# Exercise-1

**Marked questions are recommended for Revision.**

## PART - I : SUBJECTIVE QUESTIONS

### Section (A) : VSEPR theory

**A-1.** Why $NO_2^+$ and $I_3^-$ are linear species ?

**A-2.** $PCl_5$ has the shape of a trigonal bipyramidal where as $IF_5$ has the shape of square pyramidal. Explain.

**A-3.** Write the geometry of $XeF_4$ and $OSF_4$ using VSEPR theory and clearly indicate the position of lone pair of electrons.

**A-4.** Explain the structure of $ClF_3$ on the basis of VSEPR theory.

### Section (B) : Hybridisation

**B-1.** Explain hybridisation of central atom in :

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) | $XeF_2$ | (2) | $XeF_4$ | (3) | $PCl_3$ | (4) | $PCl_5$ (g) |
| (5) | $SF_6$ | (6) | $IF_3$ | (7) | $IF_5$ | (8) | $IF_7$ |
| (9) | $CH_4$ | (10) | $CCl_4$ | (11) | $SiCl_4$ | (12) | $SiH_4$ |
| (13) | $H_2O$ | (14) | $NH_3$ | (15) | $PO_4^{3-}$ | (16) | $BrF_5$ |
| (17) | $NO_3^-$ | (18) | $CO_3^{2-}$ | (19) | $NH_4^+$ | (20) | $ClO_3^-$ |

**B-2.** The order of size of the hybrid orbitals is as follows $sp < sp^2 < sp^3$. Explain.

**B-3.** Draw the structure of the following compounds. Clearly indicate the number of bond pairs and lone pairs involved on central atom. Write (i) number of bond pairs and lone pairs on the central atom (ii) the shape of the molecules (iii) hybridization of the central atom.
(a) $SF_4$ (b) $XeOF_4$

### Section (C) : Bond angle, bond length comparison

**C-1.** Draw an electron dot structure for $Br_3^-$. Deduce an approximate value of the bond angle.

**C-2.** Which compound has the smallest bond angle in each series ?

| | | | |
|---|---|---|---|
| (a) | $SbCl_3$ | $SbBr_3$ | $SbI_3$ |
| (b) | $PI_3$ | $AsI_3$ | $SbI_3$ |

**C-3.** Compare the C–H bond strength in $C_2H_6$, $C_2H_4$ and $C_2H_2$.

**C-4.** The $POCl_3$ molecule has the shape of an irregular tetrahedron with the P atom located centrally. The Cl–P–Cl angle is found to be 103.5º. Give a qualitative explanation for the deviation of this structure from a regular tetrahedron.

**C-5.** Which one has highest and least bond angle in the following ?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (1) | $CH_4$ | $PH_3$ | $AsH_3$ | $SbH_3$ | (2) | $H_2O$ | $H_2S$ | $H_2Te$ | $CO_2$ |
| (3) | $PH_3$ | $H_2O$ | | | (4) | $Cl_2O$ | $ClO_2$ | | |
| (5) | $PF_3$ | $PH_3$ | | | (6) | $BF_3$ | $NF_3$ | | |
| (7) | $NH_3$ | $NF_3$ | | | (8) | $PF_3$ | $PCl_3$ | | |

**C-6.** Write the Increasing order of Bond length of each :
(1) C–C, C=C, C≡C (2) C–N, C–O, C–F (3) H–Cl, H–Br, H–I, HF

### Section (D) : Multicentered species

**D-1.** Find number of $p\pi$–$d\pi$ bonds in
(a) Disulphate (b) triphosphate (c) trimetaphosphate
(d) trimer of $SO_3$ (e) $P_4O_{10}$ (f) $P_4O_6$

**D-2.** In which of the following compounds, the $p\pi$–$d\pi$ bonding take place ?
(a) $P_4O_{10}$ (b) $HNO_3$ (c) $N_2O_5$ (d) $HClO_3$

**D-3.** Calculate individual and average oxidation number (if required) of the marked element and also draw the structure of the following compounds or molecules.

(1) $Na_2\underline{S}_2O_3$ (2) $Na_2\underline{S}_4O_6$ (3) $H_2\underline{S}O_5$ (4) $H_2\underline{S}_2O_8$ (5) $H_2\underline{S}_2O_7$ (6) $\underline{S}_8$

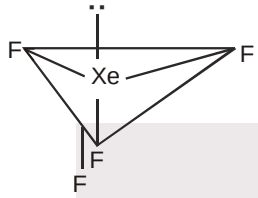
(7) $H\underline{N}O_4$ (8) $\underline{C}_3O_2$ (9) $\underline{Os}O_4$ (10) $\underline{P}H_3$ (11) $\underline{Cr}O_4^{2-}$ (12) $\underline{Cr}_2O_7^{2-}$

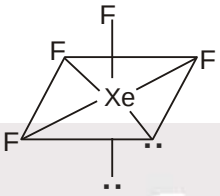
(13) $\underline{Cr}\,O_2Cl_2$ (14) $\underline{Cr}O_5$ (15) $Na_2H\,\underline{P}O_4$ (16) $\underline{Fe}S_2$ (17) $\underline{C}_6H_{12}O_6$ (18) $\underline{N}H_4\,\underline{N}O_3$

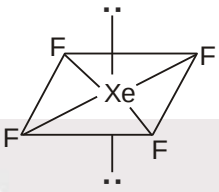
## PART - II : ONLY ONE OPTION CORRECT TYPE

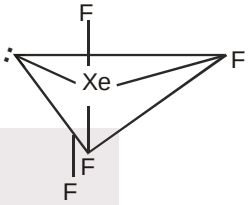
### Section (A) : VSEPR theory

**A-1.** Which is the right structure of $XeF_4$ ?

(A) 

(B) 

(C) 

(D) 

**A-2.** Identify the correct match.

| | | | |
|---|---|---|---|
| (i) | $XeF_2$ | (a) | Central atom has $sp^3$ hybridisation and bent geometry. |
| (ii) | $N_3^-$ | (b) | Central atom has $sp^3d^2$ hybridisation and octahedral. |
| (iii) | $PCl_6^-$($PCl_5$ (s) anion) | (c) | Central atom has sp hybridisation and linear geometry. |
| (iv) | $ICl_2^+$ ($I_2Cl_6$ ($\ell$) cation) | (d) | Central atom has $sp^3d$ hybridisation and linear geometry. |

(A) (i – a), (ii – b), (iii – c), (iv – d) (B) (i – d), (ii – b), (iii – d), (iv – c)

(C) (i – b), (ii – c), (iii – a), (iv – d) (D) (i – d), (ii – c), (iii – b), (iv – a)

**A-3.** Which of the following statement is true for $IO_2F_2^-$ ?

(A) The electrons are located at the corners of a trigonal bipyramidal but one of the equatorial pairs is unshared.

(B) It has $sp^3d$ hybridisation and is T-shaped.

(C) Its structure is analogous to $SF_4$.

