 Consider the following statements about graphite.

I. It has layered structure.
II. These layers are held by van der Waals' forces and distance between two layers is 340 pm.
III. Each layer is composed of planar hexagonal rings of carbon atoms.
IV. C — C bond-length within the layer is 141.5 pm.

The correct statements are

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

110 Consider the following statements about C_{60}.

I. All the carbon atoms are equal and they undergo sp^2- hybridisation.
II. Each C-atom forms three sigma bonds with other three carbon atoms.
III. The remaining electron at each carbon is delocalised in molecular orbitals, which in turn give aromatic character to molecule.

The correct statements are

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

111 Consider the following statements.

I. Graphite has planar hexagonal layers of carbon atoms in which each carbon atom undergoes sp^2-hybridisation.
II. Fullerene have smooth structure having 'danglings' bond.
III. In diamond, each atom is linked tetrahedrally to four other carbon atoms by sp^3- hybridised bonds.

The correct statement(s) is/are

(a) Both I and III (b) Only III
(c) Both I and II (d) All of these

112 Consider the following statements.

I. Activated charcoal is used in adsorbing poisonous gases, in airconditioning system to control odour.
II. Carbon black is used as black pigment in black ink.
III. Diamond is used in jewellery and is measured in carats.

The correct statement(s) is/are

(a) Only I (b) Only II (c) Only III (d) All of these

113 Consider the following statements :

I. Fullerenes was discovered by Kroto, Smalley and Curl.
II. Graphite is used as a dry lubricant in machines running at high temperature.
III. Spherical fullerenes are also called bucky sphere.
IV. Charcoal and coke are obtained by heating wood or coal respectively at high temperatures in the absence of air.

Choose the correct statements and select the correct option.

(a) Only I and II (b) Only III and IV
(c) I, II and IV (d) II, III and IV

114 Which of the following statement(s) is/are correct regarding CO?

I. It is colourless and odourless gas.
II. It is water soluble.
III. It is water insoluble.
IV. It acts as reducing agent.

The correct statement(s) is/are

(a) Only I (b) I, II and IV
(c) I, III and IV (d) Both I and IV

115 Consider the following statement(s) regarding CO.

I. CO has one σ and two π-bonds.
II. CO acts as electron donor.
III. CO has one lone pair on its carbon atom.
IV. CO reacts with all metals to produce metal carbide.

The correct statements are

(a) I, II and III (b) I, II and IV
(c) I, III and IV (d) Both I and IV

116 Consider the following statements.

I. Highly poisonous nature of CO is because of its ability to form a complex with haemoglobin.
II. Decreased CO_2 content of the atmosphere leads to increase in greenhouse effect.
III. CO_2 has linear shape with dipole moment of 1.2μ.
IV. Gaseous CO_2 is used as fire extinguisher and in manufacture of urea.

Choose the correct statement and select the correct option.

(a) I and II (b) II and IV (c) I and IV (d) I, II and IV

117 Which of the following statement(s) is/are incorrect regarding carbon dioxide?

(a) Carbon dioxide is acidic in nature.
(b) Carbon dioxide combines with alkali to form metal carbonates.
(c) It is present in atmosphere to the extent of 0.03% by volume.
(d) None of the above

118 Which of the following is correct regarding silica?

I. It is a covalent compound.
II. It is three-dimensional network solid.
III. It is non-reactive in nature.
IV. It resists attack of halogens.

Choose the correct option.

(a) I, II and III (b) II, III and IV
(c) Both II and IV (d) All of these

119 Correct statements among (I) to (IV) regarding silicones are : ***JEE Main 2019***

I. They are polymers with hydrophobic character.

II. They are biocompatible.

III. In general, they have high thermal stability and low dielectric strength.

IV. Usually, they are resistant to oxidation and used as greases.

(a) I and II (b) I, II, III

(c) I, II, III and IV (d) I, II and IV

II. Assertion and Reason

■ **Directions** (Q. Nos. 120-138) *In the following questions, a statement of Assertion* (A) *is followed by a corresponding statement of Reason* (R). *Of the following statements, choose the correct one.*

(a) Both A and R are correct; R is the correct explanation of A.

(b) Both A and R are correct; R is not the correct explanation of A.

(c) A is correct; R is incorrect.

(d) A is incorrect; R is correct.

120 **Assertion** (A) The heaviest element in each p-block group is most metallic in nature.

Reason (R) The non-metallic character decreases down the group.

121 **Assertion** (A) Boron always forms covalent bond.

Reason (R) The small size of B^{3+} favours formation of covalent bond.

122 **Assertion** (A) Boron has unusually high melting point.

Reason (R) Boron has very strong crystalline lattice.

123 **Assertion** (A) On going down the group-13, inert pair effect increases.

Reason (R) On going down the group, there is poor shielding effect of intervening d and f-orbitals. Due to this, the effective nuclear charge increases which holds ns-electrons tightly.

124 **Assertion** (A) Aluminium shows amphoteric behaviour.

Reason (R) Aluminium does not react with acids and alkalies even at moderate temperature.

125 **Assertion** (A) $AlCl_3$ is dimerised through halogen bridging.

Reason (R) Metal species, Al in $AlCl_3$ completes its octet by accepting electrons from bridged halogens and forms, Al_2Cl_6.

126 **Assertion** (A) In bivalent state, most of the halides of group 13 elements are hydrolysed in water.

Reason (R) These are covalent in nature.

127 **Assertion** (A) White fumes appear around the bottle of anhydrous aluminium chloride.

Reason (R) Anhydrous aluminium chloride is partially hydrolysed with atmospheric moisture to liberate HCl gas.

128 **Assertion** (A) Metal borides are used in nuclear industry as protective shields and control rods.

Reason (R) The boron-10 (^{10}B) isotope has high ability to absorb neutrons.

129 **Assertion** (A) The use of aluminium and its compounds for domestic purposes is now reduced considerably.

Reason (R) Aluminium and its compounds are highly toxic in nature.

130 **Assertion** (A) The elements of the group 14 are slightly more electronegative than group 13 elements.

Reason (R) Group 14 elements are larger in size than group 13 elements.

131 **Assertion** (A) The common oxidation states exhibited by the group-14 elements is +2 only.

Reason (R) Carbon exhibits both positive and negative oxidation states.

132 **Assertion** (A) Except CCl_4, other tetrachlorides are easily hydrolysed by water.

Reason (R) During hydrolysis the central atom can accommodate the lone pair of electrons from oxygen atom of water molecule in d-orbital.

133 **Assertion** (A) Heavier elements form $p\pi$ - $p\pi$ bonds.

Reason (R) Their atomic orbitals are too large. These diffuse to have effective overlapping.

134 **Assertion** (A) Graphite conducts electricity.

Reason (R) Delocalisation of electrons occurs in graphite.

