15

p-Block Elements-I

Topic 1 Group 13 Elements

Objective Questions I

(Only one correct option)

1. The correct statements among I to III regarding group 13 element oxides are: **(2019 Main, 9 April II)**

I. Boron trioxide is acidic.

II. Oxides of aluminium and gallium are amphoteric.

III. Oxides of indium and thallium are basic.

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

2. Diborane (B_2H_6) reacts independently with O_2 and H_2O to produce, respectively. **(2019 Main, 8 April I)**

(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

3. The relative stability of 1 oxidation state of group 13 elements follows the order **(2019 Main, 11 Jan II)**

(a) Al < Ga < Tl < In (b) Al < Ga < In < Tl
(c) Tl < In < Ga < Al (d) Ga < Al < In < Tl

4. The number of 2-centre-2-electron and 3-centre-2-electron bonds in B_2H_6 , respectively, are **(2019 Main, 10 Jan II)**

(a) 4 and 2 (b) 2 and 4
(c) 2 and 2 (d) 2 and 1

5. The electronegativity of aluminium is similar to **(2019 Main, 10 Jan I)**

(a) lithium (b) carbon
(c) beryllium (d) boron

6. Aluminium is usually found in 3 oxidation state. In contrast, thallium exists in 1 and 3 oxidation states. This is due to **(2019 Main, 9 Jan I)**

(a) lattice effect (b) lanthanoid contraction
(c) inert pair effect (d) diagonal relationship

7. The increasing order of atomic radii of the following Group 13 elements is **(2016 Adv.)**

(a) Al < Ga < In < Tl
(b) Ga < Al < In < Tl
(c) Al < In < Ga < Tl
(d) Al < Ga < Tl < In

8. $B(OH)_3 \quad NaOH \rightleftharpoons NaBO_2 \quad Na[B(OH)_4] \quad H_2O$

How can this reaction is made to proceed in forward direction? **(2006, 3M)**

(a) Addition of *cis* 1, 2-diol
(b) Addition of borax
(c) Addition of *trans* 1, 2-diol
(d) Addition of Na_2HPO_4

9. H_3BO_3 is **(2003, 1M)**

(a) monobasic acid and weak Lewis acid
(b) monobasic and weak Bronsted acid
(c) monobasic and strong Lewis acid
(d) tribasic and weak Bronsted acid

10. In compounds of type ECl_3, where E B, P, As or Bi, the angles Cl E Cl for different E are in the order **(1999, 2M)**

(a) B > P = As = Bi (b) B > P > As > Bi
(c) B < P = As = Bi (d) B < P < As < Bi

11. Moderate electrical conductivity is shown by **(1982, 1M)**

(a) silica (b) graphite
(c) diamond (d) None of these

Objective Questions II

(One or more than one correct option)

12. Among the following, the correct statement(s) is(are) **(2017 Adv.)**

(a) $Al(CH_3)_3$ has the three-centre two-electron bonds in its dimeric structure
(b) The Lewis acidity of BCl_3 is greater than that of $AlCl_3$
(c) $AlCl_3$ has the three-centre two-electron bonds in its dimeric structure
(d) BH_3 has the three-centre two-electron bonds in its dimeric structure

13. The crystalline form of borax has **(2016 Adv.)**

(a) tetranuclear $[B_4O_5(OH)_4]^2$ unit
(b) all boron atoms in the same plane
(c) equal number of sp^2 and sp^3 hybridised boron atoms
(d) one terminal hydroxide per boron atom

14. The correct statement(s) for orthoboric acid is/are **(2014 Adv.)**

(a) It behaves as a weak acid in water due to self ionisation

(b) Acidity of its aqueous solution increases upon addition of ethylene glycol

(c) It has a three-dimensional structure due to hydrogen bonding

(d) It is a weak electrolyte in water

15. In the reaction, $2X + B_2H_6 \quad [BH_2(X)_2]^+[BH_4]$ the amine(s) X is/are **(2009)**

(a) NH_3 (b) CH_3NH_2

(c) $(CH_3)_2NH$ (d) $(CH_3)_3N$

Assertion and Reason

Read the following questions and answer as per the direction given below :

(a) Statement I is correct; Statement II is correct Statement II is the correct explanation of Statement I

(b) Statement I is correct; Statement II is correct Statement II is not the correct explanation of Statement I

(c) Statement I is correct; Statement II is incorrect

(d) Statement I is incorrect; Statement II is correct

16. **Statement I** Boron always forms covalent bond.

Statement II The small size of B^3 favours formation of covalent bond. **(2007, 3M)**

17. **Statement I** In water, orthoboric acid behaves as a weak monobasic acid.

Statement II In water, orthoboric acid acts as a proton donor. **(2007, 3M)**

18. **Statement I** $Al(OH)_3$ is amphoteric in nature.

