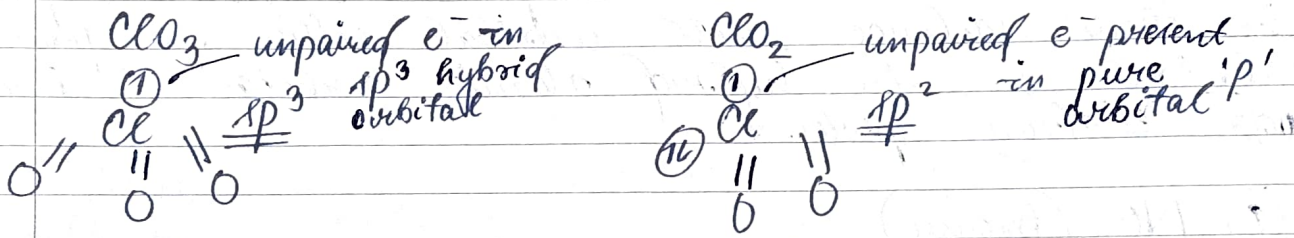
In the given example, we can see that in $\dot{C}H_3$ (free radical) unpaired electron is present in pure p-orbital but in $\dot{C}F_3$ free radical, unpaired electron is present in sp^3 hybridised orbital.

There are certain rules which decide that unpaired electron will participate in hybridisation or not:-

(1) The surrounding atom should be electronegative.

(2) Central atom should not contain any lone pair other than unpaired electron.



Conditions fulfilled unpaired e^- participates in hybridisation

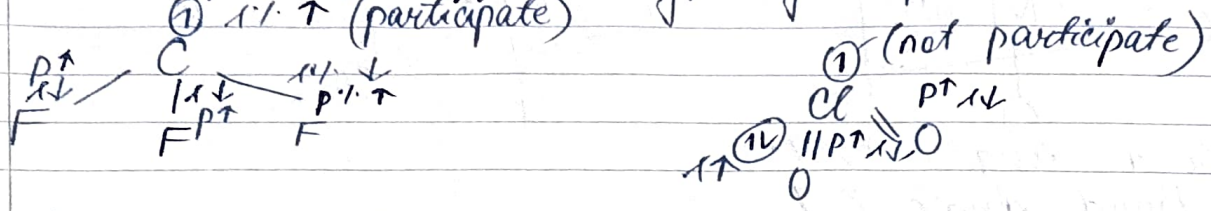
unpaired e^- does not participate in hybridisation

- All the odd electron species are paramagnetic in nature.

11/11/25

- When unpaired electron have higher 's' percentage, then that unpaired electron will participate in hybridisation.
- When central atom have both unpaired electron as well as lone pair, then s% will increase in lone pair

more rapidly than unpaired electron. So, unpaired e^- will not participate in ~~hyb~~ hybridization.



Hybridization of Some Important Compound:-

In gaseous form, all these compounds are covalent but in solid form, they become ionic in nature.

$2PCl_5(l) \longrightarrow PCl_4^+_{sp^3} + PCl_6^-_{sp^3d^2}$

$PBr_5(l) \longrightarrow PBr_4^+_{sp^3} + Br^- \quad (PBr_4^+ + PBr_6^- \times$ due to steric crowding$)$

$XeF_6(l) \longrightarrow XeF_5^+_{sp^3d^2} + F^-$

IMP $N_2O_5(l) \longrightarrow NO_2^+ + NO_3^-$

$I_2Cl_6(liq) \rightarrow ICl_2^+ + ICl_4^-$

$Cl_2O_6(l) \longrightarrow ClO_2^+ + ClO_3^-$

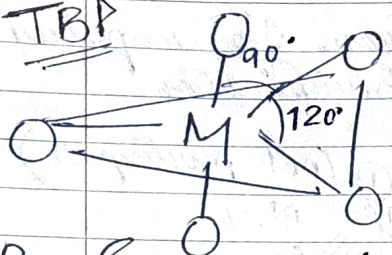
Bent Rule:-

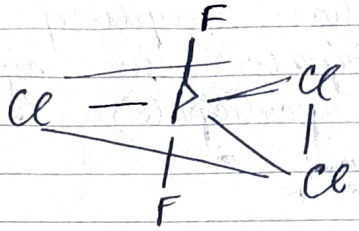
(1) More electronegative atom occupies that position of hybrid orbital which has more p-character or less s-character. (more / less)

OR

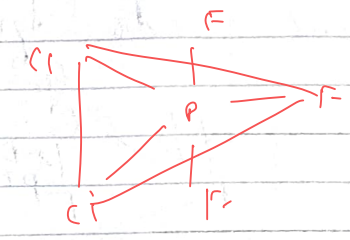
The orbital in which electronegative atom is present p% age increases or s% decreases.

TBP





PF_3Cl_2



Bond angle $\propto$ 1/p

Bond angle $\propto \frac{1}{p}$

$BeCl_2$

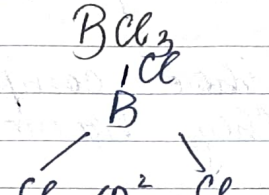
Cl – Be – Cl

sp

1/p = 50%

BA = 180°

BCl_3

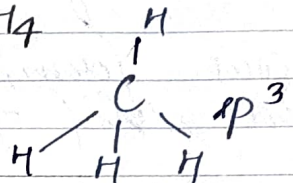


sp^2

1/p = 33.3%

BA = 120°

CH_4

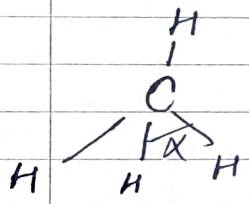


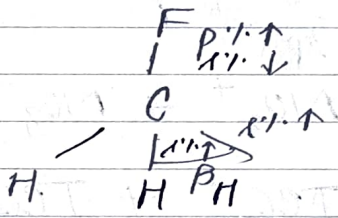
sp^3

1/p = 25%

BA = 109°28'

The electronegative atom does not have tendency to overlap with hybrid orbital in which 1/p is high

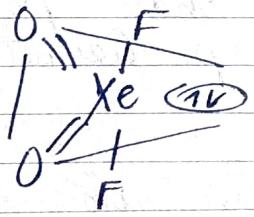




$\alpha < \beta$ (More 1/p, more bond angle)

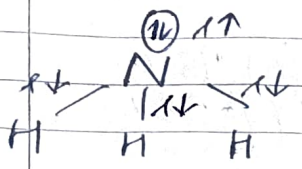
(2) Lone pair or multiple bond occupy that position of hybrid orbital which have more s character.

XeO_2F_2

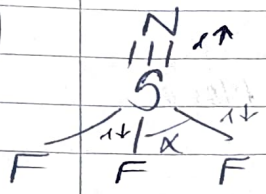


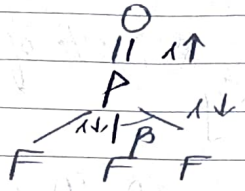
The hybrid orbital in which lone pair is placed or multiple bond is placed, s% increases by default.

__/__/____



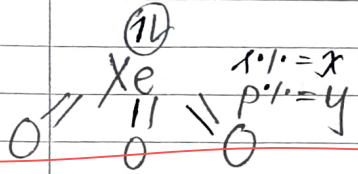
Q1





$\boxed{\alpha < \beta}$

Q2



~~x~~ $x < 25\%$

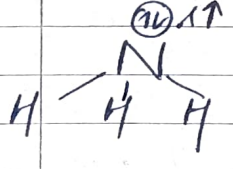
$y > 75\%$

(3) For fixed central atom and terminal atom and for same hybridisation, bond strength directly proportional to s-character.

(4) Higher the s percentage of the hybrid orbital, greater will be the bond angle b/w them.
Higher the p% of hybrid orbital, greater will be the bond length.

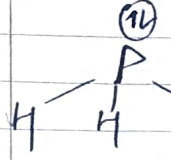
Q1 % s character of lp of NH_3

(a) $> 25\%$ (b) $< 75\%$ (c) $= 75\%$ (d) 100%



% p character $< 75\%$

Q2) % p character of ℓp of PH_3

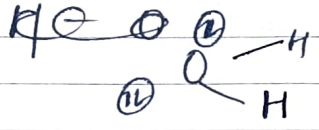


(a) = 100 % (b) 75 % (c) = 0 % (d) = 25 %

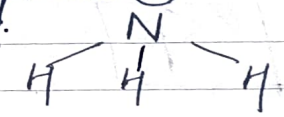
pure p-orbital

Q3) x % of ℓp of H_2O = x ; x % of ℓp of NH_3 = y

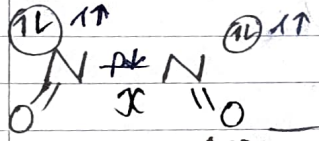
(a) x > y (b) x < y (c) x = y (d) None

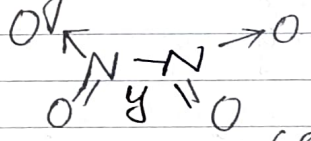


ℓp - ℓp repulsion is max.



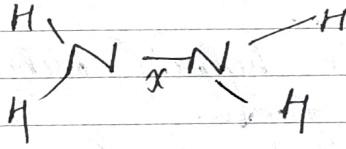
Q4) Compare N-N bond length.



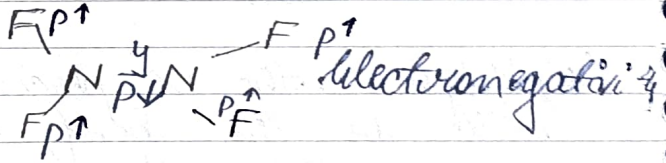


(a) x > y (b) x < y (c) x = y (d) None

Q5) Compare N-N bond length.