135 **Assertion** (A) ΔH_f^s of graphite is taken as zero.

Reason (R) Graphite is thermodynamically most stable allotrope of carbon.

136 **Assertion** (A) Buckminster fullerene is a variety of carbon.

Reason (R) Buckminster fullerene is abbreviated as C_{60}.

137 **Assertion** (A) Graphite fibres embedded in plastic material form high strength, light weight composites.

Reason (R) The composites are used in products such as tennis rackets, fishing rods, aircrafts and canoes.

138 **Assertion** (A) PbI_4 is an unstable compound.

Reason (R) +2 oxidation state of Pb is more stable than +4 state.

III. Matching Type Questions

139 Match the following columns and choose the correct option from the codes given below.

	Column I (Element)		Column II (Electronic configuration)
A.	In	1.	[He] $2s^2 2p^1$
B.	Tl	2.	[Ne] $3s^2 3p^1$
C.	B	3.	[Ar] $3d^{10} 4s^2 4p^1$
D.	Ga	4.	[Kr] $4d^{10} 5s^2 5p^1$
E.	Al	5.	[Xe] $4f^{14} 5d^{10} 6s^2 6p^1$

Codes

	A	B	C	D	E
(a)	1	2	3	4	5
(b)	4	5	1	3	2
(c)	2	3	5	1	4
(d)	5	4	3	2	1

140 Match the following columns and choose the correct option from the codes given below.

	Column I (Element)		Column II (Density/g cm^{-3}at 298 K)
A.	Ga	1.	11.85
B.	In	2.	5.90
C.	Al	3.	2.70
D.	B	4.	7.31
E.	Tl	5.	2.35

Codes

	A	B	C	D	E
(a)	2	4	3	5	1
(b)	3	5	1	4	2
(c)	2	5	4	1	3
(d)	1	4	3	2	5

141 Match the following columns and choose the correct option from the codes given below.

	Column I (Element)		Column II (Electronic configuration)
A.	Ge	1.	[Xe] $4f^{14} 5d^{10} 6s^2 6p^2$
B.	Sn	2.	[Kr] $4d^{10} 5s^2 5p^2$
C.	Pb	3.	[Ar] $3d^{10} 4s^2 4p^2$
D.	Si	4.	[Ne] $3s^2 3p^2$
E.	C	5.	[He] $2s^2 2p^2$

Codes

	A	B	C	D	E
(a)	5	4	3	1	2
(b)	3	2	1	4	5
(c)	4	3	1	2	5
(d)	2	1	5	4	3

142 Match the following columns and choose the correct option from the codes given below.

	Column I		Column II
A.	Orthoboric acid	1.	$Na_2B_4O_7 \cdot 4H_2O$
B.	Borax	2.	$Na_2B_4O_7 \cdot 10H_2O$
C.	Kernite	3.	H_3BO_3

Codes

	A	B	C		A	B	C
(a)	1	2	3	(b)	3	2	1
(c)	2	1	3	(d)	1	3	2

143 Match the following columns and choose the correct option from the codes given below.

	Column I		Column II
A.	A poisonous gas	1.	Phosgene
B.	Abrasive	2.	White lead
C.	An ore of tin	3.	Cassiterite
D.	A white pigment	4.	Diamond

Codes

	A	B	C	D		A	B	C	D
(a)	2	1	3	4	(b)	4	3	2	1
(c)	1	4	3	2	(d)	3	2	4	1

144 Match the species given in Column I with the properties mentioned in Column II and choose the correct options from the codes given below.

	Column I		Column II
A.	BF_4^-	1.	Oxidation state of central atom is +4
B.	$AlCl_3$	2.	Lewis acid
C.	SnO	3.	Can be further oxidised
D.	PbO_2	4.	Tetrahedral shape

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	1	3	2	4
(c)	1	2	3	4	(d)	3	1	2	4

145 Match the following columns and choose the correct option from the codes given below.

	Column I		Column II
A.	$H_2 + CO$	1.	Zeolite
B.	$N_2 + CO$	2.	Producer gas
C.	Aluminosilicate	3.	Synthesis gas
D.	Kieselghur	4.	Filtration of plants

Codes

	A	B	C	D		A	B	C	D
(a)	2	1	3	4	(b)	2	3	1	4
(c)	3	2	1	4	(d)	3	2	4	1

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

146 An aqueous solution of borax is

(a) neutral (b) amphoteric

(c) basic (d) acidic

147 Boric acid is polymeric due to

(a) its acidic nature

(b) the presence of hydrogen bonds

(c) its monobasic nature

(d) its geometry

148 The type of hybridisation of boron in diborane is

(a) sp (b) sp^2 (c) sp^3 (d) dsp^2

149 Which of the following is true for elements of group 14?

(a) Only exhibit oxidation state of + 4

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

(c) Form M^{2-} and M^{4+} ions

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

150 What are the states of hybridisation of carbon in CO_3^{2-}, diamond and graphite respectively?

(a) sp^2, sp^3, sp^2 (b) sp^2, sp^2, sp^3

(c) sp^2, sp^3, sp^3 (d) sp^3, sp^3, sp^2

NCERT Exemplar

151 The element which exists in liquid state for a wide range of temperature and can be used for measuring high temperature is

(a) B (b) Al

(c) Ga (d) In

152 Ionisation enthalpy ($\Delta_i H$ kJ mol^{-1}) for the elements of group 13 follows the order

(a) B > Al > Ga > In > Tl

(b) B < Al < Ga < In < Tl

(c) B < Al > Ga < In > Tl

(d) B > Al < Ga > In < Tl

153 The exhibition of highest coordination number depends on the availability of vacant orbitals in the central atom. Which of the following elements is not likely to act as central atom in MF_6^{3-}?

(a) B (b) Al

(c) Ga (d) In

154 Which of the following is a Lewis acid?

(a) $AlCl_3$ (b) $MgCl_2$

(c) $CaCl_2$ (d) $BaCl_2$

155 Which of the following oxides is acidic in nature?

(a) B_2O_3 (b) Al_2O_3 (c) Ga_2O_3 (d) In_2O_3

156 The geometry of a complex species can be understood from the knowledge of type of hybridisation of orbitals of central atom. The hybridisation of orbitals of central atom in $[B(OH_4)]^-$ and the geometry of the complex are respectively

(a) sp^3, tetrahedral

(b) sp^3, square planar

(c) sp^3d^2, octahedral

(d) dsp^2, square planar

157 Boric acid is an acid because its molecule

(a) contains replaceable H^+ ion

(b) gives up a proton

(c) accepts OH^- from water releasing proton

(d) combines with proton from water molecule

158 In the structure of diborane,

(a) All hydrogen atoms lie in one plane and boron atoms lie in a plane perpendicular to this plane