Statement II Al O and O H bonds can be broken with equal ease in Al $(OH)_3$. **(1998 , 2M)**

Match the Column

19. Match the following. **(2006, 6M)**

	Column I		Column II
A.	$Bi^3 \quad (BiO)$	p.	Heat
B.	$[AlO_2] \quad Al(OH)_3$	q.	Hydrolysis
C.	$SiO_4^4 \quad Si_2O_7^6$	r.	Acidification
D.	$(B_4O_7^2\ ) \quad [B(OH)_3]$	s.	Dilution by water

Fill in the Blank

20. The two types of bonds present in B_2H_6 are covalent and ……… **(1994, 1M)**

True/False

21. The basic nature of hydroxide of group 13 (group IIIA) decreases progressively down the group. **(1993, 1M)**

22. All the Al Cl bonds in Al_2Cl_6 are equivalent. **(1989, 1M)**

Integer Answer Type Question

23. Three moles of B_2H_6 are completely reacted with methanol. The number of moles of boron containing product formed is **(2015 Adv.)**

24. The value of n in the molecular formula $Be_nAl_2Si_6O_{18}$ is **(2010)**

Subjective Questions

25. AlF_3 is insoluble in anhydrous HF but when little KF is added to the compound it becomes soluble. On addition of BF_3, AlF_3 is precipitated. Write the balanced chemical equations. **(2004, 2M)**

26. (i) How is boron obtained from borax? Give chemical equations with reaction conditions.

(ii) Write the structure of B_2H_6 and its reaction with HCl. **(2002)**

27. Compound X on reduction with $LiAlH_4$ gives a hydride Y containing 21.72% hydrogen alongwith other products. The compound Y reacts with air explosively resulting in boron trioxide. Identify X and Y. Give balanced reactions involved in the formation of Y and its reaction with air.

Draw the structure of Y. **(2001, 5M)**

28. Aluminium sulphide gives a foul odour when it becomes damp. Write a balanced chemical equation for the reaction. **(1997, 2M)**

29. Anhydrous $AlCl_3$ is covalent. From the data given below, predict whether it would remain covalent or become ionic in aqueous solution.

(Ionisation energy for Al $\quad 5137\ \text{kJ mol}^{-1}$

$H_{\text{hydration}}$ for $Al^{3+} = -4665\ \text{kJ mol}^{-1}$

$H_{\text{hydration}}$ for Cl $\quad 381\ \text{kJ mol}\ \ ^1$ **(1997, 2M)**

Topic 2 Group 14 Elements

Objective Questions I (Only one correct option)

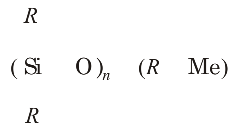
1. The C C bond length is maximum in **(2019 Main, 12 April II)**

(a) graphite (b) C_{70}

(c) C_{60} (d) diamond

2. The basic structural unit of feldspar, zeolites, mica and asbestos is **(2019 Main, 12 April I)**

(a) $(SiO_3)^2$ (b) SiO_2 (c) $(SiO_4)^4$

(d) 
$(\overset{R}{\underset{R}{Si}}\quad O)_n \quad (R \quad Me)$

3. The correct order of catenation is **(2019 Main, 10 April I)**

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

4. The amorphous form of silica is **(2019 Main, 9 April II)**

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

5. C_{60} an allotrope of carbon contains **(2019 Main, 9 April I)**

(a) 16 hexagons and 16 pentagons
(b) 20 hexagons and 12 pentagons
(c) 12 hexagons and 20 pentagons
(d) 18 hexagons and 14 pentagons

6. The element that does not show catenation is **(2019 Main, 12 Jan II)**

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

7. The element that shows greater ability to form p -p multiple bonds, is **(2019 Main, 12 Jan II)**

(a) Ge (b) Si (c) Sn (d) C

8. The chloride that cannot get hydrolysed is **(2019 Main, 11 Jan I)**

(a) $SnCl_4$ (b) CCl_4
(c) $PbCl_4$ (d) $SiCl_4$

9. Correct statements among (I) to (IV) regarding silicones are: **(2019 Main, 9 Jan I)**

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

10. Name the structure of silicates in which three oxygen atoms of $[SiO_4]^4$ are shared is **(2005, 1M)**

(a) pyrosilicate (b) sheet silicate
(c) linear chain silicate (d) three-dimensional silicate

11. Me_2SiCl_2 on hydrolysis will produce **(2003, 1M)**

(a) $(Me)_2Si(OH)_2$ (b) $(Me)_2Si{=}O$
(c) $[\quad O \quad (Me)_2Si \quad O \quad]_n$ (d) $Me_2SiCl(OH)$

12. Identify the correct order of acidic strength of CO_2, CuO, CaO, H_2O. **(2002, 3M)**

(a) $CaO < CuO < H_2O < CO_2$
(b) $H_2O < CuO < CaO < CO_2$
(c) $CaO < H_2O < CuO < CO_2$
(d) $H_2O < CO_2 < CaO < CuO$