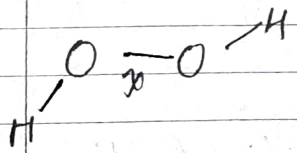


x > y

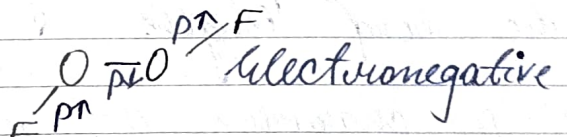


Electronegativity

Q6)

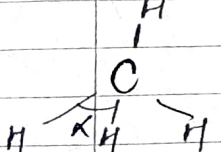


x > y

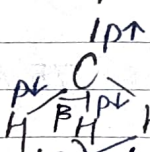


Electronegative

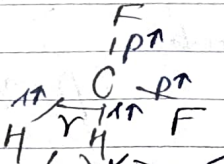
Q7)



(a) α > β > γ

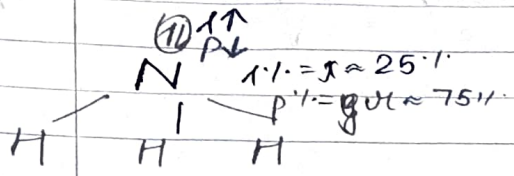


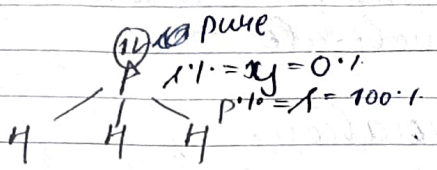
(b) α < β < γ



(c) α > β < γ (d) None

(Q8)





(a) $x > y$ (b) $x > 1$ (c) $x < y$ (d) $x < 1$

s represent electronegativity of the hybrid orbital or closeness to the nucleus.
p % represent extent of elongation of hybrid orbital.

s% ↑ — BA ↑ electronegativity ↑ BL ↓

p% ↑ — BA ↓ electronegativity ↓ BL ↑

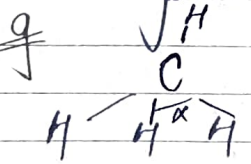
Bond Parameter :-

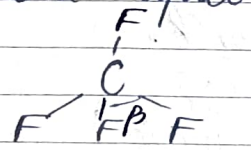
(I) Bond Angle (II) Bond length
(III) Bond order (IV) Bond energy

(1) Bond Angle —

- In ideal hybridisation, all the bond angles are equal in a molecule but in non-ideal hybridisation, all Bond angles are not equal, and will have lesser or greater value from ideal geometry.

e.g





$\alpha = \beta$ Ideal

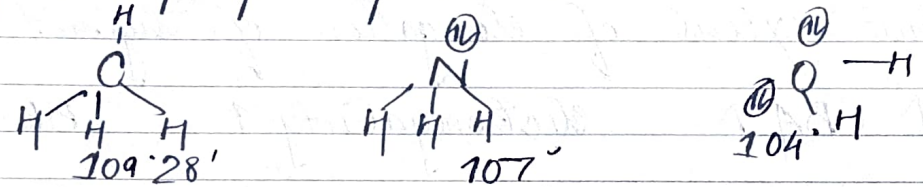
• By the following rule, the bond angle is compared b/w 2 molecules —

(a) Check hybridisation.

$sp > sp^2 > sp^3$

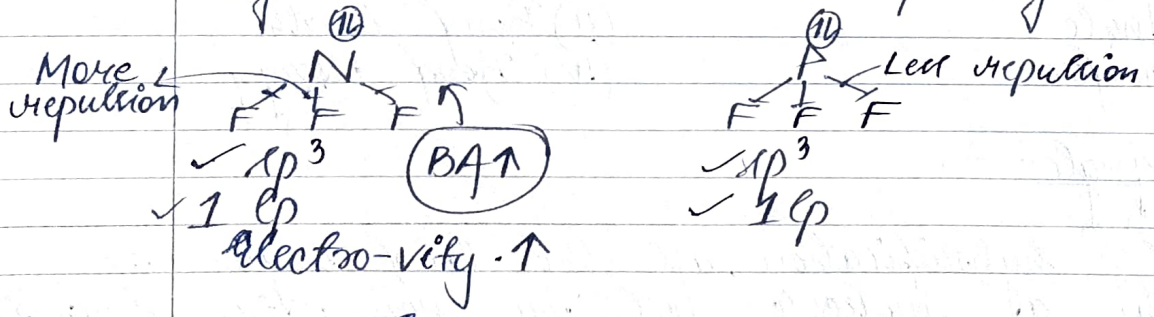
(180°) (120°) (109°28')

(b) If hybridisation is same, higher the no. of lp on central atom, lesser will be the bond angle due to higher lp-lp repulsion.



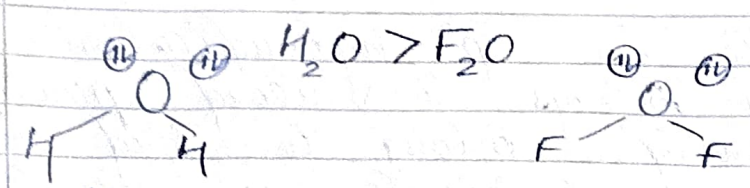
12/4/25

(c) If hybridisation & no. of lone pair on central atom is same, then higher the ~~EN~~ electronegativity of central atom, greater will be the bond angle.

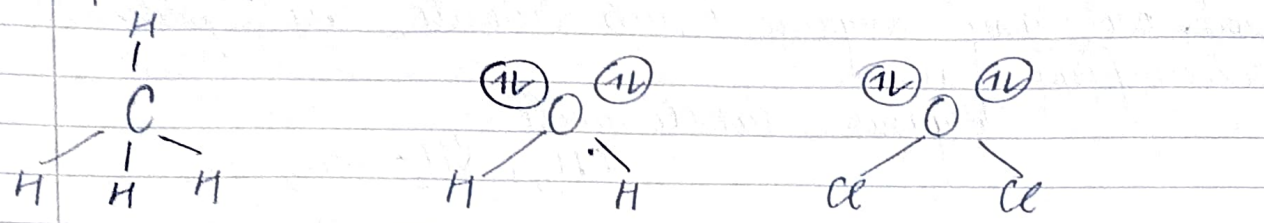


(d) If hybridisation, no. of lp on central atom and central atom is same, then higher the electronegativity of surrounding atom, lesser will be the bond angle.



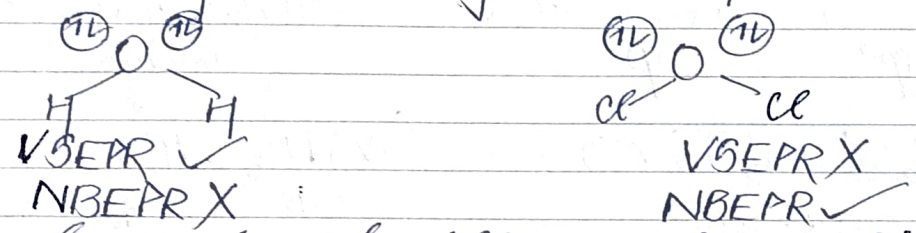


(e)



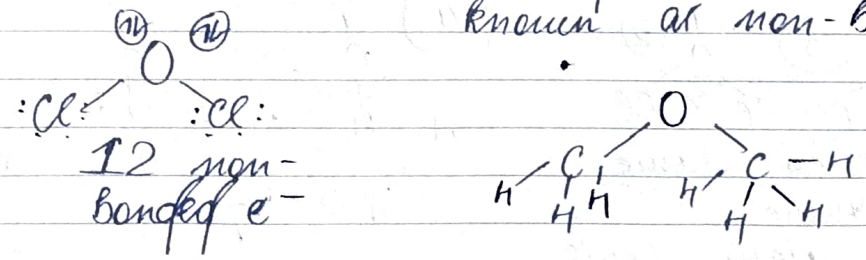
sp^3 sp^3 sp^3 (NBEPR Theory)
$109°28'$ $104°$ $110°$

- Experimentally, it was found that bond angle of OCl_2 is about 110° which is higher than ideal geometry. By this experiment, we can conclude that VSEPR theory is being violated in molecule.



- The bond angle of OCl_2 can be explained on the basis of NBEPR theory (Non-Bonded electron Pair Repulsion).

Non-Bonded electron: The electron which is not related with central atom is known as non-bonded electron



- NBEPR ~~does~~ always dominates over VSEPR.

__/__/__

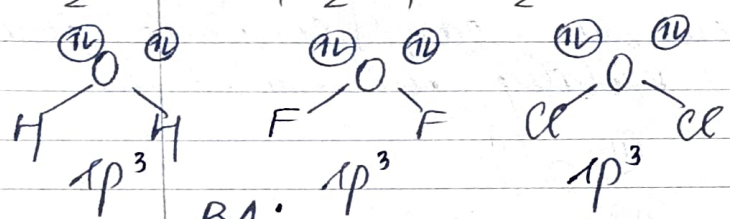
NBEPR is applicable in sp^3 hybridization in which central atom belongs to second period and surrounding atom should belong to 3rd or higher period, and any organic substituents is present at surrounding atom.

Organic substituents :-

CH_3, CH_2-CH_3

Q) Compare the bond angle of the following molecule:-

(I) H_2O , F_2O, Cl_2O



sp^3 sp^3 sp^3

BA:

$Cl_2O > H_2O > F_2O$ ~~$H_2O > Cl_2O > F_2O$~~

(NBEPR) Prago

(II) NH_3, PH_3, AlH_3, SbH_3

Hybridization same

lp same

$SbH_3 < AlH_3 < PH_3 < NH_3$

Prago

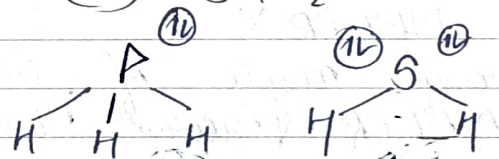
(III) H_2O , H_2S, H_2Se

Hybridization ~~same~~ in H_2O

lp same

$H_2Se < H_2S < H_2O$

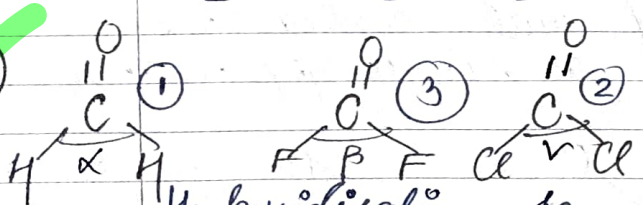
(IV) PH_3 , H_2S :



Prago

$H_2S < PH_3$ (lp - lp)

(V)



Hybridization same

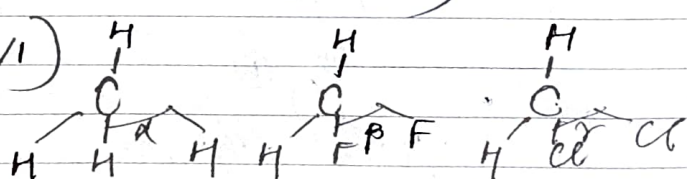
lp same

Central atom same

$\alpha > \gamma > \beta$

No NBEPR as sp^2 hybridization.

(VI)



$\gamma > \alpha > \beta$

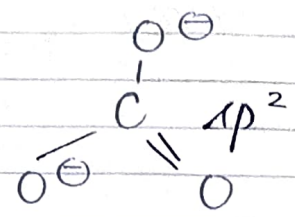
NBEAR

(VII) CO_2 , CO_3^{2-}

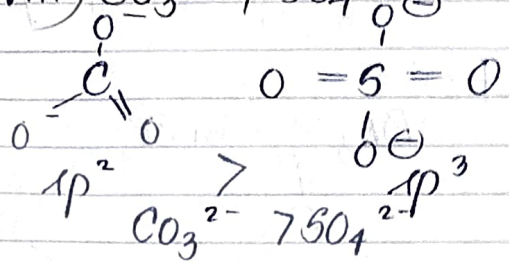
$O=C=O$

sp

$CO_2 > CO_3^{2-}$



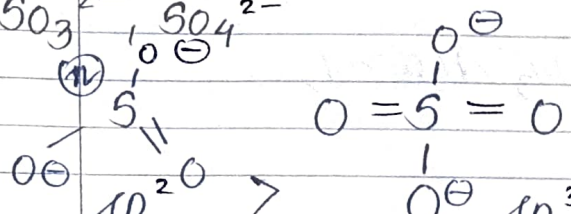
(VIII) CO_3^{2-} , SO_4^{2-}



sp^2 > sp^3

$CO_3^{2-} > SO_4^{2-}$

(IX) SO_3^{2-} , SO_4^{2-}



sp^2 > sp^3 (but ℓp in SO_3^{2-})

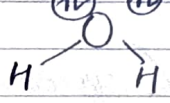
$SO_3^{2-} < SO_4^{2-}$

(X) Find no. of molecules which have more bond angle than H_2O.

