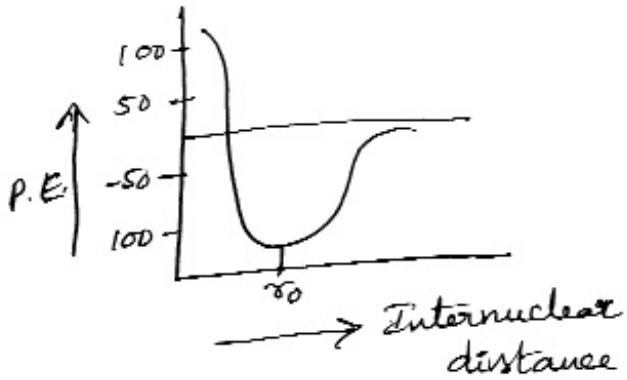
CHEMICAL BOND

Important Points:

- Atoms combine to form molecules.
- Formation of chemical bond involves redistribution of electrons.
- **Ionic Bond:** "The chemical bond formed by the complete transfer of one or more electrons from one atom to other".
  Eg: NaC*l*, MgO
- **Covalent Bond:** "The bond formed by the sharing of electrons between two atoms".
  Eg: H_2, Cl_2, F_2, H_2O
- **Octet configuration:** "The filling up of valence orbital with 8 electrons".
- As the atoms approach each other, the attractive forces between electrons of one atom and the nucleus of other atom increases, results in the decrease of combined potential energy of combined atoms.
- At the critical internuclear distance, the energy of the molecule (or) combined atoms is less than the sum of the energies of individual atoms and thus a chemical bond is formed.

Potential- Energy Level Diagram:



- Zero group elements have stable electronic configuration having 2 (or) 8 electrons.
- A covalent bond is formed by the overlap of two pure atomic orbitals (or) two hybridised orbitals (or) one hybridized and one atomic orbital.
- Strong bond is formed by the maximum overlap of orbitals.
- **Sigma-bond:** End-on-end overlap of orbitals lead to the formation of sigma bond. It is formed by the overlap of s-s orbitals, p-p orbitals and s-p orbital overlap.
- **Pi-bond:** Partial overlap of orbitals lead to the formation of pi (π) bond.
- Sigma bond is stronger than pi-bond, sigma bond exists independently.
  Eg: H_2, HC*l*, Cl_2, CH_4
- π-bond has no independent existence. It exists only after the formation of σ bond.
- In a double bond, one sigma and one π bond are present.
  Eg: C_2H_4, O_2, CO_2, etc.,
- In a triple bond, one sigma and two pi-bonds are present.
  Eg: N_2, C_2H_2, HCN etc.,
- In a co-ordinate covalent bond, both the electrons are supplied by one atom and shared between two atoms.
- The primary requirement for the formation of a covalent bond is that one atom should

have a lone pair of electrons (with octet configuration) to donate and another atom should have an empty orbital to receive it.

Eg: $F_3B \longleftarrow NH_3$, H_3O^+, NH_4^+

- Molecules having linear structure are
  Eg: CO_2, $BeCl_2$, C_2H_2, HCN etc.,
- Molecules having pyramidal structure are
  Eg: NH_3, PCl_3, PH_3, ...
- Molecules having double bond are
  Eg: O_2, CO_2, C_2H_4, ...
- Molecules having triple bond are
  Eg: N_2, HCN, C_2H_2...
- Water molecule have "V" - shape.
- PCl_5 has trigonal bi-pyramidal shape.

PART - A

SECTION - I

Short Answer Questions (2 Marks Each)

1. (a) Draw the shape of PCl_5 molecule.
   (b) Draw the shape of ammonia molecule.
2. Why sigma bond is stronger than pi-bond?
3. Distinguish between sigma bond and pi-bond.
4. Draw the bond formation of H_2 molecule?
5. Explain the formation of sigma and pi-bonds duly showing orbital overlapping.
6. Draw the shapes of the molecules.
   (1) water (H_2O) (2) PCl_3
7. Explain the formation of NH^+_4 ion?
8. Draw the bond formation of HCl molecule?

SECTION - II

Very Short Answer Questions (1 Mark Each)

1. Draw the shape of water molecule.
2. Name the two molecules having pyramidal shape?
3. What is the shape of ammonia molecule? Draw it and explain.
4. Give three examples of molecules having a double bond?
5. Give two examples of molecules having a triple bond?
6. Name two molecules having p-p overlapping?
7. Which orbitals can form pi (π) bond?
8. What is the shape of carbon dioxide molecule?
9. Show the electron dot structure of H_2 molecule?
10. What are multiple covalent bonds? Give examples?

SECTION - III

Long Answer Questions (4 Marks Each)

1. Explain the formation of a double-bond with example?

2. Explain the formation of co-ordinate covalent bond?
3. Explain s–p overlap with examples?
4. Explain the formation of triple bond in Nitrogen molecule?

(or)

Explain the formation of multiple bond with an example?