(D) (A) and (C) both

**A-4.** Which reaction involves a change in the electron–pair geometry for the under lined element ?

(A) $\underline{B}F_3 + F^- \longrightarrow \underline{B}F_4^-$ (B) $\underline{N}H_3 + H^+ \longrightarrow \underline{N}H_4^+$

(C) $2\underline{S}O_2 + O_2 \longrightarrow 2\underline{S}O_3$ (D) $H_2\underline{O} + H^+ \longrightarrow H_3\underline{O}^+$

**A-5.** In which of the following molecules number of lone paris and bond pairs on central atom are not equal ?

(A) $H_2O$ (B) $I_3^-$ (C) $O_2F_2$ (D) $SCl_2$

**A-6.** Which of the following species given below have shape similar to $XeOF_4$ ?

(A) $XeO_3$ (B) $IOF_4^+$ (C) $PCl_5$ (D) $XeF_5^{\oplus}$

### Section (B) : Hybridisation

**B-1.** The hybridization of carbon atoms in $C_2$–$C_3$ single bond of $\overset{4}{H}\overset{3}{C}\equiv\overset{2}{C}-\overset{1}{C}H=CH_2$ is :

(A) $sp^3$–$sp^3$ (B) $sp^2$–sp (C) sp–$sp^2$ (D) $sp^3$–sp

**B-2.** Specify the hybridisations of central atom in the following species respectively {$N_3^-$, NOCl, $N_2O$}

(A) sp, $sp^2$, sp (B) sp, sp, $sp^3$ (C) $sp^2$, sp, sp (D) $sp^2$, $sp^2$, sp.

**B-3.** In pent-3-en-1-yne the terminal carbon-atoms have following hybridisation

(A) sp & $sp^2$ (B) $sp^2$ & $sp^3$ (C) $sp^2$ & sp (D) sp & $sp^3$

**B-4.** $S_1$ : $[XeF_7]^+$ has $sp^3d^3$ hybridisation

$S_2$ : $[PCl_4]^+$ has $sp^3d^2$ hybridisation

$S_3$ : $[SF_6]$ has $sp^3d^2$ hybridisation

$S_4$ : $[PF_4]^+$ has $sp^3$ hybridisation

(A) T F F T (B) T T F T (C) T F T T (D) F F F T

**B-5.** $BF_3 + F^- \rightarrow BF_4^-$
What is the hybridiation state of B in $BF_3$ and $BF_4^-$ :
(A) $sp^2$, $sp^3$ (B) $sp^3$, $sp^3$ (C) $sp^2$, $sp^2$ (D) $sp^3$, $sp^3d$

## Section (C) : Bond angle, bond length comparison

**C-1.** The ONO angle is maximum in :
(A) $HNO_3$ (B) $NO_2^+$ (C) $HNO_2$ (D) $NO_2$

**C-2.** Which statement is correct for $N_3^-$ ion.
(A) It is bent molecule (B) Bond angle is < 120°
(C) Central atom is $sp^2$ hybridized (D) None of these

**C-3.** Consider the following molecules ; $H_2O$ (I) $H_2S$ (II) $H_2Se$ (III) $H_2Te$ (IV)
Arrange these molecules in increasing order of bond angles.
(A) I < II < III < IV (B) IV < III < II < I (C) I < II < IV < III (D) II < IV < III < I

**C-4.** In which of the following bond angle is maximum
(A) $NH_3$ (B) $NH_4^+$ (C) $PCl_3$ (D) $SCl_2$

**C-5.** In which of the following central atom is unhybridised?
(A) $S(CH_3)_2$ (B) $SO_2$ (C) $SiH_4$ (D) $PCl_3$

## Section (D) : Multicentered species

**D-1.** The no. of S-O-S bonds in the trimer of $SO_3$ is
(A) 1 (B) 2 (C) 3 (D) None

**D-2.** Which of the following species do not contain S–S linkage?
(A) $H_2S_2O_5$ (B) $H_2S_2O_7$ (C) $H_2S_2O_3$ (D) $H_2S_4O_6$

**D-3.** Which statement is **incorrect** about pyrosilicate ion.
(A) $sp^3$ hybridisation
(B) One oxygen atom is shared between two tetrahydron
(C) there are eight Si–O bond
(D) There is one Si-Si bond

**D-4.** Which is correct about the cyclic silicate $[Si_6O_{18}]^{n-}$ :
(A) The value of n is 12
(B) each Si atom is bonded with three oxygen atoms
(C) each oxygen atom is bonded with two Si atoms
(D) all the above are correct.

# PART - III : MATCH THE COLUMN

**1. Match the following :**

| | **Column–I** | | **Column–II** |
|---|---|---|---|
| (A) | $SF_2$ | (p) | $sp^3$ and bent |
| (B) | $KrF_4$ | (q) | two lone pairs on central atom |
| (C) | NOCl | (r) | bond angle < 109º28' |
| (D) | $NF_3$ | (s) | $sp^2$ and bent |
| | | (t) | $sp^3d^2$ and square planar |

**2.** Match the compounds listed in column-I with characteristic(s) listed in column-II.

| | **Column – I** | | **Column –II** |
|---|---|---|---|
| (A) | $ClF_2^-$, $ClF_2^+$ | (p) | Square pyramidal. |
| (B) | $IO_2F_2^-$, $F_2SeO$ | (q) | See–saw and pyramidal shaped respectively. |
| (C) | $IOF_4^-$, $XeOF_2$ | (r) | Linear and bent shaped respectively. |
| (D | $BrF_5$, $XeOF_4$ | (s) | Square pyramidal and T-shaped respectively. |
| | | (t) | Both $sp^3d^2$. |

**3. Match the following :**

| | Column-I | | Column-II |
|---|---|---|---|
| (A) | $H_3P_3O_9$ | (p) | S–O–S bond is present |
| (B) | $H_2S_2O_7$ | (q) | Di-basic acid |
| (C) | $H_2S_4O_6$ | (r) | P–O–P bond is present |
| (D) | $H_4P_2O_5$ | (s) | Central atom (S or P) in maximum oxidation state. |

# Exercise-2

**Marked Questions may have for Revision Questions.**

## PART - I : ONLY ONE OPTION CORRECT TYPE

**1.** The hybridisation of P in phosphate ion ($PO_4^{3-}$) is the same as :
(A) I in $ICl_4^-$ (B) S in $SO_3$ (C) N in $NO_3^-$ (D) S in $SO_3^{2-}$

**2.** Choose the molecules in which hybridisation occurs in the ground state ?
(a) $BCl_3$ (b) $NH_3$ (c) $PCl_3$ (d) $BeF_2$
The correct answer is -
(A) a, b, d (B) a, b, c (C) b, c (D) c, d

**3.** The bent or V–shape of the molecule can be resulted from which of the following hybridization.
(A) $sp^3$ (B) $sp^2$ (C) Both (A) and (B) (D) None of these

**4.** $sp^3d$ hybridization is considered to be a combination of two hybridization. They are
(A) $p^3 + sd$ (B) $sp^2 + pd$ (C) $spd + p^2$ (D) none of these