C_2H_2 , CO_2 , BF_3 , CH_4 , BH_4^- , $SnCl_2$, OCl_2 , OF_2 , NH_3 , PH_3 , NH_4^+ , PH_4^+

H_2O

$H_2O - sp^3$



104°

(I) $H-C\equiv C-H$

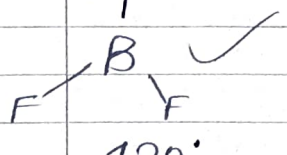
sp ✓

(II) CO_2

$O=C=O$

✓

(III) BF_3



✓

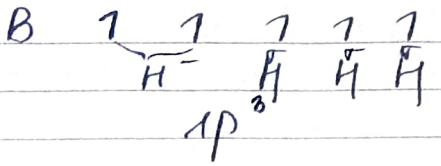
120°

(IV) CH_4

109°28'

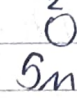
✓

(V) BH_4^-



sp^3

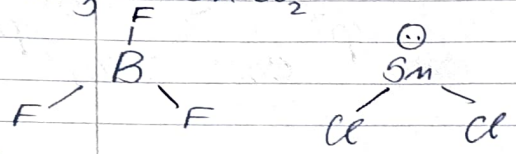
(VI) $SnCl_2$



sp $C_2H_2 = CO_2$ (BA equal = 180°)

sp^2

$BF_3 > SnCl_2$



sp^3 $OCl_2 > \underbrace{CH_4 = BH_4^- = NH_4^+ = PH_4^+}_{\text{Ideal intermixing}} > NH_3 > H_2O > OF_2$

(10)

(XI) $BF_3 = CF_3^+ \quad CH_3^+ \quad CH_3^- \quad CF_3^-$
$sp^2 \quad sp^2 \quad sp^2 \quad sp^3 \quad sp^3$

$BF_3 = CF_3^+ = CH_3^+$
(as no lp & same hybridisation)

$CH_3^- > CF_3^-$ (surrounding atom is more electronegative)

(XII) $\dot{C}H_3 \quad \dot{C}F_3 \quad CH_3^- \quad CF_3^-$

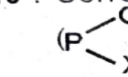
(XIII) $NO_2^+ \quad NO_2 \quad NO_3^- \quad NO_2^-$
sp

42. The decreasing order of bond angles in BF_3, NH_3, PF_3 and I_3^- is :- **[JEE-MAINS(online)-2018]**

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

CBO0156

10*. Correct order of bond angle for O—P—X



angle) in the given molecules is

I. POF_3
II. $POCl_3$
III. $POBr_3$
IV. POI_3

(1) I > II > III > IV
(2) IV > III > II > I
(3) II > III > I > IV
(4) III > II > IV > I

Try Yourself

1. Compare the bond angle in given pairs
   (i) NH_3 NF_3
   (ii) $NO_2^{\oplus}$ $NO_2^{\ominus}$
2. Arrange the following compounds in the increasing order of bond angle.
   BF_3, H_2O, CH_4, $NO_2^{\oplus}$

$NO_2^+ > BF_3 > CH_4 > H_2O$

__/__/____

(XIV) ClO_2 ClO_3

(XV) ClO_3 $ClO_3^{\ominus}$ $ClO_4^{\ominus}$

(2) Bond Length –

- The minimum distance between two co-valently bonded atom is known as bond length.

- Comparison of bond length –

(a) Higher the shell number, greater will be the bond length.

e.g. H-F < H-Cl < H-Br < H-I
1s-2p 1s-3p 1s-4p 1s-5p

F-F < Cl-Cl < Br-Br < I-I
2p-2p 3p-3p 4p-4p 5p-5p

(b) When covalently bonded atoms are same, then higher the p% age (or lesser the s% age), higher will be the bond length.

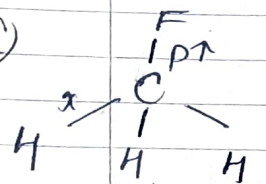
e.g

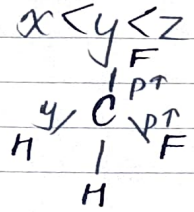
① $H-\overset{x}{C}\equiv C-H$ — sp — p.l. = 50%

$H_2\overset{y}{C}=CH_2$ — sp^2 — p.l. = 66.67%

$H_3\overset{z}{C}-CH_3$ — sp^3 — p.l. = 75%

$x < y < z$

② 



$x > y$

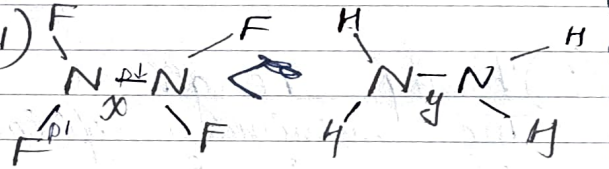
Q Compare the bond length :-

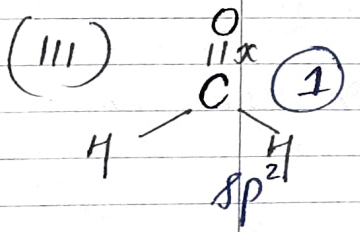
(I) CO, CO_2

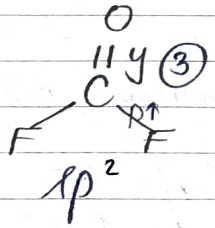
sp sp

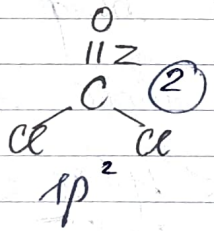
CO

C

(II) 

(III) 





13/11/25

- Higher the no. of bond between 2 co-valently bonded atom, lesser will be the bond length

e.g $C\overset{x}{\equiv}C$, $C\overset{y}{=}C$, $C\overset{z}{-}C$

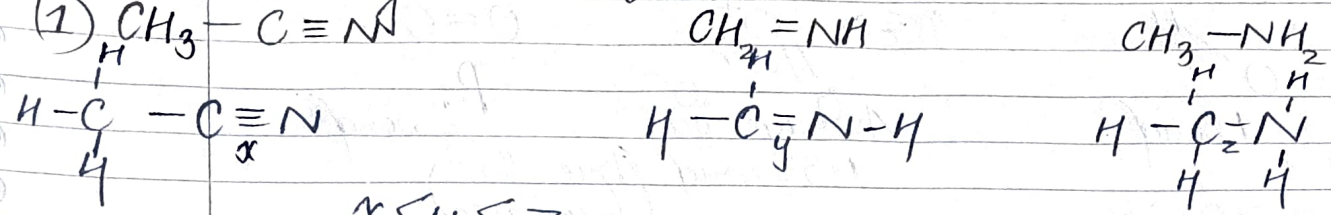
$x > y > z$

$C\overset{x}{\equiv}N$ $C\overset{y}{=}N$

$x < y$

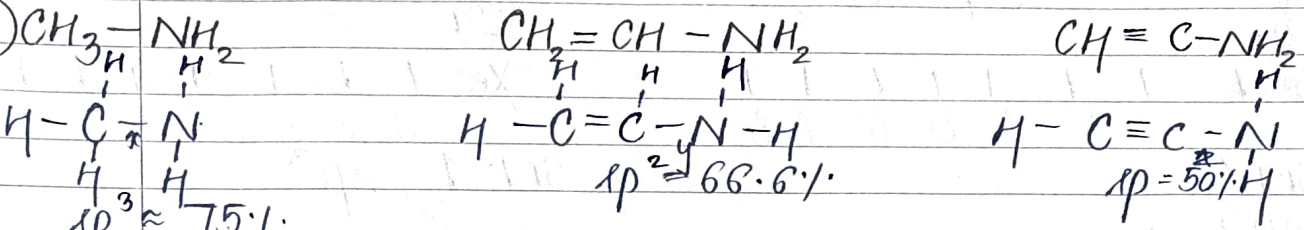
Q2) Compare bond length between carbon and nitrogen in the given molecules:

(1) $CH_3-C\equiv N$; $CH_2=NH$; CH_3-NH_2



$x < y < z$

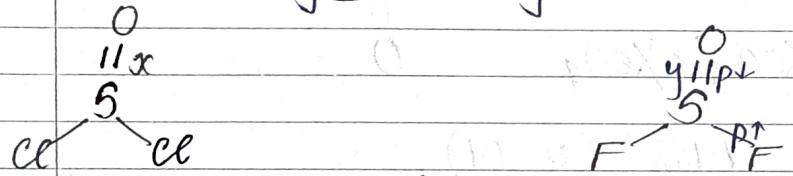
(2) CH_3-NH_2 ; $CH_2=CH-NH_2$; $CH\equiv C-NH_2$



$sp^3 \approx 75\%$; $sp^2 \approx 66.6\%$; $sp = 50\%$

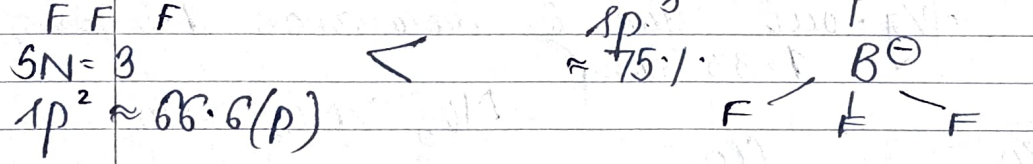
$x > y > z$

(3)



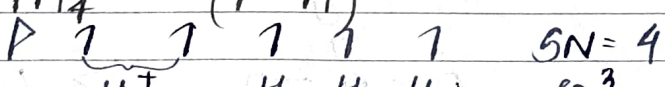
$y < x$

(4) BF_3 ; BF_4^- (B–F)



$SN = 3$; $sp^2 \approx 66.6\%(p)$; $sp^3 \approx 75\%$

(5) PH_3 ; PH_4^+ (P–H)