13. Which one of the following oxides is neutral ? **(1996, 1M)**

(a) CO (b) SnO_2 (c) ZnO (d) SiO_2

14. Which of the following halides is least stable and has doubtful existence? **(1996, 1M)**

(a) CCl_4 (b) GeI_4 (c) SnI_4 (d) PbI_4

Objective Question II

(One or more than one correct option)

15. With respect to graphite and diamond, which of the statement(s) given below is/are correct? **(2012)**

(a) Graphite is harder than diamond
(b) Graphite has higher electrical conductivity than diamond.
(c) Graphite has higher thermal conductivity than diamond.
(d) Graphite has higher C C bond order than diamond

Assertion and Reason

(a) Statement I is correc;t Statement II is correct Statement II is the correct explanation of Statement I
(b) Statement I is correct; Statement II is correct Statement II is not the correct explanation of Statement I
(c) Statement I is correct; Statement II is incorrect
(d) Statement I is incorrect; Statement II is correct

16. **Statement I** Pb^4 compounds are stronger oxidising agents than Sn^2 compounds.

Statement II The higher oxidation states for the group 14 elements are more stable for the heavier members of the group due to 'inert pair effect'. **(2008, 3M)**

17. **Statement I** Between $SiCl_4$ and CCl_4, only $SiCl_4$ reacts with water.

Statement II $SiCl_4$ is ionic and CCl_4 is covalent. **(2001, S, 1M)**

Fill in the Blanks

18. A liquid which is permanently supercooled is frequently called ……… . **(1997, 1M)**

19. The recently discovered allotrope of carbon (e.g. C_{60}) is commonly known as ……… . **(1994, 1M)**

20. The hydrolysis of trialkyl chlorosilane R_3SiCl, yields ……… . **(1994, 1M)**

21. The hydrolysis of alkyl substituted chlorosilanes gives ……… . **(1991, 1M)**

True/False

22. The tendency for catenation is much higher for C than for Si. **(1993, 1M)**

23. Diamond is harder than graphite. **(1993, 1M)**

24. Graphite is a better lubricant on the moon than on the earth. **(1987, 1M)**

25. Carbon tetrachloride burns in air when lighted to give phosgene gas. **(1983, 1M)**

Subjective Questions

26. Starting from $SiCl_4$, prepare the following in steps not exceeding the number given in parenthesis (give reactions only).

(i) Silicon
(ii) Linear silicon containing methyl group only
(iii) Na_2SiO_3 **(2001, 5M)**

27. Draw the structure of a cyclic silicate, $(Si_3O_9)^{6-}$ with proper labelling. **(1998, 4M)**

28. Write the balanced equation for the preparation of crystalline silicon from $SiCl_4$. **(1990, 1M)**

29. Each entry in column *X* is in some way related to the entries in columns *Y* and *Z*. Match the appropriate entries.

X	*Y*	*Z*
Yeast	Fermentation	Ethanol
Mica	Graphite	Abrasive
Superphosphate	Crystalline cubic	Insulator
Carbon fibres	Layer structure	Fertiliser
Rock salt	Diamond structure	Reinforced plastics
Carborundum	Bone ash	Preservative

(1989, 3M)

30. Give reasons for the following in one or two sentences :
"Graphite is used as a solid lubricant." **(1985, 1M)**

31. Give reason for the following in one or two sentences :
"Solid carbon dioxide is known as dry ice." **(1983, 1M)**

32. Carbon acts as an abrasive and also as a lubricant, explain. **(1981, 1M)**

Answers

Topic 1

1. (a) **2.** (a) **3.** (b) **4.** (a)
5. (c) **6.** (c) **7.** (b) **8.** (a)
9. (a) **10.** (b) **11.** (b) **12.** (a, b, c)
13. (a, c, d) **14.** (b, d) **15.** (a, b, c) **16.** (a)
17. (a) **18.** (a)
19. A q; B r; C p ; D q, r
20. Three centre two electron bond or banana bond.
21. F **22.** F **23.** (3) **24.** (3)

Topic 2

1. (d) **2.** (c) **3.** (c) **4.** (b)
5. (b) **6.** (d) **7.** (d) **8.** (b)
9. (d) **10.** (a) **11.** (c) **12.** (a)
13. (a) **14.** (d) **15.** (b, d) **16.** (a)
17. (c) **18.** glass **19.** Buckminster
20. $(R_3SiO)_2$ **21.** silicones **22.** T **23.** T
24. T **25.** F

Hints & Solutions

Topic 1 Group 13 Elements

1. All the given statements are correct. For group 13 elements, the acidic nature of oxides decreases and the basic nature of oxides increases on moving from B to Tl. This is because as we move down the group, the atomic size of elements goes on increasing, whereas the ionisation energy decreases, due to which the strength of metal oxide (MO) bond goes on decreasing. Thus, boron trioxide or boron oxide is acidic and reacts with basic oxides to give metal borates. Aluminium and gallium oxides are amphoteric while oxides of indium and thallium are basic in nature.