**5.** If the equatorial plane is x–y plane in $sp^3d$ hybridisation then the orbital used in pd hybridisation are -
(A) $p_z$ and $d_{z^2}$ (B) $p_x$ and $d_{xy}$ (C) $p_y$ and $d_{yz}$ (D) none of these

**6.** A $\sigma$-bonded molecule $MX_3$ is T-shaped. The number of lone pairs of electrons can be
(A) 0 (B) 2 (C) 1 (D) none of these

**7.** Which of the following should have pyramidal shape :
(A) $[ClOF_2]^+$ (B) $ICl_3$ (C) $[BrICl]^-$ (D) All of these

**8.** Which of the following molecules has two lone pairs and bond angle (need not be all bond angles) < 109.5°?
(A) $SF_2$ (B) $KrF_4$ (C) $ICl_4^-$ (D) All of these

**9.** The correct order of bond angle is :
(A) $H_2S < NH_3 < BF_3 < CH_4$ (B) $NH_3 < H_2S < CH_4 < BF_3$
(C) $H_2S < NH_3 < CH_4 < BF_3$ (D) $H_2S < CH_4 < NH_3 < BF_3$

**10.** In which of the following molecules are all the bonds not equal?
(A) $NF_3$ (B) $ClF_3$ (C) $BF_3$ (D) $AlF_3$

**11.** Which of the following is correct order of bond length ?
(A) $BF_4^- < BF_3$ (B) $NO_2^+ < NO_2^-$ (C) $CCl_4 < CF_4$ (D) $^+CH_3 > CH_4$

**12.** Identify the correct statement :
(A) single N–N bond is stronger than single P–P bond
(B) single N–N bond is weaker than single P–P bond
(C) N ≡N is weaker than P≡P
(D) None of these

**13.** In which of the following species peroxide group is not present :
(A) $[B_4O_5(OH)_4]^{2-}$ (B) $[S_2O_8]^{2-}$ (C) $CrO_5$ (D) $HNO_4$

**14.** Which of the following is correct ?
(A) $S_3O_9$ : contains no S–S linkage.
(B) $S_2O_6^{2-}$ : contains –O–O– linkage.
(C) $(HPO_3)_3$ : contains P–P linkage
(D) $S_2O_8^{2-}$ : contains S–S linkage

**15.** The percentage of s–character in the orbital forming P–S bonds in $P_4S_3$ is :
(A) 25 (B) 33 (C) 75 (D) 50

**16.** Indicate the incorrect statement :
(A) Number of hybrid orbitals formed is equal to no. of atomic orbitals involved.
(B) $2p_x$ and $2p_y$ - orbitals of carbon can be hybridized to yield two new more stable orbitals
(C) Effective hybridisation is not possible with orbitals of widely different energies
(D) The concept of hybridisation has a greater significance in the VB theory of localised orbitals than in the MO theory.

**17.** In which of the following compounds B atoms are in $sp^2$ and $sp^3$ hybridisation states ?
(A) Borax (B) Diborane (C) Borazole (D) All

## PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

**1.** Find the number of planar species
(a) $BF_3$ (b) $BCl_3$ (c) $CO_3^{2-}$ (d) $SO_3$
(e) $NH_3$ (f) $NCl_3$ (g) $PCl_3$ (h) $XeF_4$

**2.** Find the number of species having bond angle less than 109°28'.
(a) $H_2S$ (b) $SO_4^{--}$ (c) $CCl_4$ (d) $NH_3$
(e) $PH_3$ (f) $SiH_4$ (g) $NH_4^+$ (h) $PF_3$
(i) $NH_2^-$ (j) $SO_3$ (k) $H_2O$

**3.** Find out total number of $\pi$ bond in following xenon compounds.
$XeOF_2$, $XeO_2F_4$, $XeO_3$, $XeO_4$, $XeO_3F_2$, $XeOF_4$, $XeO_2F_2$

**4.** $P_4O_{10}$ has two different types of P–O bonds. Find the no. of P–O bonds with shorter bond length.

**5.** Difference in the oxidation number of sulphur atom is in $Na_2S_4O_6$ is x, that of $H_2S_2O_5$ is y. Find value of x × y is :

**6.** In a $P_4O_6$ molecule, the total number of P–O–P bonds is :

## PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

**1.** Which statement is correct about hybridization ?
(A) In hybridisation orbitals take part.
(B) In hybridisation electrons take part.
(C) In hybridisation fully filled, half filled or empty orbitals can take part.
(D) Hybridised orbitals only contains bond pair electron.

**2.** Which of the following represent the given mode of hybridisation $sp^2$–$sp^2$–sp–sp from left to right
(A) $H_2C=C=C=CH_2$ (B) $HC\equiv C-C\equiv CH$
(C) $H_2C=CH-C\equiv N$ (D) $H_2C=CH-C\equiv CH$

**3.** Which is/are in linear shape ?
(A) $NO_2^+$ (B) $XeF_2$ (C) $I_3^-$ (D) $I_3^+$

**4.** Which is true about $NH_2^-$, $NH_3$, $NH_4^+$ ?
(A) Hybridization of N is same. (B) No. of lone pair of electron on N are same.
(C) Molecular geometry (i.e. shape) is different. (D) Bond angle is same.

**5.** Which of the following molecule (s) has/have bond angle close to 90º ?
(A) $NH_3$ (B) $H_2S$ (C) $PH_3$ (D) $ICl_3$

**6.** Which of the following statements are true about borax :
(A) Boron atoms are present in 2 different oxidation state and it different by 1
(B) the average oxidation state of boron is same that in $B_2H_6$.
(C) Boron atoms are present in different hybridization
(D) 2 boron atoms are connected with 4 oxygen each and 2 boron atoms are connected with 3 oxygen atom each.

**7.** Identify the correct statement
(A) $H_2S_2O_7$ has peroxy linkage
(B) $H_2S_2O_6$ has S–S linkage
(C) $H_2S_2O_8$ has peroxy linkage
(D) $H_2SO_3$(Sulphurous acid) has S in +4 oxidation state

**8.** In which of the following compound(s) oxidation number of one central atom is/are $\geq 6$ ?
(A) $N_2O_6$ (B) $CrO_5$ (C) $H_3PO_5$ (D) $H_2S_2O_8$