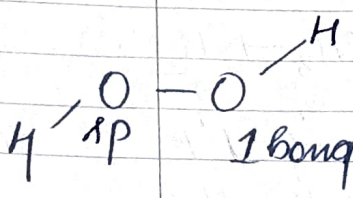


$SN = 4$; sp^3 ; 75%

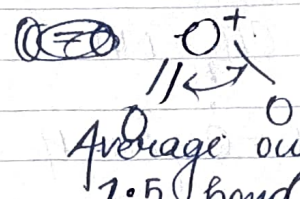
Vago $p \approx 100\%$

$PH_3 > PH_4^+$

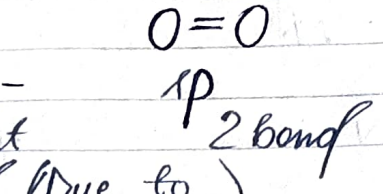
(6) H_2O_2 O_3 O_2 (O–O)



1 bond



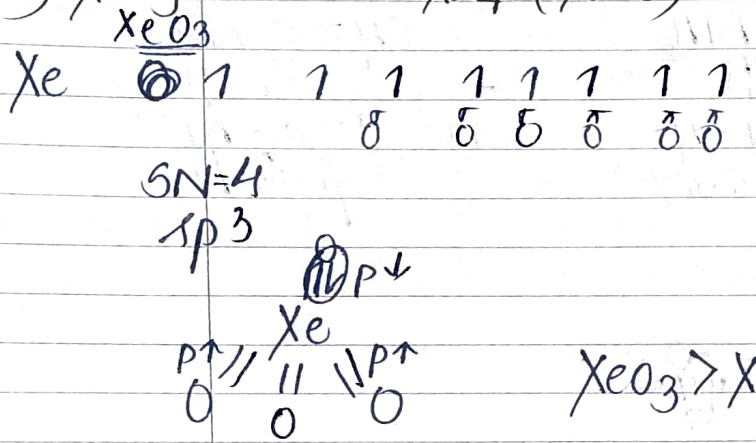
Average out 1.5 bond (due to resonance)



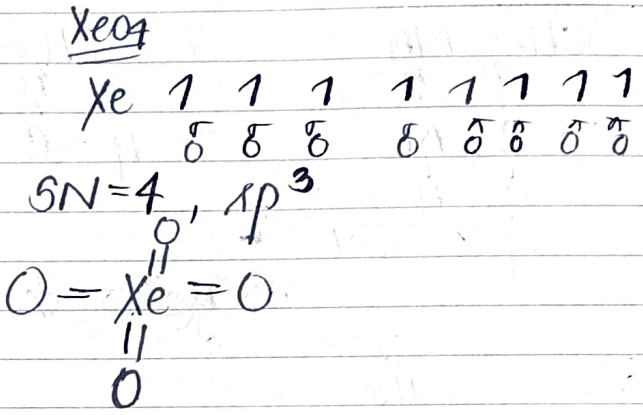
2 bond

$H_2O_2 > O_3 > O_2$

(7) XeO_3 XeO_4 (Xe–O)



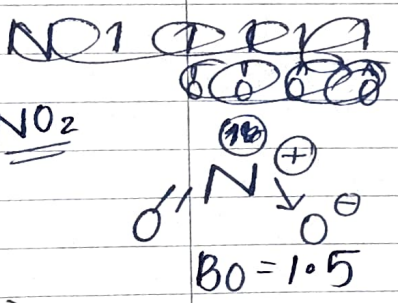
SN = 4, sp^3



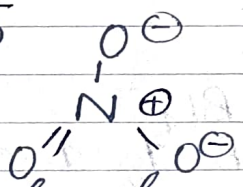
SN = 4, sp^3

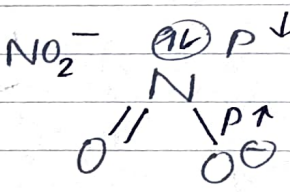
$XeO_3 > XeO_4$

(8) NO_2 NO_3^- NO_2^- (O–N)



$BO = 1.5$



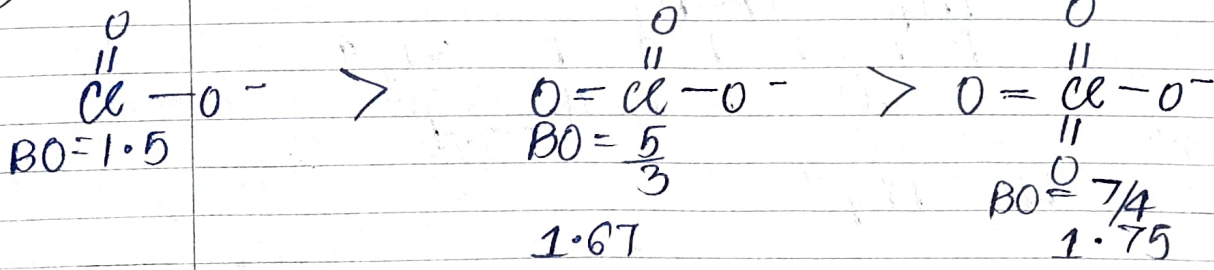


Avg. out due to resonance 1.5 bond

1.33 bond

$NO_3^- > NO_2^- > NO_2$

(9) ClO_2^- ClO_3^- ClO_4^-



$BO = 1.5$

$BO = \frac{5}{3}$

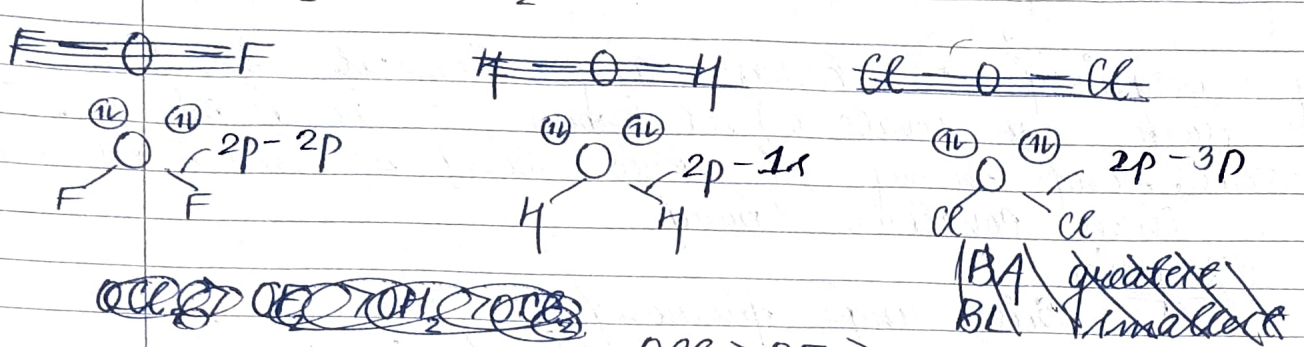
1.67

$BO = 7/4$

1.75

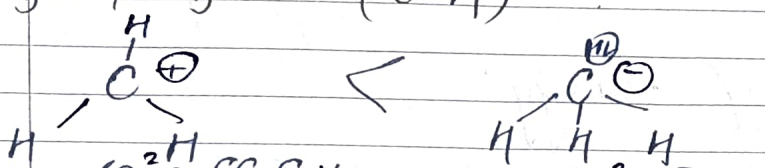
__/__/____

(10) OF_2 OH_2 OCl_2



$OCl_2 > OF_2 > OH_2$

(11) CH_3^+, CH_3^- (C-H)



(3) Bond Order —

- Number of bond present between two covalently bonded atom is known as bond order.
- Higher the bond order, greater will be the bond energy, and lesser will be the bond length (for same covalently bonded atoms)

e.g-1

$\overset{\ominus}{C}\equiv O^{\oplus}$ $O=C=O$ $H-\underset{H}{\overset{H}{C}}-O-H$

$BO_{(C-O)} = 3$ $BO_{(C-O)} = 2$ $BO_{(C-O)} = 1$

e.g-2

$R-C\equiv N$ (Cyanide) $R-CH=NH$ (Imine) $R-CH_2-NH_2$ (Amine)

$BO_{(C-N)} = 3$ $BO_{(C-N)} = 2$ $BO_{(C-N)} = 1$

(4) Bond energy –

Energy required to break any chemical bond (maybe ionic or covalent) is known as bond energy. In general, bond energy of ionic bond is much much higher than covalent bond.

Exception

SiO_2 and diamond (bond energy is very high)

Factors Affecting Bond Energy:

(1) Higher the bond ~~is~~ order, greater will be the bond energy.

(2) If bond order is same, then higher the extent of overlapping, greater will be the bond energy.

e.g.

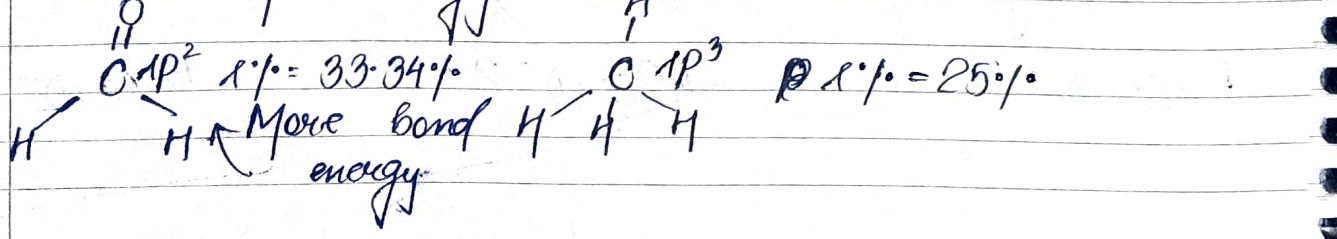
H-F > H-Cl > H-Br > H-I

1s-2p 1s-3p 1s-4p 1s-5p

Higher the size of orbital, lesser is the extent of overlapping.

~~p > sp^3 > sp^2 > sp > s (extent of overlapping)~~

Higher the s(%age) in hybrid orbital, greater will be the bond energy.



Only one correct

1. Which of the bond length order data is **INCORRECT** -

(A) P–Cl > P–F in PCl_3F_2

(B) $S–F_{(axial)} > S – F_{(eq)}$ in SF_6

(C) $S–F_{(axial)} > S – F_{(eq)}$ in SF_4

(D) $NO_2^- < NO_3^-$ (N – O)

2. O_2F_2 is an unstable yellow orange solid and H_2O_2 is a colourless liquid, both have O–O bon O–O bond length in H_2O_2 & O_2F_2 is respectively.

