

Chemical bonding

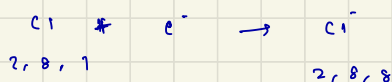
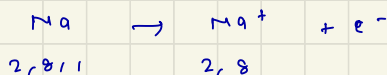
why bond formation take place

i) To achieve inert gas configuration

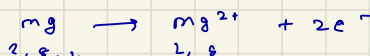
① By sharing of e^- (covalent bond formation take place)

② By losing and gaining of e^- (ionic bond formation take place)

NaCl



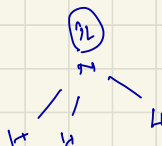
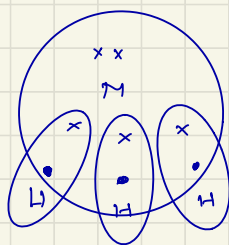
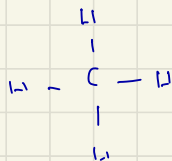
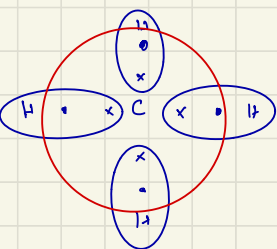
MgCl₂



MgCl₂

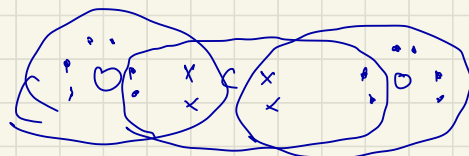
By sharing e^-

CH₄ $e^-: 2, 4$



NH₃ $(\text{N}: 1s^2 \underline{2s^2 2p^3})$

CO₂ (



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Types of Interaction:-

Chemical bond

Type -

Ionic bond

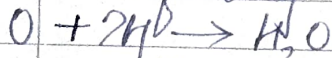
Covalent bond

Co-ordinate bond

Metallic bond

- The energy released maybe 200 - 400 kJ/mol.

- With the help of chemical bond, two isolated gaseous atoms combine either by sharing their electrons or by transferring electron.



- Does not explain the physical state of the system.

- This is actual chemical bond and cannot be broken by normal heating.

- It is known as inter-atomic phenomena.

Chemical force

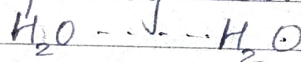
Type -

Non-Vanderwaal force

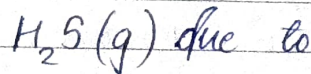
Vanderwaal force

- Energy released maybe 2 kJ - 40 kJ/mol

- With the help of chemical force, two individual gaseous molecules are held together.



- It explains the physical state of any system.
 $H_2O(lig)$ due to hydrogen bonding



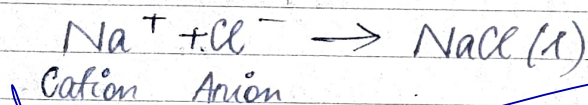
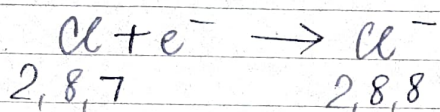
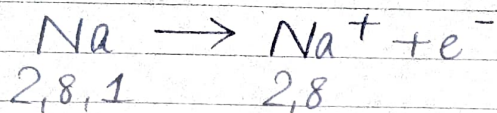
- This type of chemical force can be removed at ordinary heating.

- Existence of chemical force is inter-molecular phenomena.

Chemical Bond :-

(1) Ionic bond :

When bond formation take place by loss and gain of electron, then this is known as ionic bond.

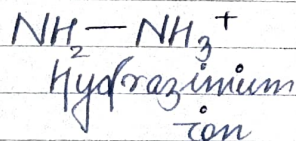
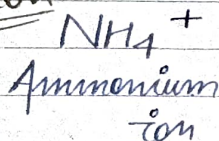


are held together
Coulombic force

Characteristics of ionic bond -

- (1) The bond formation take place between metal and non-metal, in general.

Exception



Cations, in general, are made by metals.

- (2) While bond formation, cations and anions form and both are held together with the help of Coulombic force.

- (3) In general, elements having less EN have tendency to form cation & atom having more EN have tendency

do form anion.

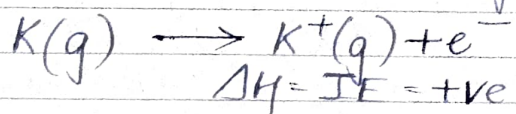
Factors Affecting Ionic bond-

- (1) Low IE of metal
- (2) High Electron affinity of nonmetal
~~not high~~

(3) Lattice energy (LE):

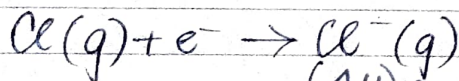
~~Then~~ Higher the value of lattice energy, greater is the strength of ionic bond.

~~e.g~~

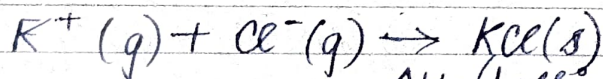


$$\Delta H = IE = +ve$$

} Does not favour process



$$(\Delta H)_{eg Cl(g)} = -ve$$



$$\Delta H = (\text{Lattice energy})_{KCl}$$

} Among all these 3 factors, lattice energy is ~~favoured~~ ~~process~~ deciding factor.

Factors Affecting Lattice energy-

(1) Charge on ions:

Higher the charge on ions, greater will be the lattice energy. $LE \propto Z^+, Z^-$ (More dominating)

(2) Lesser the size of ions, greater will be lattice energy.

Q1 Compare the lattice energy for the following salt:-

(i) NaF KF CsF
~~KF~~ NaF > KF > CsF

(ii) NaF > NaCl > NaBr > NaI

Q2

(3) Higher the negative value of formation energy, greater will be the stability of ionic compound.

Formation energy/Heat of formation:

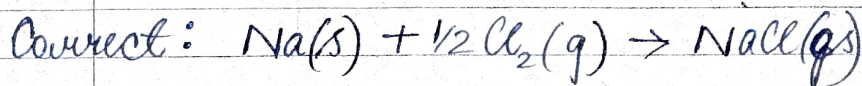
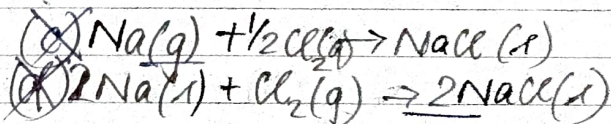
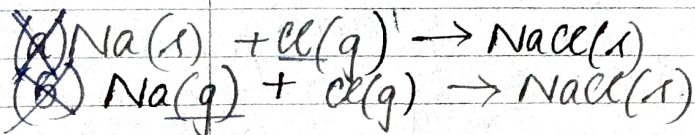
When 1 g of ionic crystal is formed from their constituent elements present in their standard form, some amount of energy is released. The released energy is known as heat of formation.

e.g.

ΔH_f°
AX - -100 kJ
BX - -150 kJ

ΔH_f°
CX - -200 kJ
DX - -250 kJ
(Highest stable)

Q3 Correct rxn for heat of formation:-



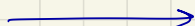
Born Haber Cycle -

This method is used for the calculation of heat of formation for any ionic crystal. or lattice energy

The rule is based on Hess's law of constant heat summation

method 1

A



B

$\Delta H_1 = x$

method 2

A



P

$\Delta H_2 = y$

-P

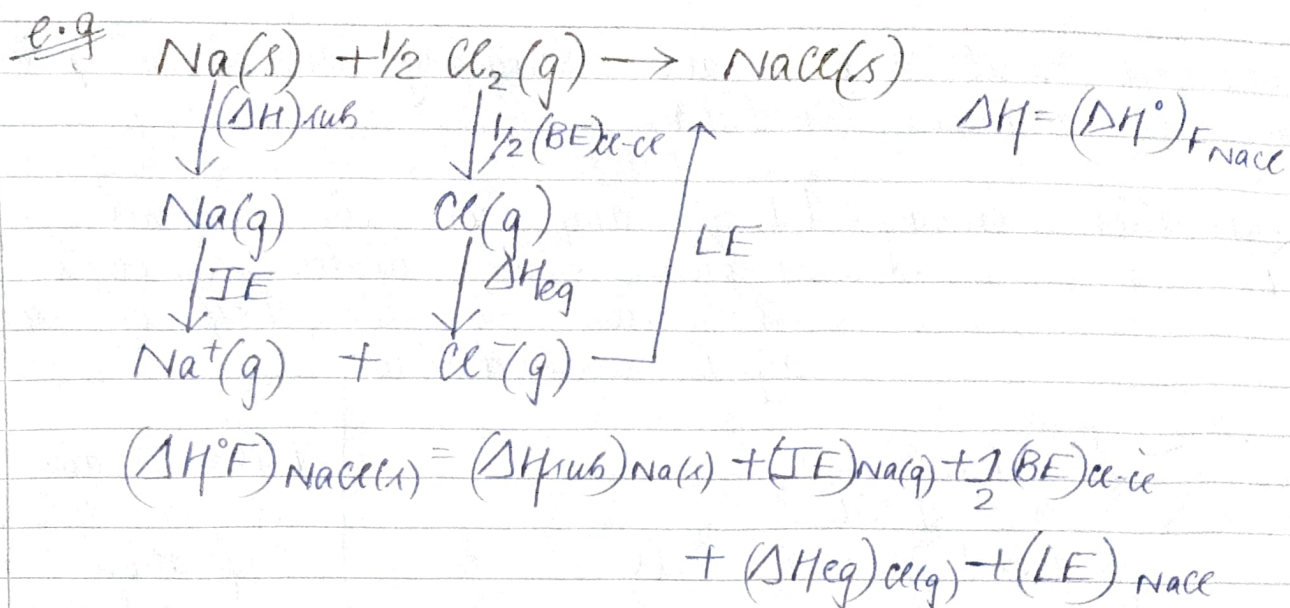


B

$\Delta H_3 = z$

$$\Delta H_1 = \Delta H_2 + \Delta H_3 \quad (\text{Hess's law of heat summation})$$

$$x = y + z$$



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Properties of Ionic Bond-

- (1) Ionic bond is non-directional in nature.
- (2) Ionic bond is relatively stronger bond than other chemical bond.
- (3) Ionic bond is formed with the help of Coulombic force and cations, anion interaction exist.
- (4) The bond formation take place between metal and non-metal, in general.
exception NH_4Cl non-metal exception $\text{AlCl}_3 \rightarrow \text{covalent (gas)}$
 $\text{AlCl}_3 \rightarrow \text{ionic (aqueous)}$

Properties of Ionic Compound-

(1) solubility:

In general, ionic compound are soluble in aqueous

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[JEE-MAIN 2013 (On-Line)]

6. Given

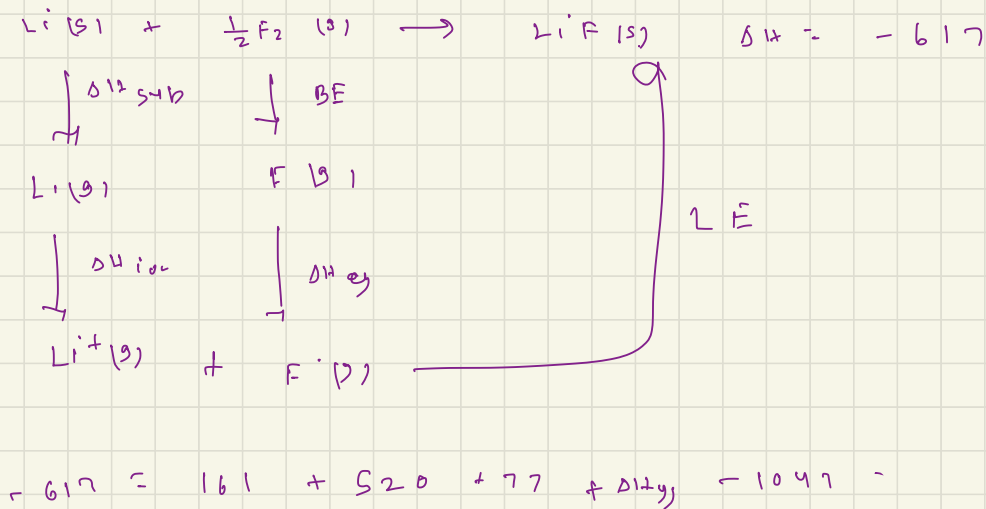
Reaction	Energy Change (in kJ)
$\text{Li(s)} \longrightarrow \text{Li(g)}$	161
$\text{Li(g)} \longrightarrow \text{Li}^+(\text{g})$	520
$\frac{1}{2} \text{F}_2(\text{g}) \longrightarrow \text{F(g)}$	77
$\text{F(g)} + \text{e}^- \longrightarrow \text{F}^-(\text{g})$	(Electron gain enthalpy)
$\text{Li}^+(\text{g}) + \text{F}^-(\text{g}) \longrightarrow \text{LiF(s)}$	-1047
$\text{Li(s)} + \frac{1}{2} \text{F}_2(\text{g}) \longrightarrow \text{LiF(s)}$	-617

Based on data provided, the value of electron gain enthalpy of fluorine would be :

(1) -300 kJ mol^{-1} (2) -328 kJ mol^{-1} (3) -350 kJ mol^{-1} (4) -228 kJ mol^{-1}

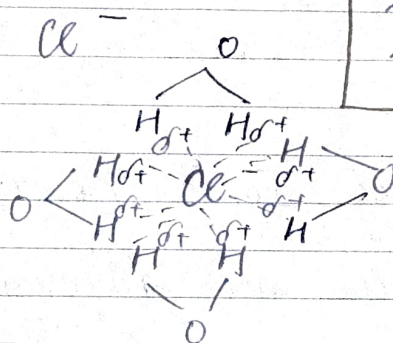
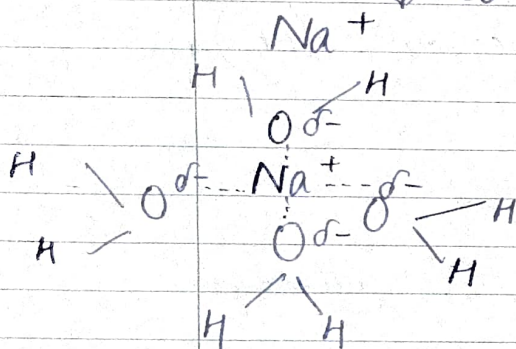
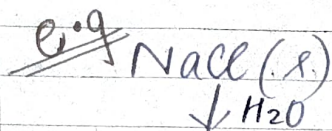
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medium but some have tendency to form precipitate in the aqueous medium.

Hydration energy: When any ion is present in aqueous medium, the water molecule surround the ion by the help of ion dipole interaction.

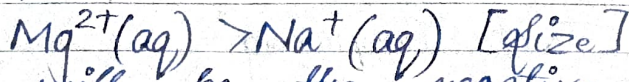
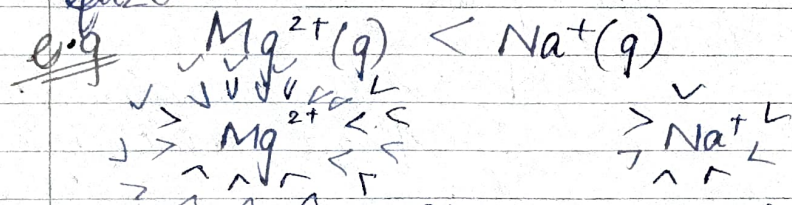


When water is acting as a solvent, then hydration is called solvation.

Dielectric constant is highest for H_2O (81)

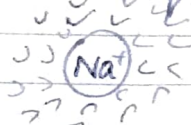
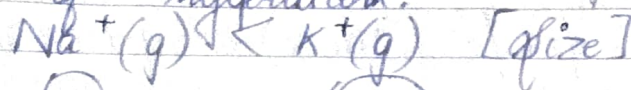
Factors affecting hydration energy -

(1) Higher the charge, greater will be the hydration energy. Higher the hydration, ~~less~~ larger will be the ionic size in aqueous medium. Higher the extent of solvation:

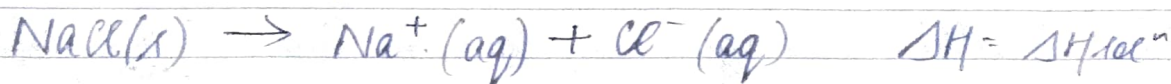


hydration, greater will be the negative value of hydration energy (released energy $\uparrow$).