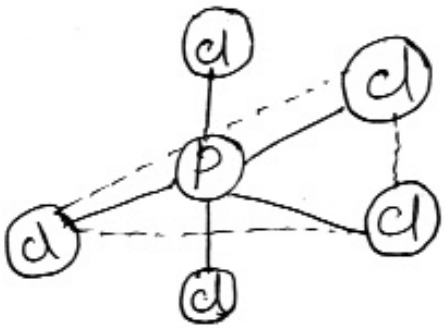
5. Discuss the type of overlaps that are possible with s and p orbitals.

SECTION - IV
DIAGRAMS (5 Marks Each)

1. Draw the bond formation of Hydrogen Chloride and Nitrogen molecules in a diagram.
2. Draw the diagram showing the formation of a double bond (oxygen molecule)?
3. Draw the diagram showing the formation of p–p overlap in fluorine molecule.

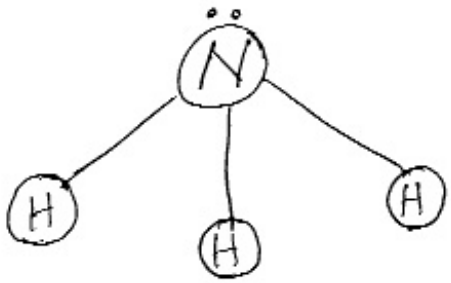
KEY
PART - A
SECTION - I

1.A (a) Phosphorus Penta Chloride (PCl_5):



1) In the vapour state PCl_5 molecule has a "trigonal bi-pyramid" structure.
2) Three chlorines and phosphorus lie in one plane.
3) One chlorine above the plane and one chlorine below the plane are present.

(b) Ammonia molecule (NH_3):



1) Ammonia has a "pyramidal" shape.
2) The three hydrogens in one plane and nitrogen above the plane, as shown in the figure.
3) Nitrogen has one lone pair of electrons in ammonia.

2.A The strength of the bond depends on extent of overlap. The extent of overlap is maximum in sigma bond and minimum in pi-bond. Hence sigma bond is stronger than

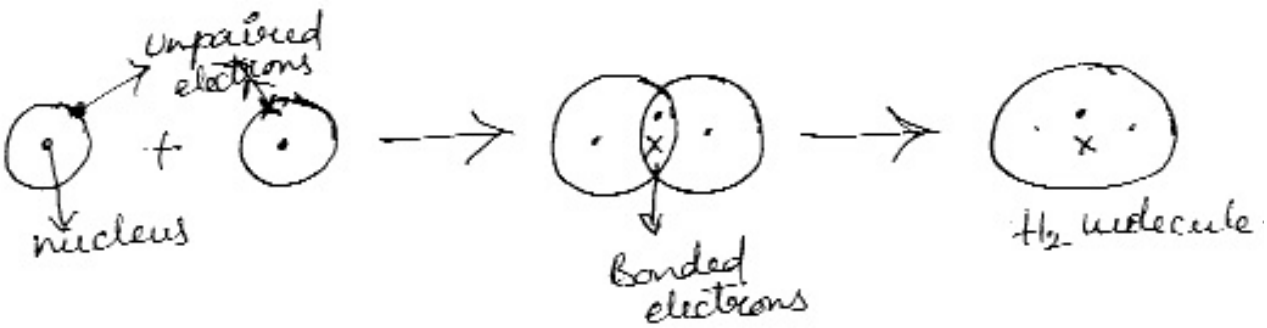
pi-bond.

3.A

Sl.No.	Sigma Bond	Pi - Bond
1	The bond formed by the end-on-end overlap of orbitals of atoms is called sigma bond.	The bond formed by the side-on-overlap of orbitals of atoms is called pi-bond.
2	It has independent existence.	It has no independent existence.
3	It is the strongest bond.	It is the weakest bond.
4	It is formed by the over-lapping of i) s–s ii) s–p and iii) p–p orbitals.	It is formed by the overlapping of i) p–p and ii) p-d orbitals.

4.A Bond Formation of H_2 Molecule:

Consider two hydrogen atoms having one unpaired electron, approaching each other. Each atom has one unpaired electron in '1s' orbital. As these two atoms approach each other, 's' orbital gets overlap at the internuclear distance as shown in the figure and thus a hydrogen molecule is formed due to 's–s' overlap.



5.A (a) Sigma Bond:

(1) A strong bond formed by end-on-end overlap of two orbitals is called a "sigma-bond".

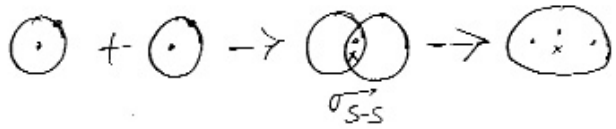
(2) In this type of bond, maximum overlap of orbitals takes place and therefore the bond formed is strong.

(3) Sigma bond can exist independently.
Eg: Molecules having σ bonds are H_2, HCl, Cl_2 etc.,

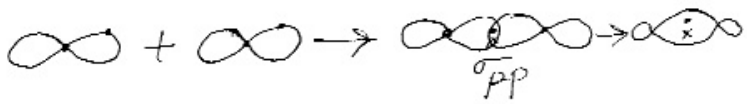
(4) Sigma bond is formed by
(i) s–s overlap
(ii) s–p overlap and

(iii) p–p overlap.