(b) 2 boron atoms and 4 terminal hydrogen atoms lie in the same plane and 2 bridging hydrogen atoms lie in the perpendicular plane

(c) 4 bridging hydrogen atoms and boron atoms lie in one plane and two terminal hydrogen atoms lie in a plane perpendicular to this plane

(d) All the atoms are in the same plane

159 A compound X, of boron reacts with NH_3 on heating to give another compound Y, which is called inorganic benzene. The compound X can be prepared by treating BF_3 with lithium aluminium hydride. The compounds X and Y are represented by the formulae

(a) B_2H_6, $B_3N_3H_6$ (b) B_2O_3, $B_3N_3H_6$

(c) BF_3, $B_3N_3H_6$ (d) $B_3N_3H_6$, B_2H_6

160 Catenation i.e., linking of similar atoms depends on size and electronic configuration of atoms. The tendency of catenation in group 14 elements follows the order

(a) C > Si > Ge > Sn (b) C >> Si > Ge ≈ Sn

(c) Si > C > Sn > Ge (d) Ge > Sn > Si > C

161 The most commonly used reducing agent is

(a) $AlCl_3$ (b) $PbCl_4$ (c) $SnCl_4$ (d) $SnCl_2$

162 Dry ice is

(a) solid NH_3 (b) solid SO_2

(c) solid CO_2 (d) solid N_2

163 Silicon has a strong tendency to form polymers, like silicones. The chain length of silicon polymer can be controlled by adding

(a) $MeSiCl_3$ (b) Me_2SiCl_2
(c) Me_3SiCl (d) Me_4Si

164 Quartz is extensively used as a piezoelectric material, it contains ....

(a) Pb (b) Si (c) Ti (d) Sn

165 Cement, the important building material is a mixture of oxides of several elements. Besides calcium, iron and sulphur, oxides of elements of which of the group(s) are present in the mixture?

(a) Only group-2
(b) Only groups-2, 13 and 14
(c) Only groups-2 and 13
(d) Only groups-2 and 14

Answers

> *Master NCERT With MCQs*

1 (a)	*2* (b)	*3* (b)	*4* (b)	*5* (c)	*6* (a)	*7* (a)	*8* (b)	*9* (d)	*10* (c)
11 (a)	*12* (d)	*13* (d)	*14* (c)	*15* (d)	*16* (d)	*17* (c)	*18* (b)	*19* (b)	*20* (b)
21 (b)	*22* (d)	*23* (a)	*24* (c)	*25* (a)	*26* (c)	*27* (a)	*28* (a)	*29* (b)	*30* (a)
31 (d)	*32* (a)	*33* (b)	*34* (b)	*35* (a)	*36* (b)	*37* (b)	*38* (d)	*39* (a)	*40* (b)
41 (d)	*42* (c)	*43* (b)	*44* (b)	*45* (b)	*46* (b)	*47* (c)	*48* (b)	*49* (c)	*50* (a)
51 (a)	*52* (d)	*53* (c)	*54* (c)	*55* (a)	*56* (b)	*57* (a)	*58* (c)	*59* (b)	*60* (b)
61 (b)	*62* (d)	*63* (c)	*64* (c)	*65* (c)	*66* (d)	*67* (b)	*68* (a)	*69* (b)	*70* (a)
71 (d)	*72* (b)	*73* (c)	*74* (a)	*75* (b)	*76* (d)	*77* (a)	*78* (c)	*79* (a)	*80* (c)
81 (b)	*82* (c)	*83* (d)	*84* (a)	*85* (c)					

> *Spcial Types Questions*

86 (b)	*87* (b)	*88* (c)	*89* (d)	*90* (a)	*91* (d)	*92* (b)	*93* (d)	*94* (a)	*95* (b)
96 (d)	*97* (a)	*98* (d)	*99* (d)	*100* (b)	*101* (d)	*102* (c)	*103* (b)	*104* (c)	*105* (b)
106 (a)	*107* (d)	*108* (a)	*109* (d)	*110* (d)	*111* (a)	*112* (d)	*113* (c)	*114* (c)	*115* (a)
116 (c)	*117* (d)	*118* (d)	*119* (d)	*120* (a)	*121* (c)	*122* (a)	*123* (a)	*124* (c)	*125* (a)
126 (d)	*127* (a)	*128* (a)	*129* (a)	*130* (c)	*131* (d)	*132* (a)	*133* (d)	*134* (a)	*135* (a)
136 (b)	*137* (b)	*138* (a)	*139* (b)	*140* (a)	*141* (b)	*142* (b)	*143* (c)	*144* (a)	*145* (c)

> *NCERT & NCERT Exemplar Questions*

146 (c)	*147* (b)	*148* (c)	*149* (b)	*150* (a)	*151* (c)	*152* (d)	*153* (a)	*154* (a)	*155* (a)
156 (a)	*157* (c)	*158* (b)	*159* (a)	*160* (b)	*161* (d)	*162* (c)	*163* (c)	*164* (b)	*165* (b)

Hints & Explanations

4 (*b*) The compounds formed by the highly reactive non-metals with highly reactive metals are generally ionic because of large differences in their electronegativities.

The compounds formed by non-metals are covalent because of small differences in their electronegativities.

8 (*b*) Boron forms $[BF_4]^-$, while aluminium forms $[AlF_6]^{3-}$ as it expands its covalency beyond four by utilising $3d$-orbitals for bond formation.

10 (*c*) Carnallite is $KCl \cdot MgCl_2 \cdot 6H_2O$. It is not a mineral of boron.

11 (*a*) Aluminium is the most abundant metal and the third most abundant element in the earth's crust (8.3% by mass) after oxygen (45.5%) and Si (27.7%).

12 (*d*) The atomic radii as well as ionic radii increases on moving down the group 13 elements because of the successive addition of one extra shell of electrons.

However, there is an anomaly in case of atomic radius. Atomic radius of Ga is lesser as compared to that of Al. Gallium (Ga) with electronic configuration, $[Ar]_{18} 3d^{10} 4s^2 4p^1$ has extra d-electrons which do not screen the nucleus effectively. Consequently, electrons of Ga are more attracted by nucleus.

Thus, the increasing order of atomic radii of the group 13 elements is B (85 pm) < Ga (135 pm) < Al (143 pm) < In (167 pm) < Tl (170 pm).

13 (*d*) The ionisation enthalpy values as expected from the general trends, do not decrease smoothly down the group.

The decrease from B to Al is associated with increase in size. The observed discontinuity in the ionisation enthalpy values between Al and Ga, and that between In and Tl are due to the inability of d-and f-electrons, which have low screening effect, to compensate the increase in nuclear charge down the group.