(A) 1.22Å, 1.48Å (B) 1.48Å, 1.22Å (C) 1.22Å, 1.22Å (D) 1.48Å, 1.48Å

3. Select the correct order of following property.

(A) % s-character : $sp^3 > sp^2 > sp$

(B) $\hat{ONO}$ bond angle : $NO_3^- > \overset{\oplus}{N}O_2$

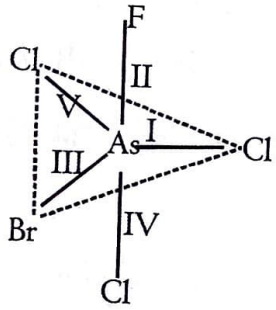
(C) All angles in CH_2F_2 are not identical

(D) C – F bond length : $CF_4 > CH_3F > CH_2F_2 > CF_3H$

4. The strongest P–O bond is found in the molecule

(A) F_3PO (B) Cl_3PO (C) Br_3PO (D) $(CH_3)_3PO$

5. The order of bond length from the following structure.



(A) III > I = V > IV > II

(B) IV > II > I = V > III

(C) III > IV > I = V > II

(D) I > II > III > IV > V

6. Comment on the C – C bond length for C_2H_6 and C_2F_6 compounds :

(A) $d_{C–C}(C_2H_6) > d_{C–C}(C_2F_6)$

(B) $d_{C–C}(C_2F_6) > d_{C–C}(C_2H_6)$

(C) $d_{C–C}(C_2F_6) = d_{C–C}(C_2H_6)$

(D) Can't be predicted

More than one may be correct

7. The **CORRECT** set of their indicated bond length is:-

(A) S–S (S_8) > P–P (P_4)

(B) d_{N-N}; NH_2–NH_2 > NF_2–NF_2

(C) d_{S-Cl}; $SOCl_2 < SO_2Cl_2$

(D) d_{B-O}; $B(OH)_3 < [B(OH)_4]^-$

8. The **CORRECT** statements about the structures of H_2O_2, O_2F_2 and OF_2 is/are :

(A) H_2O_2, O_2F_2, OF_2 are polar compounds

(B) d_{O-O} of $H_2O_2 > d_{O-O}$ of O_2F_2

(C) d_{O-F} of $OF_2 > d_{O-F}$ of O_2F_2

(D) the strength of O – O bond in O_2F_2 is greater than that of H_2O_2

Paragraph for Q.9 to 10

According VSEPR theory, in the electronic geometry of the molecule(s), electron pair tend to minimise repulsion and follow the repulsion order in presence of lone pair of electrons with bond pair of electrons.

$\ell p - \ell p > \ell p - bp > bp - bp$

and similarly double bond pair of electrons follow the repulsion order with single bond pair of electrons.

double bond – double bond > double bond – single bond > single bond – single bond

9. Which of the following molecular geometry is distored geometry from their ideal geometry.

(A) PCl_3F_2 (B) SOF_4 (C) $XeF_5^{\ominus}$ (D) XeO_3F_2

10. Which of the following statement is **CORRECT** about XeO_2F_2?

(A) XeO_2F_2 is sp^3d hybridized and has lone pair of electron at axial position of its electronic geometry.

(B) XeO_2F_2 has maximum 10- lone pair of electrons.

(C) XeO_2F_2 has distorted see-saw shape.

(D) XeO_2F_2 contains $d\pi$–$d\pi$ bond.

FILL THE ANSWER HERE

1.	Ⓐ Ⓑ Ⓒ Ⓓ	2.	Ⓐ Ⓑ Ⓒ Ⓓ	3.	Ⓐ Ⓑ Ⓒ Ⓓ	4.	Ⓐ Ⓑ Ⓒ Ⓓ
5.	Ⓐ Ⓑ Ⓒ Ⓓ	6.	Ⓐ Ⓑ Ⓒ Ⓓ	7.	Ⓐ Ⓑ Ⓒ Ⓓ	8.	Ⓐ Ⓑ Ⓒ Ⓓ
9.	Ⓐ Ⓑ Ⓒ Ⓓ	10.	Ⓐ Ⓑ Ⓒ Ⓓ				

1. Which of the following statement is **CORRECT** for

$$F_3C - CF_2 - CF_3$$

(A) All C–F bond lengths are identical

(B) Two C–F bonds attached to middle C-atom are longer compared to other C–F bonds at the termin C–atoms

(C) Two C–F bonds attached to middle C-atom are shorter compared to other C–F bonds at the termin C-atoms

(D) None is correct

2. Choose the **CORRECT** statement regarding bond angle :-

(A) $\widehat{FCF}$ in F_2CO < $\widehat{HCH}$ in H_2CO

(B) $\widehat{BrPBr}$ in PBr_3 < $\widehat{FPF}$ in PF_3

(C) $\widehat{FSF}$(eq) > $\widehat{FSF}$(ax) in SF_4

(D) All $\widehat{FIF}$ angles in IF_5 are identical

3. If the %- s-character in one Sb-H bond in SbH_3 is 1.0%. What is % p-character is the orbital occupi by its lone pair -

(A) 99.0 (B) 97 (C) 90 (D) None

4. Choose **CORRECT** order of bond length

(A) S – S bond length : $S_2O_4^{2-} > S_2O_6^{2-}$

(B) O – O bond length : $H_2O_2 > O_2F_2$

(C) N – N bond length : $N_2O_3 > N_2O_4$

(D) All are correct

***Assertion* & Reason**

5. **Statement-1 :** ClF_2^- is linear while ClF_2^+ is bent.

Statement-2 : Cl - atom in ClF_2^- and in ClF_2^+, is having same state of hybridisation.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

One or more than one correct :

6. In which of the following, the theory of hybridisation does not help to predict the bond angle ?

(A) PH_3 (B) SbH_3 (C) SiH_4 (D) H_2S

7. Choose the **CORRECT** statements :-

(A) d_{P-F}(axial) > d_{P-F}(equatorial) in PF_3Cl_2

(B) $d_{P-F} > d_{P-Cl}$ in PF_2Cl_3

(C) $d_{P-Cl}(PF_2Cl_3) > d_{P-Cl}(PF_3Cl_2)$

(D) All d_{P-Cl} (in PF_2Cl_3) are identical while all d_{P-F}(in PF_3Cl_2) are not identical

8. **Column I**

(A) XeF_5^+

(B) ICl_4^-

(C) $TeCl_4$

(D) I_3^+

Column II

(P) Two lone pairs on central atom

(Q) Planar

(R) Non-planar

(S) sp^3d^2 (Hybridization of central atom)

Subjective :

9. Identify the pair in which the specified bond length of first is greater than second.

PCl_3F_2 , PF_3Cl_2 : BL_{P-Cleq}

SO_2Cl_2 , SO_2F_2 : $BL_{S=O}$

BF_3 , BCl_3 : BL_{B-X} X = F/Cl

NO_3^- , NO_2^- : BL_{N-O}

O_3 , O_2 : BL_{O-O}

CO , CO_2 : BL_{C-O}

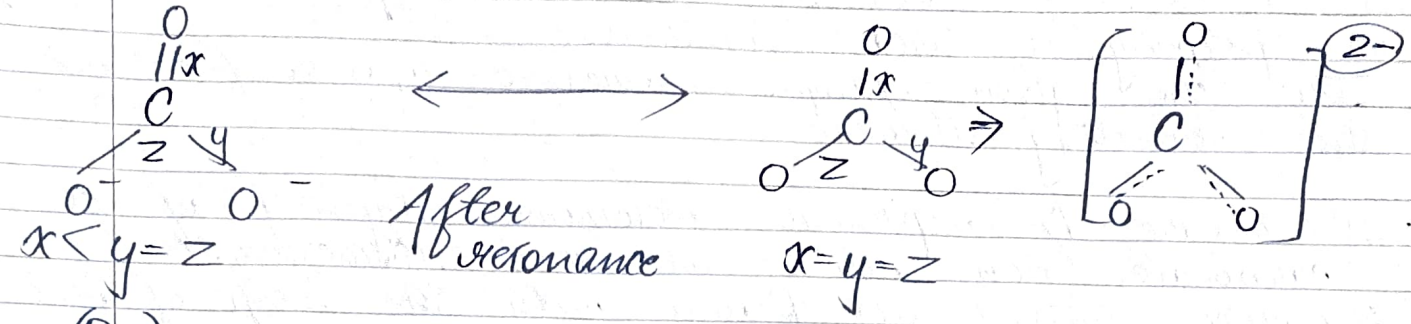
10. How many of the following species have no d-orbitals involved in their hybridisation

XeF_2, SnF_2 $PbCl_2$, SF_4, CCl_4, BF_3, SO_2Cl_2, XeO_2F_2, $XeOF_4$, $POCl_3$

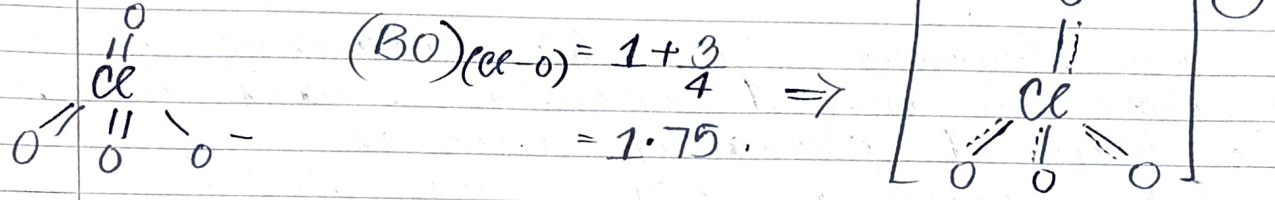
FILL THE ANSWER HERE

1. Ⓐ Ⓑ Ⓒ Ⓓ
2. Ⓐ Ⓑ Ⓒ Ⓓ
3. Ⓐ Ⓑ Ⓒ Ⓓ
4. Ⓐ Ⓑ Ⓒ Ⓓ
5. Ⓐ Ⓑ Ⓒ Ⓓ
6. Ⓐ Ⓑ Ⓒ Ⓓ
7. Ⓐ Ⓑ Ⓒ Ⓓ
8. A Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ
   B Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ
   C Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ
   D Ⓟ Ⓠ Ⓡ Ⓢ Ⓣ
9. ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
10. ⓪ ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

Resonance :-

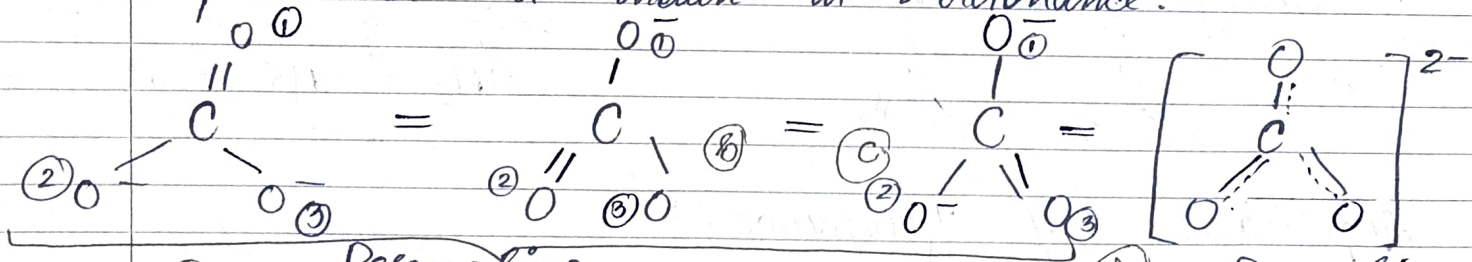


$(BO)_{(C-O)} = 1 + 1/3 = 1.33$



Delocalization of π-bond is known as resonance.
Dotted line represent delocalized π-bond.