(i) s–s overlap :



(ii) p–p overlap :



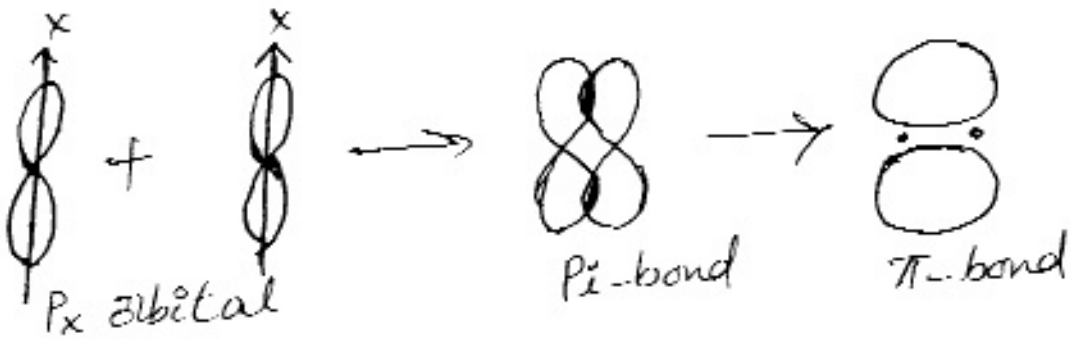
(iii) s–p overlap :



(b) Pi-Bond:

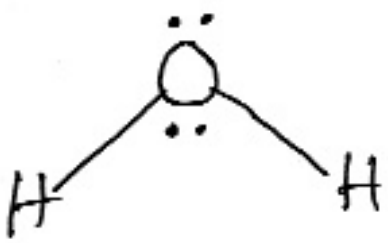
1) A weak-bond formed by lateral overlap of two orbitals is called a pi-bond.
2) The extent of overlap is much less than in σ-bond.
3) It always exists along with a σ-bond.
4) It can not exist independently.

Eg: Molecules having π-bond are C_2H_4, CO_2, N_4O_2 etc.,



6.A 1. Water Molecule:

(1) Water molecule is non-linear and has "V"-shape.
(2) In water molecule, two lone pairs of electrons are present on oxygen atom.

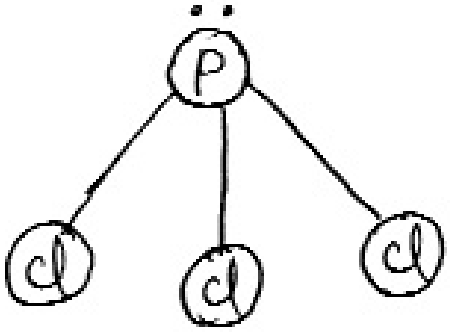


2. PCl_3 molecule:

(1) PCl_3 has "pyramidal shape".

(2) Three chlorines are in one plane and phosphorus lies above the plane.

(3) Phosphorus has one lone-pair of electrons in PCl_5.



7.A Formation of NH_4^+ ion:

(1) In NH_3, a lone pair of electrons are available on Nitrogen [**:**NH_3]

(2) In H^+ ion, the '1s' orbital is empty.

(3) In ammonia (**:**NH_3), nitrogen contributes a pair of electrons for bond formation with H^+.

(4) This results in the formation of co-ordinate covalent bond.

$H^+ + $ **:**$NH_3 \rightarrow [H$ **:** $NH_3]^+$ (or) H $\leftarrow$ **:**NH_3

(or) $[NH_4]^+$

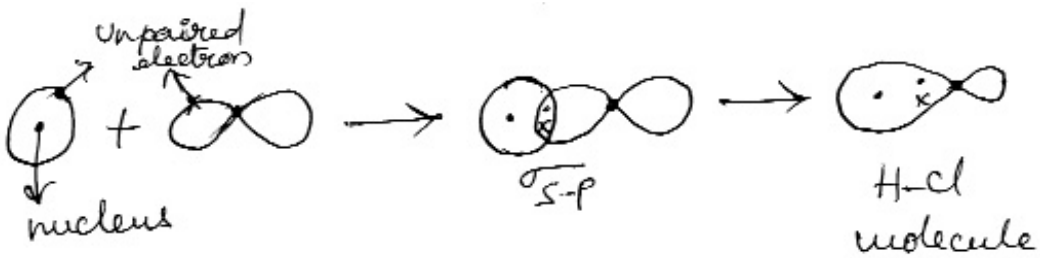
8.A Formation of HC*l* molecule:

(1) Consider the formation of HC*l* molecule.

(2) Hydrogen atom has an unpaired electron is '1s' orbital and chlorine atom has an unpaired electron in $2p_z$ orbital.

(3) As the two atoms approach each other overlap takes place between 's' and 'p' orbitals.

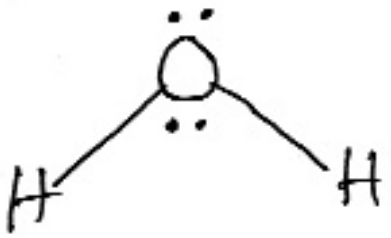
(4) Thus HC*l* molecule is formed by s-p overlap.



SECTION - II
Very Short Answers

1.A 1) Water molecule has 'V'-shape.

2) Oxygen has two lone pair electrons in H_2O molecule.