(2) Smaller the size of ion, greater will be the extent of hydration.

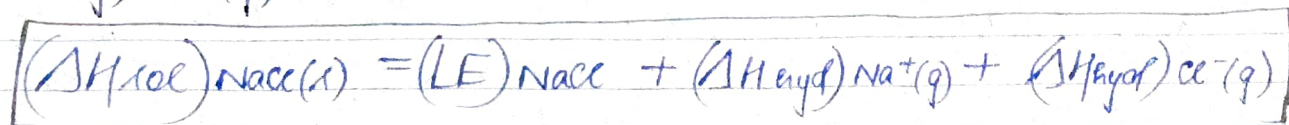
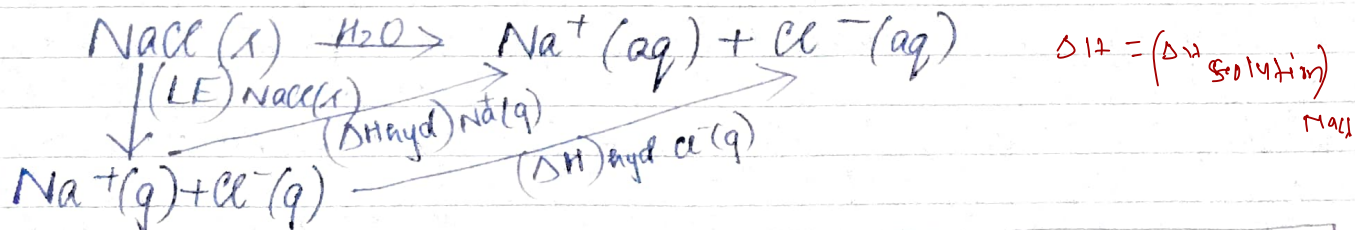
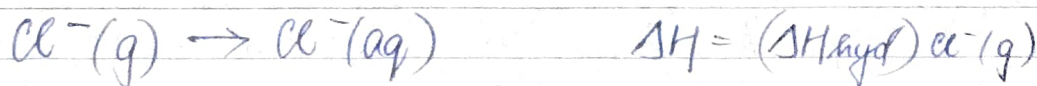
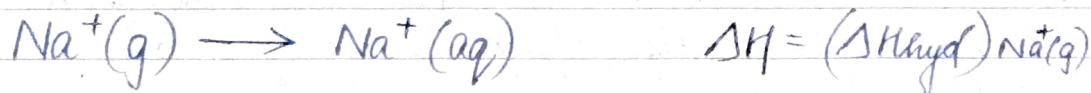


(#) KCl will conduct electricity better because ~~Na~~ K^+ is light and is easy to move.



Co-relation between Hydration energy & Lattice energy -

Heat of solution is defined as energy released when 1 mol of gaseous ion is dissolved in water to form aqueous medium ionic crystal is dissolved in water for the formation of aqueous solⁿ.



$$i) F^-(a_1) > Cl^-(a_1) > Br^-(a_1) > I^-(a_1)$$

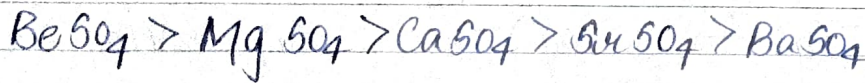
$$ii) Li^+(a_1) > Na^+(a_1)$$

- If (ΔH_{sol}) is (-ve), then the salt will be soluble;
 (ΔH_{sol}) will be -ve
 when $|LE| < |(\Delta H_{hyd}) Na^+(g)| + |(\Delta H_{hyd}) Cl^-(g)|$
- If (ΔH_{sol}) is (+ve), then it will have tendency to form precipitate.

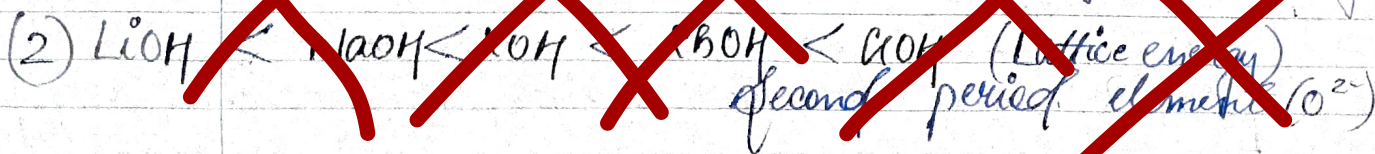
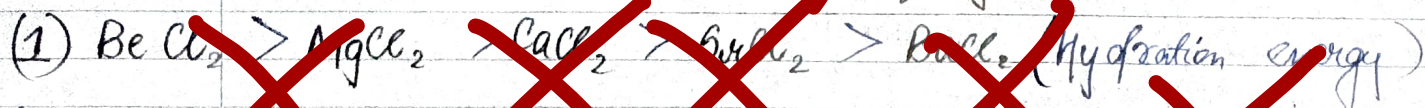
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- Higher the extent of hydration, greater will be the ionic size in aqueous medium and lesser will be its mobility.
- When lattice energy is dominating factor, then salt have less tendency to get dissolved in aqueous medium.
 $C^{4-}, N^{3-}, O^{2-}, F^-$ (lattice energy dominates)
- e.g. $NaF > MgF_2 > AlF_3$
 due to F^- ion, lattice energy dominates
- In case of larger anions, hydration energy is dominating factor. Higher the negative value of hydration energy, greater is the solubility.

e.g.



Q) Compare the solubility order of given compound:-



• Melting point depends on -

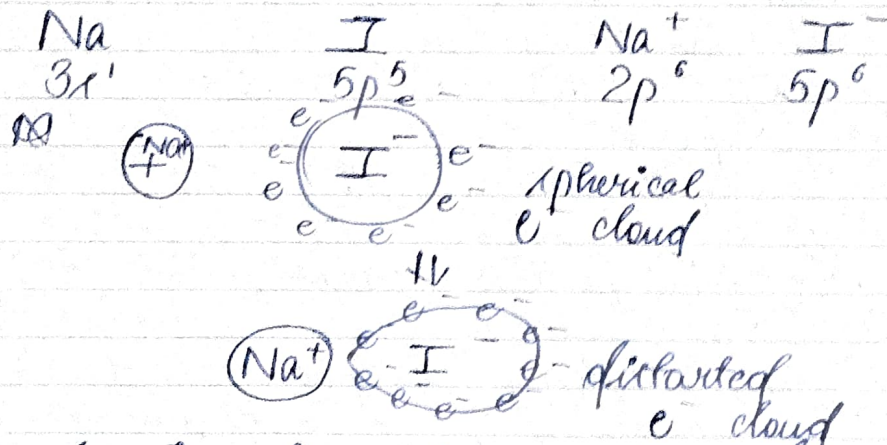
- (i) Polarisation
- (ii) Lattice energy

Polarization

Fajan's rule:

Fajan's rule explains the covalent character in any ionic bond.

	NaI	NaCl
water	sparingly soluble	completely soluble
acetone	completely soluble	sparingly soluble



• Ionic bond formation takes place due to the loss of e⁻ by the electropositive element and gain of e⁻ by the electronegative element.

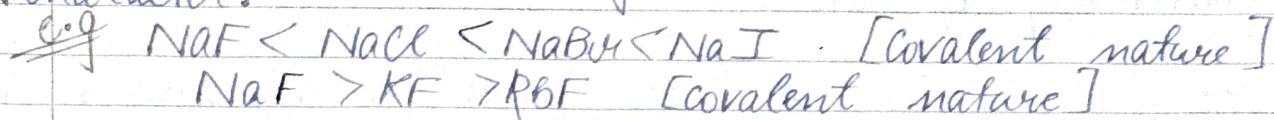
• Due to higher effective nuclear charge of cation, it has tendency to attract the e⁻ cloud of anion, and make the spherical e⁻ cloud distorted.

• Due to the distortion, ionic bond develop some electron sharing tendency. Hence, covalent character is developed.

• Distortion of e^- cloud of cation by the anion is negligible. So, we do not consider that.

⑧ Distortion of electron cloud of anion due to cation to develop covalent character in ionic bond is known as polarization.

→ Higher the polarisation, greater will be the covalent character.



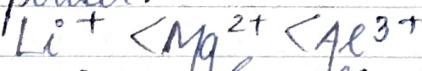
The phenomena of polarisation depends on 2 factors -

- Polarizing power of cation (AP)
- Polarisability of anion

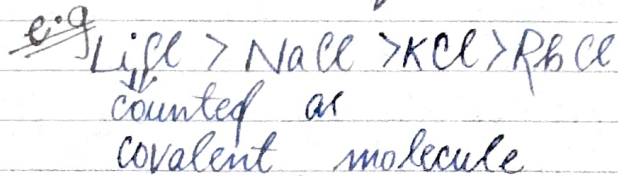
(a) Polarising power of cation:

• It is defined for cation.

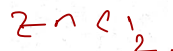
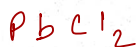
• Higher the charge on cation, greater will be the polarising power.



• Smaller the size of cation, greater will be polarizing power.

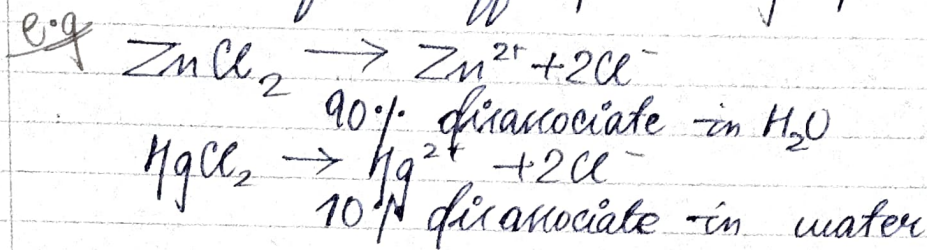


• Electronic configuration



$8e^-$ species < $(18+2)e^-$ species < $18e^-$ species
s-block cation p-block cation d-block cation

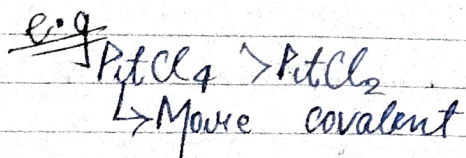
- When we go from top to bottom in d-block, due to increase of z -eff, polarising power increases.



(b) Polarizability of anion:

Ability of anions to get polarized in presence of cation is known as polarizability.

- Higher the charge on anion, greater is the polarizability. e.g. $S^{2-} > Cl^-$
- Larger the size of anion, greater is the polarizability. e.g. $Cl^- < Br^- < I^-$
- N^{3-} , O^{2-} and F^- do not have tendency to get polarised but very small cations (Li^+ , Be^{2+}) can polarise these anion.



64. An element 'E' has the ionisation enthalpy value of 374 kJ mol^{-1} . 'E' reacts with elements A, B, C and D with electron gain enthalpy values of -328 , -349 , -325 and -295 kJ mol^{-1} , respectively. The correct order of the products EA, EB, EC and ED in terms of ionic character is

[JEE (Main)-2025]

- (1) $ED > EC > EA > EB$
- (2) $EA > EB > EC > ED$
- (3) $EB > EA > EC > ED$
- (4) $ED > EC > EB > EA$

53. Order of covalent bond :

- A. $KF > KI$; $LiF > KF$
- B. $KF < KI$; $LiF > KF$
- C. $SnCl_4 > SnCl_2$; $CuCl > NaCl$
- D. $LiF > KF$; $CuCl < NaCl$
- E. $KF < KI$; $CuCl > NaCl$

Choose the correct answer from the options given below:

[JEE (Main)-2023]

- (1) B, C only
- (2) C, E only
- (3) B, C, E only
- (4) A, B only

87. Arrange the following in the decreasing order of their covalent character :

[JEE (Main)-2022]

- (A) $LiCl$
- (B) $NaCl$
- (C) KCl
- (D) $CsCl$

Choose the **most appropriate** answer from the options given below :

- (1) $(A) > (C) > (B) > (D)$
- (2) $(B) > (A) > (C) > (D)$
- (3) $(A) > (B) > (C) > (D)$
- (4) $(A) > (B) > (D) > (C)$

88. Arrange the following in increasing order of their covalent character.

- A. CaF_2
- B. $CaCl_2$
- C. $CaBr_2$
- D. CaI_2

Choose the correct answer from the option given below.

[JEE (Main)-2022]

- (1) $B < A < C < D$
- (2) $A < B < C < D$
- (3) $A < B < D < C$
- (4) $A < C < B < D$

(3) Physical State:-

- In general, ionic compounds are found in solidous form due to high lattice energy.
- Some of the covalent molecules are also exist in solid form due to very high Vanderwaal force.
e.g: $I_2(s)$; graphite; diamond

(4) Electrical Conductivity:-

- In solid state, ionic compound does not conduct electricity but in aqueous form, it conduct.
- Conductivity of ionic compound depends on mobility of ion.

(5) Isomerism:-

- Since ionic compound contain ionic bond which is non-directional in nature.
Non-directional bond does not show isomerism property.

(6) Isomorphism:-

- When two ionic crystal exist in same crystalline structure, then they are known as isomorphous of each other.

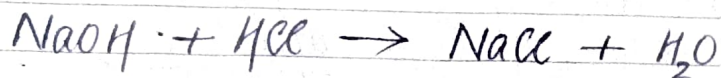
Condition to show isomorphism-

- (a) Both ionic crystal should have same number of ions.

(6) Both cations should be isoelectronic or having comparable size. Both anions should be isoelectronic or have comparable size.
 e.g. (NaF, MgO); (NaNO₃, MgCO₃); (Na₂SO₃, Na₂CO₃)

(7) Types of Reaction:-

Ionic compound generally have ionic reaction which is very fast in nature.



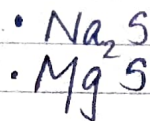
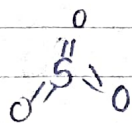
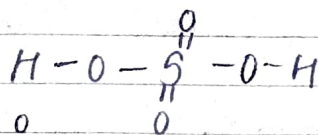
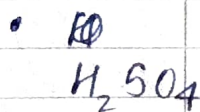
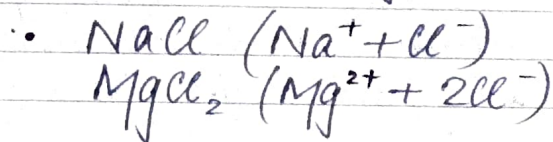
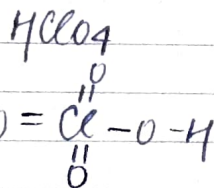
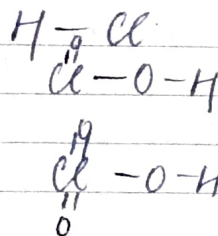
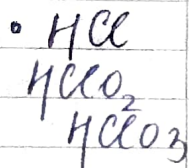
Valency:-

Combining capacity of any atom is valency.

Valency

Covalency

Electrovalency



(#) Electrovalency - Metal + Non-metal
 Covalency - Non-metal + non-metal

Covalency

- The max. number of electrons which can be shared by any atom for the formation of covalent bond is known as covalency.
- For any atom, max. covalency can be 8.
Max. $\Rightarrow$ $\begin{array}{c} \text{O} \\ || \\ \text{O} \end{array} \equiv \text{O}$
- Covalency is variable, an atom can show more than one covalency as per the requirement.
- For s-block metal, except Beryllium or hydrogen, covalency is not defined.

Electrovalency

- Max. no. of electron lost or gained by any atom for the formation of ionic bond is known as electrovalency.
- Max. electrovalency of any atom can be 3!
exception Ti^{4+} 4^-C (Ionic)
- s-block metal have fixed electrovalency, d-block metal can show more than one electrovalency $[\text{Cu}^+, \text{Cu}^{2+}]; [\text{Fe}^{2+}, \text{Fe}^{3+}]$
- For s-block metal, electrovalency is defined.