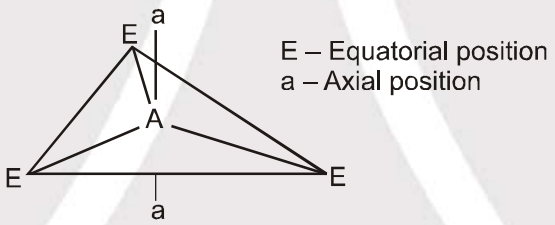
## PART - IV : COMPREHENSION

**Read the following passage carefully and answer the questions.**

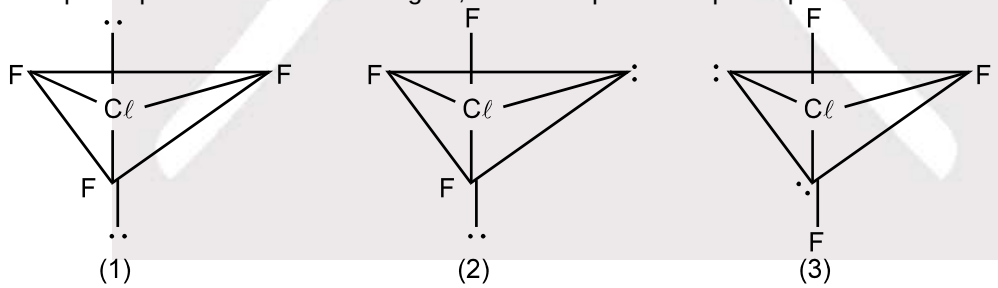
**Comprehension # 1**

**VSEPR THEORY**

The trigonal bipyramid is not a regular shape since the bond angles are not all the same. It therefore follows that the corners are not equivalent in $ClF_3$ molecule. Lone pairs occupy two of the corners, and F atoms occupy the other three corners. These different arrangements are theoretically possible, as shown in figure.




(i) The most stable structure will be the one of lowest energy, that is the one with the minimum repulsion between the five orbitals. The greatest repulsion occurs between two lone pairs. Lone pair bond pair repulsions are next strongest, and bond pair-bond pair repulsions the weakest.

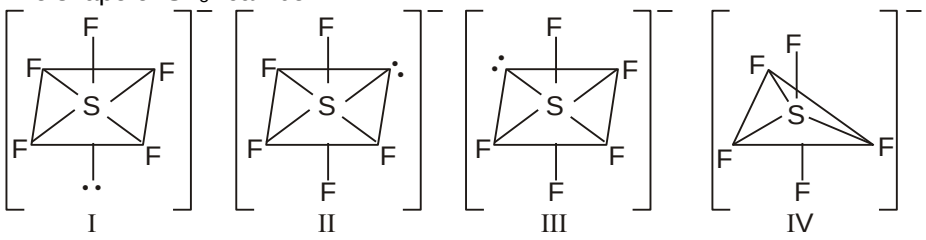



(1) (2) (3)

A rule of thumb can be theorised, that the position having maximum repulsion amongst them are occupied at equatorial points. Therefore (3) structure is right.
(ii) Since double bond occupies more space compared to single bond therefore it will prefer equatorial position.
(iii) More electronegative element will occupy axial position in case of trigonal bipyramidal geometry
(iv) In case of $sp^3d^2$ hybridisation lone pairs should be placed opposite to each other because all the corners are identical.

**1.** Geometry (i.e. arrangement of electron pairs around central atom) of $ClOF_3$ is similar to the :
(A) $XeF_4$ (B) $SOCl_2$ (C) $I_3^-$ (D) $ClO_4^-$

**2.** The shape of $SF_5^-$ can be :



I II III IV

(A) I only (B) I and II only (C) IV only (D) I, II, & III

**3.** Actual shape of the molecule $BrF_5$ is similar to the molecule :
(A) $PCl_5$ (B) $XeF_4$ (C) $PCl_4^+$ (D) None of these

**4.*** Which of the following do not exist ?
(A) $SH_6$ (B) $HFO_4$ (C) $SI_6$ (D) $HClO_3$

**Comprehension # 2**

**Answer Q.5, Q.6 and Q.7 by appropriately matching the information given in the three columns of the following table.**

Observe the three columns in which column-1 : compound, column-2 : shape while in column-3 : Hybridisation are given.

| Column-1 (Compound) | | Column-2 (Shape) | | Column-3 (Hybridisation) | |
|---|---|---|---|---|---|
| (I) | $XeF_4$ | (i) | Tetrahedral | (P) | $sp^3$ |
| (II) | $ClF_3$ | (ii) | Square planar | (Q) | $sp^2$ |
| (III) | $SiF_4$ | (iii) | Bent | (R) | $sp^3d$ |
| (IV) | $CH_3OCH_3$ | (iv) | T-shape | (S) | $sp^3d^2$ |

**5.** Which of the following combination is true for compound which have 2 lone pair of electrons on central atom?
(A) (I), (ii), (S) (B) (I), (ii), (R) (C) (I), (i), (P) (D) (II), (iv), (Q)

**6.** Which combination is correct for the compound having bond angle > 109º28' ?
(A) (III), (i), (P) (B) (IV), (iii), (P) (C) (IV), (ii), (P) (D) (I), (ii), (S)

**7.** Which of the following is true for a planar compound ?
(A) (III), (i), (P) (B) (I), (iv), (P) (C) (II), (iv), (R) (D) (II), (i), (P)

# Exercise-3

## PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

*** Marked Questions may have more than one correct options.**

**1.** The hybridization of atomic orbitals of nitrogen in $NO_2^+$, $NO_3^-$ and $NH_4^+$ are : **[JEE–2000(S), 1/135]**
(A) sp, $sp^3$ and $sp^2$ respectively (B) sp, $sp^2$ and $sp^3$ respectively
(C) $sp^2$, sp and $sp^3$ respectively (D) $sp^2$, $sp^3$ and sp respectively

**2.** The number of P—O—P bonds in tricyclic metaphosphoric acid is : **[JEE–2000(S), 1/135]**
(A) zero (B) two (C) three (D) four

**3.** Draw the molecular structures of $XeF_2$, $XeF_4$ and $XeO_2F_2$, indicating the location of lone pair of electrons. **[JEE–2000(M), 3/135]**

**4.** The correct order of hybridisation of the central atom in the following species; $NH_3$, $PCl_5$ and $BCl_3$ is : **[JEE–2001(S), 1/135]**
(A) $dsp^2$, $sp^2$, $sp^3$ (B) $sp^3$, $dsp^3$, $sp^2$ (C) $dsp^2$, $sp^3$, $dsp^3$ (D) $dsp^2$, $sp^2$, $dsp^3$

**5.** The number of S–S bonds, in sulphur trioxide trimer ($S_3O_9$) is : **[JEE–2001(S), 1/135]**
(A) three (B) two (C) one (D) Zero

**6.** Which of the following are isoelectronic and isostructural ? **[JEE–2003(S), 3/144]**
$NO_3^-$, $CO_3^{2-}$, $ClO_3^-$, $SO_3$
(A) $NO_3^-$, $CO_3^{2-}$ (B) $SO_3$, $NO_3^-$ (C) $ClO_3^-$, $CO_3^{2-}$ (D) $CO_3^{2-}$, $SO_3$ .