2.A Molecules having pyramidal shape are

i) ammonia (NH_3)

ii) phosphorus trichloride (PCl_3)

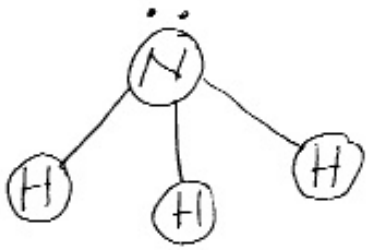
iii) phosphine (PH_3)

3.A Ammonia molecule:

1) NH_3 molecule has a pyramidal structure.

2) Three Hydrogens in one plane and nitrogen is above the plane.

3) Nitrogen has one lone pair of electrons in ammonia.

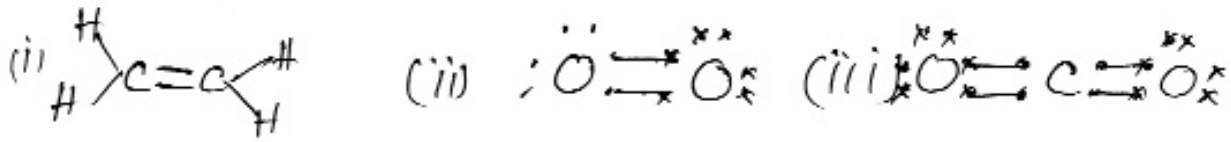


4.A Molecules having a double bond are

i) ethylene (C_2H_4)

ii) oxygen (O_2)

iii) carbon dioxide (CO_2)



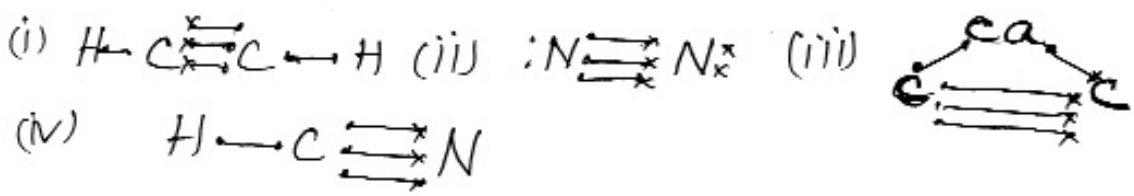
5.A Molecules having a triple bond are

i) acetylene (C_2H_2)

ii) Nitrogen (N_2)

iii) Calcium Carbide (Ca C_2)

iv) Hydrogen Cyanide (HCN)



6.A Molecules having p–p overlap are

(1) Bromine (Br_2)

(2) Chlorine (Cl_2)

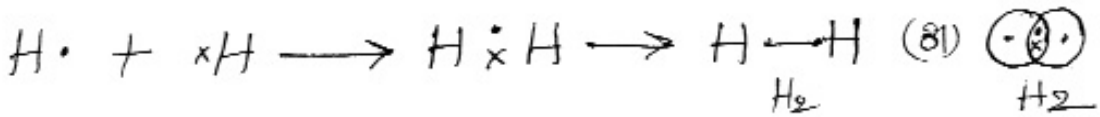
(3) Fluorine (F_2)

(4) Oxygen (O_2)

7.A 'p' and 'd' orbitals can form pi-bonds.

8.A The shape of carbon-di-oxide molecule is linear.

9.A The electron dot structure of H_2 molecule is



10.A "Molecules having double and triple covalent bonds are" called as "multiple covalent bonds".

Eg: 1) Nitrogen molecule (N≡N)

2) Oxygen molecule (O=O)

3) Hydrogen cyanide molecule (H–C≡N)

SECTION - III
Long Answers

1.A **Double Bond:**

"The bond formed by sharing of two pairs of electrons between two atoms" is called a "double bond".

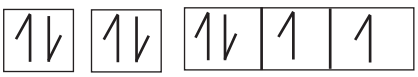
Eg: O_2, CO_2, C_2H_4, etc.,

Formation of Double bond in oxygen molecule:

(1) Consider the formation of oxygen molecule (O_2)

(2) The electronic configuration of oxygen is $1s^2\ 2s^2\ 2p^4$ ie.

$1s^2$ $2s^2$ $2p_x^2\ 2p_y^1\ 2p_z^1$

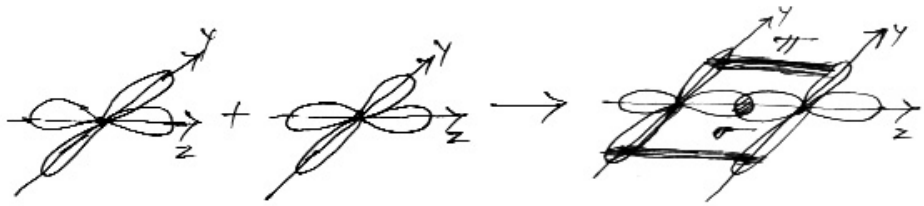


(3) Oxygen has two unpaired electrons one each in $2p_y$ and $2p_z$ orbitals.

(4) The $2p_z$ orbital of one oxygen atom overlap with the '$2p_z$' orbital of another oxygen by end-on-end overlap resulting in the formation of a 'σ' bond.

(5) Two '$2p_y$' orbitals of two oxygen atoms are parallel to each other, and perpendicular to $2p_z$. So '$2p_y$' orbitals overlap side-ways and form a 'π'-bond.