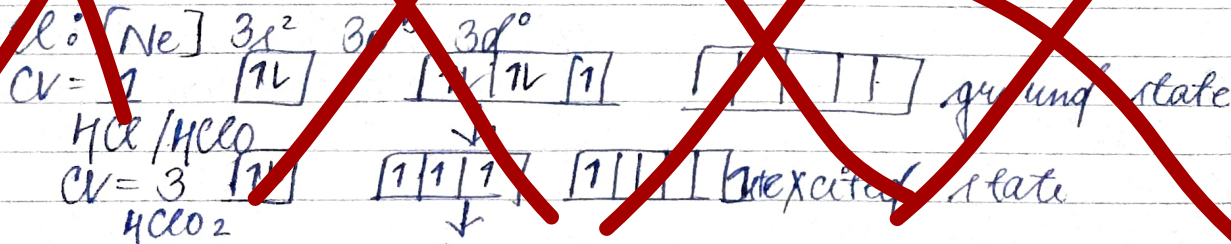
Covalency

- The max. number of electrons which can be shared by any atom for the formation of covalent bond is known as covalency.
- For any atom, max. covalency can be 8.
Max. $\Rightarrow$ $\begin{array}{c} \text{O} \\ || \\ \text{O} = \text{C} = \text{O} \\ || \\ \text{O} \end{array}$
- Covalency is variable, an atom can show more than one covalency as per the requirement.
- For s-block metal, except Beryllium or hydrogen, covalency is not defined.

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- The third period element and onwards can expand their covalency due to availability of vacant d-orbital.

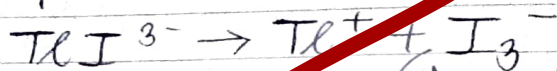
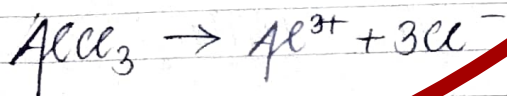
e.g.



Electrovalency

- Max. no. of electron lost or gained by any atom for the formation of ionic bond is known as electrovalency.
- Max. electrovalency of any atom can be 3!
exception Ti^{4+} C^{4-} (Ionic)
- s-block metal have fixed electrovalency, d-block metal can show more than one electrovalency $[\text{Cu}^+, \text{Cu}^{2+}]; [\text{Fe}^{2+}, \text{Fe}^{3+}]$
- For s-block metal, electrovalency is defined.

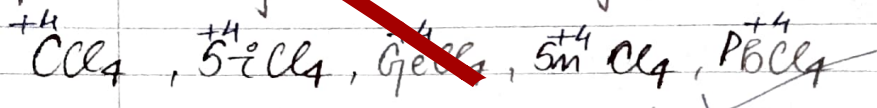
Q1) How many moles of ion is produced when 1m of $AlCl_3$ and 1m of TlI_3 is dissolved in aq. medium?



→ Deep Brown colour

$$\text{No. of moles} = 3 + 1 + 1 = 6m$$

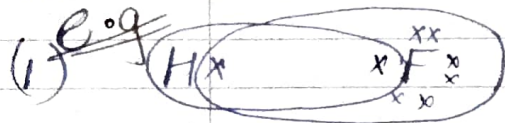
Q2) Which of the following salt will give chlorine gas spontaneously on heating?



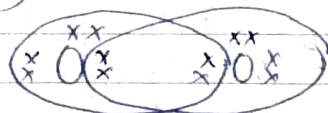
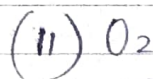
2) Covalent Bond:-

The bond formation taking place by the sharing of electron is known as covalent bond.

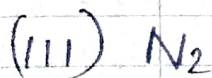
When two non-metals (in general) approaches each other then there is tendency for formation of covalent bond.



H^+ has very high I.E.,
so, it won't be formed.
 HF (1 σ bond)
3 lone pair



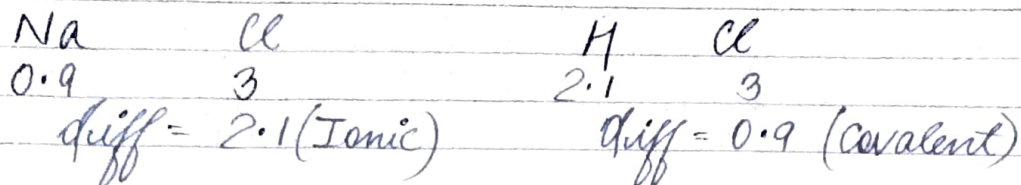
$\text{O} = \text{O}$ (1 σ bond)
(1 π bond)
4 lone pair



$N \equiv N$ (1 σ bond)
(2 π bond)
2 lone pair

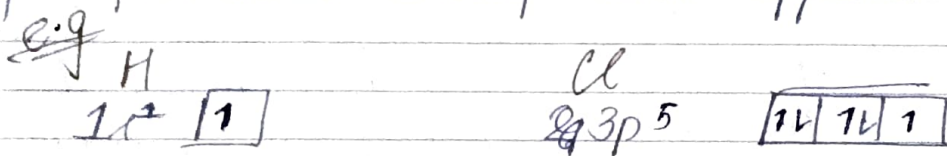
Condition for formation of covalent bond:-

- (1) The combining atom should have less electronegativity difference.



- (2) The atom should have very high ionisation energy. Non-metals have high ionisation energy so have tendency to form covalent bond. Metals have low ionisation energy so they do not form covalent bond, in general.

- (3) The electrons which are being overlapped in the bond formation should have opposite spin.



(1)

opposite spin

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Octate Theory -

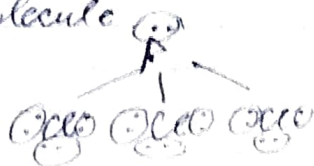
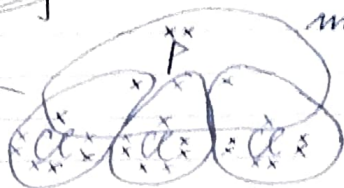
For the formation of covalent bond, or to gain stability, isolated gaseous atom combine with another atom by sharing equal no. of electrons. After sharing the electron, atom has tendency to achieve noble gas configuration. In general, atom in combined form, keeps 8 electron in its valence shell. This is

Known as octet rule.
Hydrogen follow duplet rule.

Atom have 8 e in valence shell in combined form
Electron precise

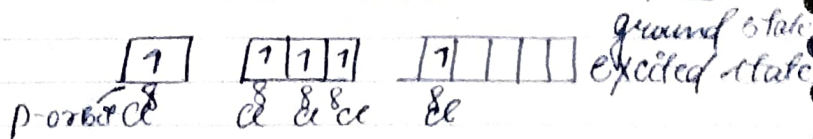
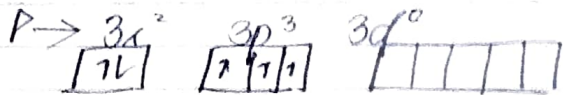
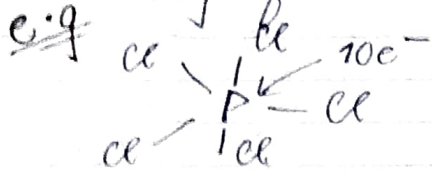
CN(C)C

Octate molecule

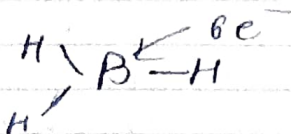


Limitations of octet theory -

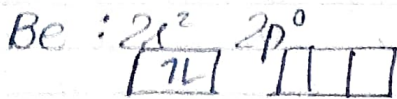
- * In some molecule, it was found that in combined form atom have more than 8 electron i.e. valence shell and these molecules are known as hypervalent molecule. ~~Molecule~~ Atom having vacant ~~of~~ ~~the~~ orbital may form hypervalent molecule.



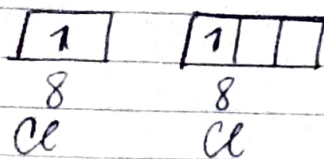
- When any atom in combined form have less than 8 e in its valence shell, then this type of molecule is known as hypovalent molecule.



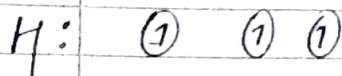
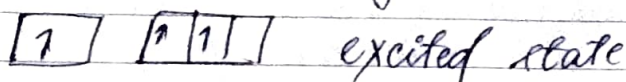
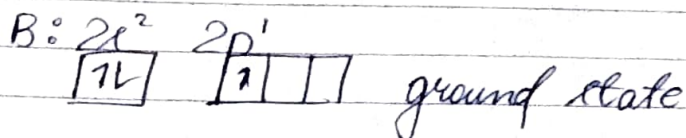
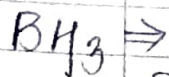
In general, second period element forms hypovalent molecule.



ground state

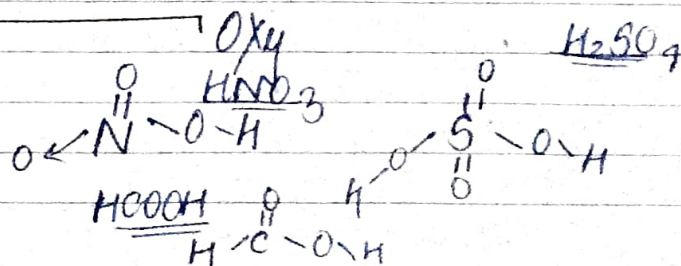
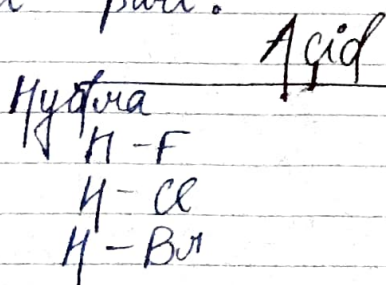


★ Hypovalent molecules are always Lewis acid.

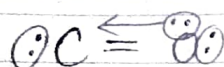
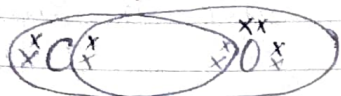


Rules to Draw Lewis Dot structure:-

- (1) The atom which is present in lesser number is kept at centre.
- (2) The atom which is more electronegative is kept at centre part.
- (3) In any ^{oxy-}acid, hydrogen is first connected with oxygen.
- (4) Hydrogen and Fluorine is never kept at centre part.
- (5) Atom having maximum covalency is kept at the central part.



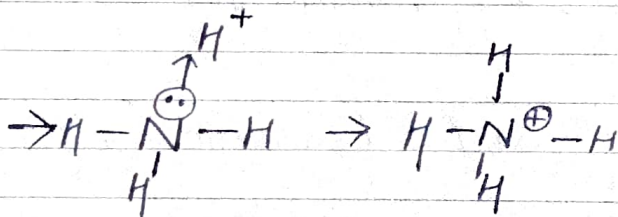
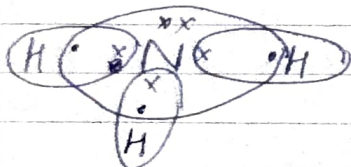
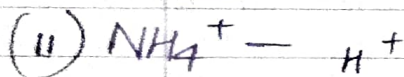
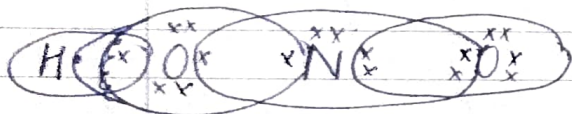
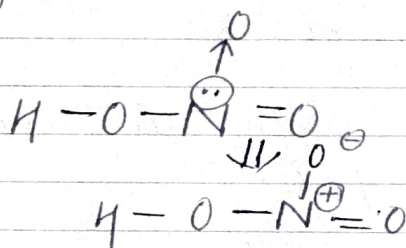
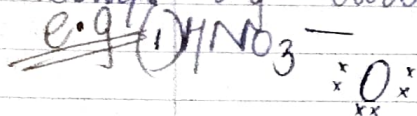
CO (co-ordinate bond)



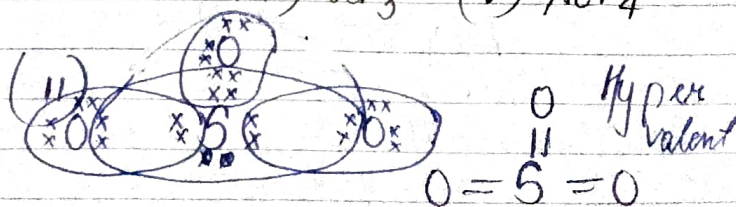
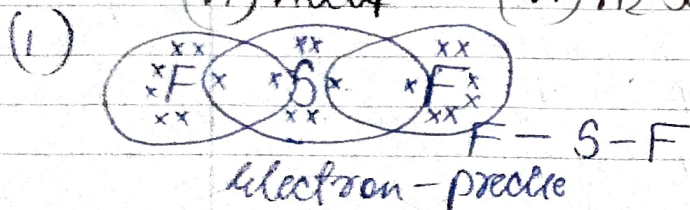
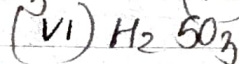
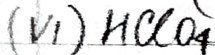
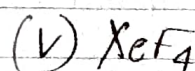
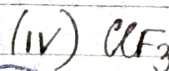
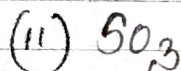
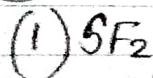
Fluorine does not form co-ordinate bond because of electro-ve. Chlorine has less electron density.

Co-ordinate Bond:

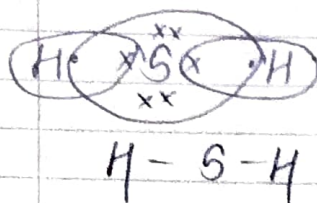
When covalent bond formation take place by electron pair belongs to one atom is known as co-ordinate bond. e.g. - carbon monoxide



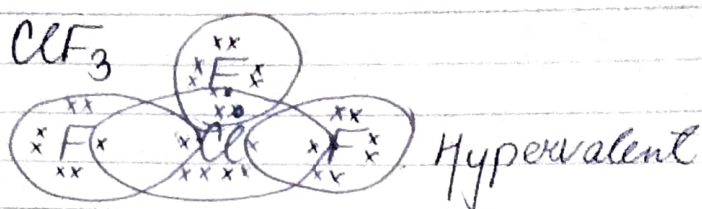
(3) Draw the LVS for:



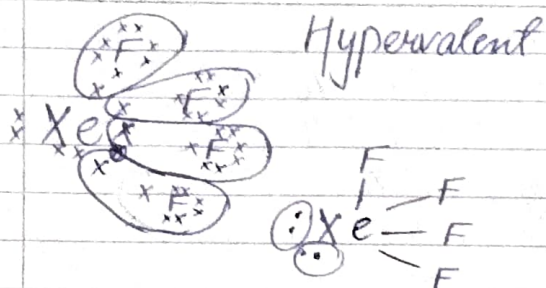
(III) H_2S



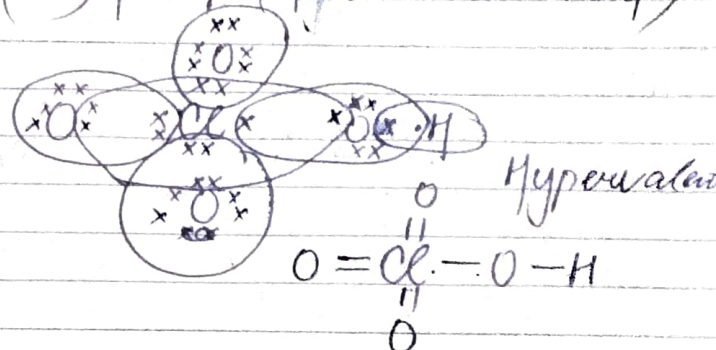
(IV) ClF_3



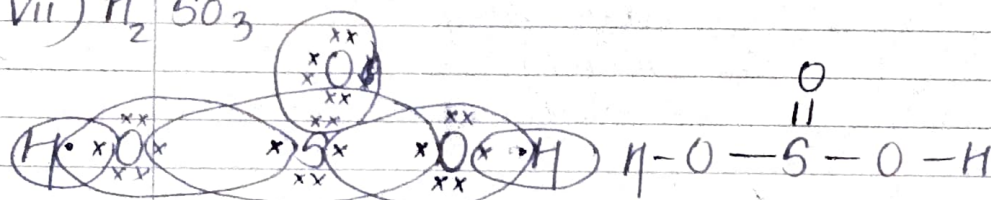
(V) XeF_4



(VI) $HClO_4$ (perchloric acid)