**7.** Using VSEPR theory, draw the shape of $PCl_5$ and $BrF_5$. **[JEE–2003(M), 2/144]**

**8.** Use VSEPR model to draw the structures of $OSF_4$ and $XeF_4$ (indicate the lone pair(s) on central atom) and specify their geometry. **[JEE–2004(M), 2/144]**

**9.** The percentage of p-character in the orbitals forming P–P bonds in $P_4$ is : **[JEE–2007, 3/162]**
(A) 25 (B) 33 (C) 50 (D) 75

**10.*** The nitrogen oxide(s) that contain(s) N—N bond(s) is(are) : **[JEE–2009, 4/160]**
(A) $N_2O$ (B) $N_2O_3$ (C) $N_2O_4$ (D) $N_2O_5$

**11.** The species having pyramidal shape is : **[IIT-JEE-2010, 5/163]**
(A) $SO_3$ (B) $BrF_3$ (C) $SiO_3^{2-}$ (D*) $OSF_2$

**12.** Based on VSEPR theory, the number of 90 degree F–Br–F angles in $BrF_5$ is : **[JEE–2010, 3/163]**

**13.** The shape of $XeO_2F_2$ molecule is **[JEE–2012, 3/136]**
(A) trigonal bipyramidal (B) square plannar
(C) tetrahedral (D) see-saw

**14.** The total number of lone pairs of electrons in $N_2O_3$ is : **[JEE(Advanced) 2015, 4/168]**

**15.** Among the triatomic molecules/ions, $BeCl_2$, $N_3^-$, $N_2O$, $NO_2^+$, $O_3$, $SCl_2$, $ICl_2^-$, $I_3^-$ and $XeF_2$, the total number of linear molecules(s)/ion(s) where the hybridization of the central atom does not have contribution from the d-orbital(s) is **[JEE(Advanced) 2015, 4/168]**
[Atomic number : S = 16, Cl = 17, I = 53 and Xe = 54]

**16.*** The crystalline form of borax has **[JEE Advanced 2016, 4/124]**
(A) tetranuclear $[B_4O_5(OH)_4]^{2-}$ unit
(B) all boron atoms in the same plane
(C) equal number of $sp^2$ and $sp^3$ hybridized boron atoms
(D) one terminal hydroxide per boron atom

**17.** The total number of compounds having at least one bridging oxo group among the molecules given below is _____ . **[JEE Advanced 2018, 3/120]**
$N_2O_3$, $N_2O_5$, $P_4O_6$, $P_4O_7$, $H_4P_2O_5$, $H_5P_3O_{10}$, $H_2S_2O_3$, $H_2S_2O_5$

## PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

### JEE(MAIN) OFFLINE PROBLEMS

**1.** The hybridisation of the underline atom changes in : **[AIEEE-2002, 3/225]**
(1) $\underline{Al}H_3$ changes to $AlH_4^-$ (2) $H_2\underline{O}$ changes to $H_3O^+$
(3) $\underline{N}H_3$ changes to $NH_4^+$ (4) in all cases

**2.** Bond angle of 109º 28' is found in : **[AIEEE-2002, 3/225]**
(1) $NH_3$ (2) $H_2O$ (3) $CH_3^+$ (4) $NH_4^+$

**3.** Which of the following compounds has the smallest bond angle in its molecule ? **[AIEEE-2003, 3/225]**
(1) $SO_2$ (2) $H_2O$ (3) $H_2S$ (4) $NH_3$

**4.** The pair of species having identical shapes for molecules of both species is : **[AIEEE-2003, 3/225]**
(1) $CF_4$, $SF_4$ (2) $XeF_2$, $CO_2$ (3) $BF_3$, $PCl_3$ (4) $PF_5$, $IF_5$.

**5.** The maximum number of 90º angles between bond pair–bond pair of electrons is observed in : **[AIEEE-2004, 3/225]**
(1) $dsp^3$ (2) $sp^3d$ (3) $dsp^2$ (4) $sp^3d^2$

**6.** The correct order of bond angles (smallest first) in $H_2S$, $NH_3$, $BF_3$ and $SiH_4$ is : **[AIEEE-2004, 3/225]**
(1) $H_2S < SiH_4 < NH_3 < BF_3$ (2) $NH_3 < H_2S < SiH_4 < BF_3$
(3) $H_2S < NH_3 < SiH_4 < BF_3$ (4) $H_2S < NH_3 < BF_3 < SiH_4$

**7.** The molecular shapes of $SF_4$, $CF_4$ and $XeF_4$ are : **[AIEEE-2005, 3/225]**
(1) the same with 2, 0 and 1 lone pairs of electrons on the central atom, respectively.
(2) the same with 1, 1 and 1 lone pair of electrons on the central atom, respectively.
(3) different with 0, 1 and 2 lone pairs of electrons on the central atom, respectively.
(4) different with 1, 0 and 2 lone pairs of electrons on the central atom, respectively.

**8.** The hybridisation of orbitals of N atom in $NO_3^-$, $NO_2^+$ and $NH_4^+$ are respectively : **[AIEEE-2011, 4/120]**
(1) sp, $sp^2$, $sp^3$ (2) $sp^2$, sp, $sp^3$ (3) sp, $sp^3$, $sp^2$ (4) $sp^2$, $sp^3$, sp

**9.** The structure of $IF_7$ is : **[AIEEE-2011, 4/120]**
(1) square pyramid (2) trigonal bipyramid (3) octahedral (4) pentagonal bipyramid

**10.** The molecule having smallest bond angle is : **[AIEEE-2012, 4/120]**
(1) $NCl_3$ (2) $AsCl_3$ (3) $SbCl_3$ (4) $PCl_3$

**11.** In which of the following pairs the two species are not isostructural ? **[AIEEE-2012, 4/120]**
(1) $CO_3^{2-}$ and $NO_3^-$ (2) $PCl_4^+$ and $SiCl_4$ (3) $PF_5$ and $BrF_5$ (4) $AlF_6^{3-}$ and $SF_6$

**12.** The species in which the N atom is in a state of sp hybridization is : **[JEE(Main)-2016, 4/120]**
(1) $NO_2^-$ (2) $NO_3^-$ (3) $NO_2$ (4) $NO_2^+$

## JEE(MAIN) ONLINE PROBLEMS

**1.** Which one of the following does not have a pyramidal shape? **[JEE(Main) 2014 Online (11-04-14), 4/120]**
(1) $(CH_3)_3N$ (2) $(SiH_3)_3N$ (3) $P(CH_3)_3$ (4) $P(SiH_3)_3$

**2.** The geometry of $XeOF_4$ by by VSEPR theory is : **[JEE(Main) 2015 Online (10-04-15), 4/120]**
(1) pentagonal planar (2) octahedral (3) square pyramidal (4) trigonal bipyramidal

**3.** Which of the following compound has a P–P bond ? **[JEE(Main) 2015 Online (11-04-15), 4/120]**
(1) $H_4P_2O_5$ (2) $(HPO_3)_3$ (3) $H_4P_2O_6$ (4) $H_4P_2O_7$

**4.** Choose the incorrect formula out of the four compounds for an element X below :
(1) $X_2O_3$ (2) $X_2Cl_3$ (3) $X_2(SO_4)_3$ (4) $XPO_4$

**5.** The group of molecules having identical shape is : **[JEE(Main) 2016 Online (09-04-16), 4/120]**
(1) $PCl_5$, $IF_5$, $XeO_2F_2$ (2) $BF_3$, $PCl_3$, $XeO_3$ (3) $ClF_3$, $XeOF_2$, $XeF_3^+$ (4) $SF_4$, $XeF_4$, $CCl_4$

**6.** **Assertion:** Among the carbon allotropes, diamond is an insulator, Whereas, graphite is a good conductor of electricity.
**Reason:** Hybridization of carbon in diamond and graphite are $sp^3$ and $sp^2$, respectively. **[JEE(Main) 2016 Online (10-04-16), 4/120]**
(1) Both assertion and reason are correct, but the reason is not the correct explanation for the assertion.
(2) Assertion is incorrect statement, but the reason is correct.
(3) Both assertion and reason are correct, and the reason is the correct explanation for the assertion.
(4) Both assertion and reason are incorrect.