2. 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:

$$B_2H_6 \quad 3O_2 \qquad B_2O_3 \quad 3H_2O \quad 1976\,kJ/mol$$

It gets hydrolysed readily to give boric acid.

$$\underset{\text{Borane}}{B_2H_6} \quad 6H_2O \qquad \underset{\text{Orthoboric acid}}{2H_3BO_3} \quad \underset{\text{Dihydrogen}}{6H_2}$$

3. 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)

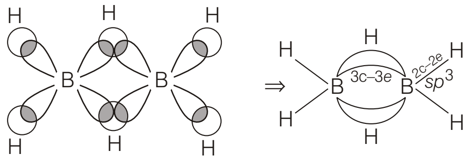
$$B << Al < Ga < In < Tl$$

(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-electron ionises to give 1 oxidation state.

4. The structure of B_2H_6 can be shown as :



In B_2H_6, four 2-centre-2-electron (2*c* 2*e*) bonds are present in the same plane and two 3-centre-2-electron (3*c* 2*e*) bonds are present in another plane.

5. 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.

6. Due to inert pair effect, group-13 elements (ns^2np^1) show 3 and 1 oxidation states in their compounds. Stability order of these oxidation states will be as,

- **3 oxidation states**

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

B^{3} does not exist in free states. All B(III) compounds are covalent.

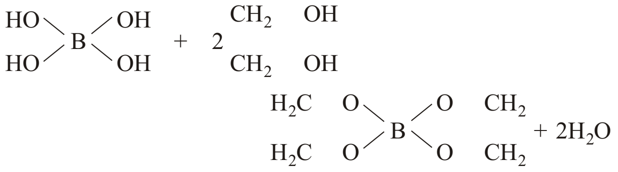
- **1 oxidation states**

B Al Ga In Tl

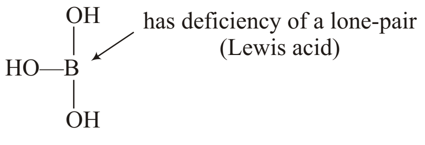
B does not exist in ionic as well covalent compounds.

7. Due to poor shielding of *d*-orbital in Ga, atomic radius of Ga is smaller than that of Al. Thus, Ga < Al < In < Tl.

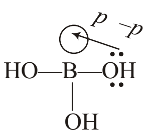
8. Orthoboric acid is a very weak acid, direct neutralisation does not complete. However, addition of *cis*-diol allow the reaction to go to completion by forming a stable complex with $[B(OH)_4]$ as:



9. Orthoboric acid is a weak, monobasic, Lewis acid.



p -*p* backbonding between ‘B’ and ‘O’ decreases acid strength greatly :



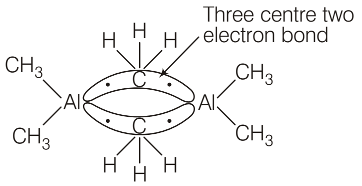
10. In BCl_3, bond angle 120 .

In PCl_3, $AsCl_3$ and $BiCl_3$, central atom is sp^3 hybridised. Since P, As and Bi are from the same group, bond angle decreases down the group. Hence, overall order of bond angle is :

$$B > P > As > Bi$$

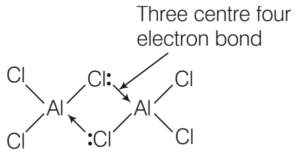
11. Graphite has layered structure and conducted electricity moderately. Silica and diamond have 3-dimensional network structures and non-conducting.

12. (a)

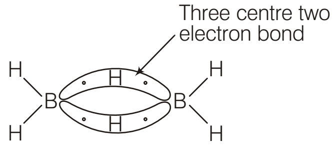


(b) BCl_3 is stronger Lewis acid than $AlCl_3$ due to greater extent of *p* *p* back bonding in $AlCl_3$.

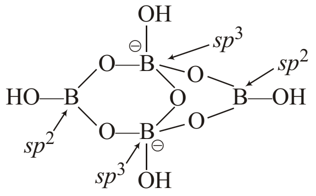
(c)



(d)



13. $Na_2B_4O_7$ $10H_2O$ (borax) is actually made of two tetrahedral and two triangular units, and is actually written as$Na_2[B_4O_5(OH)_4]$ $5H_2O$.



(a) Thus, correct.

(b) Boron atoms are in different planes thus, incorrect.

(c) Two sp^2 and two sp^3-hybridised B atoms thus, correct.

(d) Each boron has one OH group thus, correct.