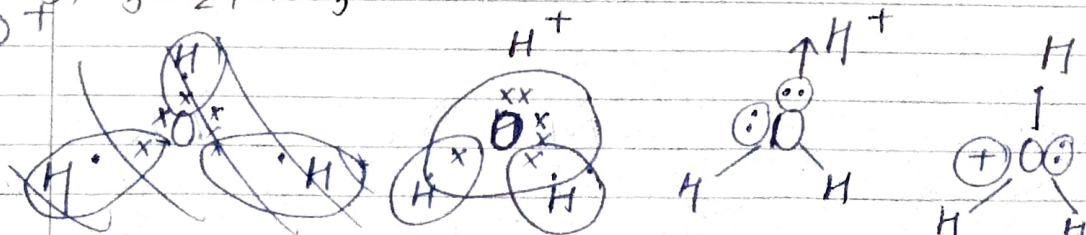


(VII) H_2SO_3

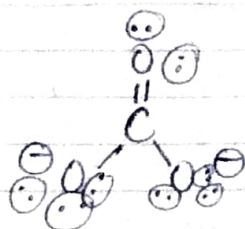
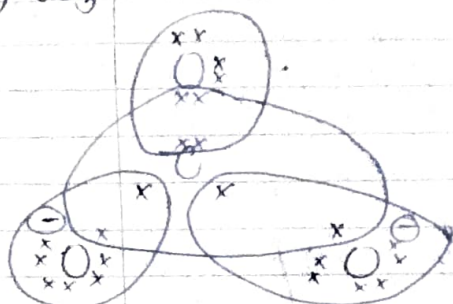
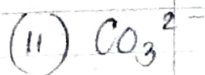


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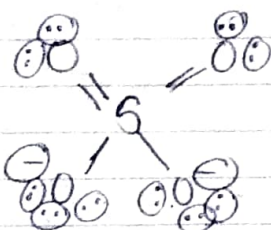
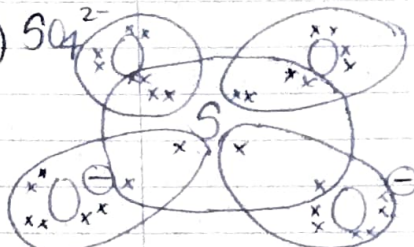
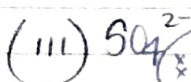
Draw the LVS for H_3O^+ , CO_3^{2-} , SO_4^{2-} , O_3 , NO_2^- , CCl_3^- , I_3^- , $COCl_2$, N_3^- , CH_3Cl , NH_2Cl , CN^- , SCN^- , HCN , SiF_4 , $SnCl_3^-$, BH_4^- , HNC , BeF_4^{2-} , PO_4^{3-} , XeF_5^- , ClO_3^- , PCl_4^+ , $POCl_3$, XeF_5^+ , H_3PO_4 , H_3PO_3 , H_3PO_2 , H_2SO_3 , H_3O^+



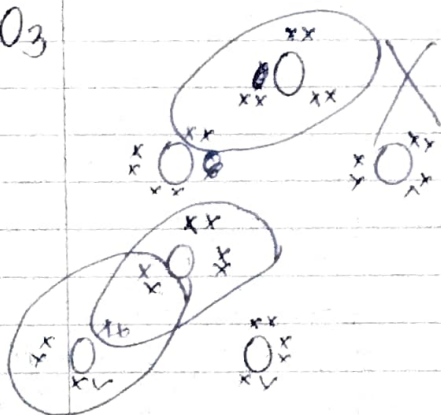
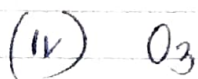
Formal charge: $O = +1$
 $lp = 1$



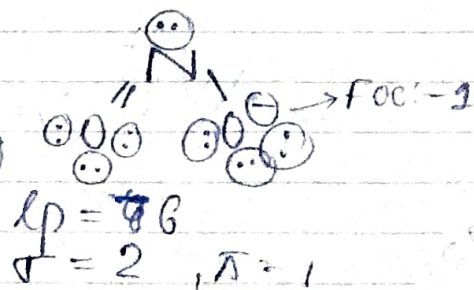
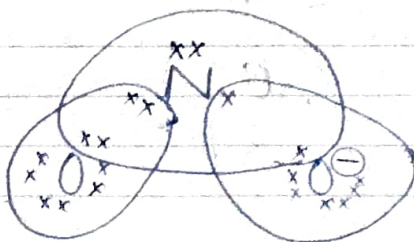
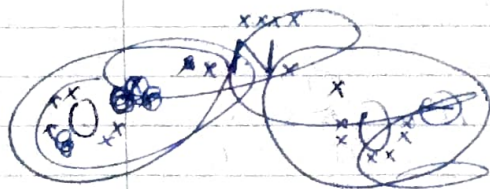
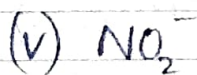
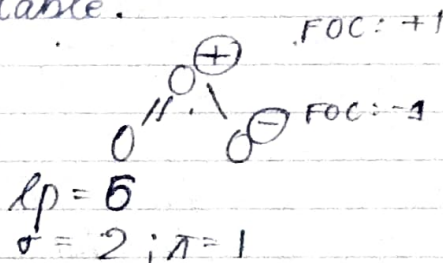
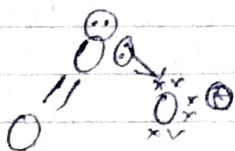
$$\begin{aligned} \text{lp} &= 8 \\ \sigma &= 3 \\ \pi &= 1 \end{aligned}$$



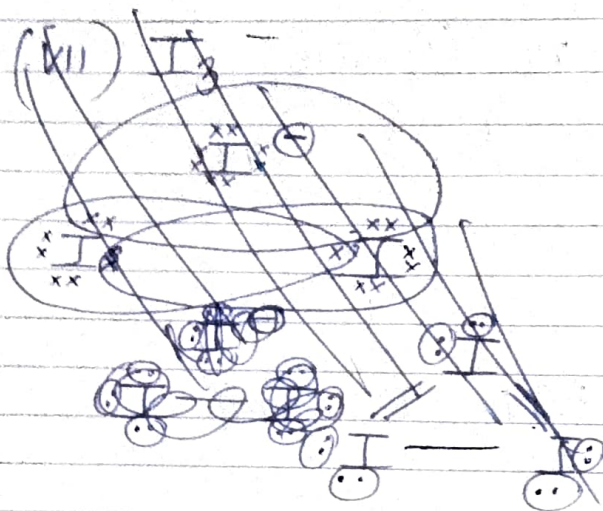
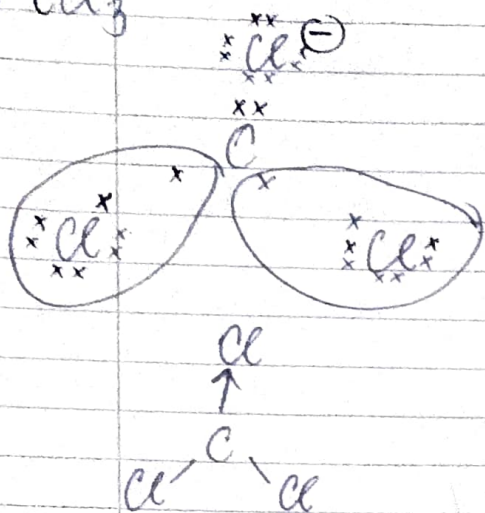
$$\begin{aligned} \text{lp} &= 10 \\ \sigma &= 4 \\ \pi &= 2 \end{aligned}$$



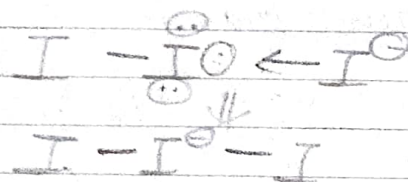
3 member ring
is highly
unstable.



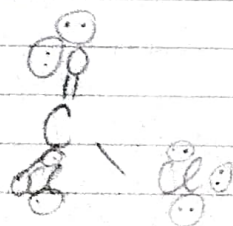
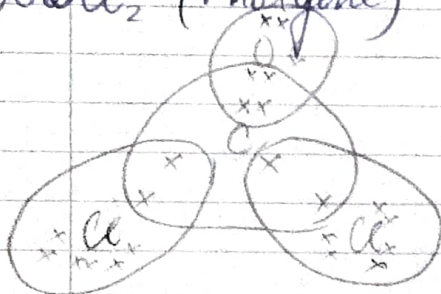
(vi) CCl_3^-



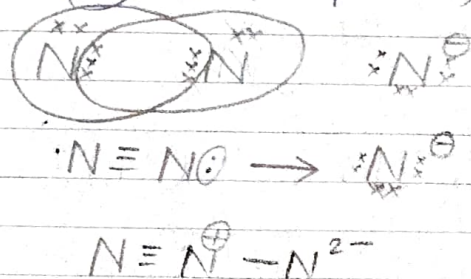
(vii) I_3^-



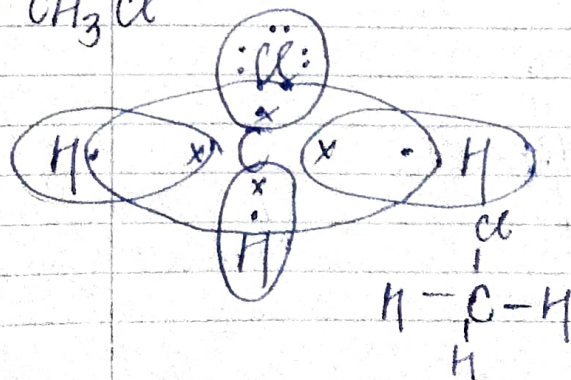
(viii) COCl_2 (Phosgene) -



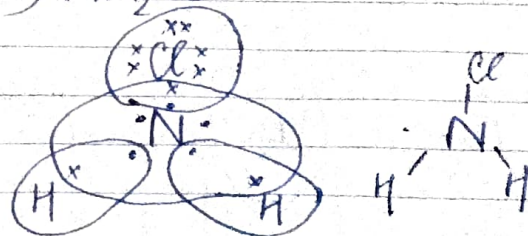
(ix) N_3^- (azide ion)

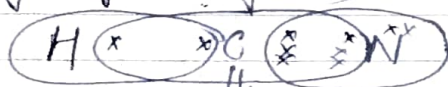
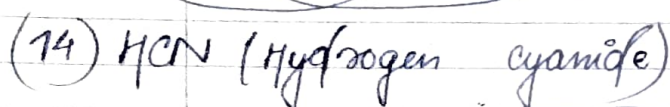
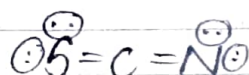
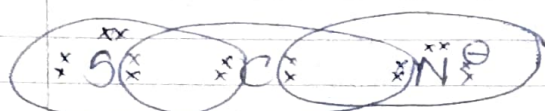
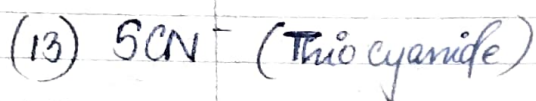
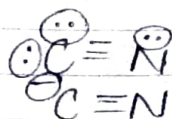
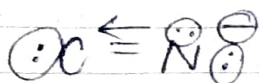
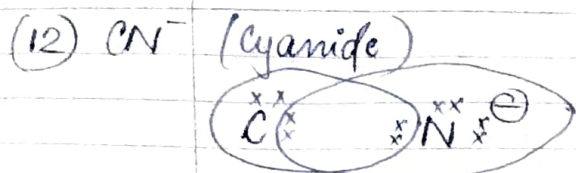


(x) CH_3Cl

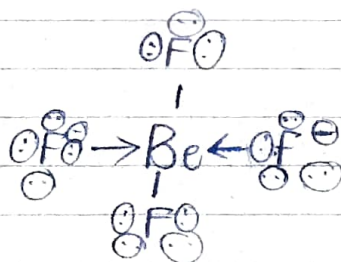
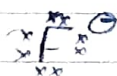
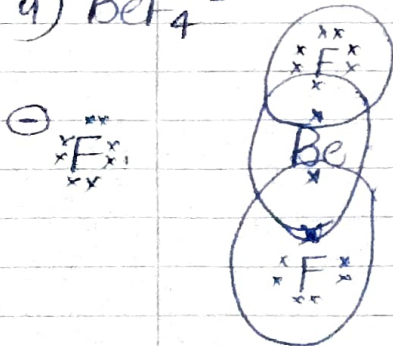
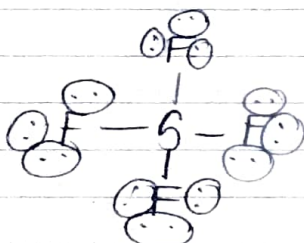
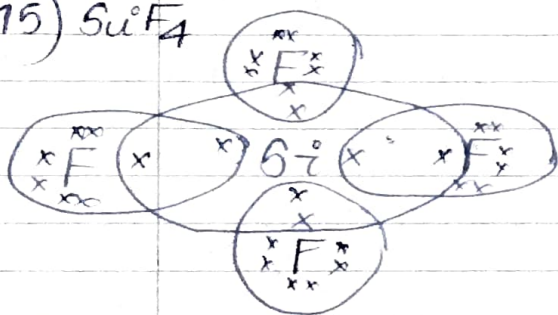
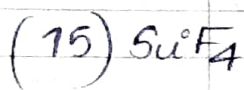


(xi) NH_2Cl

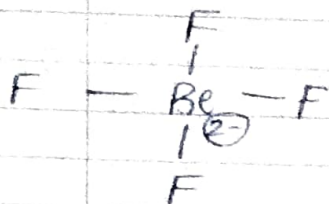




lp carbon (3 bond)



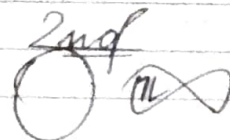
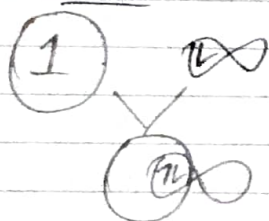
F^- has veryyy less electro-ve.



Valence Bond Theory -

- The concept is based on the wave nature of electron.
- According to this theory, valence atomic orbital overlap with another valence atomic orbital of another atom for the formation of co-ordinate or covalent bond.
- The orbital which is being overlapped should contain 1 e⁻ with opposite spin or 1 orbital should be vacant & another orbital should contain lone pair. In 1st type, covalent bond forms & in 2nd type, coordinate bond forms.

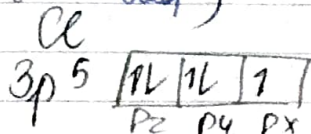
① 1st



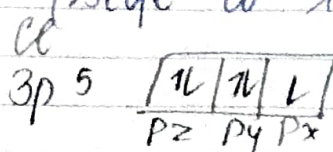
- Number of bond formed = number of orbitals overlapped
- There are 2 types of overlapping taking place for the formation of covalent bond:

(I) Axial overlapping
(head to head)

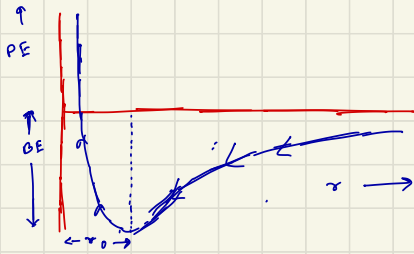
e.g.