(6) Thus oxygen molecule is formed by one sigma bond and one pi-bond and having a double bond.



2.A Co-ordinate Covalent Bond:

A chemical bond formed by the sharing of an electron pair, contributed by one of the two combining atoms is called "co-ordinate covalent bond".

Eg: NH_3 BF_3, NH^+_4, H_3O^+ etc.,

Formation of Ammonia-Boron Trifluoride molecule:

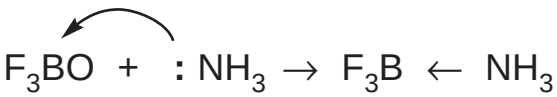
(1) Ammonia molecule has pyramidal shape and has a lone pair of electrons on nitrogen.

(2) Boron Trifluoride (BF_3) molecule has an empty orbital.

(3) NH_3 molecule donates an electron pair to BF_3 and forms a "co-ordinate covalent bond".

(4) Co-ordinate covalent bond is designate as "$\rightarrow$" from donor to acceptor.

(5) Nitrogen donates its lone pair of electrons and Boron accepts. Thus Ammonia Boron Tri-fluoride molecule is formed by the formation of a "co-ordinate covalent bond".



3.A s–p overlap:

"The overlap of 's' orbital of one atom and 'p' orbital of another atom" is called "s–p overlap".

Eg: HC*l*, HF, HBr

Formation of HC*l* molecule:

(1) Consider the formation of HC*l* molecule.

(2) The electronic configuration of hydrogen is '1s' and the the electronic configuration of chlorine is $1s^2\ 2s^2\ 2p^5\ 3s^2\ 3p^5$

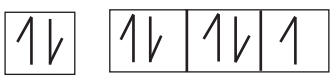
Hydrogen : $1s^1$ 

Chlorine : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

$1s^2$ $2s^2$ $2p^6$



$3s^2$ $3p_x^2$ $3p_y^2$ $3p_z^1$

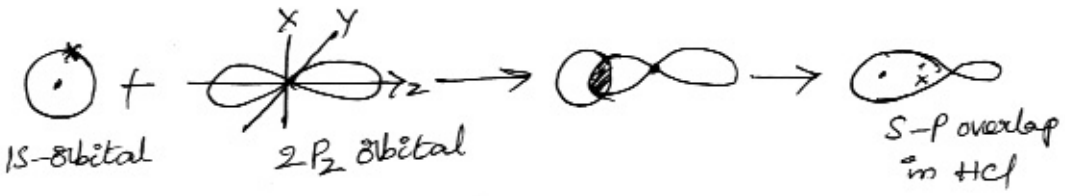


(3) Hydrogen atom has one unpaired electron in '1s' orbital and chlorine has one unpaired electron in '$3p_z$' orbital.

(4) When the two atoms approach other, overlap takes place between s and p orbitals at

inter nuclear distance.

(5) Thus HC*l* molecules is formed due to s–p overlap.



4.A Triple Bond:

"The bond formed by sharing of three pairs of electrons between two atoms", is called "Triple covalent bond".

Eg: N_2, C_2H_2, HCN etc.,

Formation of a Triple Bond in Nitrogen Molecule:

(1) The electronic configuration of nitrogen is N = 7 = $1s^2\ 2s^2\ 2p^3$ =

$1s^2$ $2s^2$ $2p_x^1\ 2p_y^1\ 2p_z^1$



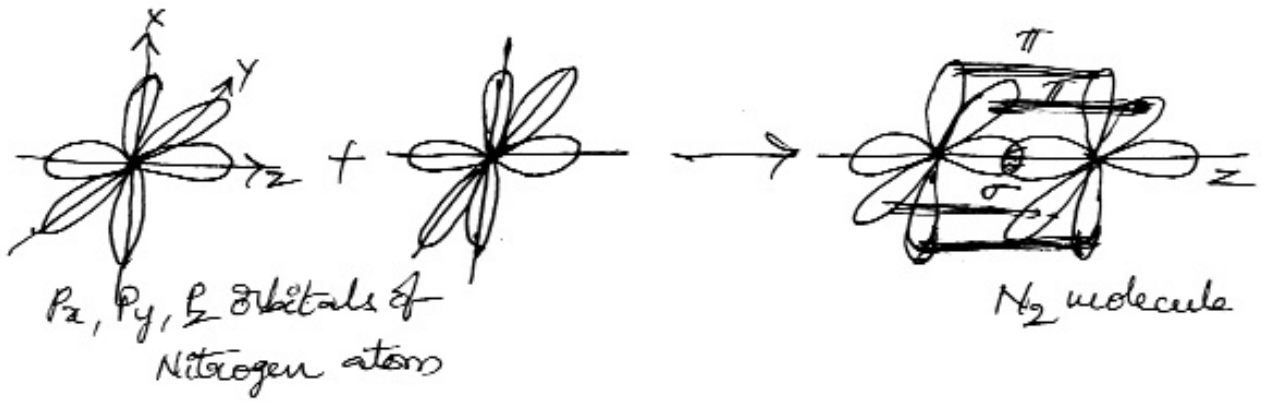
(2) There are three unpaired electrons, one each in $2p_x$, $2p_y$, $2p_z$ orbitals.