14 (*c*) Let, us consider the electronegativity values of the given elements,

	Group-1	Group-2	Group-13	Group-19
Period 2 ⇒	Li (1.0)	Be (1.5) ↘	B (2.0)	C (2.5)
Period 3 ⇒			Al (1.5)	

Be and Al show diagonal relationship which is based on their same $\frac{z^*}{r}$ value (Z^* is effective nuclear charge, r = atomic radius)

So, they have similar electronegativity.

18 (*b*) The stability order of + 3 and + 1 oxidation states of group 13 elements will be :

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

(order of + 3 oxidation state)

$$B^+ << Al^+ < Ga^+ < In^+ < Tl^+$$

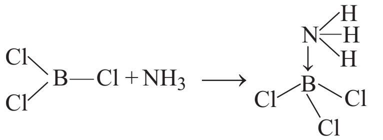
(order of + 1 oxidation state)

The presence of two oxidation states in p-block elements is due to the inert pair effect.

Because of the presence of poor shielding d and f-orbitals, as we move from Ga to Tl, effective nuclear charge of these elements increases so as to hold the valence ns^2 electrons tightly. It causes difficulty to the ionisation of ns^2-electrons and it remains inert, only np^1-electrons ionises to give + 1 oxidation state.

19 (*b*) In a trivalent state, the number of electrons around the central atom of group 13 elements in a molecule will be only six because sharing of only three electrons is possible.

20 (*b*) BCl_3 (Lewis acid) reacts with NH_3 (Lewis base) to form an addition product. The complete reaction is shown below.



Addition product

24 (*c*) Aluminium dissolves in dil. HCl and liberates dihydrogen.

The complete reaction is given below.

$$\underset{(p)}{2Al(s)} + \underset{(q)}{6HCl(aq)} \rightarrow \underset{(r)}{2Al^{3+}(aq)} + \underset{(s)}{6Cl^-(aq)} + \underset{(t)}{3H_2(g)}$$

Hence, the stoichiometric coefficients (p, q, r, s, t) are 2, 6, 2, 6, 3 respectively.

26 (*c*) The trichlorides, tribromides and triiodides of all the group-13 elements are covalent in nature and they are hydrolysed in water.

Species like tetrahedral $[M(OH)_4]^-$ and octahedral $[M(H_2O)_6]^{3+}$, except in boron, exist in aqueous medium.

27 (*a*) Species like tetrahedral $[M(OH)_4]^-$ and octahedral $[M(H_2O)_6]^{3+}$ does not exist in case of boron due to non-availability of d orbitals for expanding its covalency.

28 (*a*) The monomeric trihalides of elements of group 13, being electron deficient, are strong Lewis acids. Boron trifluoride (BF_3) easily reacts with Lewis base such as NH_3 to complete its octet around boron. This can be expressed as shown below :

$$F_3B + :NH_3 \longrightarrow F_3B \longleftarrow NH_3$$

29 (*b*) The elements of group 13 react with halogens to form trihalides (except TlI_3). Tl forms TlI instead of TlI_3.

The reaction is given below :

$$2E(s) + 3X_2(g) \longrightarrow 2EX_3(s) \quad [X = F, Cl, Br, I]$$

30 (*a*) Boron belongs to 2nd period of the periodic table with electronic configuration $1s^2, 2s^2, 2p^1$. It does not have vacant *d*-orbitals, thus it cannot increase its covalency above four.

Therefore, boron (B) is unable to form MF_6^{3-} ion. The elements like aluminium (Al), gallium (Ga) and indium (In) have vacant 3*d*-orbitals, thus they can increase their covalence above four and form MF_6^{3-} ion.

31 (*d*) Boron forms acidic hydroxide $B(OH)_3$, while Al forms amphoteric hydroxide $Al(OH)_3$.

32 (*a*) The complete reaction is shown below :

$$\underset{\text{Borax}}{Na_2B_4O_7} + 7H_2O \longrightarrow 2NaOH + \underset{\substack{\text{Orthoboric acid}\\(A)}}{4H_3BO_3}$$

So, *A* is orthoboric acid.

33 (*b*) On heating borax, it first loses water molecules and swells up. On further heating, it turns into a transparent liquid, which solidifies into glass like material known as borax bead.

The corresponding reaction is given below :

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

34 (*b*) The borax bead test can be used to identify transition metals as their metaborates have characteristic colours. When borax is heated in a bunsen burner flame with CoO(*X*) on a loop of platinum wire, a blue coloured $Co(BO_2)_2$ (*Y*) bead is formed.

Therefore, *X* and *Y* are CoO and $Co(BO_2)_2$ respectively and the correct option is (b).

35 (*a*) The complete reaction is shown below :

$$Na_2B_4O_7 + \underset{'X'}{2HCl} + 5H_2O \longrightarrow 2NaCl + \underset{'Y'}{4B(OH)_3}$$

So, *X* is HCl.

36 (*b*) On heating, orthoboric acid above 370 K forms metaboric acid, HBO_2 which on further heating yields boric oxide, B_2O_3.

$$H_3BO_3 \xrightarrow{\Delta} \underset{\substack{\text{Metaboric acid}\\(X)}}{HBO_2} \xrightarrow{\Delta} \underset{\substack{\text{Boric oxide}\\(Y)}}{B_2O_3}$$

37 (*b*) The industrial scale production of diborane involves the reaction of BF_3 with sodium hydride as shown below :

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

39 (*a*) Diborane (B_2H_6) reacts independently with O_2 and H_2O to produce B_2O_3 and H_3BO_3 respectively. Diborane is a colourless, highly toxic gas, having boiling point 180 K. Because of its inflammable nature. It catches fire spontaneously when exposed to air and burns in oxygen releasing an enormous amount of energy as :

$$B_2H_6 + 3O_2 \longrightarrow B_2O_3 + 3H_2O + 1976\text{ kJ/mol}$$

It gets hydrolysed readily to give boric acid.

$$\underset{\text{Borane}}{B_2H_6} + 6H_2O \longrightarrow \underset{\text{Orthoboric acid}}{2H_3BO_3} + \underset{\text{Dihydrogen}}{6H_2\uparrow}$$

40 (*b*) The correct structure of diborane is given in option (b). The four terminal hydrogen atoms and the two boron atoms lie in one plane. Above and below this plane, there are two bridging hydrogen atoms.

41 (*d*) Boron forms a series of hydridoborates; the most important one is the tetrahedral $[BH_4]^-$ ion. Tetrahydridoborates of several metals are known. Lithium and sodium tetrahydridoborates are also known as borohydrides.

43 (*b*) Nihonium ($Z = 113$) and flerovium ($Z = 114$) are prepared only in small amounts. Their half-life is short and their chemistry has not been established yet.

44 (*b*) There is a considerable increase in covalent radius from C to Si, thereafter from Si to Pb a small increase in radius is observed. This is due to the presence of completely filled *d* and *f*-orbitals in heavier members.