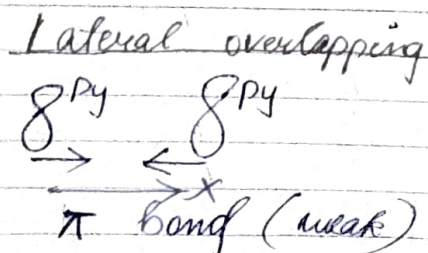
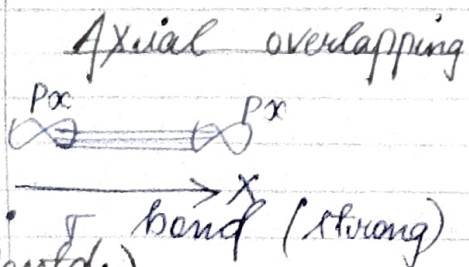
(II) Lateral overlapping
(side to side)



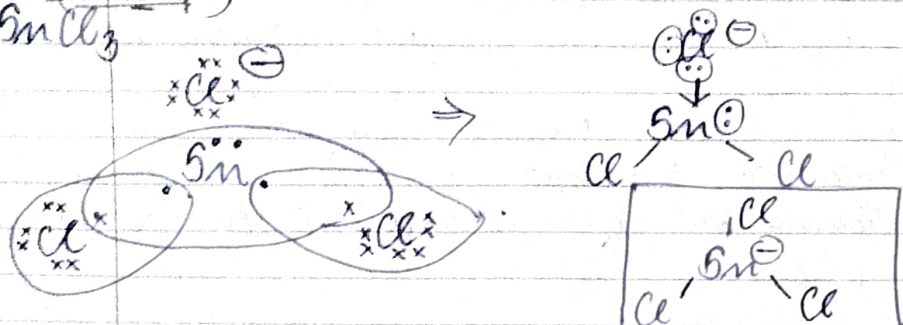
② to gain stability



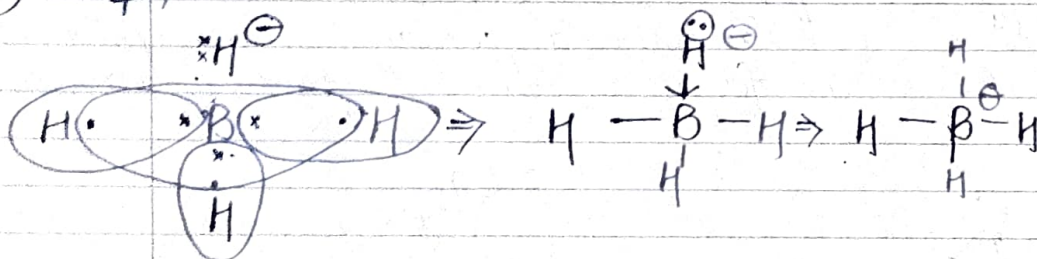
- As atoms approach each other potential energy decreases
- $\left. \begin{array}{l} e^- - e^- \\ p - p \end{array} \right\}$,
 $\left. \begin{array}{l} p - e \\ e - p \end{array} \right\}$ dominates
 $\left. \begin{array}{l} p - e \\ e - p \end{array} \right\}$ dominates
- At min PE bond parameter



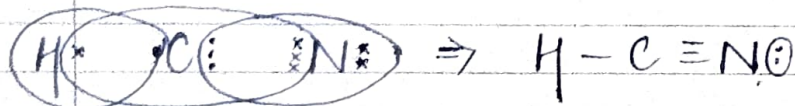
(16) SnCl_3^-



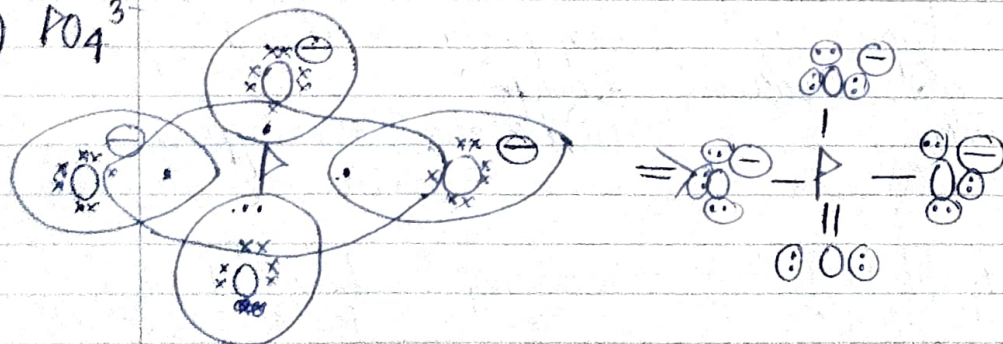
(17) BH_4^-

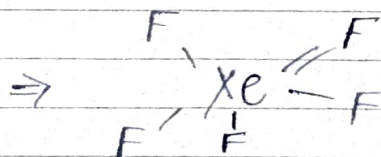
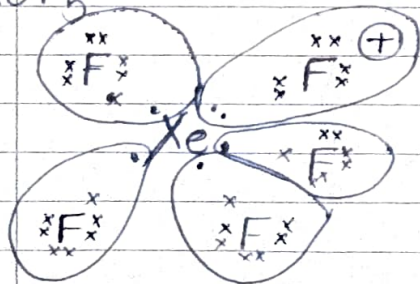
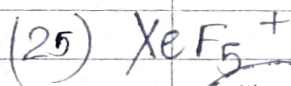
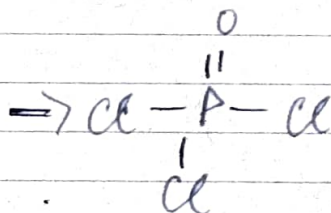
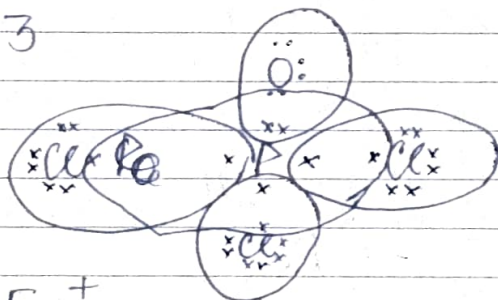
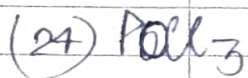
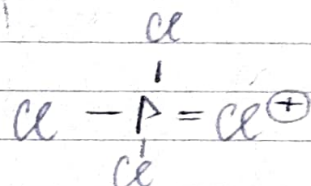
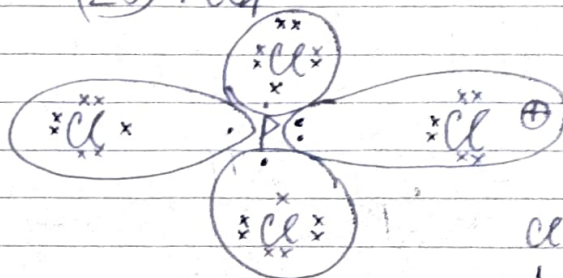
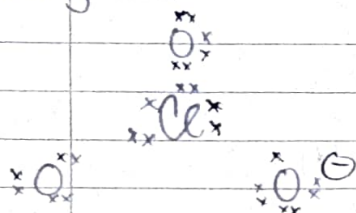
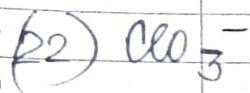
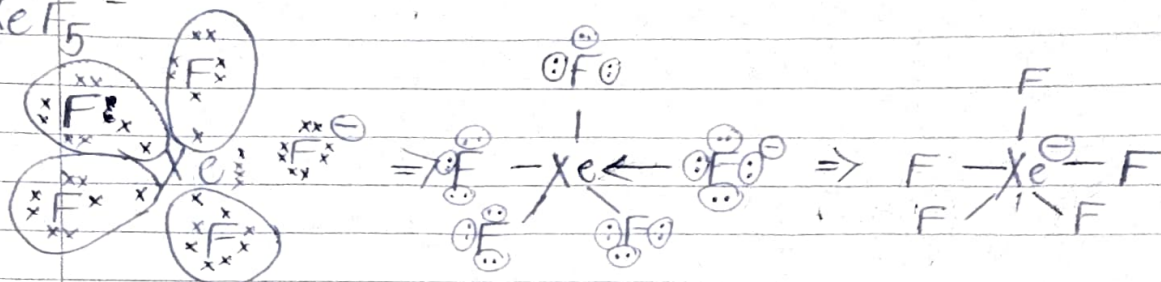
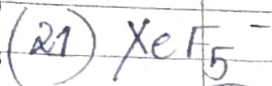


(18) HNC

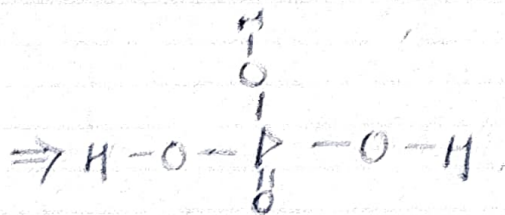
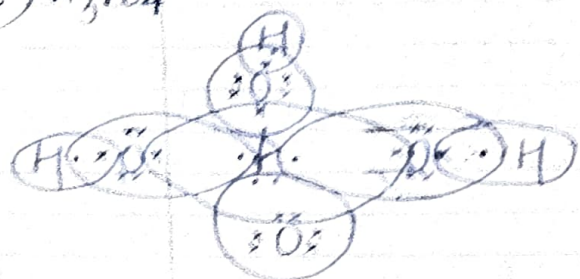


(20) PO_4^{3-}

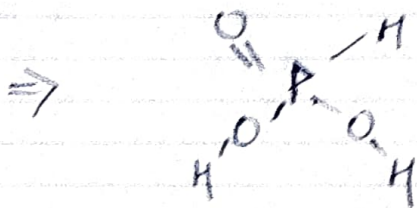
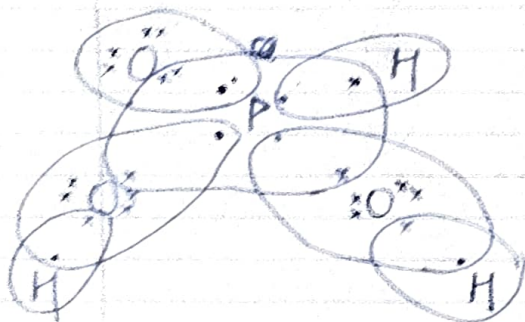




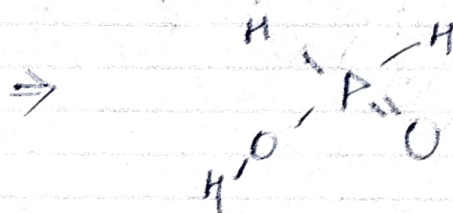
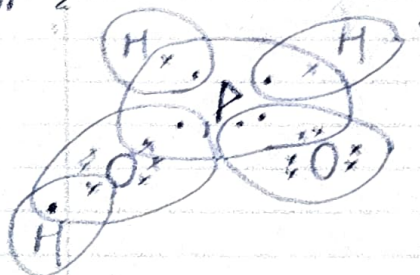
(26) H_3PO_4



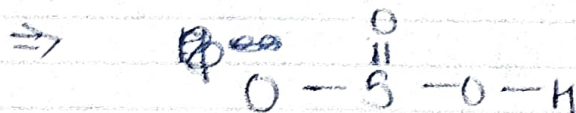
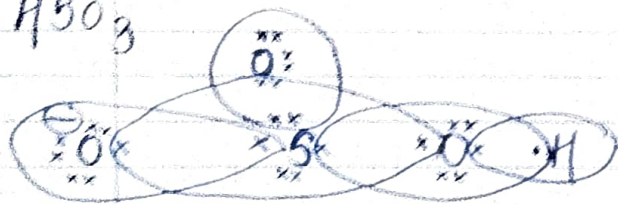
(27) H_3PO_3



(28) H_3PO_2



(29) HBO_3^-



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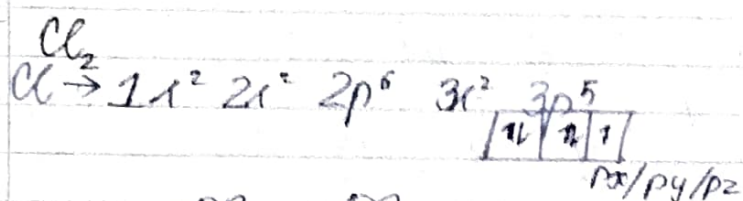
Types of Overlapping

Axial overlapping
(Head to head)

Lateral overlapping
(side to side)

- By axial overlapping, σ -bond formation takes place.
- 1st overlapping b/w 2nd orbitals is axial in nature.

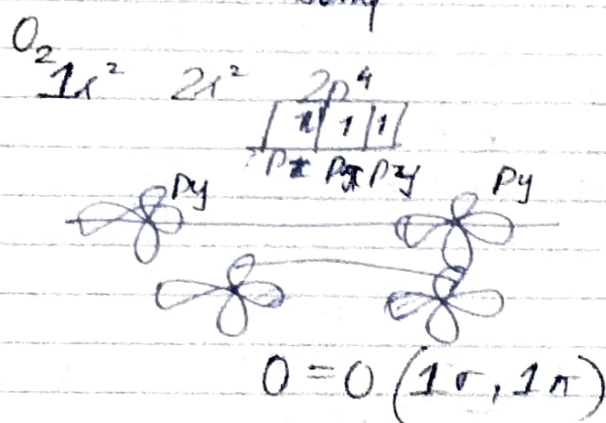
e.g¹



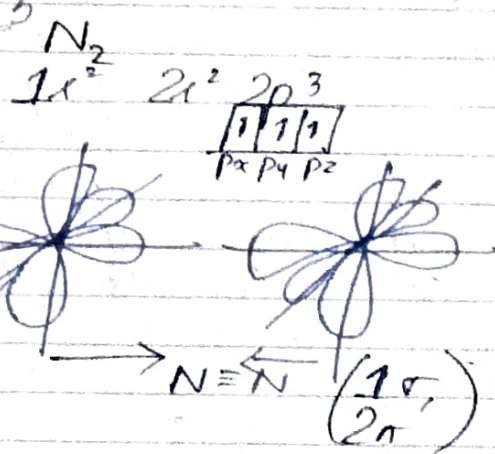
- By lateral overlapping, π -bond forms.

• After the 1st overlapping, remaining all overlapping is lateral in nature.

e.g²



e.g³



Some Important Points:-

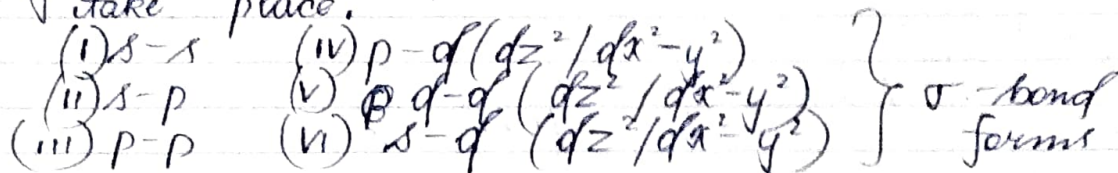
- The axis in which axial overlapping takes place is known as inter-nuclear axis (INA).
- The direction of axial overlapping is parallel to

INA but direction of lateral overlapping is perpendicular to INA.

• 1st overlapping b/w 2 atoms is axial in nature and later one is lateral in nature.

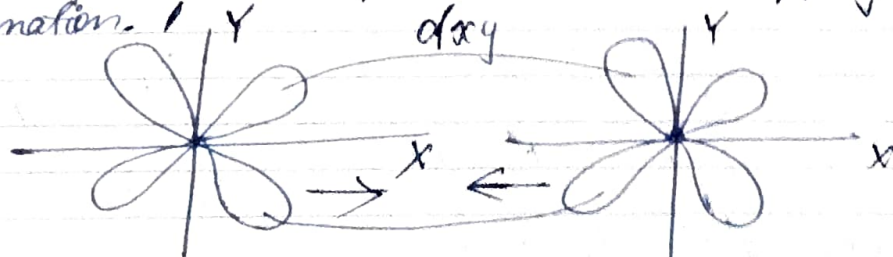
• Hybrid orbital does not have tendency for the formation of π -bond.

• When single lobes overlap with each other, then σ -bond formation takes place.



• When two lobes interact with each other, then π -bond formation takes place.

dz^2 bond formation. dz^2 does not do lateral overlapping for π -bond formation.



★ dx^2-y^2 and dz^2 only form σ -bond, not π -bond.

• When 4 lobes interact with each other, then σ -bond formation takes place.

dxy, dyz, dzx, dx^2-y^2 only

dz^2 does not form σ -bond.