When more than one structure is required to explain the bond parameters of the species, then this pheomena is known as resonance.



(a) Resonating structure

(b) ~~Resonating~~ Resonance hybrid

14/11/25

Resonating Structure –

It is not a real structure but explain some of the property of real molecule.

In the given example, structure a, b and c are the resonating structure

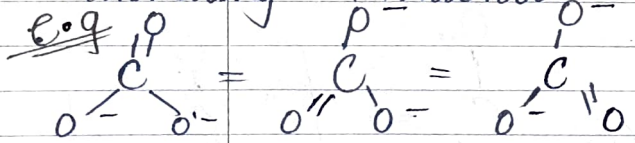
- Structure d represent resonance hybrid of the carbonate ion which is real structure. Resonance hybrid is drawn with the help of resonating structures.

- For any structure in which resonance is taking place, there is only 1 resonance hybrid but maybe more than 1 resonating structure. Resonance hybrid is real & more stable but resonating structure is hypothetical and least stable.

Resonance

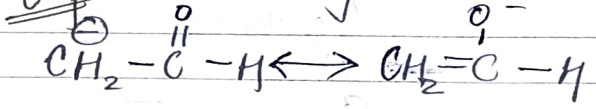
Equal contributing resonating structure

e.g.



Non-equal contributing resonating structure

e.g.



Application of Resonance :–

Equal contributing resonating structure —

When all the resonating structures are identical in all respect.

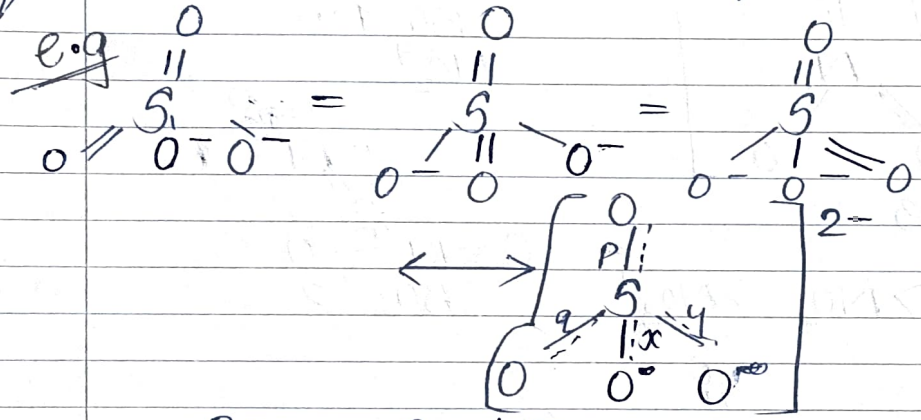
Non-equal contributing resonating structure -
When resonating structures are not identical, then this type of resonance is known as non-equal contributing resonating structure.

Characteristics of ECR5:-

(1) In this type of resonance, π-bond gets equally distributed throughout the molecule.

(2) Due to equal no. of bond between the atoms in a polyatomic molecule or ion, the structure becomes symmetric. Hence, bond angle & bond length become equal.

e.g

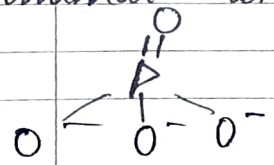


$\sigma(S-O) = 1$
$\pi(S-O) = 0.5$

$BO_{S-O} = \frac{6}{4} = 1.5$

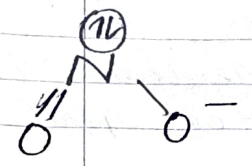
BA = 109° 28'
BL ⇒ p = q = x = y

Q Calculate bond order between CA (central atom) & terminal atom (TA)

(a) 

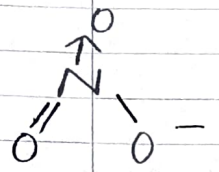
$1\sigma, 0.25\pi$

$BO_{(P-O)} = \frac{5}{4} = 1.25$

(b) 

$BO_{(N-O)} = \frac{3}{2} = 1.5$

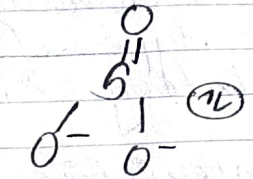
$1\sigma, 0.5\pi$

(c) 

$BO_{(N-O)} = \frac{4}{3}$

$= 1.33$

$1\sigma, 0.33\pi$

(d) 

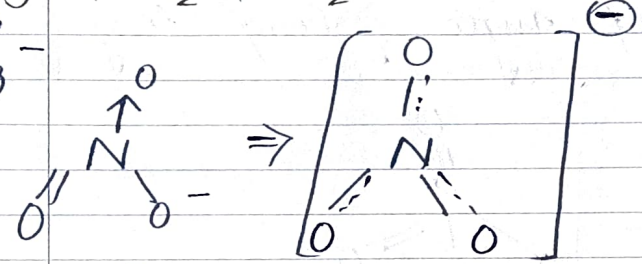
$BO_{(S-O)} = \frac{4}{3}$

$= 1.33.$

Q) Compare bond length between Nitrogen & oxygen in the given structures:-

(a) NO_3^-, NO_2^-, NO_2^+

NO_3^-

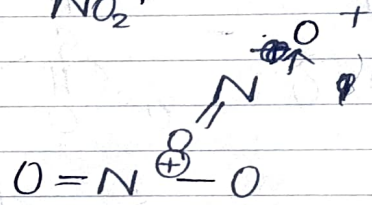


$BO = 1.33$

NO_2^-

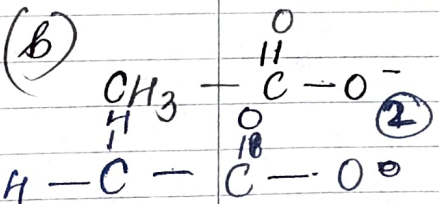
$BO = 1.5$

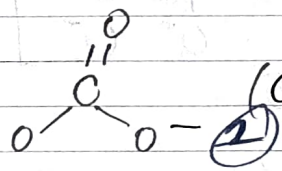
NO_2^+



$BO = 2$

$NO_3^- > NO_2^- > NO_2^+$

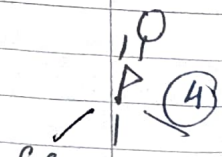
(b) 



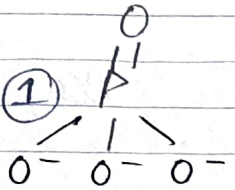
$1 + \frac{1}{3} = 1.33$

$BO = 1 + \frac{1}{2} = 1.5$

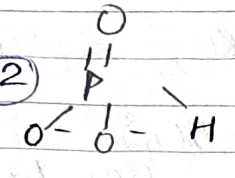
(c)



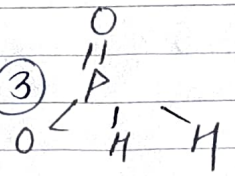
BO = 2



BO = 1 + 0.25
= 1.25



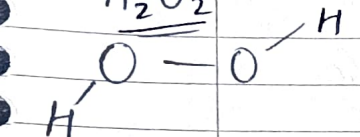
BO = 1.33



BO = 1.5

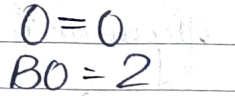
(d) H_2O_2 , O_2 , O_3 (O-O)

H_2O_2



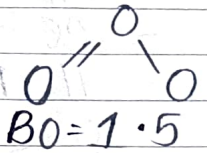
BO = 1

O_2



BO = 2

O_3



BO = 1.5

$H_2O_2 > O_3 > O_2$

(e) ClO_2^- , ClO_3^- , ClO_4^- (Cl-O)

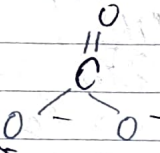
(f) CO , CO_2 , CO_3^{2-} (C-O)

(g) Compare the bond angle in the given molecules:

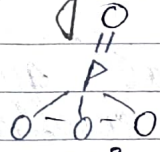
(1) $CO_3^{2-} > PO_4^{3-} = SO_4^{2-}$

BO = 1.33 1.25 1.5

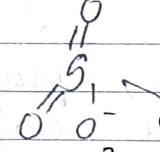
BA : $SO_4^{2-} > CO_3^{2-} > PO_4^{3-}$



sp^2

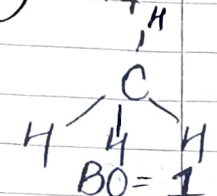


sp^3



sp^3

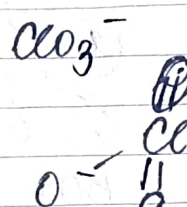
(II) CH_4, SO_4^{2-}, ClO_3^-, ClO_4^-



BO = 1
109°28'

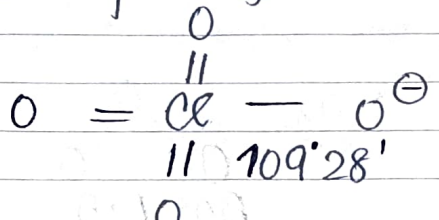
SO_4^{2-}
BO = 1.5
Symmetrical
Angle = 109°28'

ClO_3^-



~~BO = 1 + 2/3 = 1.66~~
Repulsion due to lp.

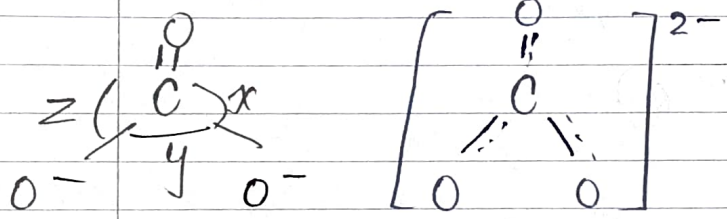
ClO_4^-



~~BO = 1 + 3/4 = 1.75~~
109°28' Symmetrical due to resonance

~~BA: $ClO_4^- > ClO_3^- > SO_4^{2-} > CH_4$~~ BA: $CH_4 = SO_4^{2-} = ClO_4^- > ClO_3^-$

(III)



x = y = z

~~Resonance~~ makes structure symmetrical. So, bond angle is equal in PO_4^{3-} and SO_4^{2-}

Dipole Moment :-

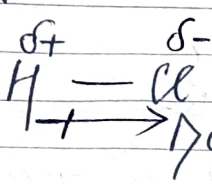
It is a physical quantity which explain the polarity of any covalent bond.

OR

The physical quantity which explain ionic nature in any covalent bond.

__/__/____

▷ipole moment is a vector quantity in which it is directed from less electronegative atom to more electronegative atom (~~opposite~~ opposite of Physics).



- ▷ipole vector is represented as given which explain the flow of electron from less to more electro-ve atom and cut sign represent it is opposite of Physics.
- ▷ipole moment vector is written by the given —

$$\boxed{\vec{\mu} = |q| \times \vec{d}}$$

μ = dipole moment vector
q = Charge
d = distance b/w covalently bonded atom

- SI Unit of dipole moment is Coulomb – meter (C-m), and by one more unit, it is represent, i.e., ▷ebye. (D).