45 (*b*) There is a small decrease in $\Delta_i H$ from Si to Ge to Sn and slight increase in $\Delta_i H$ from Sn to Pb. This is the consequence of poor shielding effect of intervening *d* and *f*-orbitals and an increase in size of the atom.

46 (*b*) The tendency of Ge, Sn and Pb to show +2 oxidation state increases on moving from Ge to Pb. Thus, the correct sequence is Ge < Sn < Pb. It is because of inert pair effect, due to which ns^2 electrons of valence shell are unable to participate in bonding.

47 (*c*) $[SiCl_6]^{2-}$ is not stable and does not exist because

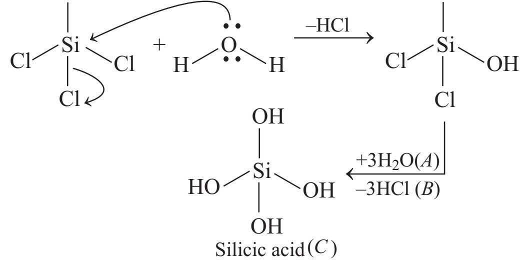
(i) six large chloride ions cannot be accommodated around Si^{4+} due to limitation of its size.

(ii) interaction between lone pair of chloride ion and Si^{4+} is not very strong.

On the other hand, due to presence of *d*-orbital in Si, Ge and Sn they form species like $[SiF_6]^{2-}$, $[GeCl_6]^{2-}$ and $[Sn(OH)_6]^{2-}$. Hence, option (c) is correct.

50 (*a*) PbI_4 does not exist because Pb—I bond, initially formed during the reaction, does not release enough energy to unpair $6s^2$ electrons and excite one of them to higher orbital to have four unpaired electrons around lead (Pb) atom.

51 (*a*) The complete reaction is given below :



Silicic acid (*C*)

Hence, *A* is $3H_2O$, *B* is 3HCl and C is silicic acid.

54 (*c*) Diamond, graphite and fullerene are crystalline allotropes of carbon. Whereas, soot is not an allotrope of carbon.

55 (*a*) Diamond has a crystalline lattice. In diamond, each carbon atom undergoes sp^3 -hybridisation and linked to four other carbon atoms by using hybridised orbitals in tetrahedral fashion. The structure extends in space and produces a rigid three dimensional network of carbon atoms.

56 (*b*) The figures *A* and *B* represent diamond and graphite respectively.

60 (*b*) C_{60} is aromatic allotrope of carbon containing 12 pentagons and 20 hexagons. It is a fullerene having a shape like soccer ball and called Buckminster fullerene.

62 (*d*) On small scale, pure CO is prepared by dehydration of formic acid with conc. H_2SO_4 at 373 K. Concentrated H_2SO_4 is a dehydrating agent. So, it removes water from HCOOH as shown below :

$$\underset{\text{Formic acid}}{\mathrm{HCOOH}} \xrightarrow[\text{Conc. } H_2SO_4]{373\text{ K}} H_2O + CO$$

64 (*c*) Mixture of CO and N_2 is known as producer gas which can be prepared as follows :

$$2C(s) + O_2(g) + 4N_2(g) \xrightarrow{1273\text{ K}} \underbrace{2CO(g) + 4N_2(g)}_{\text{Producer gas}}$$

65 (*c*) CO reduces all metal oxides except Al_2O_3, alkali and alkaline earth metal oxides. A few reduction reactions are given below :

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$$

$$ZnO(s) + CO(g) \xrightarrow{\Delta} Zn(s) + CO_2(g)$$

66 (*d*) The reaction of CO with H_2O is as follows :

$$CO + H_2O \longrightarrow CO_2 + H_2$$

So, the products obtained are carbon dioxide and hydrogen.

68 (*a*) In laboratory, CO_2 can be prepared by the reaction of dil. HCl and $CaCO_3$ as shown below :

$$\underset{(B)}{CaCO_3(s)} + \text{dil.}\underset{(A)}{2HCl(aq)} \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

71 (*d*) 0.03% of carbon dioxide present in atmosphere can be removed by photosynthesis, which is a process of conversion of atmospheric CO_2 to carbohydrate like glucose.

The overall chemical change can be expressed as shown below :

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{h\nu} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

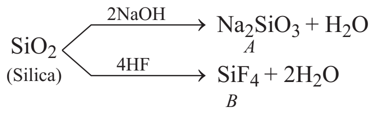
72 (*b*) The CO_2 molecule is shown below :

$$O \overset{\pi}{=} C \overset{\pi}{=} O$$

The C atom in CO_2 possesses *sp*-hybridisation due to the presence of 2π bonds. (∵ 2π bonds)

73 (*c*) Silica (SiO_2) is a major constituent present in earth crust and it occurs in many crystallographic forms such as quartz, cristobalite, tridymite etc.

74 (*a*) The complete reactions are given below :



$$\underset{\text{(Silica)}}{SiO_2} \xrightarrow{2NaOH} \underset{A}{Na_2SiO_3} + H_2O$$

$$\underset{\text{(Silica)}}{SiO_2} \xrightarrow{4HF} \underset{B}{SiF_4} + 2H_2O$$

Hence, *A* and *B* are Na_2SiO_3 and SiF_4 respectively.

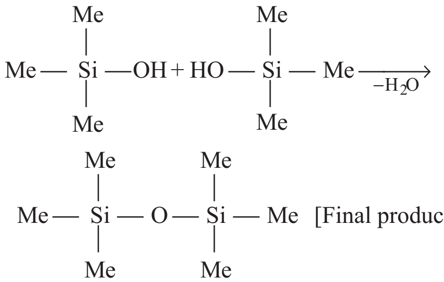
75 (*b*) Silica occurs in nature in several amorphous and crystalline forms. Kieselguhr is the amorphous form of silica. Quartz, tridymite and cristobalite are crystalline forms of silica.

76 (*d*) Quartz is used as piezoelectric material which is used in making clock, modern radio etc.

77 (*a*) Silica gel is used as dehydrating agent as it removes moisture from the atmosphere.

78 (*c*) Me_3SiCl is not a monomer for a high molecular mass silicone polymer because it generates Me_3SiOH when subjected to hydrolysis which contains only one reacting site.