- ~~When~~ The overlapping in which none of the bond formation take place is known as zero overlapping.
- When orbitals are of bigger size, then lateral overlapping does not take place.
 e.g. O_2 exists S_2 does not exist N_2 exists P_2 does not exist

Elements other than 3rd period does not have tendency for the lateral overlapping. So, S_2 , P_2 does not exist.

Overlapping	INA	Type of bond
(1) $S + S$	X-axis	σ -bond
(2) $S + S$	Y-axis	σ -bond
(3) $S + S$	Z-axis	σ -bond
(4) $S + P_x$	X-axis	σ -bond
(5) $S + P_y$	X-axis	No bond
(6) $S + P_z$	X-axis	No bond
(7) $P_x + P_x$	X-axis	σ -bond
(8) $P_y + P_y$	Y-axis	σ -bond
(9) $P_z + P_z$	Z-axis	σ -bond
(10) $S + P_x$	Y-axis	No bond
(11) $S + P_y$	Y-axis	σ -bond
(12) $S + P_z$	Y-axis	No bond
(13) $S + P_x$	Z-axis	No bond
(14) $S + P_y$	Z-axis	No bond
(15) $S + P_z$	Z-axis	σ -bond
(16) $P_x + P_x$	Y/Z	π -bond
(17) $P_y + P_y$	X/Z	π -bond
(18) $P_z + P_z$	X/Y	π -bond

Overlapping

- (19) $p_z + d_{z^2}$
 (20) $p_x + d_{xy}$
 (21) $p_y + d_{xy}$
 (22) $p_z + d_{xy}$
 (23) $p_y + d_{yz}$
 (24) $p_z + d_{yz}$
 (25) $p_x + d_{xz}$
 (26) $p_z + d_{xz}$
 (27) $d_{xy} + d_{xy}$
 (28) $d_{xy} + d_{xy}$
 (29) $d_{xy} + d_{xy}$

INA

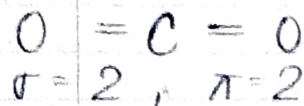
- Z-axis
 Y-axis
 X-axis
 any axis
 Z-axis
 Y-axis
 Z-axis
 X-axis
 X-axis
 Y-axis
 Z-axis

Type of Bond

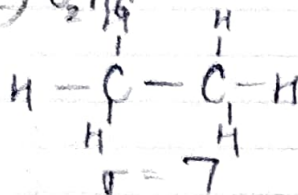
- σ -bond
 π -bond
 π -bond
 No bond
 π -bond
 π -bond
 π -bond
 π -bond
 δ -bond
 δ -bond
 δ -bond

(Q) Count total number of σ and π in the given molecules?

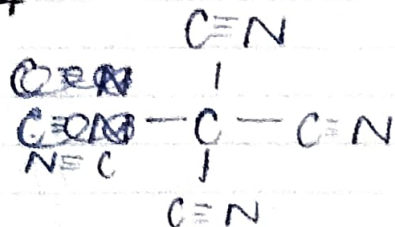
(1) CO_2



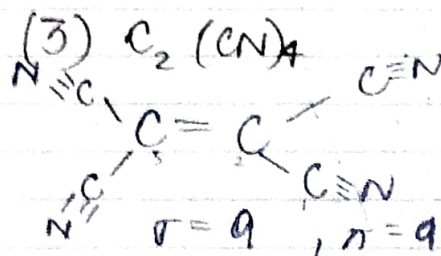
(2) C_2H_6



(3) $\text{C}(\text{CN})_4$



$\sigma = 8$
 $\pi = 8$

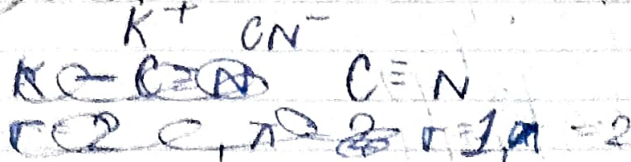


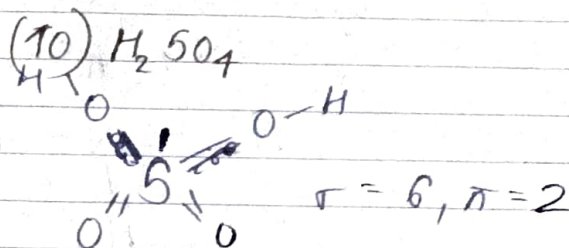
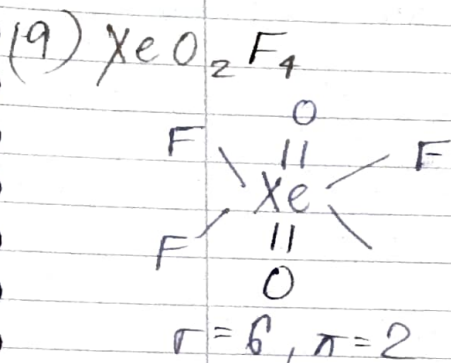
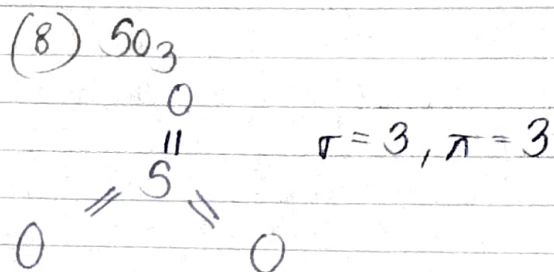
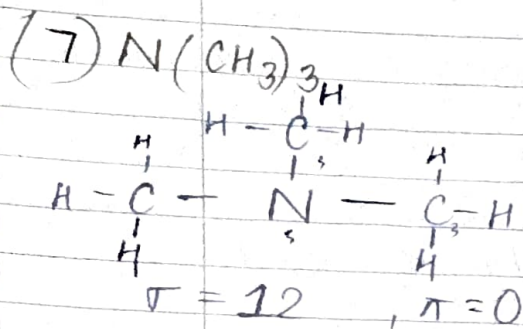
$\sigma = 9, \pi = 9$

(V) C_2H_2 Alkyne



(6) KCN

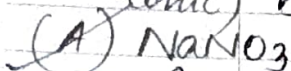




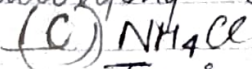
Q2) How many overlapping will form σ bond?

- | | | |
|-----------------------|---------|--------------------------------------|
| (i) $p_x + p_y$ | INA - X | No (Zero) |
| (ii) $p_z + p_z$ | INA - Y | No bond No (π -bond) |
| (iii) $p_z + d_{z^2}$ | INA - Y | No (π -bond) |
| (iv) $p_x + d_{xy}$ | INA - X | No (Zero) |
| (v) $p_z + d_{z^2}$ | INA - Z | Yes (σ -bond) |
| (vi) $p_x + d_{yz}$ | INA - X | No bond (Zero) |

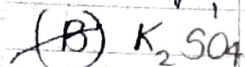
Q3) In how many of them all type (σ , π , coordinate, ionic) bond is present? according to VSEPR theory?



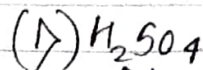
Ionic, co-ordinate,
 σ , π



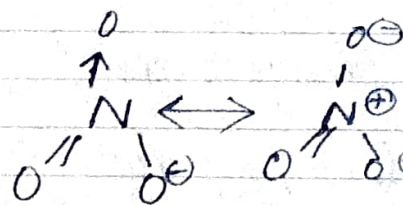
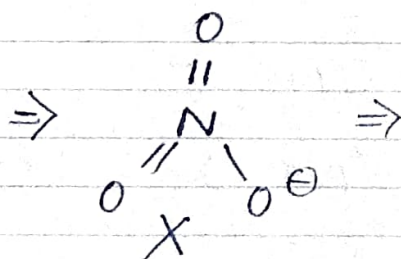
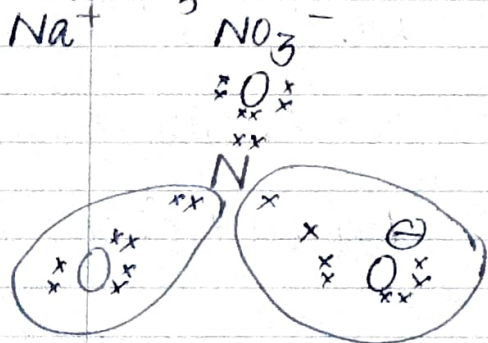
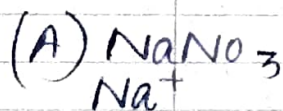
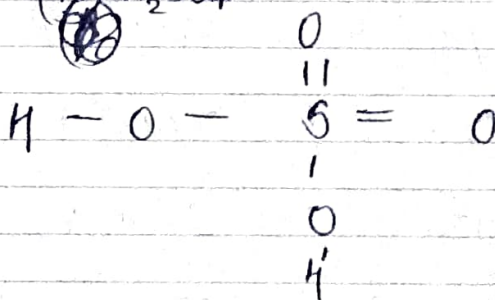
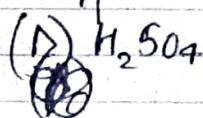
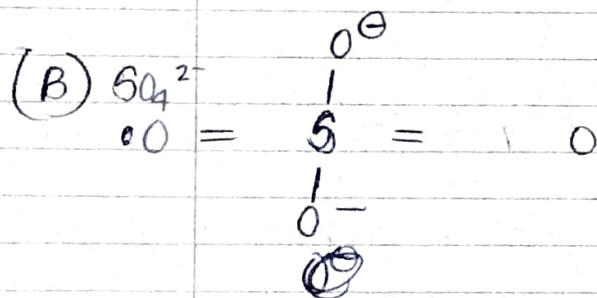
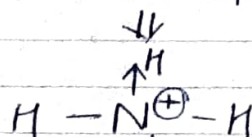
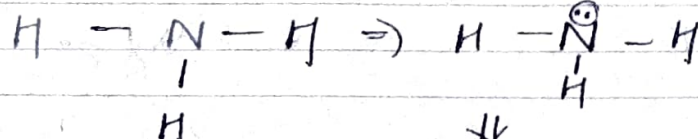
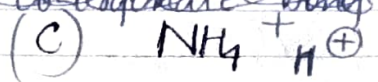
Ionic, co-ordinate
No π -bond



Ionic, ~~no co-ordinate bond~~

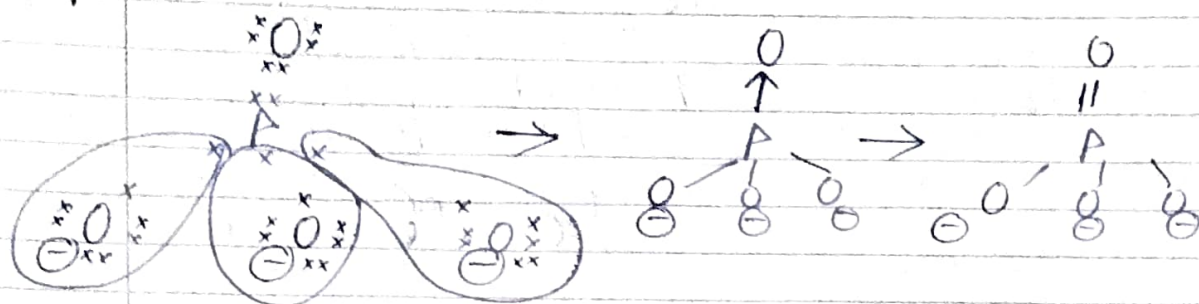


No co-ordinate bond



01/11/25

#) PO_4^{3-}

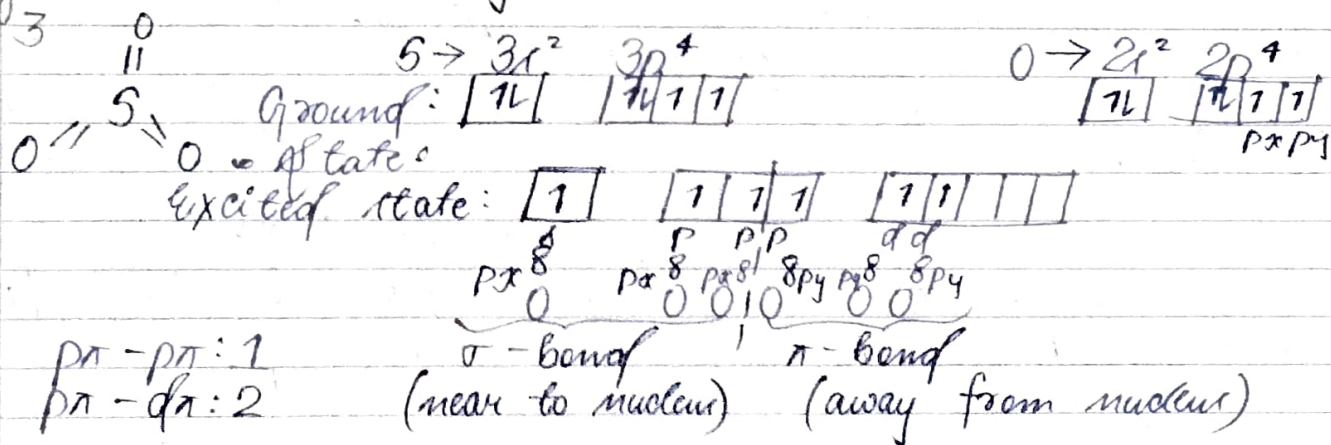


#) L175 identifies co-ordinate bond whereas VBT does not in hypervalent atoms.

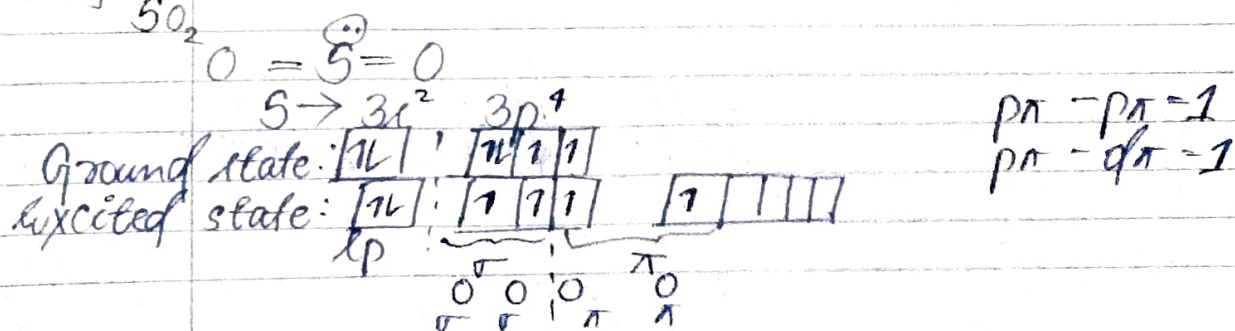
The lateral overlapping maybe

$p\pi - p\pi$
 $p\pi - d\pi$
 $d\pi - d\pi$ types.

e.g. SO_3

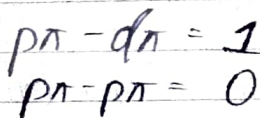


e.g. SO_2



$$\begin{array}{c}
 \text{O} \\
 || \\
 \text{Fe} \\
 / \quad \backslash \\
 \text{Cl} \quad \text{Cl} \\
 / \quad \backslash \\
 \text{Cl} \quad \text{Cl}
 \end{array}$$

$$\text{O} \rightarrow 2s^2 \quad 2p^6$$



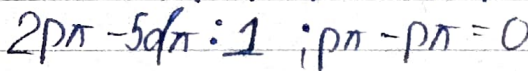
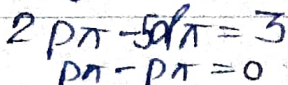
$\ominus C \equiv O \oplus$