**7.** The bond angle H–X–H is the greatest in the compound : **[JEE(Main) 2016 Online (10-04-16), 4/120]**
(1) $NH_3$ (2) $PH_3$ (3) $CH_4$ (4) $H_2O$

**8.** Identify the pair in which the geometry of the species is T-shape and square-pyramidal, respectively :
**[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) $ICl_2^-$ and $ICl_5$ (2) $IO_3^-$ and $IO_2F_2^-$ (3) $ClF_3$ and $IO_4^-$ (4) $XeOF_2$ and $XeOF_4$

**9.** In graphite and diamond, the percentage of p-characters of the hybrid orbitals in hybridization are respectively :
**[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) 33 and 25 (2) 67 and 75 (3) 50 and 75 (4) 33 and 75

**10.** The decreasing order of bond angles in $BF_3$, $NH_3$, $PF_3$ and $I_3^-$ is :

(1) $I_3^-$ > $BF_3$ > $NH_3$ > $PF_3$ (2) $BF_3$ > $I_3^-$ > $PF_3$ > $NH_3$

(3) $BF_3$ > $NH_3$ > $PF_3$ > $I_3^-$ (4) $I_3^-$ > $NH_3$ > $PF_3$ > $BF_3$

**11.** The number of P–O bonds in $P_4O_6$ is :
**[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) 6 (2) 9 (3) 12 (4) 18

**12.** In $XeO_3F_2$, the number of bond pair(s), $\pi$-bond(s) and lone pair(s) on Xe atom respectively are :
**[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) 5, 2, 0 (2) 4, 2, 2 (3) 5, 3, 0 (4) 4, 4, 0

**13.** Among the oxides of nitrogen :
**[JEE(Main) 2018 Online (16-04-18), 4/120]**

$N_2O_3$, $N_2O_4$ and $N_2O_5$ ; the molecule(s) having nitrogen-nitrogen bond is/are :

(1) $N_2O_3$ and $N_2O_4$ (2) $N_2O_4$ and $N_2O_5$ (3) $N_2O_3$ and $N_2O_5$ (4) Only $N_2O_5$

**14.** Which of the following conversions involves change in both shape and hybridisation ?
**[JEE(Main) 2018 Online (16-04-18), 4/120]**

(1) $H_2O \rightarrow H_3O^+$ (2) $BF_3 \rightarrow BF_4^-$ (3) $CH_4 \rightarrow C_2H_6$ (4) $NH_3 \rightarrow NH_4^+$

**15.** The **incorrect** geometry is represented by :
**[JEE(Main) 2018 Online (16-04-18), 4/120]**

(1) $NF_3$ – trigonal planar (2) $BF_3$ – trigonal planar
(3) $AsF_5$ – trigonal bipyramidal (4) $H_2O$ – bent

**16.** The type of hybridisation and number of lone pair(s) of electrons of Xe in $XeOF_4$, respectively, are :
**[JEE(Main) 2019 Online (10-01-19), 4/120]**

(1) $sp^3d^2$ and 1 (2) $sp^3d^2$ and 2 (3) $sp^3d$ and 1 (4) $sp^3d$ and 2

**17.** The pair that contains two P–H bonds in each of the oxoacid is:
**[JEE(Main) 2019 Online (10-01-19), 4/120]**

(1) $H_4P_2O_5$ and $H_3PO_3$ (2) $H_4P_2O_5$ and $H_4P_2O_6$
(3) $H_3PO_2$ and $H_4P_2O_5$ (4) $H_3PO_3$ and $H_3PO_2$

**18.** The element that shows greater ability to form $p\pi$-$p\pi$ multiple bonds, is:
**[JEE(Main) 2019 Online (12-01-19), 4/120]**

(1) Ge (2) Sn (3) C (4) Si

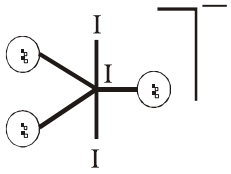
# Answers

## EXERCISE - 1

### PART - I

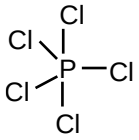
**A-1.** In $NO_2^+$ the N has sp hybridisation; so it is linear $O = \overset{+}{N} = O$

In $I_3^-$ there are 5 electron pairs around central iodine atom (3 lone pairs and 2 bond pairs). The hybridisation of iodine is thus $sp^3d$. To have minimum repulsions between lp-lp and lp-bp it acquires linear shape as shown below.

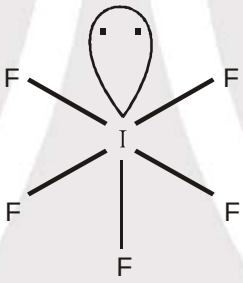


linear

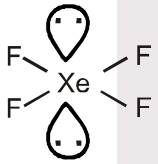
**A-2.** In $PCl_5$ there are 5 electron pairs around central phosphorus atom and all are bond pairs. The hybridisation of phosphorus is thus $sp^3d$. To have minimum repulsions between bp-bp it acquires trigonal bipyramidal shape as shown below.



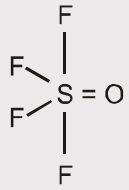
In $IF_5$ there are 6 electron pairs around central iodine atom. The hybridisation of iodine is thus $sp^3d^2$. 6 electron pairs contain 5 bond pairs and one lone pair so it will be square pyramidal to have minimum repulsions between lp-bp and bp-bp.



**A-3.**

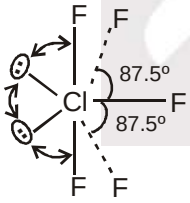


Square planar



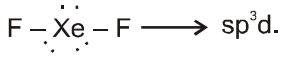
Trigonal bipyramidal

**A-4.**

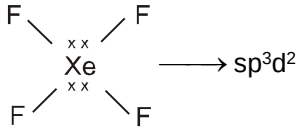


nearly 'T' shaped.