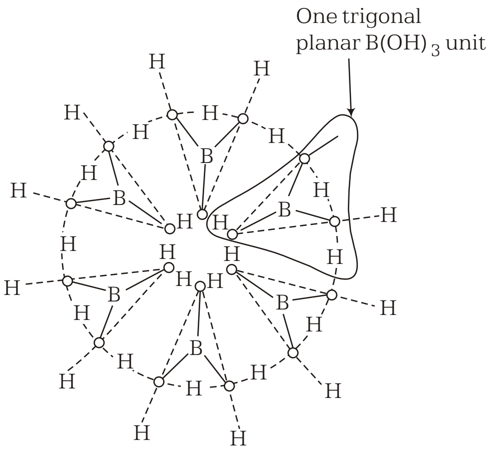
14. (a) It does not undergo self ionisation in water but accepts an electron pair from water, so it behaves as weak monobasic acid.

$$H_3BO_3 + H_2O \rightleftharpoons B(OH)_4 \quad H$$

Hence, (a) is incorrect.

(b) When treated with 1, 2-dihydroxy or polyhydroxy compounds, they form chelate (ring complex) which effectively remove $[B(OH)_4]$ species from solution and thereby produce maximum number of H_3O or H ions, i.e. results in increased acidity.

(c) Boric acid crystallises in a layer structure in which planar triangular BO_3^3 ` ions are bonded together through hydrogen bonds.

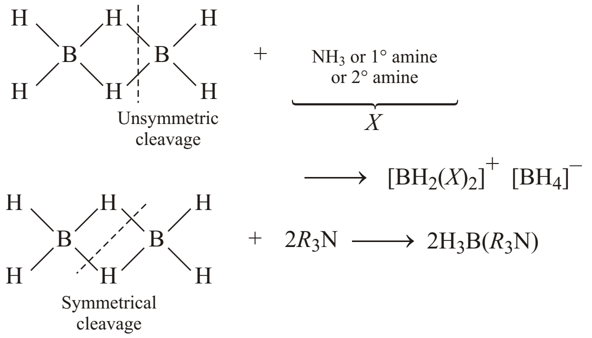


(d) In water the pK_a value of H_3BO_3 is 9.25.

$$H_3BO_3 + H_2O \rightleftharpoons B(OH)_4 \quad H \ ; \ pK_a \quad 9.25$$

So, it is a weak electrolyte in water.

15. Diborane (B_2H_6) undergoes unsymmetric cleavage with NH_3, primary and secondary amine while tertiary amine brings about symmetrical cleavage of B_2H_6 as :



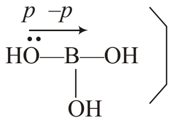
$$\longrightarrow [BH_2(X)_2]^+ \ [BH_4]^-$$

$$+ \ 2R_3N \longrightarrow 2H_3B(R_3N)$$

16. Small size and high charge on B^{3+} makes it highly polarising. Therefore, in most of its compounds, boron forms covalent bonds.

Hence, both statement I and statement II are correct and statement II is a correct explanation of statement I.

17. Orthoboric acid is a weak, monobasic, Lewis acid and the poor acidic character is due to $p \quad p$ backbondings as:



Backbonding decreases electron deficiency at boron, decreases its Lewis acid strength.

18. Due to small size and high charge on Al in $Al(OH)_3$ the fission ability of Al—O and O—H bonds become comparable and compound can give both H^+ and HO under appropriate reaction conditions as:

$$\underset{\text{Base}}{Al(OH)_3} + 3HCl \qquad AlCl_3 + 3H_2O$$

$$\underset{\text{Acid}}{Al(OH)_3} + NaOH \qquad Na[Al(OH)_4]$$

Therefore, both statements are correct and statement II is a correct explanation of statement I.

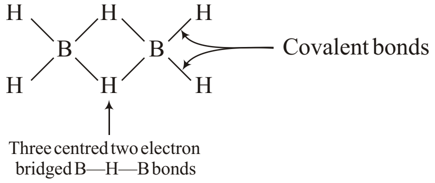
19. (A) Bi^{3+} hydrolysis to $(BiO)^+$ $\quad q$.

(B) $[AlO_2]$ exist in basic medium, on acidification gives $Al(OH)_3$ $\quad r$.

(C) Orthosilicate (SiO_4^4) on heating changes into pyrosilicate $Si_2O_7^6$ $\quad p$.

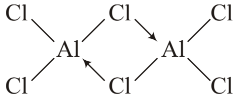
(D) Tetraborate ion $[B_4O_7^2\ ]$ on treatment with dil. acid hydrolysis gradually to orthoboric acid $\quad q, r$.

20. Three centred two electron bonds.



12. The basic nature of hydroxide of group-13 increases from top to bottom due to increase in electropositive character.

22. In Al_2Cl_6, Al–Cl bonds are not equivalent :



The bridged Al—Cl bonds are different from terminal Al—Cl bonds.