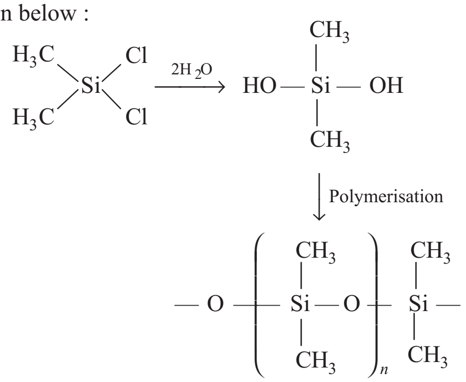
Hence, the polymerisation reaction stops just after first step as shown below :



$$Me-\underset{Me}{\overset{Me}{\underset{|}{\overset{|}{Si}}}}-OH + HO-\underset{Me}{\overset{Me}{\underset{|}{\overset{|}{Si}}}}-Me \xrightarrow[-H_2O]{}$$

$$Me-\underset{Me}{\overset{Me}{\underset{|}{\overset{|}{Si}}}}-O-\underset{Me}{\overset{Me}{\underset{|}{\overset{|}{Si}}}}-Me$$ [Final product (dimer)]

79 (*a*) The reaction of hydrolysis of dimethyl dichloro silicone followed by condensation polymerisation is given below :

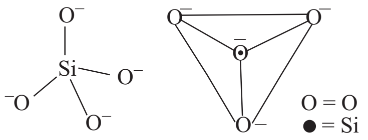


Silicone (straight chain polymer)

80 (*c*) Silicones are synthetic organosilicon polymers containing repeated R_2SiO units. It is used in surgical and cosmetic implants. They are also used as low temperature lubricants, in making waterproof clothes and paper, etc.

81 (*b*) The basic structural unit of all silicates is the tetrahedral SiO_4^{4-}.

It is represented as shown below :

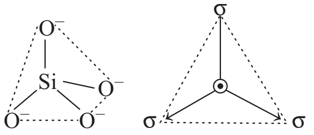


Structure of SiO_4^{4-} ion

82 (*c*) The basic structural unit of feldspar, zeolites, mica and asbestos is $(SiO_4)^{4-}$. These all are silicates. All silicates involve two types of Si—O bonds.

(i) Terminal Si—O bonds in which oxygen is bonded to a silicon and not other atom.

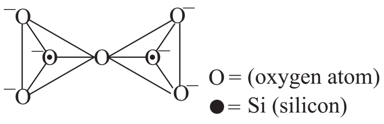
(ii) Bridging Si—O—Si bonds in which oxygen is bonded to two silicon atoms.



Tetrahedral structure of SiO_4^{2-} anion

In SiO_4^{4-} ion, each Si atom is bonded to four oxygen atoms tetrahedrally.

83 (*d*) In pyrosilicates, two SiO_4^{4-} tetrahedrons share a corner oxygen atom as shown below :



$Si_2O_7^{6-}$ anion of pyrosilicate

84 (*a*) The zeolite ZSM-5 is used to convert alcohols directly into gasoline.

85 (*c*) *P* and *Q* are boron and silicon, as they yield boranes and silicanes respectively.

86 (*b*) The electrons in *d*-orbitals cannot screen the nucleus effectively and hence effective nuclear charge of Ga (It contains 10 electrons) is greater in magnitude than that of Al. So, electrons of Ga experience greater force of attraction than Al and hence atomic radius of Ga is lesser than that of Al.

90 (*a*) Statement I is correct regarding the properties of boron, while the statements II and III are incorrect.

Corrected form are as follows :

II. Boron has high melting point and low density.

III. Boron shows low electrical conductivity.

92 (*b*) Statement (b) is correct, while other statements are incorrect. Corrected form are as follows :

(a) Density of the group-13 elements increases down the group from boron to thallium.

(c) Boron is a hard non-metal.

(d) Melting point of Ga is unusually low (i.e. 303 K).

93 (*d*) Statement (d) is incorrect. It's correct form is as follows :

Aluminium forms a very thin oxide layer on its surface which protects the metal from further attack by oxygen.

Rest other statements are correct.

94 (*a*) Statement (a) is correct, while the other statements are incorrect. Corrected form are as follows :

(b) Aluminium vessel cannot be used to store NaOH.

NaOH reacts with Al as follows :

$$2NaOH + 3Al \longrightarrow 2NaAlO_2 + 3H_2 + 2H_2O$$

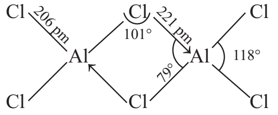
Thus, NaOH cannot be stored in a vessel made of Al.

(c) Aluminium chloride dissociates in water.

(d) AlF_3 is insoluble in anhydrous HF.

95 (*b*) Statements II, III and IV are correct, while statement I is incorrect. It's correct form is as follows :

The structure of Al_2Cl_6 is shown below :



The six Al—Cl bonds are not of the same length.

96 (*d*) Statement III is incorrect.

It's correct form is as follows :

The compounds of group-13 elements in +1 oxidation state, as expected from energy considerations, are more ionic than those in +3 oxidation state.

Rest other statements are correct.

97 (*a*) Statement (a) is incorrect.

It's correct form is as follows :

Tl^{3+} is a powerful oxidising agent.

Thus, Tl^{+} is more stable in solution than Tl^{3+}.

Rest other statements are correct.

99 (*d*) Statement (d) is correct, while other statements are incorrect. Corrected form are as follows :

(a) The four terminal hydrogen atoms and the two boron atoms lie in one plane. Above and below this plane, there are two bridging hydrogen atoms.

(b) The four terminal B—H bonds are regular 2-centre-2-electron bonds.

(c) The two bridged (B—H—B) bonds are different and can be described in terms of 3-centre-2-electron bonds.

100 (*b*) Statement II is correct, while statement I is incorrect. It's correct form is as follows :

$LiBH_4$ is used as reducing agent in organic synthesis.

102 (*c*) Statements III and IV are incorrect.

It's correct form are as follows :

III. Borazine is more reactive than boron.

IV. Aluminium is stable in air and water.

Rest other statements are correct.

103 (*b*) Statement (b) is incorrect.
It's correct form is as follows :

Carbon and silicon are non-metals, germanium is metalloid, whereas tin and lead are soft metals with low melting points.

Rest other statements are correct.

104 (*c*) Statement (c) is incorrect.
It's correct form is as follows :
Most of the tetrahalides are covalent in nature.

Rest other statements are correct.

105 (*b*) Statement II is correct, while statements I and III are incorrect. Corrected form are as follows :

I. Sn in +2 oxidation state is a reducing agent.
III. Pb compounds act as oxidising agent in +4 state.

106 (*a*) Statements I and IV are correct, while II and III are incorrect. Corrected form are as follows :

II. Because of sp^2-hybridisation trisilyl amine is planar.
III. $SnCl_2$ is more stable than $SnCl_4$ due to inert pair effect.

108 (*a*) The major difference between diamond and graphite is due to the crystal structure of diamond which is different from that of graphite.

111 (*a*) Statements I and III are correct while statement II is incorrect. It's correct form is as follows :

Fullerene are the only pure form of carbon because they have smooth structure without having 'dangling' bonds.

113 (*c*) Statement I, II and IV are correct, while statement III is incorrect. It's correct form is as follows :

Spherical fullerenes are also called bucky balls in short.