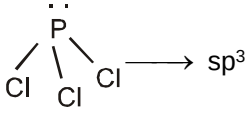
**B-1.** **1.**



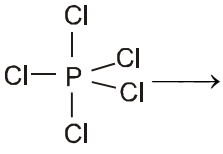
**2.**

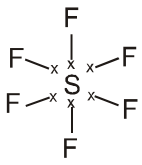


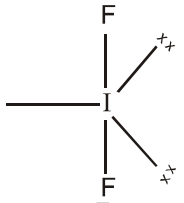
**3.**

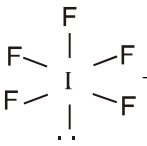


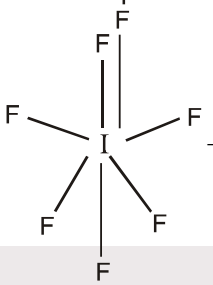
**4.**

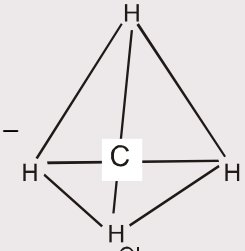


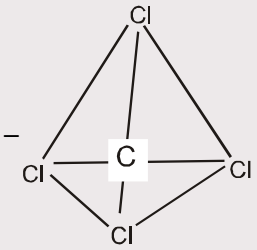
**5.**  $\longrightarrow sp^3d^2$

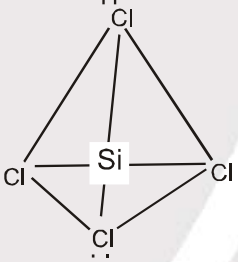
**6.** $IF_3$ : –  $\longrightarrow sp^3d$

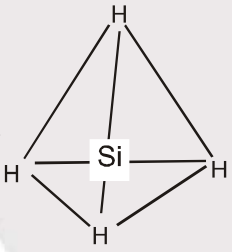
**7.** $IF_5$ : –  $\longrightarrow sp^3d^2$

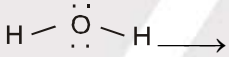
**8.** $IF_7$ : –  $\longrightarrow sp^3d^3$

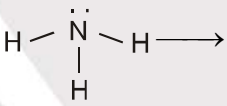
**9.** $CH_4$ : –  $\longrightarrow sp^3$

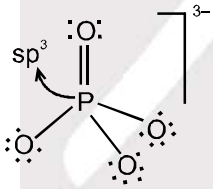
**10.** $CCl_4$ : –  $\longrightarrow sp^3$

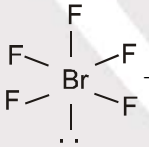
**11.** $SiCl_4$ : –  $\longrightarrow sp^3$

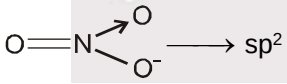
**12.** $SiH_4$ : –  $\longrightarrow sp^3$

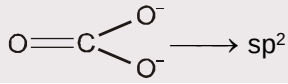
**13.** $H_2O$ : –  $\longrightarrow sp^3$

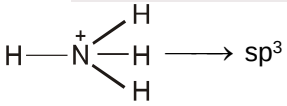
**14.** $\ddot{N}H_3$ :–  $\longrightarrow sp^3$

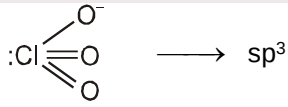
**15.** 

**16.** $BrF_5$  $\longrightarrow sp^3d^2$

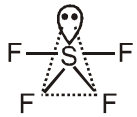
**17.** 

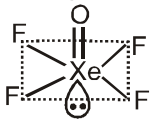
**18.** 

**19.** 

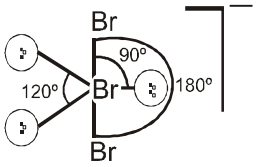
**20.** 

**B-2.** True, As the s character in hybrid orbital decrease, size of hybrid orbital increases.

**B-3.** (a) $SF_4$  4 bond pair & 1 lone pair, Hybridization = $sp^3d$ Shape : see saw

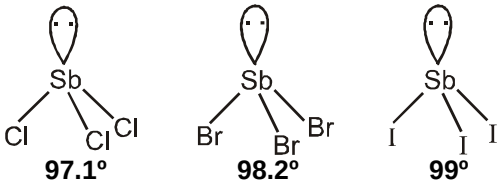
(b) $XeOF_4$  5 bond pair & 1 lone pair, Hybridization = $sp^3d^2$ Shape : Square pyramidal

**C-1.** In $Br_3^-$ there are 5 electron pairs around central bromine atom (3 lone pairs and 2 bond pairs). The hybridisation of bromine is thus $sp^3d$. To have minimum repulsions between lp-lp and lp-bp it acquires linear shape as shown below.

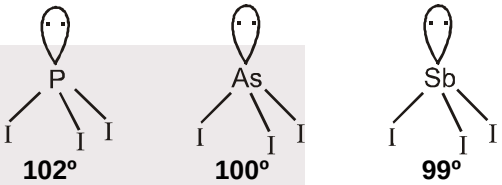


linear

**C-2.** **(a)** Cl, the most electronegative of the halogens in this series, pulls shared electrons the most strongly away from Sb, reducing electron density near Sb. The consequence is that the lone pair exerts the strongest influence on shape in $SbCl_3$.

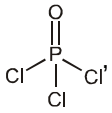



**(b)** Phosphorus is the most electronegative of the central atoms. Consequently, it exerts the strongest pull on shared electrons, concentrating these electrons near P and increasing bonding pair-bonding pair repulsions– hence, the largest angle in $PI_3$. Sb, the least electronegative central atoms, has the opposite effect: Shared electrons are attracted away from Sb, reducing repulsions between the Sb–I bonds.




The consequence is that the effect of the lone pair is greatest in $SbI_3$, which has the smallest angle. Atomic size arguments can also be used for these species. Larger outer atoms result in larger angles; larger central atoms result in smallest angles.

**C-3.** Order of C–H bond strength is $C_2H_2 > C_2H_4 > C_2H_6$ as %s character decreases in the same order.

**C-4.** 

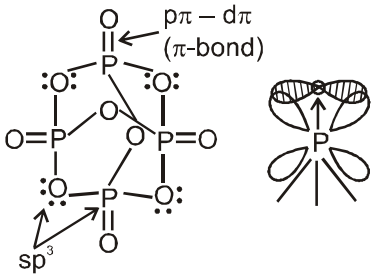
double bond occupies large area and has large electron density. So there is intrinsic repulsion between P=O and P–Cl bond pairs. To minimize this repulsion bond angle decrease from 109.5º to 103.5º.

**C-5.**

| | Highest bond angle | Lowest bond angle |
|---|---|---|
| (1) | $CH_4$ | $SbH_3$ |
| (2) | $CO_2$ | $H_2Te$ |
| (3) | $H_2O$ | $PH_3$ |
| (4) | $ClO_2$ | $Cl_2O$ |
| (5) | $PF_3$ ($sp^3$ hybridisation) | $PH_3$ (no hybridisation) |
| (6) | $BF_3$ ($sp^2$ hybridisation) | $NF_3$ ($sp^3$ hybridisation) |
| (7) | $NH_3$ | $NF_3$ |
| (8) | $PCl_3$ | $PF_3$ |

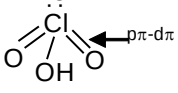
**C-6.** (1) C≡C < C=C < C–C (2) C–F < C–O < C–N (3) HF < H–Cl < H–Br < H–I

**D-1.** (a) 4 (b) 3 (c) 3 (d) 6 (e) 4 (f) 0

**D-2.** (a) $P_4O_{10}$, 




(b) and (c) nitrogen does not have empty d-orbital.