(3) The two $2p_z$ orbitals of two nitrogen atoms overlap end-on-end to form a sigma (σ) bond.

(4) The remaining two orbitals $2p_y$ and $2p_z$ are perpendicular to each other, hence these orbitals overlap sideways to give rise to two π-bonds.

(5) Thus, in nitrogen a triple bond is formed.

(6) In nitrogen molecule, one sigma bond and two pi bonds are present.



5.A Overlapping with 's' and 'p' orbitals:

Three types of overlaps are possible with 's' and 'p' orbitals. They are

(i) s–s overlap

(ii) p–p overlap

(iii) s–p overlap

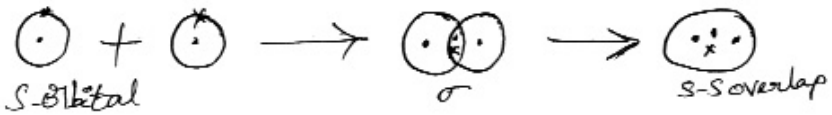
(i) s–s overlap: The overlap of 's' orbitals of two atoms is called 's–s' overlap.

Eg: H_2

Formation of H_2 molecule:

(1) Consider two hydrogen atoms having one unpaired electron each in '1s' orbital.

(2) As two hydrogen atoms approach each other, '1s' orbitals of two atoms overlap by end-on-end manner and forms a sigma bond.



(ii) p–p overlap: The overlap of 'p' orbitals of two atoms is called "p–p overlap".
Eg: F_2, Cl_2, Br_2...

Formation of F_2 molecule:

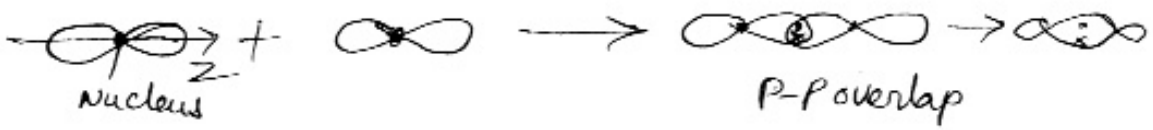
(1) The electronic configuration of fluorine atom is F = 9 =

$1s^2$ $2s^2$ $2p_x^2$ $2p_y^2$ $2p_z^1$

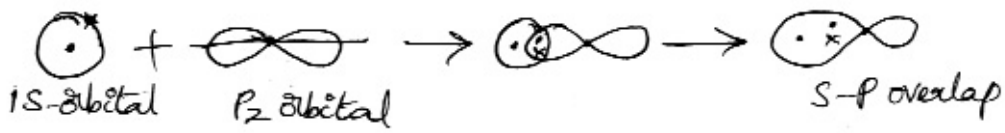


(2) Fluorine atom has one unpaired electron in '$2p_z$' orbital.

(3) So, when two fluorine atoms approach each other. Their $2p_z$ orbitals overlap by end-on-end manner and forms a sigma bond.



(iii) s–p overlap: "The overlap of 's' orbital of one atom and 'p' orbital of another atom" is called "s–p" overlap.
Eg: HC*l*, HF, HBr

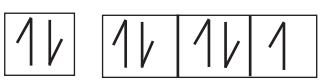


Formation of HC*l* molecule:

(1) The electronic configuration of hydrogen and chlorine are $1s^1$ and $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ respectively.

(2) Hydrogen = $1s^1$ 

Chlorine = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_x^2\ 3p_y^2\ 3p_z^1$

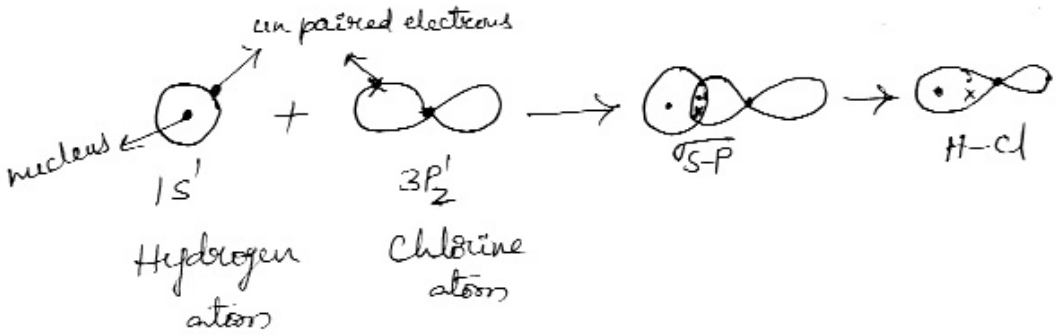


(3) Hydrogen has one unpaired electron in '1s' orbital and chlorine has one unpaired electron in '$3p_z$' orbital.