23. $B_2H_6 \quad 6\ CH_3OH \qquad 2[B(OCH_3)_3] \quad 6H_2$

Therefore, from 3 moles of B_2H_6, 6 moles of $B(OCH_3)_3$ will be

24. $Be_nAl_2Si_6O_{18}$, $\ 2n \quad 6 \quad 24 \quad 36 \quad 0 \qquad n \quad 3$

25. $3KF + AlF_3 \qquad B_2H_5Cl + H_2$

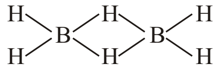
$K_3AlF_6 + 3BF_3 \qquad \underset{\text{ppt}}{AlF_3} \ + 3KBF_4$

26. (i) $Na_2B_4O_7 + HCl \qquad NaCl + H_3BO_3$

$H_3BO_3 + HCl \qquad BCl_3 + H_2O$

$BCl_3 + Al \qquad B + AlCl_3$

(ii) B_2H_6 :



It has 4 terminal B—H bonds. There are two B—H—B, three centred two electron bridged bonds.

$B_2H_6 + HCl \qquad B_2H_5Cl + H_2$

27. Compound $X \overset{LiAlH_4}{\quad\quad} Y$ a hydride + other compound. Hydride Y contains 21.72% hydrogen.

$$Y \quad O_2 \qquad B_2O_3 + H_2O$$

Therefore, Y is a hydride of boron and it is obtained by reduction of X with $LiAlH_4$. So, X is either BCl_3 or BF_3.

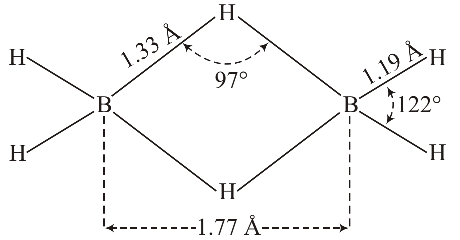
$$\underset{X}{4BCl_3} + LiAlH_4 \qquad \underset{Y}{B_2H_6} + \underbrace{3AlCl_3 + 3LiCl}_{\text{Other products}}$$

Molar mass of $B_2H_6 = 2 \quad 11 + 6 = 28$

% of H in $B_2H_6 = \frac{6}{28}$ 100 = 21.5   21.72

B_2H_6 + $3O_2$ $B_2O_3 + 3H_2O$ + Heat
Y

Structure of *Y* (B_2H_6)



(a) There are 4 terminal B—H bonds.
(b) There are two 3-centre-2-electron B—H—B bridged bonds.
(c) Terminal H—B—H planes are perpendicular to bridged B—H—B bonds.

28. $Al_2S_3 + 6H_2O$ $2Al(OH)_3$ + $3H_2S(g)$
Foul odour

Foul odour on damping of Al_2S_3 is due to the formation of H_2S gas as shown above.

29. The total hydration energy of $AlCl_3$

= Hydration energy of Al^{3+} + 3   Hydration energy of Cl

4665   3 (381) kJ/mol
5808 kJ/mol

The above hydration energy is more than the energy required for ionisation of $AlCl_3$ into Al^{3+} and 3Cl .

Due to this reason, $AlCl_3$ becomes ionic in aqueous solution. In aqueous solution, it is ionised completely as

$AlCl_3 + 6H_2O$ $[Al(H_2O)_6]^{3+}$ + 3Cl

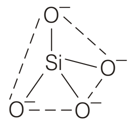
Topic 2 Groups 14 Elements

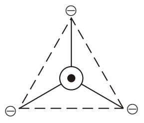
1. The C   C bond length is maximum in diamond having value 154 pm. Here, each carbon atom undergoes sp^3 hybridisation and linked to four other carbon atoms by using hybridised orbitals in tetrahedral fashion. It has a rigid three-dimensional network of carbon atoms.

C   C bond length within the layers of graphite is 141.5 pm. In C_{60}, C   C distances between single and double bonds are 143.5 pm and 138.3 pm respectively.

2. 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.





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

3. Catenation property is an unique property of group 14 elements. Down the group 14, catenation power decreases as:

C   Si   Ge   Sn

Pb does not show catenation.

4. 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.

5. 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.

6. The property of self-linking of atoms of an element through covalent bonds to form straight or branched chains and rings of different sizes is called catenation. Down the group, catenation tendency decreases due to decrease in element bond strength. Carbon (C), silicon (Si), germanium (Ge), tin (Sn), lead (Pb) are group-14 elements.

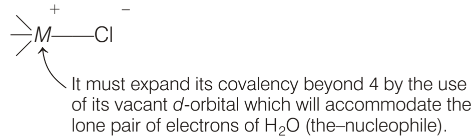
Catenation tendency is highest in carbon while silicon has second highest tendency of catenation among all elements of family due to higher bond energy. The decreasing tendency of catenation among group 14 elements is as follows:

C >> Si > Ge   Sn

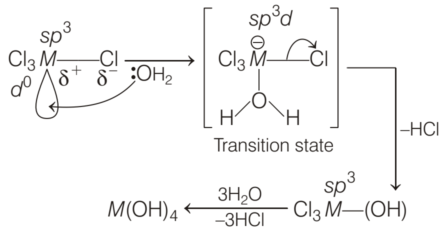
However, Pb does not show catenation.