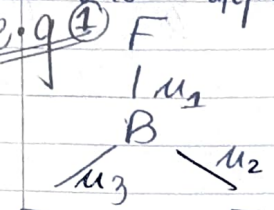
$$\boxed{\begin{aligned} 1\text{ ▷ebye} &= 3.33 \times 10^{-30}\ \text{C-m} \\ 1\text{ ▷ebye} &= 10^{-18}\ \text{esu cm} \end{aligned}}$$

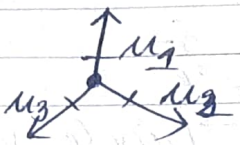
17/11/25

- If $\vec{\mu}_{net} = \vec{0}$, then it is non-polar molecule and if $\vec{\mu}_{net} \neq 0$, then this is a polar molecule.

- When more than one polar bond is present in molecule, then net dipole moment is vector sum of all the dipole moment vector.

e.g ①

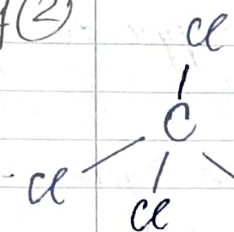


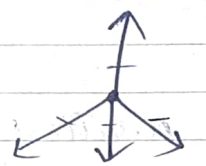


$\mu_{net} = \vec{\mu_1} + \vec{\mu_2} + \vec{\mu_3}$

$= 0$ [Origin from same point with same angle]

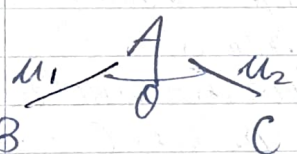
e.g ②





$\mu_{net} = 0$

- When a molecule contain two different dipole moment vector, then μ_{net} can be written as –



$$\mu_{net} = \sqrt{\mu_1^2 + \mu_2^2 + 2\mu_1\mu_2\cos\theta}$$

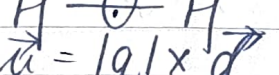
- If a molecule having polar bond, then the molecule maybe polar or may not be polar.

e.g



$\vec{\mu} = |q| \times d$

HF is polar



$\vec{\mu} = |q| \times d$

$\vec{\mu} = 0$

H_2 is non-polar

__/__/____

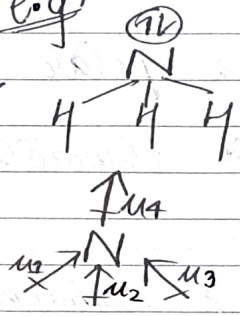
- For ionic compound, dipole moment is not defined because 'd' is undefined.
- Net dipole moment consist of bond pair moment and lone pair moment.

μ_{Net}

Bond pair Moment

- It is caused by covalently-bonded atoms. In the given example, μ_1, μ_2 and μ_3 are bond pair moment.
- It is always directed from +ve pole to -ve pole.

e.g



Lone pair moment

- Dipole moment caused by lone pair is known as lp moment. Here, μ_4 is lone pair moment.
- It is always directed towards outer direction from CA.
- We don't consider lp moment when it is present in pure atomic orbitals.
- For lp, $sp > sp^2 > sp^3$ ($\vec{\mu}$)

e.g HF, HCl, HBr, HI

$H^{\delta+}-d_1-F^{\delta-}$

$H^{\delta_2+}-d_2-Cl^{\delta_2-}$

$H^{\delta_3+}-d_3-Br^{\delta_3-}$

$H^{\delta_4+}-d_4-I^{\delta_4-}$

$\mu_1 = |\delta_1| d_1$

$\mu_2 = |\delta_2| d_2$

$\mu_3 = |\delta_3| d_3$

$\mu_4 = |\delta_4| d_4$

$\delta_1 > \delta_2 > \delta_3 > \delta_4$

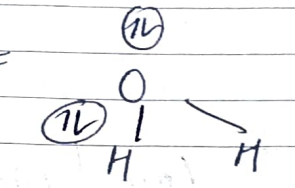
$d_1 < d_2 < d_3 < d_4$

Charge dominates while $\mu_1 > \mu_2 > \mu_3 > \mu_4$ comparing

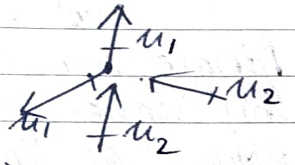
Application of Dipole Moment :-

(1) It is used to compare the polarity of the molecule.

e.g. H_2O $\quad$ CS_2



$S = C = S$





Non-polar

$\vec{\mu net} = \vec{\mu_1} + \vec{\mu_1} + \vec{\mu_2} + \vec{\mu_2}$

$\vec{\mu net} \neq 0$

H_2O is more polar than CS_2.

(2) To calculate % ionic character in a given covalent molecule.

$$\% \text{ ionic character} = \frac{\mu \text{observed}}{\mu \text{theoretical}} \times 100$$

Q) Given, $d = 1.275\,\text{Å}$, $(\mu obs)_{HCl} = 1.03\,D$

% ionic character = ? H & Cl

$\mu_{Theo} = q \times d$

$= (1.67 \times 10^{-19} \times 1.275 \times 10^{-10})$ CM

$1\,D = 3.33 \times 10^{-30}$ C-m

% ionic character $= \frac{1.03 \times 3.3 \times 10^{-30} \text{ C-m}}{1.67 \times 10^{-19} \times 1.275 \times 10^{-10} \text{ C-m}} \times 100$

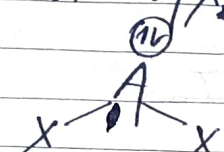
$\approx 0.16\,\%$

(3) To predict the shape of the molecule.

- If molecule is AX_2 type and $\mu_{net} = 0$

$X - A - X$ (Linear)

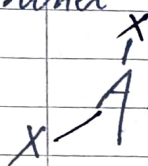
- If molecule is AX_2 and $\mu_{net} \neq 0$



(Bent)

- If molecule is AX_3 and

$\mu_{net} = 0$



(Trigonal Planner)

$\mu_{net} \neq 0$



(Triagonal Pyramidal)

Q) Comment/Analyse the given molecule is polar or non-polar :-

(a) XeO_3F_2 (b) PCl_3F_2 (c) XeO_2F_2 (d) PCl_5 (e) SF_4 (f) SF_6
(g) CCl_3^- (h) BH_3 (i) SO_2 (j) H_2S (k) SF_2 (l) ClF_3 (m) BF_3 (n) AF_3
(o) H_2O_2 (p) CO (q) O_3 (r) $SnCl_2$

(a) ~~Polar~~ Non-polar (b) Polar (c) Polar (d) Non-polar (e) Polar
(f) Non-polar (g) Polar (h) Non-polar (i) Polar (j) Polar
(k) Polar (l) Polar (m) Non-polar (n) Polar
(o) Polar (p) Polar (q) ~~Non-polar~~ Polar (r) Polar

* In H_2S, both the lp is present in pure atomic orbital. So, lp moment is not present.

Some Important Points :-

(1) CH_3-F, CH_3Cl, CH_3Br, CH_3I

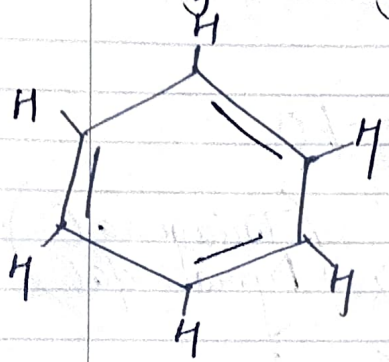
Exception

$C-F > C-Cl$ ✗

$C-F < C-Cl$ ✓

$CH_3Cl > CH_3F > CH_3Br > CH_3I$

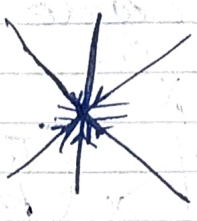
(2)



Benzene

$\mu_{net} = 0$

Non-polar solvent

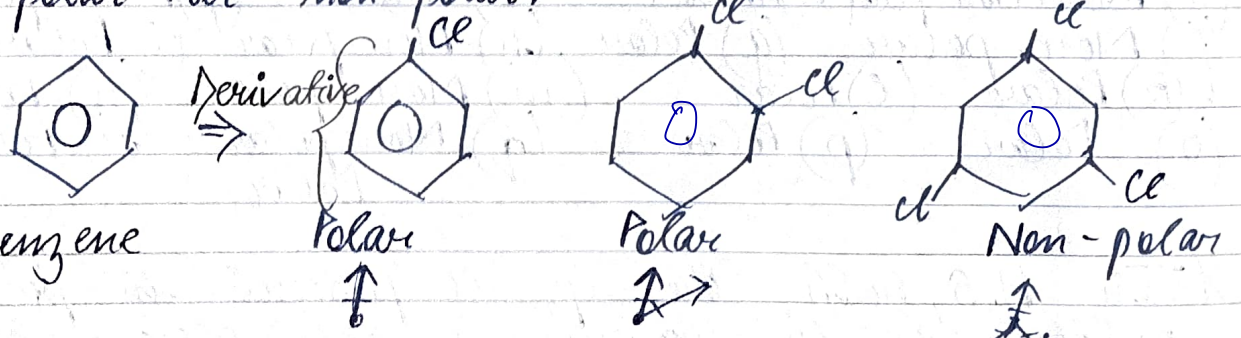


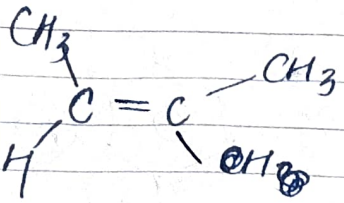
(3) $\overset{\ominus}{C} \equiv O^{\oplus}$ $\mu_{CO} = 0.017$

18/11/25

(4) Benzene is non-polar compound but its derivative maybe polar or non-polar.

e.g

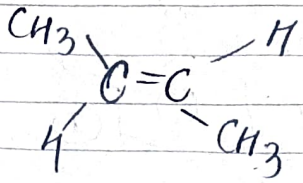




cis But-2-ene

Polar

$\mu net \neq 0$



Trans But-2-ene

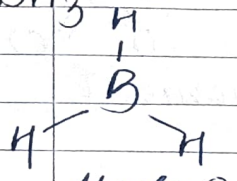
Non-polar

$\mu net = 0$

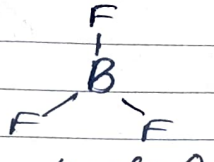
Q) Compare dipole moment for given molecules:

(i) NH_3 NF_3

(ii) BH_3 BF_3

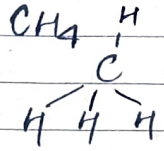


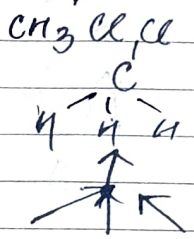
$\mu net = 0$



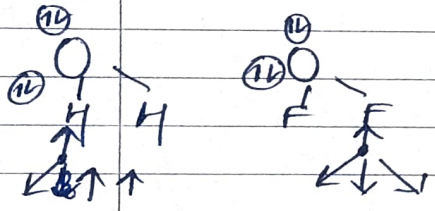
$\mu net = 0$

(iii) CH_4 CH_3Cl CH_2Cl_2 $CHCl_3$ CCl_4

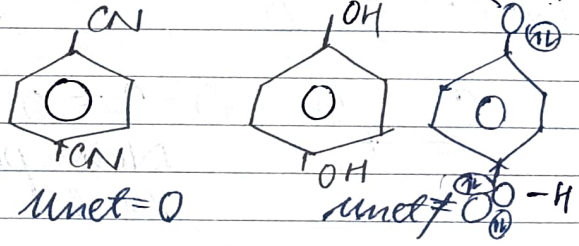




(iv) $H_2O > OF_2$



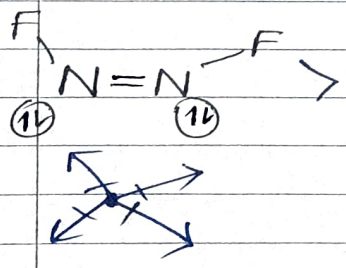
(v)



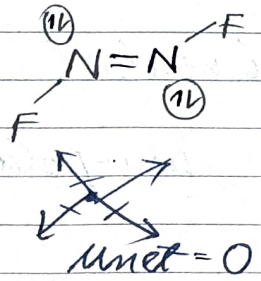
$\mu net = 0$

$\mu net \neq 0$

(vi)

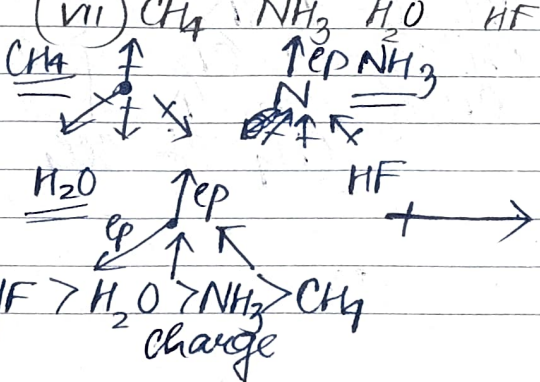


>



$\mu net = 0$

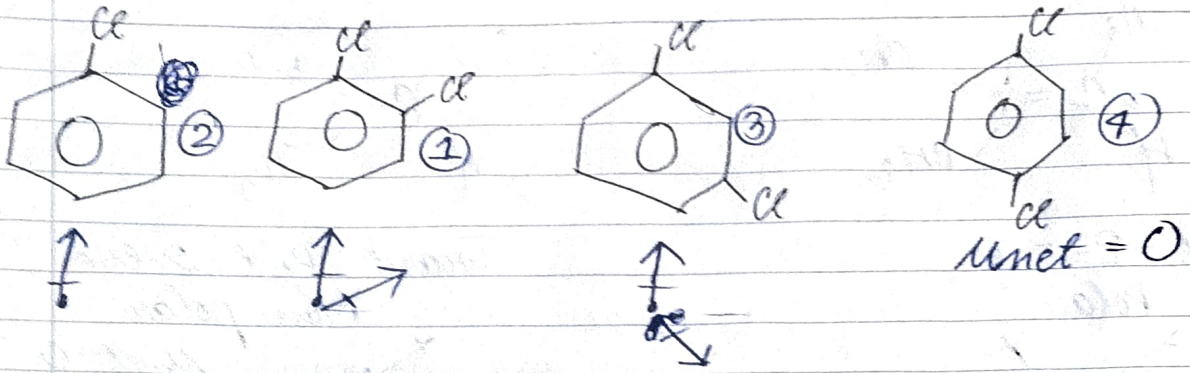
(vii) CH_4 NH_3 H_2O HF



$HF > H_2O > NH_3 > CH_4$

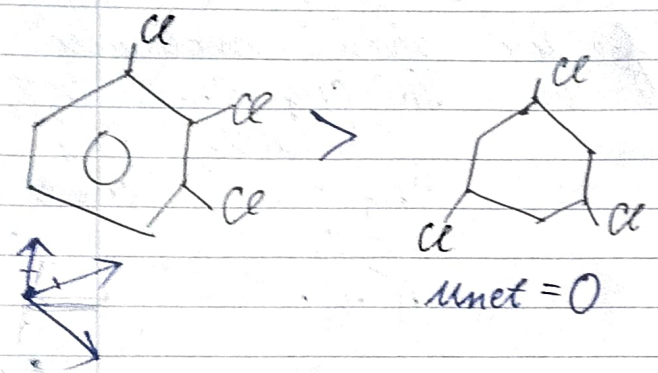
Charge

(viii)

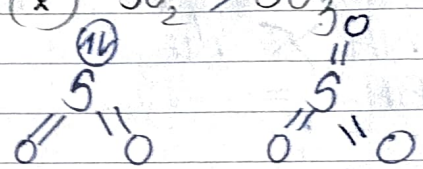


(II) > (I) > (III) > (IV)

(ix)



(x) $SO_2 > SO_3$



lp ment

(xi) $CO > CO_2$

$\overset{+}{C} \leftarrow \overset{-}{O}$ $\quad O=C=O$

Non-polar

μnet = 0

☆ $CH_3Cl - 1.81$ D
$CH_2Cl_2 - 1.61$ D
$CHCl_3 - 1.0$ D
} Experimental

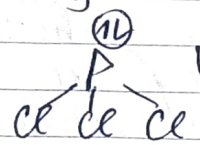
CH_4 & CCl_4 are non-polar.

__/__/____

(Q2) For what value of x and y PCl_xF_y will be non-polar?

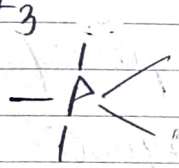
(A) 3,0 (B) 2,3 (C) 0,3 (D) 3,2

(A) PCl_3

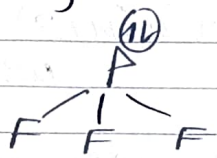


↳ ep moment

(B) 2,3 PCl_2F_3

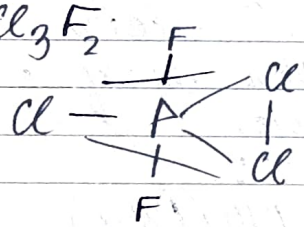


(C) PF_3



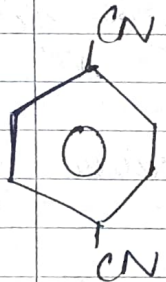
ep moment

(D) PCl_3F_2

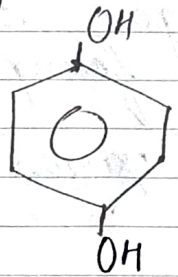


$\mu_{net} = 0$

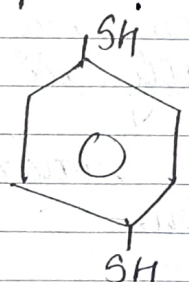
(Q3) How many of them are polar?



$\mu_{net} = 0$



$\mu \neq 0$



$\mu \neq 0$



$\mu = 0$

91. Arrange the following compounds in increasing order of their dipole moment:

HBr, H_2S, NF_3 and $CHCl_3$ [JEE (Main)-2025]

(1) $NF_3 < HBr < H_2S < CHCl_3$

(2) $H_2S < HBr < NF_3 < CHCl_3$

(3) $HBr < H_2S < NF_3 < CHCl_3$

(4) $CHCl_3 < NF_3 < HBr < H_2S$

and Bond Parameters]

131. A diatomic molecule has a dipole moment of 1.2 D. If the bond distance is 1 Å, then fractional charge on each atom is _____ $\times 10^{-1}$ esu.

(Given 1 D = 10^{-18} esu cm) [JEE (Main)-2024]

132. Number of compounds from the following with zero dipole moment is _____.

HF, H_2, H_2S, CO_2, NH_3, BF_3, CH_4, $CHCl_3$, SiF_4, H_2O, BeF_2 [JEE (Main)-2024]

16. Which pair is correct regarding bond angle?

(1) $H_2O > OF_2$

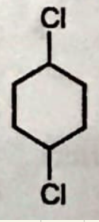
(2) $PCl_3 < PBr_3$

(3) $NO_2^{\oplus} > H_2O$

(4) All of these

17. Which of the following compounds have zero dipole moment?

(1) CH_3Cl (2) CH_2Cl_2

(3) BF_3 (4) 

9. The compound that has the largest H – M – H bond angle (M = N, O, S, C) is

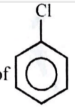
(1) H_2S (2) CH_4

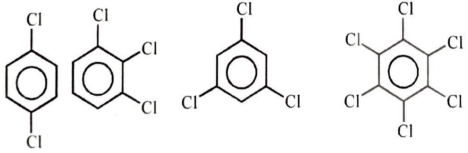
(3) NH_3 (4) H_2O

The molecules / ions which are planar as well as polar.

(A) BF_3 , H_2O, H F , NH_2^- (B) $SnCl_2$, I_3^+ , NH_2^- , IF_3

(C) CO_3^{2-} , I_3^-, SF_2, XeF_2 (D) NO_2^-, XeF_4, ICl_4^-, NH_2^+

Find the number of molecule having dipole moment less than the dipole moment of 



CBO009

12.

Column I	Column II
(A) BrF_3	(P) Atleast one angle $\leq 90°$
(B) TeF_5^-	(Q) Central atom is sp^3d^2 hybridised
(C) IF_7	(R) Non planar
(D) XeF_4	(S) Polar

13.

Column I	Column II
(A) $I(CN)_2^-$	(P) Having $p\pi$–$p\pi$ bond & $\mu_D = 0$
(B) CO_3^{2-}	(Q) Having $p\pi$–$d\pi$ bond & $\mu_D \neq 0$
(C) XeO_2F_2	(R) Planar
(D) SOF_4	(S) Central atom is sp^3d

Which of the following molecules have permanent dipole moment ?

(A) H_2O (B) BrF_5 (C) XeO_2F_2 (D) All of these

Find out the **incorrect** order of the dipole moment among the following pair of compound

(A) $NH_3 > NF_3$ (B) p-dichloro benzene > o-dichloro benzene

(C) $CH_3Cl > CH_2Cl_2$ (D) $SiF_4 < SF_4$

Statement-1 : Dipole moment of H_2O is more than that of OF_2.

Statement-2 : In H_2O, the resultant bond dipole of O – H bond and the resultant lone pair moment a in opposite direction.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-

(C) Statement-1 is true, statement-2 is false.

(D) Statement-1 is false, statement-2 is true.

In which of the following both are nonpolar –

(A) XeF_4, O_3, (B) XeF_5^-, I_2Cl_6 (C) SF_4, XeF_2 (D) BrF_3, SCl_2