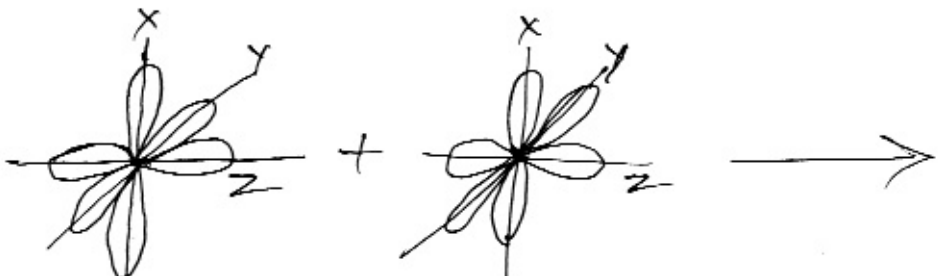
(4) When these two atoms approach each other, their 1s and $3p_z$ orbitals overlap by end-on-end manner and forms a sigma bond.

SECTION - IV
DIAGRAMS
(5 Marks Each)

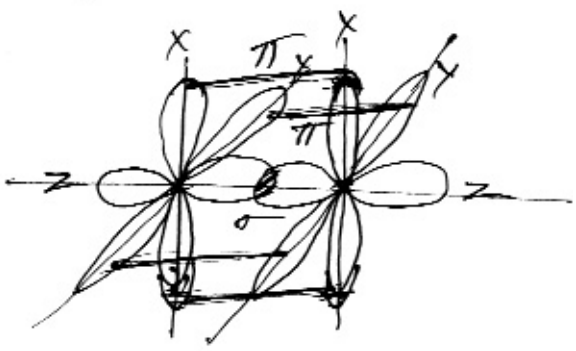
1.A (a) Bond formation of HC*l*:



(b) Bond formation in N_2 molecule:

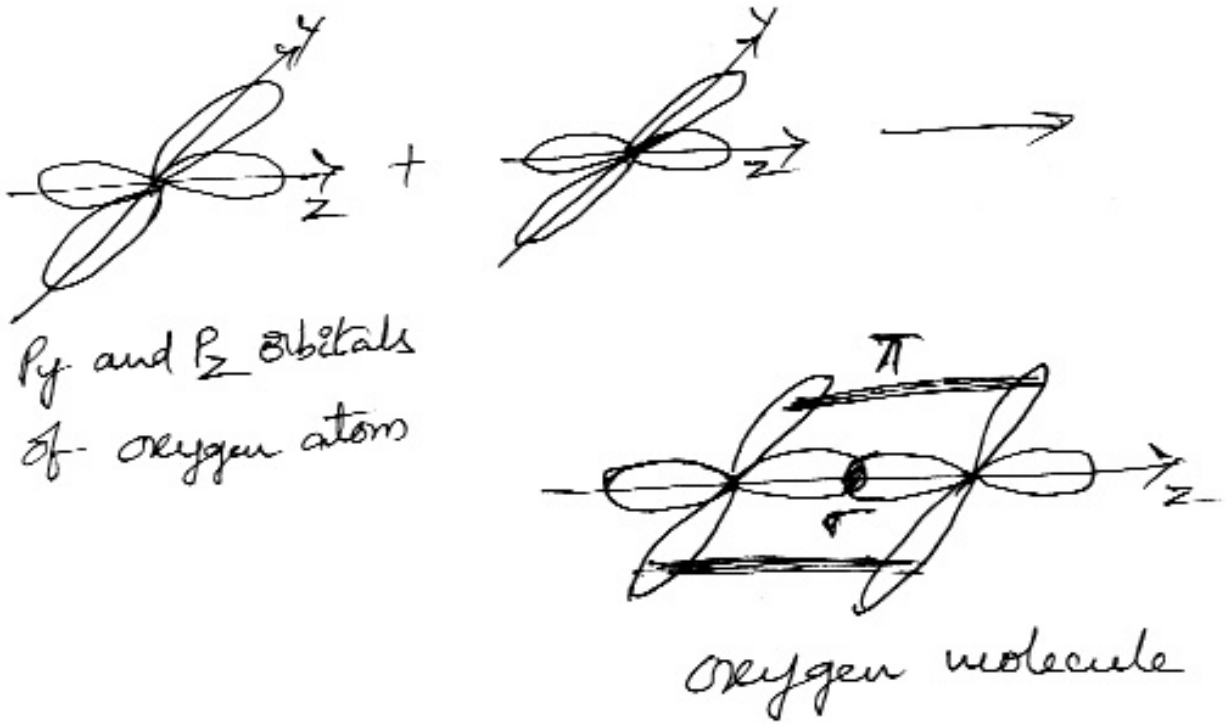


P_x, P_y, P_z orbitals of nitrogen atom.