7. Carbon (C) has greatest ability to form stable p -p multiple bonds. 2p-orbitals of this element participate in the process. The stability of multiple bonds of C is attributed to their closeness with C-nucleus. Thus, the smaller size of C plays a significant role in the process.

8. The compounds given are the tetrahalides (MCl_4) of group 14 elements. For the hydrolysis, (nucleophilic substitution) of MCl_4 the nature of the M—Cl bond should be as:



It must expand its covalency beyond 4 by the use of its vacant *d*-orbital which will accommodate the lone pair of electrons of H_2O (the–nucleophile).



Here, M can be Si, Sn and Pb because they have vacant nd-orbital. But, carbon is a member of second period (n 2, l 0, 1),
it does not have d-orbital (l 2). So, CCl_4 will not be hydrolysed and correct option is (b).

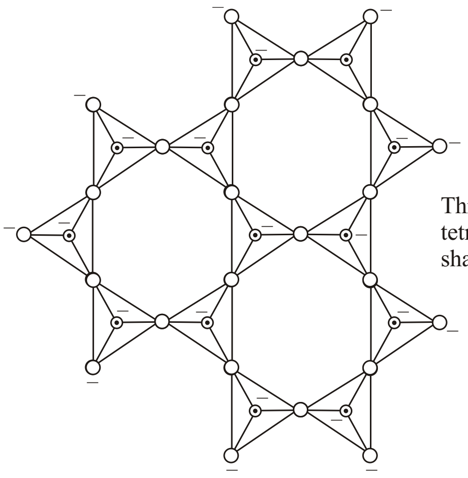
9. Silicones are polysiloxanes with general chemical formula, $[R_2SiO]_n$, where R is an organic group such as:

CH_3, C_2H_5, C_6H_5 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.

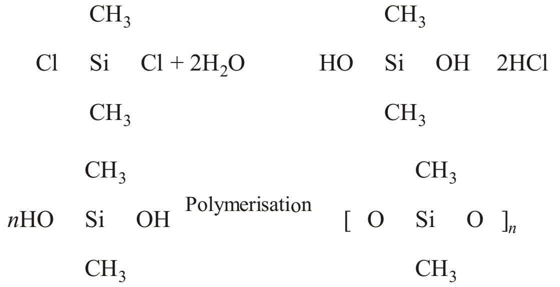
10. In sheet silicates, three out of four oxygen of SiO_4^{4} unit are shared as shown below :



Three oxygens of every tetrahedra are shared with others

In pyrosilicates, there is only one shared oxygen, in linear chain silicates, two oxygen per tetrahedra are shared while in three-dimensional silicates, all four oxygens are shared.

11. Me_2SiCl_2 on hydrolysis yields a linear chain silicone as :



$$Cl\ \overset{CH_3}{\underset{CH_3}{Si}}\ Cl + 2H_2O \qquad HO\ \overset{CH_3}{\underset{CH_3}{Si}}\ OH \quad 2HCl$$

$$nHO\ \overset{CH_3}{\underset{CH_3}{Si}}\ OH \xrightarrow{\text{Polymerisation}} [\ O\ \overset{CH_3}{\underset{CH_3}{Si}}\ O\ ]_n$$

12. CO_2 is acidic oxide, H_2O is neutral, CaO is strongly basic and CuO is weakly basic. Therefore, order of acid strength is :

$$CaO < CuO < H_2O < CO_2$$

13. Carbon monoxide is a neutral oxide, all others are amphoteric :

$$SnO_2 + 4HCl \qquad SnCl_4 + 2H_2O$$
$$ZnO + 2HCl \qquad ZnCl_2 + H_2O$$
$$SiO_2 + 2NaOH \qquad Na_2SiO_3 + H_2O$$

SnO_2 and ZnO also react with NaOH. SiO_2 is also attacked by H_3PO_4.

14. PbI_4 is least stable, has doubtful existence. It is due to inert pair effect, the stable oxidation state of lead is 2.

15. Diamond has a three-dimensional network structure, a hard substance where graphite is soft due to layered structure.

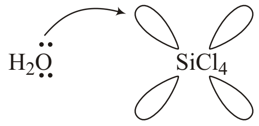
In graphite, only three valence electrons are involved in bonding and one electron remain free giving electrical conductivity. In diamond, all the four valence electrons are covalently bonded hence, insulator.

Diamond is better thermal conductor than graphite. Electrical conductivity is due to availability of free electrons, thermal conduction is due to transfer of thermal vibrational energy from one atom to another atom. A compact and precisely aligned crystals like diamond thus facilitate better movement of heat.

In graphite C C bond acquire some double bond character, hence, higher bond order than in diamond.

16. In group 13, 14, 15 as we descend down in group, the higher oxidation state becomes less tenable due to inert pair effect. Therefore, lead show 2 as stable oxidation state. Hence, Pb^{4+} act as a strong oxidising agent, itself reduced to Pb^{2+} very easily. Both statement I and statement II are correct and statement II is a correct explanation of statement I.