(d) $HClO_3$, 

**D-3.** (1) +2 (6, –2) (2) +5/2(5, 5, 0, 0) (3) +6 (4) +6 (+6, +6) (5) +6 (+6, +6)
(6) 0 (7) +5 (8) 4/3 (+ 2, +2, 0) (9) +8 (10) –3
(11) +6 (12) +6 (+6, +6) (13) +6 (14) +6 (15) +5
(16) +2 (17) 0 (18) –3, +5
**Note: Inside the bracket ( ) answer for individual oxidation number is given.**

### PART - II

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **A-1.** | (C) | **A-2.** | (D) | **A-3.** | (D) | **A-4.** | (A) | **A-5.** | (B) |
| **A-6.** | (D) | **B-1.** | (B) | **B-2.** | (A) | **B-3.** | (D) | **B-4.** | (C) |
| **B-5.** | (A) | **C-1.** | (B) | **C-2.** | (D) | **C-3.** | (B) | **C-4.** | (B) |
| **C-5.** | (A) | **D-1.** | (C) | **D-2.** | (B) | **D-3.** | (D) | **D-4.** | (A) |

### PART - III

**1.** (A – p, q, r) ; (B – q, r, t) ; (C – s) ; (D – r) **2.** (A – r) ; (B – q) ; (C – s) ; (D – p, t)

**3.** (A – r,s); (B – p,q,s) ; (C – q); (D – q,r)

## EXERCISE - 2

### PART - I

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | (D) | **2.** | (C) | **3.** | (C) | **4.** | (B) | **5.** | (A) |
| **6.** | (B) | **7.** | (A) | **8.** | (D) | **9.** | (C) | **10.** | (B) |
| **11.** | (B) | **12.** | (B) | **13.** | (A) | **14.** | (A) | **15.** | (A) |
| **16.** | (B) | **17.** | (A) | | | | | | |

### PART - II

| | | | | | |
|---|---|---|---|---|---|
| **1.** | 5 (a, b, c, d, h) | **2.** | 6 (a, d, e, h, i, k) | **3.** | 16 |
| **4.** | 4 | **5.** | 10 | **6.** | 6 |

### PART - III

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | (AC) | **2.** | (CD) | **3.** | (ABC) | **4.** | (AC) | **5.** | (BCD) |
| **6.** | (BCD) | **7.** | (BCD) | **8.** | (BD) | | | | |

### PART - IV

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** | (C) | **2.** | (D) | **3.** | (D) | **4.*** | (ABC) | **5.** | (A) |
| **6.** | (B) | **7.** | (C) | | | | | | |

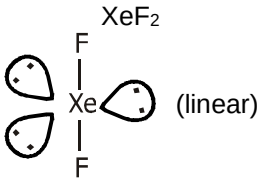
## EXERCISE - 3

### PART - I

**1.** (B) **2.** (C)

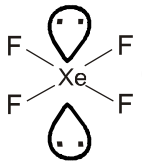
**3.** According to VSEPR theory

Number of electron pairs = 5,
Number of bond pairs = 2,
So, Number of lone pairs = 3.
Thus $XeF_2$ is linear with 3 lone pairs occupying 3 equatorial positions of trigonal bipyramidal so as to minimize the repulsions.




Number of electron pairs = 6, $XeF_4$

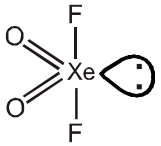
Number of bond pairs = 4,
So, Number of lone pairs = 2.
Thus $XeF_4$ is linear with 2 lone pairs occupying 2 axial positions of octahedral pyramidal so as to minimize the repulsions.



(square planar)

Number of electron pairs (including super electron pairs) = 5,
Number of bond pairs = 4,
So, Number of lone pairs = 1.
Thus $XeO_2F_2$ is see-saw with 1 lone pairs occupying one equatorial position and two double bonds occupying other two equatorial positions of trigonal bipyramidal so as to minimize the repulsions.

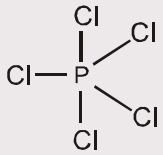
$XeO_2F_2$



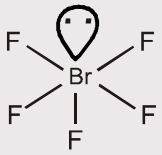
(see-saw)

**4.** (B) **5.** (D) **6.** (A)

**7.** There are 5 electron pairs and all are bonds pairs in $PCl_5$. So to have the minimum repulsions between bond pairs it acquires trigonal bipyramidal shape. In $BrF_5$, there are 6 electrons pairs out of which one lone pair and rest all are bond pairs. So to have the minimum repulsions between bond pairs and lone pairs it acquires square pyramidal shape.



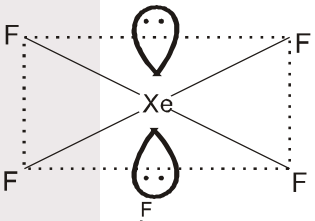
, $PCl_5$ (trigonal bipyramidal),



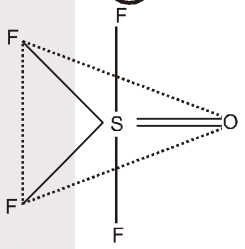
$BrF_5$ (square pyramidal)

**8.**

According to VSEPR theory two lone pairs out of six electron pairs are trans to each other to have minimum repulsion. The shape of $XeF_4$ is square planar and geometry is octahedral with $sp^3d^2$ hybridisation. The molecule looks like :




In $OSF_4$, there are five electron pairs and all are bond pairs. So geometry is trigonal bipyramidal. As double bond creates more repulsion than singles bond, the double bond acquires one of equatorial position of trigonal bipyramidal to have minimum repulsions.
The structure looks like:




**9.** (D) **10.*** (ABC) **11.** (D) **12.** 0 or 8 **13.** (D)
**14.** 8 **14.** 4 **16.*** (ACD) **17.** **5 or 6**

## PART - II

### JEE(MAIN) OFFLINE PROBLEMS

**1.** (1) **2.** (4) **3.** (3) **4.** (2) **5.** (4)
**6.** (3) **7.** (4) **8.** (2) **9.** (4) **10.** (3)
**11.** (3) **12.** (4)

### JEE(MAIN) ONLINE PROBLEMS

**1.** (2) **2.** (3) **3.** (3) **4.** (2) **5.** (3)
**6.** (1) **7.** (3) **8.** (4) **9.** (2) **10.** (1)
**11.** (3) **12.** (3) **13.** (1) **14.** (2) **15.** (1)
**16.** (1) **17.** (3) **18.** (3)