114 (*c*) Statements, I, III and IV are correct while statement II is incorrect. It's correct form is as follows :

CO is water insoluble.

115 (*a*) Statements I, II and III are correct, while IV is incorrect. It's correct form is as follows :

CO reacts with certain metals when heated to form metal carbonyls.

116 (*c*) Statements I and IV are correct while statements II and III are incorrect. Corrected form are as follows :

II. Increase in combustion of fossil fuels and decomposition of limestone for cement manufacture increases CO_2 content of the atmosphere. This may lead to increase in greenhouse effect.
IV. In CO_2 molecule, carbon atom undergoes *sp*-hybridisation. Two *sp*-hybridised orbitals of carbon atom overlap with two *p*-orbitals of oxygen atoms to make two sigma bonds while other two electrons of carbon atom are involved in $p\pi$-$p\pi$ bonding with oxygen atom. This results in its linear shape with no dipole moment.

119 (*d*) Silicones are polysiloxanes with general chemical formula, $[R_2SiO]_n$, where R is an organic group such as :

$$—CH_3, —C_2H_5, —C_6H_5 \text{ etc.}$$

Silicones have many useful properties :

(i) They repel water and form watertight seals.
(ii) They are heat resistant because of constancy of properties over a wide range of temperature (−100° to 250° C).
(iii) Silicones are non-toxic.
(iv) Silicones are biocompatible because these do not support microbiological growth and these have high gas permeability at room temperature.
(v) They are resistant to O_2, O_3 and UV-radiation.
(vi) Silicones are formulated to be electrically insulative.
(vii) Silicone grease is typically used as a lubricant for brake components in automobiles, since it is stable at high temperature, is not water soluble and is a odourless viscous liquid.

120 (*a*) The heaviest element in each *p*-block group is the most metallic in nature as the non-metallic character decreases down the group.

Thus, both A and R are correct and R is the correct explanation of A.

121 (*c*) Boron always forms covalent bond because of its small size. B never forms B^{3+} ion.

Thus, A is correct but R is incorrect.

123 (*a*) On moving down the group, due to poor shielding effect of intervening *d* and *f*-orbitals, the increased effective nuclear charge holds electrons tightly (responsible for inert pair effect) and thereby, restricting their participation in bonding. As a result of this, only *p*-orbital electron may be involved in bonding. So, inert pair effect increases on going down the group 13.

Thus, both A and R are correct and R is the correct explanation of A.

124 (*c*) Aluminium dissolves in mineral acids and aqueous alkalies. Thus, Al shows amphoteric character.

Thus, A is correct and R is incorrect.

125 (*a*) Since, *d*-orbitals are available in Al the maximum covalence can be expected beyond 4. Thus, $AlCl_3$ is dimerised through bridged halogen, to form Al_2Cl_6.

Al completes its octet by accepting electrons from halogens present at bridge.

Thus, both A and R are correct and R is the correct explanation of A.

126 (*d*) In trivalent state most of the halides of group 13 are hydrolysed in water as they are covalent in nature.

Thus, A is incorrect but R is correct.

127 (*a*) White fumes appear around the bottle of anhydrous aluminium chloride because anhydrous aluminium chloride is partially hydrolysed with atmospheric moisture to liberate HCl gas. Moist HCl appears white in colour.

Thus, both A and R are correct and R is the correct explanation of A.

128 (*a*) The boron-10 (^{10}B) isotope has high ability to absorb neutrons and therefore, metal borides are used in nuclear industry as protective shields and control rods.

Thus, both A and R are correct and R is the correct explanation of A.

129 (*a*) The use of aluminium and its compounds for domestic purposes is now reduced considerably because of toxic nature of aluminium and its compounds.

Thus, both A and R are correct and R is the correct explanation of A.

130 (*c*) Group 14 elements are actually smaller in size than group 13 elements. Group 14 elements are slightly more electronegative than the latter.

Thus, A is correct but R is incorrect.

131 (*d*) The common oxidation states exhibited by the group-14 elements are +4 and +2.

Thus, A is incorrect but R is correct.

132 (*a*) Except CCl_4, other tetrachlorides are easily hydrolysed by water because the central atom can accommodate the lone pair of electrons from oxygen atom of water molecule in d -orbital.

Thus, both A and R are correct and R is the correct explanation of A.

133 (*d*) Heavier elements do not form $p\pi$- $p\pi$ bonds because their atomic orbitals are too large and diffuse to have effective overlapping.

Thus, A is incorrect but R is correct.

134 (*a*) In graphite, each carbon atom in hexagonal ring undergoes sp^2-hybridisation and makes three sigma bonds with three neighbouring carbon atoms. Fourth electron forms π –bond. Due to delocalisation of this fourth electron, graphite conducts electricity.

Thus, both A and R are correct and R is the correct explanation of A.

135 (*a*) Graphite is thermodynamically most stable allotrope of carbon and therefore, $\Delta_f H^S$ of graphite is taken as zero.

Thus, both A and R are correct and R is the correct explanation of A.

136 (*b*) Buckminster fullerene is a variety of carbon, which is abbreviated as C_{60}.

Thus, both A and R are correct and R is not the correct explanation of A.

137 (*b*) Due to layered structure of graphite, graphite fibres embedded in plastic material form high strength, light weight composites. The composites are used in products such as tennis rackets, fishing rods, aircrafts and canoes.

Thus, both A and R are correct and R is not the correct explanation of A.

138 (*a*) Due to inert pair effect, +2 oxidation state of Pb is more stable than +4 oxidation state. That is why, PbI_4 is an unstable compound.

Thus, both A and R are correct and R is the correct explanation of A.

146 (*c*) Borax is a salt of strong base (NaOH) and weak acid (H_3BO_3), therefore, its aqueous solution is basic in nature.

147 (*b*) Boric acid is polymeric due to the presence of hydrogen bonds. (as it has polar O—H bonds).

148 (*c*) In B_2H_6, each boron atom is sp^3-hybridised.

149 (*b*) Due to inert pair effect, elements of group-14 exhibit oxidation states of + 2 and + 4.

151 (*c*) In gallium, the crystal structure is different, i.e. each Ga-atom has one close neighbour at a distance of 2.43 Å and six more distant neighbours at distance between 2.70 Å to 2.79 Å suggesting that Ga consists of almost discrete Ga_2 molecule. That's why, its melting point is the lowest. Ga exists as liquid from 30°C upto 2000°C and hence, it is used in high temperature thermometry.

152 (*d*) On moving from B to Al, the ionisation enthalpies decreases as expected and this decrease is due to an increase in atomic size and shielding effect.

On moving from Al to Ga, the ionisation enthalpy increases slightly, because on moving from Al to Ga, both nuclear charge and shielding effect increases. Due to poor shielding by *d*-electrons in Ga, effective nuclear charge on valence electron increases resulting in *d*-block contraction, that's why ionisation enthalpy increases.