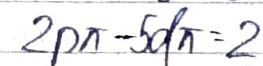
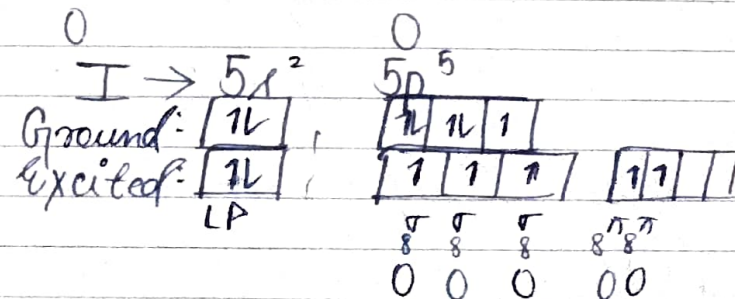
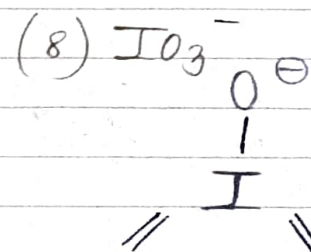
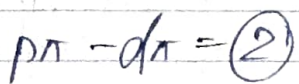
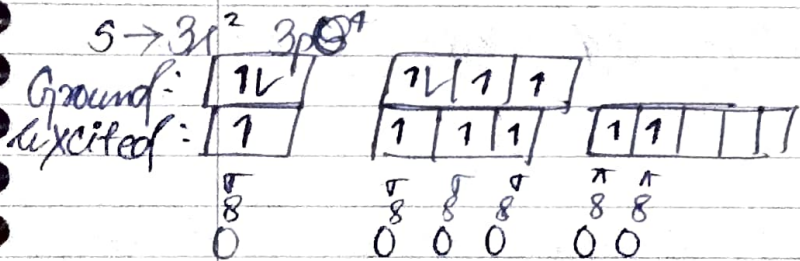
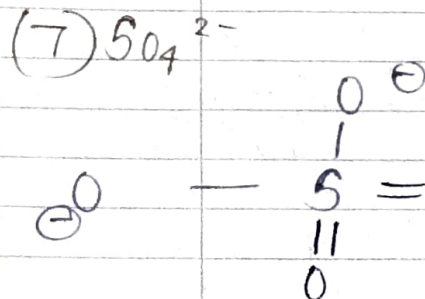
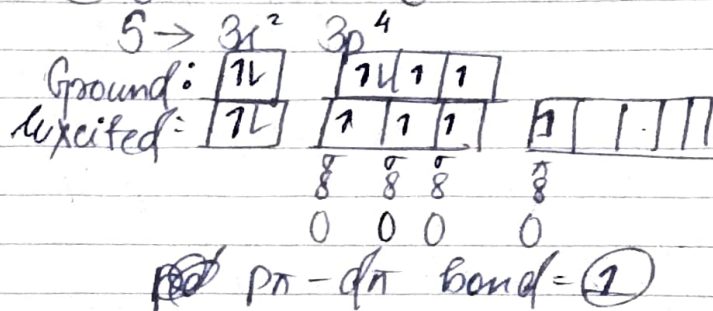
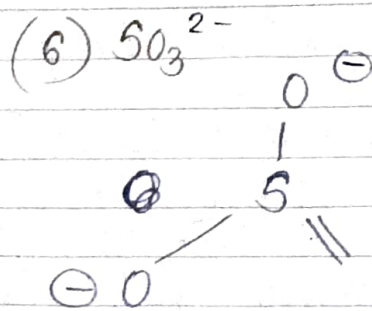
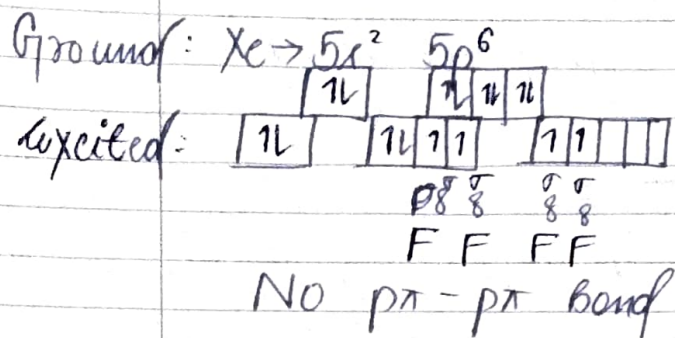
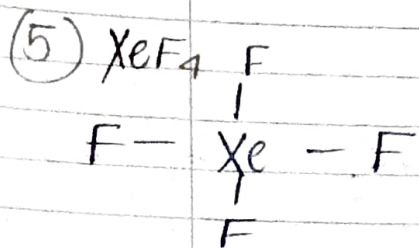
$C \rightarrow 2s^2 \quad 2p^2$

$pn - dn$ is zero

as both C & O have no d-orbital as both belong to 2nd period.

$pn - pn = 2$

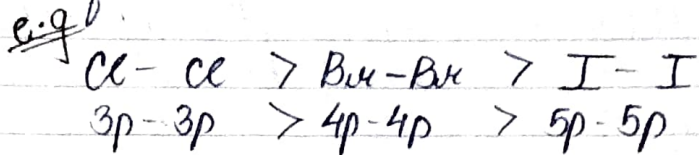
$$\begin{array}{c} \text{O} \\ || \\ \text{F} - \text{Xe} - \text{F} \\ / \quad \backslash \\ \text{F} \quad \text{F} \end{array}$$

$$\begin{array}{c} \text{O} \\ \parallel \\ \text{O} = \text{Xe} = \text{O} \end{array}$$




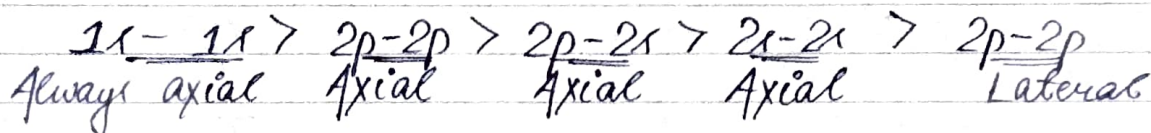
Factors Affecting Bond strength:-

(1) Bond strength is directly proportional to number of bond present b/w two atoms.
e.g. $C-C < C=C < C \equiv C$

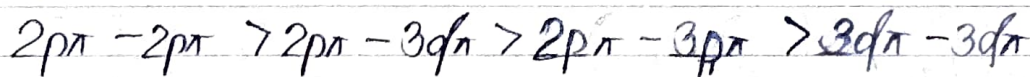
(2) Bond strength is inversely proportional to shell number of the orbitals.



(3) If shell number of orbital is same, then bond strength is directly proportional to extent of overlapping.



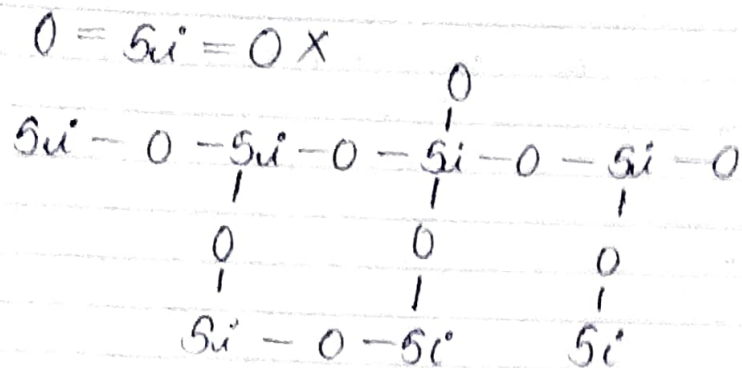
(4) The order of lateral overlapping follow the given order



Some Important Points:-

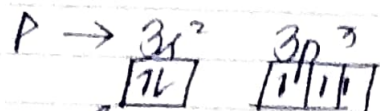
(1) Oxygen molecule exist but S_2 molecule does not exist, due to bigger size of p-orbital, lateral overlapping is not possible in S_2 molecule. In the same way, N_2 exist but P_2 does not exist.

(2) CO_2 exist but SiO_2 does not exist. SiO_2 exist in polymeric form $[SiO_2]_n$.

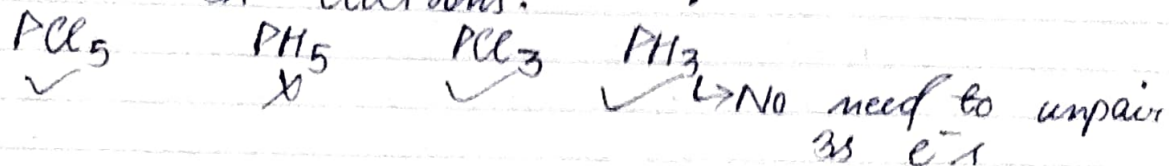


3p of Silicon & 2p of oxygen is not strong enough. $\therefore$ polymerisation starts.

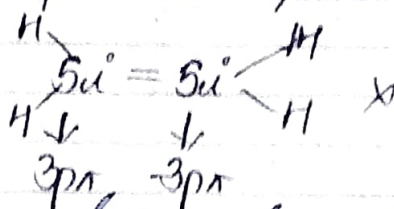
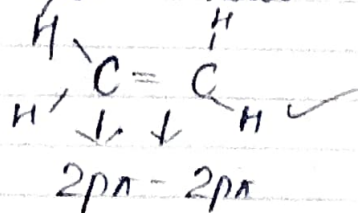
(3) PCl_5 exists but PH_5 does not exist.



Hydrogen is not so powerful as to unpair 3s electrons.



(4) C_2H_4 exists but Si_2H_4 does not exist.



does not exist as 3p is large

(5) PCl_5 exists but PBr_5 and PI_5 does not exist. Due to steric crowding, PBr_5 and PI_5 does not exist.

Steric Crowding:

Repulsion between surrounding atom in any covalent molecule is known as steric crowding/repulsion.

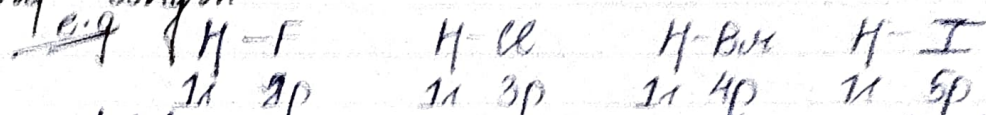
Higher the size of surrounding atom, greater is the steric crowding & lesser is the stability of molecule.

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Drawbacks of VBT:

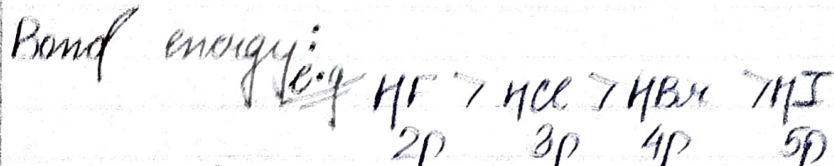
- (1) VBT explain the various bond parameters like bond length, bond energy, bond order but does not explain bond angle of the molecule.

Bond length:



Higher shell number, greater will be bond length.
 $\text{HF} < \text{HCl} < \text{HBr} < \text{HI}$ [Bond length]

Bond energy:



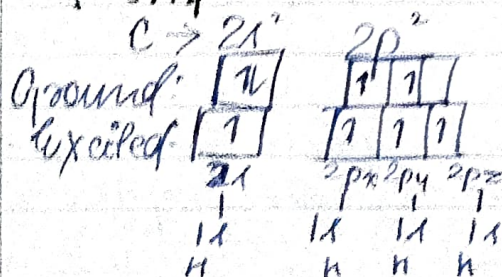
Lower the shell no., greater will be the bond energy

Bond order:



Bond order is no. of bonds formed between two covalently bonded atom.

e.g. CH_4



Bond angle - $90^\circ \times$

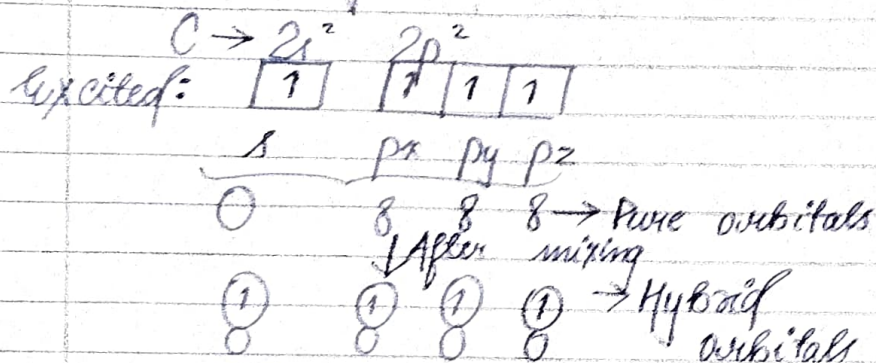
BA = 109.28° ✓
 experimental observation

(2) VBT cannot explain geometry or shape of the molecule

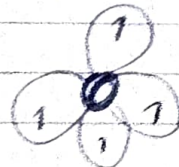
(3) VBT also could not explain the quantitative relationship between bond energy and extent of overlapping.

Hybridisation:-

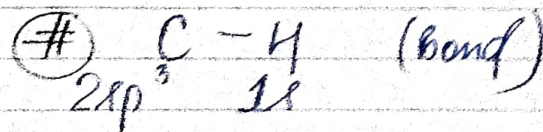
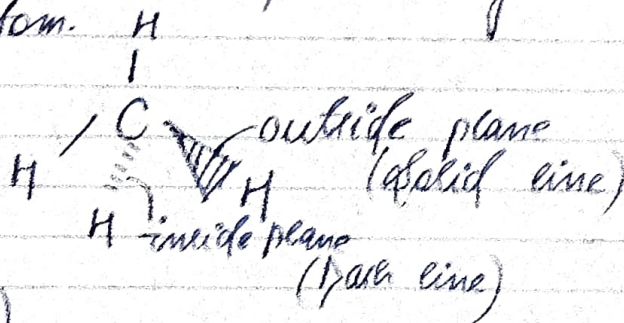
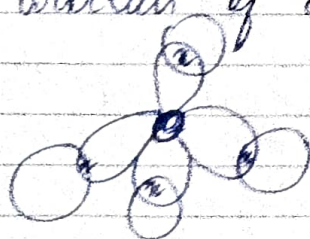
• It is an hypothetical concept.



After arrangement (in such a way that repulsion b/w them is minimum)



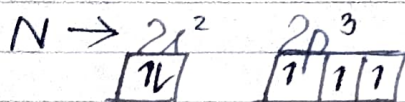
Now, the 'H' (1s) will approach towards arrange hybrid orbitals of central atom.



Some Important Points:-

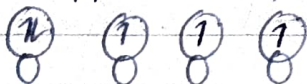
- (1) Intermixing of atomic orbitals having almost same energy for the formation of new set of hybrid orbitals which is known as hybridisation.
- (2) In the hybridisation process, pure atomic orbitals (valence shell) intermix with each other for the formation of hybrid orbitals. Now these hybrid orbitals arrange themselves in such a way that repulsion between them is minimum.
- (3) Now the surrounding atoms with their valence orbitals overlap with the hybrid orbitals.

NH_3

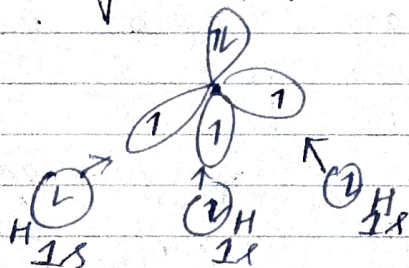


② 8 8 8 $\rightarrow$ pure orbitals

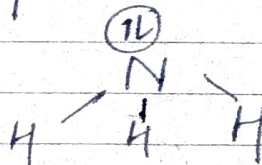
$\downarrow$ After mixing



Arrangement for least repulsion:



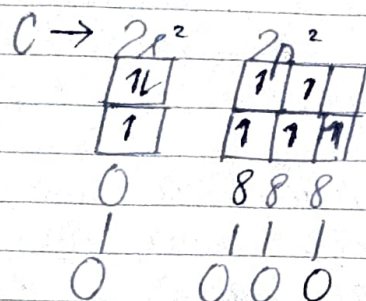
repulsion:



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Characteristics of Hybridisation:-

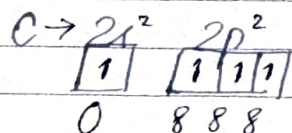
(1) Hybridisation occurs for better overlapping and highly stable molecular structure.