17. $SiCl_4$ reacts with water due to vacant *d*-orbitals available with Si as:



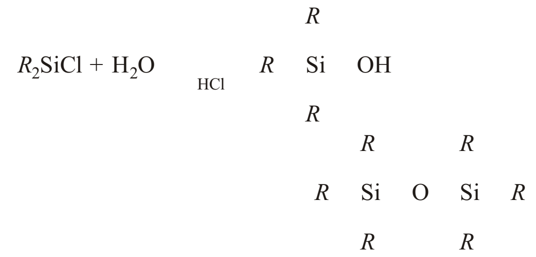
No such vacant *d*-orbitals are available with carbon, hence CCl_4 does not react wtih water. Otherwise, both $SiCl_4$ and CCl_4 are covalent.

Statement I is correct but statement II is incorrect.

18. Glass is commonly known as supercooled liquid.

19. Buckminster fullerene is the name of recently discovered allotrope of carbon.

20. After dimerisation, no reactive function group remains.



$$R_2SiCl + H_2O \underset{HCl}{\quad} R\ \overset{R}{\underset{R}{Si}}\ OH$$

$$R\ \overset{R}{\underset{R}{Si}}\ O\ \overset{R}{\underset{R}{Si}}\ R$$

Dimeric silicone

21. Silicones are organosilicon polymers, obtained by hydrolysis of alkyl substituted chlorosilanes.

22. Due to smaller size of carbon than silicon, C—C bond is stronger than Si—Si bond, hence former is more likely to extend than later.

23. Graphite has a layered structure of hexagonal carbon rings stacked one over other which makes it slippery.

On the other hand, in diamond, each carbon is tetrahedrally bond to other four carbons extended in three dimensional space, giving a giant, network structure. Due to this reason, diamond is harder than graphite.

24. Graphite is better lubricant on moon than on earth because of absence of gravitational pull on the moon.

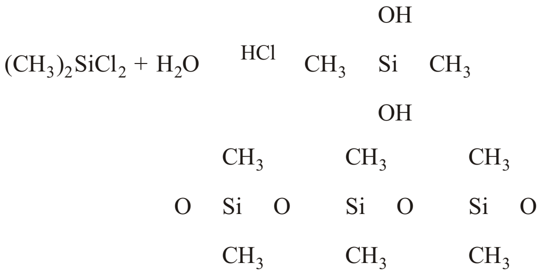
25. Phosgene gas is obtained by treatment of CCl_4 with superheated steam :

$$CCl_4 + H_2O \text{ (vapour)} \qquad COCl_2 + 2HCl$$

26. (i) $3SiCl_4 + 4Al \qquad 3Si + 4AlCl_3$;

Mg or Zn can also be used.

(ii) $SiCl_4 + 2CH_3MgCl \qquad (CH_3)_2SiCl_2 + 2MgCl_2$



$$(CH_3)_2SiCl_2 + H_2O \quad \overset{HCl}{} \quad CH_3-\underset{OH}{\overset{OH}{Si}}-CH_3$$

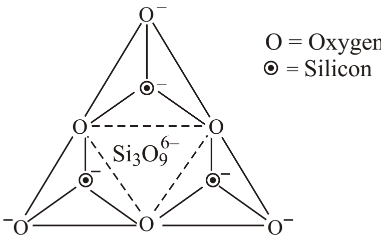
$$O-\underset{CH_3}{\overset{CH_3}{Si}}-O-\underset{CH_3}{\overset{CH_3}{Si}}-O-\underset{CH_3}{\overset{CH_3}{Si}}-O$$

(iii) $SiCl_4 + 4H_2O \qquad \underset{\text{Unstable}}{Si(OH)_4} + 4HCl$

$$Si(OH)_4 \quad \overset{\text{heat}}{} \quad SiO_2 + 2H_2O$$

$$SiO_2 \quad Na_2CO_3 \qquad Na_2SiO_3 + CO_2$$

27.



28. $\underset{\text{Vapour}}{3SiCl_4} + \underset{\text{Molten}}{4Al} \qquad \underset{\text{Volatilizes}}{4AlCl_3} + \underset{\text{Crystalline}}{3Si}$

29.

X	*Y*	*Z*
Yeast	Fermentation	Ethanol
Mica	Layered structure	Insulator
Superphosphate	Bone ash	Fertiliser
Carbon fibres	Graphite	Reinforced plastics
Rock salt	Crystalline cubic	Preservative
Carborundum	Diamond structure	Abrasive

30. Graphite has layered structure and the adjacent layers are weakly associated giving slippery nature, used as solid lubricant.

31. Carbon dioxide solidifies at very low temperature, hence solid CO_2 is very cold, commonly known as dry ice. Also solid carbon dioxide sublime, without passing through liquid state.

32. The two common allotropes of carbon are diamond and graphite. Diamond is the hardest, natural, substance, used as an abrasive while graphite is soft, used as a lubricant.