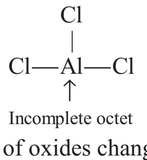
On moving from Ga to In, again there is slight decrease in ionisation enthalpies due to increased shielding effect by additional ten 4*d* electrons, which outweighs the effect of increased nuclear charge.

On moving from ln to Tl, ionisation enthalpy again increases because fourteen 4*f* electrons shield valence electrons poorly (order of shielding effect $s > p > d > f$) and so effective nuclear charge increases, consequently ionisation enthalpy increases.

153 (*a*) The lowest atomic number among the given is of boron. Boron has atomic number 5 and does not have vacant *d*-orbital. The element M in the complex ion MF_6^{3-} has a coordination number of six. Boron can show maximum coordination number of 4 due to absence of *d*-orbitals. Thus, B cannot form complex of the type MF_6^{3-}.

154 (*a*) Alkaline earth metals form ionic chloride whereas aluminium chloride is covalent. Despite of sharing electrons with chlorine, the octet of aluminium is incomplete. To complete the octet, it needs electrons and thus, acts as a Lewis acid as shown below :

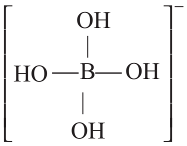
$_{13}Al = 2, 8, 3$ and $_{17}Cl = 2, 8, 7$



$$\begin{array}{c} Cl \\ | \\ Cl—\underset{\uparrow}{Al}—Cl \end{array}$$

155 (*a*) The acidic nature of oxides changes from acidic to basic through amphoteric on moving down the group as shown below :

$$\underbrace{B_2O_3}_{\text{Acidic}}\ \underbrace{Al_2O_3 \text{ and } Ga_2O_3}_{\text{Amphoteric}},\ \underbrace{In_2O_3 \text{ and } Tl_2O_3}_{\text{Basic}}$$

156 (*a*) Structure of $B(OH)_4^-$ is 

$$\left[\begin{array}{c} OH \\ | \\ HO—B—OH \\ | \\ OH \end{array}\right]^-$$

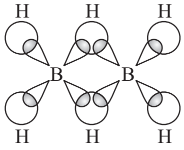
$[B(OH)_4]^-$ contains four bond pairs and no lone pairs. Thus, the hybridisation of central atom is sp^3 and the geometry of the complex is sp^3.

157 (*c*) Lewis acids are the substances in which octet is incomplete and hence, they accept electrons. Boric acid is a monobasic weak acid. It does not liberate H^+ ion but accept electrons from OH^- ion, i.e. behaves as Lewis acid as shown below :

$$H_3BO_3 + H_2O \longrightarrow [B(OH)_4]^- + H^+$$

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

158 (*b*) In diborane, there are 12 valence electrons, three from each boron atoms and six from the six hydrogen atoms. The geometry of B_2H_6 can be represented as shown below :



Bonding in diborane

The four terminal hydrogen atoms and two boron atoms lie in one plane. Above and below the plane, there are two bridging hydrogen atoms. Each boron atom forms four bonds even though it has only three electrons. The terminal B—H bonds are regular bonds but the bridge B—H bonds are different. Each bridge hydrogen is bonded to the two boron atoms only by sharing of two electrons. Such covalent bond is called 3-centre-2-electron bond or a multicentre bond or banana bond.

159 (*a*)

(i) Reaction of ammonia with diborane gives initially $B_2H_6 \cdot 2NH_3$, which is formulated as : $[BH_2(NH_3)_2]^+ [BH_4]^-$. On further heating, it gives borazine, $B_3N_3H_6$ as shown by the reaction given below :

$$\underset{\substack{\text{Diborane} \\ (X)}}{3B_2H_6} + 6NH_3 \longrightarrow 3[BH_2(NH_3)_2]^+ [BH_4]^-$$
$$\xrightarrow{473\text{ K}} \underset{\substack{\text{Borazine} \\ (Y)}}{2B_3N_3H_6} + 12H_2$$

Borazine has cyclic structure and is isoelectronic with benzene and thus called inorganic benzene.

(ii) Diborane can be prepared by the reduction of BF_3 with lithium aluminium hydride in diethyl ether.

$$4BF_3 + 3LiAlH_4 \longrightarrow \underset{(X)}{2B_2H_6} + 3AlF_3 + 3LiF$$

160 (*b*) The tendency to form long open or closed atom chains by combination of some atoms among themselves is known as catenation. The catenation is maximum in carbon and decreases down the group as shown below :

$$C >> Si > Ge \approx Sn > Pb$$

This is due to high bond energy of C — C bonds. Down the group, size increases and electronegativity decreases, thereby, the tendency to show catenation decreases.

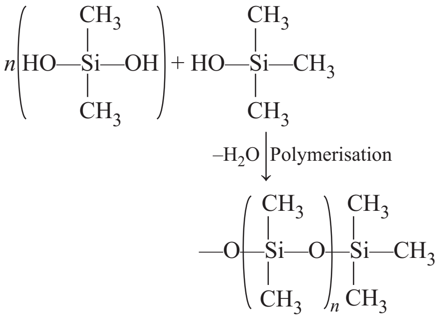
161 (*d*) Reducing agents are those substances, which reduces other substances and itself gets oxidised.

In $SnCl_2$, Sn exists in +2 oxidation state, thus acts as a strong reducing agent. i.e.

$$SnCl_2 + 2FeCl_3 \longrightarrow 2FeCl_2 + SnCl_4$$
$$SnCl_2 + 2CuCl_2 \longrightarrow 2CuCl + SnCl_4$$

162 (*c*) Carbon dioxide can be obtained as a solid in the form of dry ice by allowing the liquefied CO_2 to expand rapidly.

163 (*c*) Silicon has a strong tendency to form polymers like silicones. The chain length of silicon polymer can be controlled by adding Me_3SiCl which blocks the ends as shown below :



$$n\left(HO—\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{Si}}—OH\right) + HO—\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{Si}}—CH_3 \xrightarrow[\text{Polymerisation}]{-H_2O} —O\left(\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{Si}}—O\right)_n\overset{\overset{CH_3}{|}}{\underset{\underset{CH_3}{|}}{Si}}—CH_3$$

Silicone

164 (*b*) Quartz (crystalline form of silica, SiO_2) is extensively used as a piezoelectric material as it contains Si.

165 (*b*) Cement is a product obtained by combining a material rich in lime. The average composition of Portland cement is given below :

CaO (50 – 60%)	SiO_2 (20 – 25%)
Al_2O_3 (5 – 10%)	Fe_2O_3 (1 – 2%)
SO_3 (1 – 2%)	MgO (2 – 3%).

Thus, it contains elements of group 2 (Ca, Mg), Group 13 (Al) and group 14 (Si).