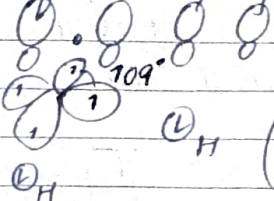
According to VBT
 $s-s$ $p-s$ (overlapping extent)
 $p-s$ (if it is not much effective)

Bond angle = 90°

Lesser the bond angle, lesser will be the stability



After mixing



sp^3-s
 (extent of overlapping is good)

Bond angle = 109°

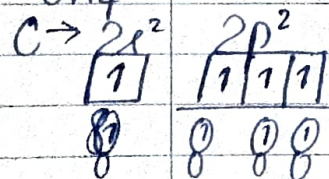
comparatively more stable

(2) Hybridisation is an exothermic process.

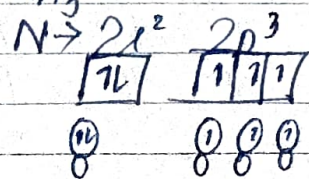
(3) Orbitals having almost equal energy and different shape intermix with each other in hybridisation process.

(4) Orbitals having Fully-filled orbitals, half-filled orbitals or sometime vacant orbital (in case of co-ordinate bond) intermix in hybridisation process.

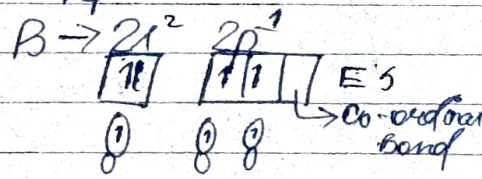
e.g. CH_4



NH_3



BF_4^-



(5) The hybridisation process occurs before overlapping.

Characteristics of hybrid orbitals:

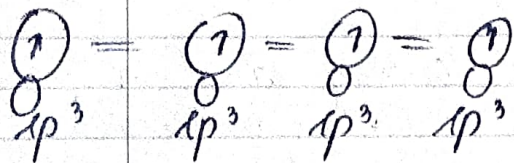
(1) Hybrid orbital is formed by intermixing of pure atomic orbitals having almost similar energy or may have different or same shape.

(2) All the hybrid orbitals are identical in all respect. If central atom does not have any lone pair and surrounding atom is same.

Intermixing

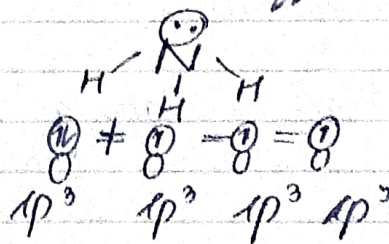
Ideal intermixing

When central atom does not have lone pair and surrounding all atoms are same.



Non-ideal intermixing

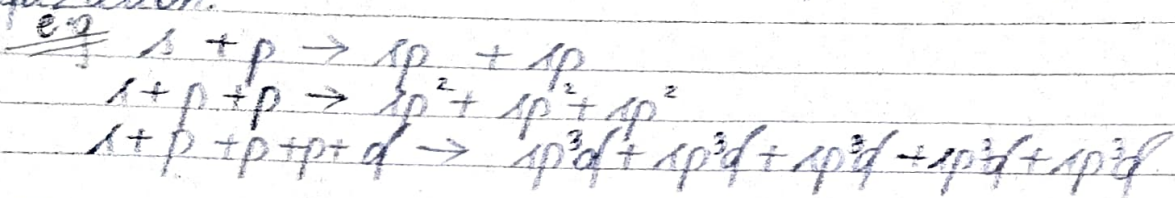
When central atom has lone pair or surrounding atom is different.



(3) Hybrid orbital is more directional in nature and have average energy of pure atomic orbital.

Energy {	$\frac{1}{2p}$	$\frac{1}{2p}$	$\frac{1}{2p}$	(Higher)
	$\frac{1}{2s}$ (Lower)	$\frac{1}{sp^3}$	$\frac{1}{sp^3}$	$\frac{1}{sp^3}$ (Average of Both)

- (4) Number of hybrid orbital is same as that of number of pure atomic orbital participated in hybridization.

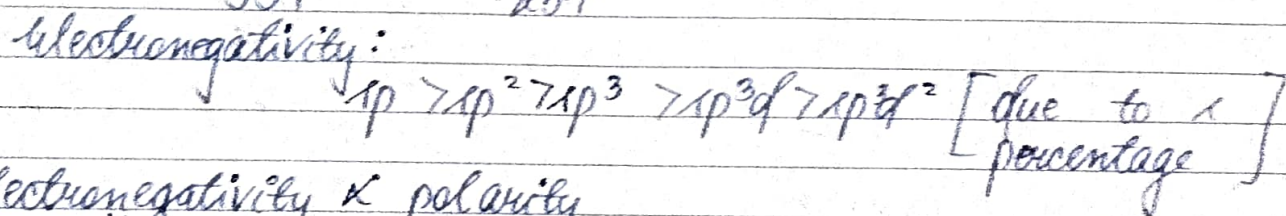


- (5) Hybrid orbital does not do lateral overlapping. Hence, π -bond is not formed.

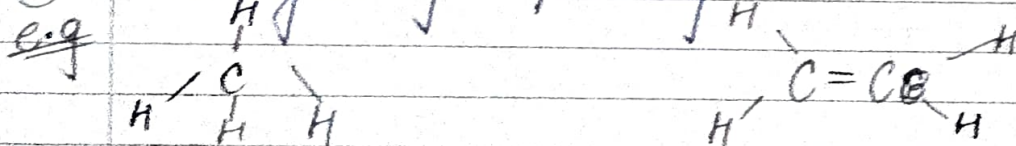
- (6) Higher the s percentage in hybrid orbital, greater will be its electronegativity.

$$s\% = \frac{sp}{50} \cdot 100 = 50\% \quad \frac{sp^2}{\left(\frac{1}{3} \times 100\right)} \cdot 100 = 33\% \quad \frac{sp^3}{\left(\frac{1}{4} \times 100\right)} \cdot 100 = 25\% \quad \frac{sp^3d}{\left(\frac{1}{5} \times 100\right)} \cdot 100 = 20\% \quad \frac{sp^3d^2}{\left(\frac{1}{6} \times 100\right)} \cdot 100 = 16\%$$

Electronegativity:

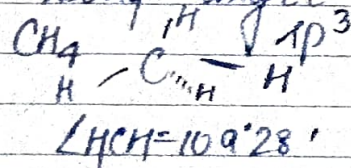
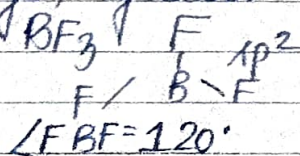
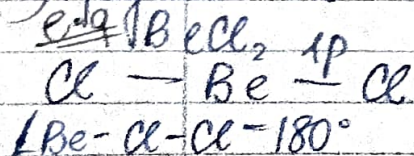


(*) Electronegativity & polarity



Higher the $s\%$, more close to nucleus. $\rightarrow$ More electronegative
 $\rightarrow$ More polar

- (7) Higher the s percentage, greater is the bond angle



(b) Higher the ρ percentage in hybrid orbital, greater will be the bond length.

④ Find the χ character in sp^3d , sp^3d^2 , and sp^3 hybrid orbitals.

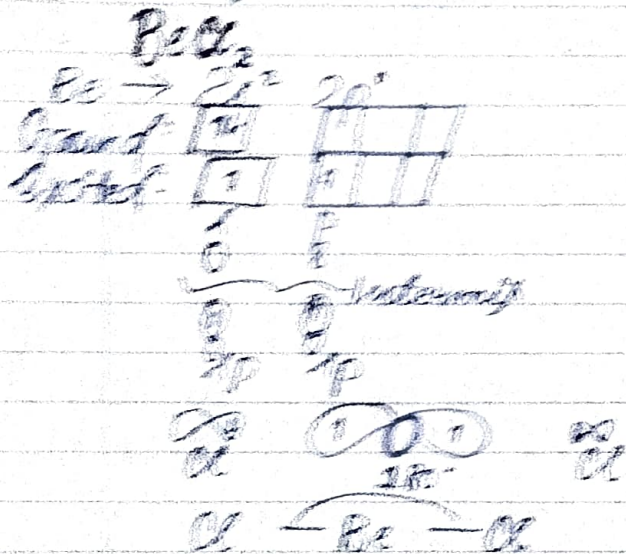
$$1.438 = \frac{3 \times 10^3}{E} = 60 \times 10^{-6}$$

225

$$10^3 d^2 = \frac{Z \times 10^3}{82} = 60.1$$

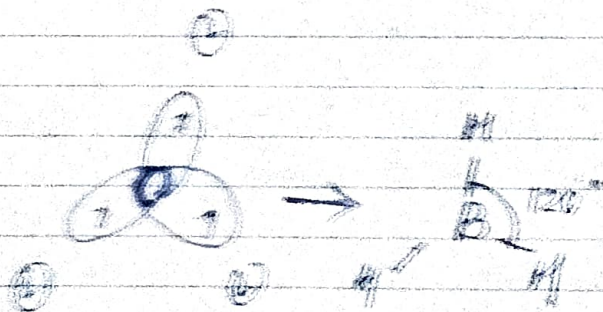
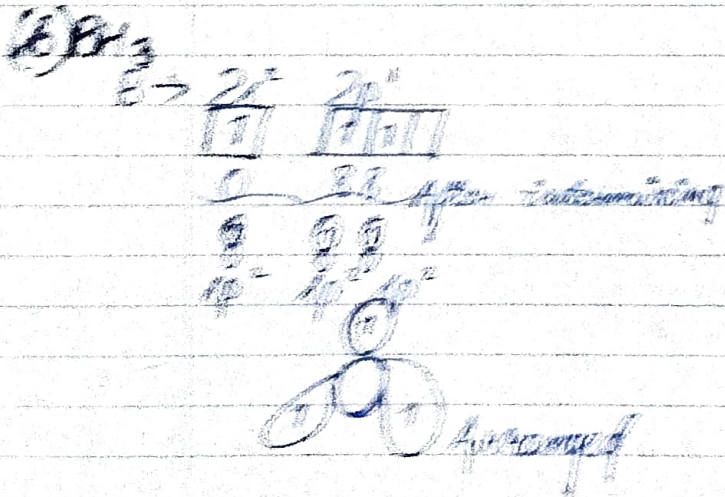
- 75 -

Analysis of overlapping in Hybrid orbitals:-

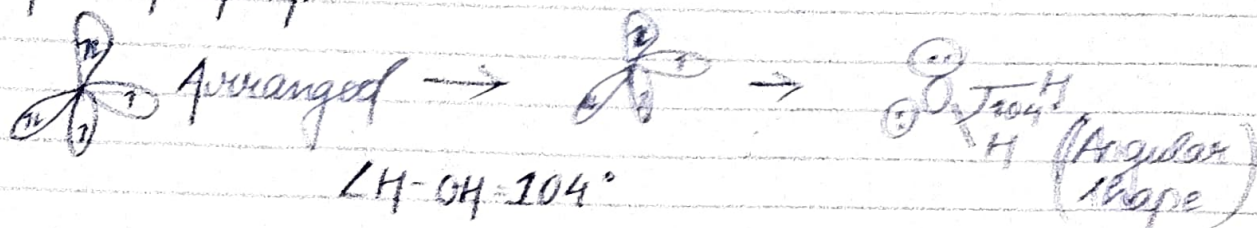
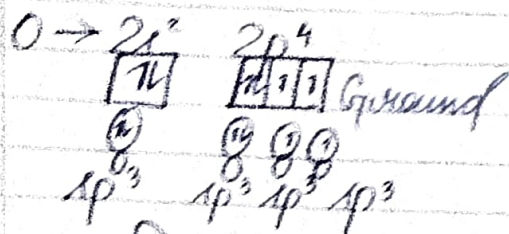


* According to Hydrophilic head forming between sp and p orbitals

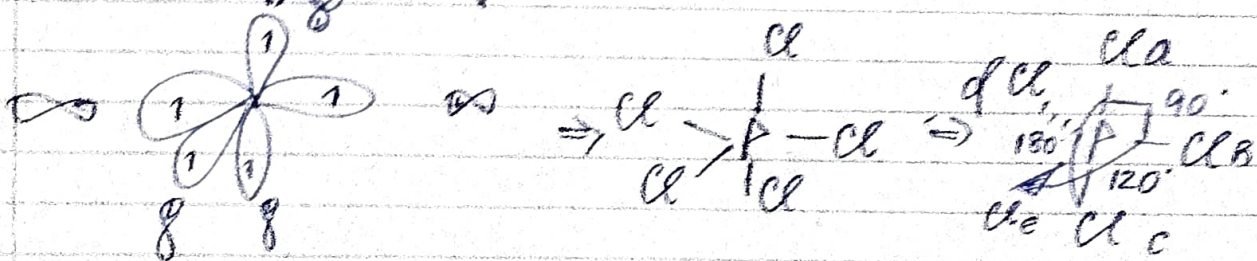
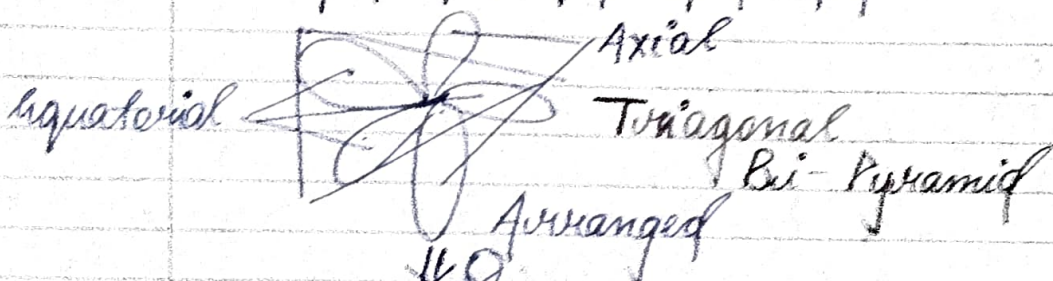
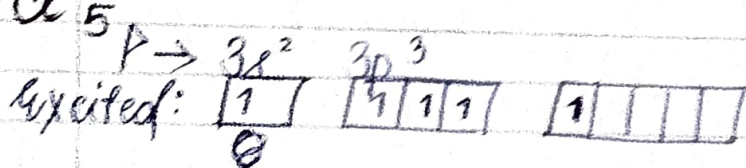
* According to VBT,
bond formed between
d-p and p-p



(c) H_2O



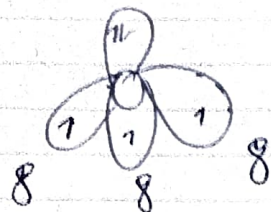
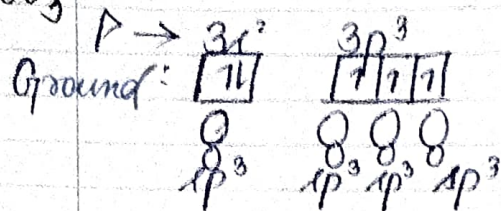
(d) PCl_5



$\angle Cl_a P Cl_a = 180^\circ$
 $\angle Cl_a P Cl_e = 90^\circ$
 $\angle Cl_e P Cl_e = 120^\circ$

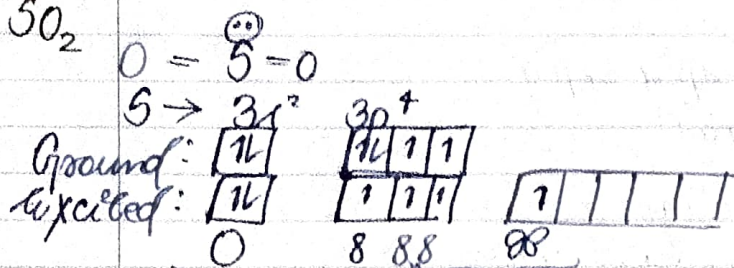
- Cl_a and Cl_e is present in axial position.
- Cl_b , Cl_d & Cl_c are present in equatorial position.

(e) PCl_3



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(f) SO_2



Intermix $\downarrow$

will be utilized for π -bond formation