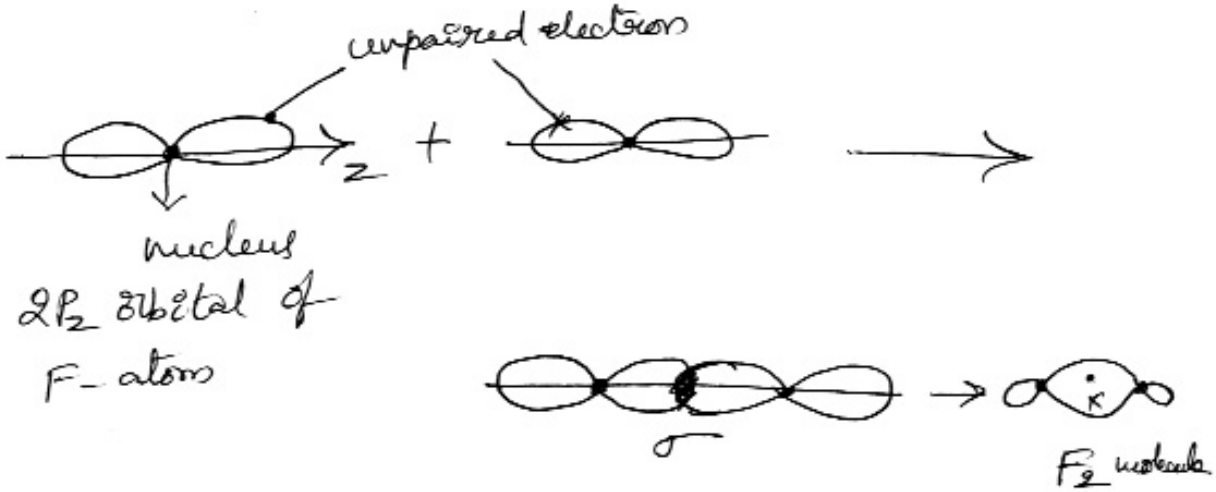


N_2 molecule

2.A Formation of a Double Bond in O_2 molecule:



3.A p–p overlap in F_2 molecule:



PART - B

I. Multiple Choice Questions (1/2 Mark Each)

1. Shape of CO_2 is
   A) V-shape
   B) Pyramidal
   C) Linear
   D) Tetrahedral

2. End-on-End overlap results in
   A) pi-bond
   B) sigma bond
   C) hydrogen bond

D) ionic bond

3. The number of valency electrons in carbon atom.
   A) 0
   B) 2
   C) 4
   D) 6

4. The octet rule is not valid for the molecule
   A) CO_2
   B) SO_2
   C) H_2O
   D) O_2

5. "V" shaped molecule is
   A) PCl_3
   B) H_2O
   C) PCl_5
   D) NH_3

6. s–p overlap is present in
   A) H_2
   B) Cl_2
   C) O_2
   D) HCl

7. An element has the electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$. Its valence electrons are
   A) 2
   B) 6
   C) 3
   D) 4

8. Co-ordinate covalent bond is present in
   A) HCl
   B) H_2O
   C) H_3O^+
   D) H_2

9. A triple bond has
   A) one σ, two π bonds
   B) one π, two σ bonds

C) three σ bonds
D) three π bonds

10. The shape of Boron Trifluoride molecule is
A) Planar triangular
B) Linear
C) Trigonal bi-pyramidal
D) Tetrahedral

11. In ammonia Boron trifluoride, the donor is
A) Boron
B) N and B
C) N
D) None

12. The no.of σ and π bonds in CO_2
A) 1 and 2
B) 2 and 1
C) 2 and 2
D) 3 and 3

13. Bond angle in water molecule is
A) 109°28'
B) 120°
C) 180°
D) 105°

14. Molecule having single bond is
A) O_2
B) N_2
C) CO_2
D) HCl

15. The type of bond present in ethylene is
A) single bond
B) double bond
C) triple bond
D) ionic bond

II. Fill in the blanks (1/2 Mark Each)

16. The shape of ammonia molecule is _____
17. The shape of PCl_5 molecule is _____
18. The bond angle in H_2O molecule is _____
19. The strength of bond depends on _____
20. The bond in HCN is _____

21. The chemical formula of hydronium ion is _____
22. Sigma bond is formed by _____ overlap of orbitals.
23. Covalent bond was suggested by _____
24. The filling of valence orbital with 8 electrons is called _____
25. The bond present in NH^+_4 molecule is _____
26. _____ bond is formed by maximum overlap of orbitals.
27. In co-ordinate covalent bond, both the electrons are supplied by _____
28. The bond that can not exist independently is _____
29. The shape of acetylene molecule is _____
30. The shape of PCl_3 molecule is _____

III. Match the following (1/2 Mark Each)

I.

	Group - A		**Group - B**
31.	s–s overlap	( )	A) O_2
32.	s–p overlap	( )	B) H_2
33.	p–p overlap	( )	C) NH_4^+
34.	double bond	( )	D) HCl
35.	Co-ordinate covalent	( )	E) Cl_2

II.

	Group - A		**Group - B**
36.	Linear	( )	A) Kossel
37.	Pyramidal	( )	B) PCl_5
38.	Trigonal pyramidal	( )	C) H_2O
39.	Ionic bond	( )	D) CO_2
40.	'V'-shape	( )	E) PH_3

KEY

PART - B

I.

1.	C	2.	B	3.	C	4.	B	5.	B	6.	D	7.	D	8.	C
9.	A	10.	A	11.	C	12.	C	13.	D	14.	D	15.	B		

II.

16.	Pyramidal	17.	Trigonal bi-pyramidal	18.	105°
19.	maximum extent of overlapping	20.	Triple bond		
21.	H_3O^+	22.	end-on-end		
23.	Lewis	24.	octet configuration		
25.	co-ordinate covalent bond	26.	sigma bond	27.	donor
28.	pi-bond	29.	Linear	30.	pyramidal

III.I

31.	B	32.	D	33.	E	34.	A	35.	C

IV

36.	D	37.	E	38.	B	39.	A	40.	C