

# Chemistry

## Short Answer Collection

Year (2026-27)

B.Sc 1st Semester

Chemistry



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**Q1.** What is Fajan's Rule of polarisation ?

**Sol:** Fajan's Rule  $\Rightarrow$

This Rule is for covalent character of an ionic bond. The covalent character of an ionic bond is favoured by -

- i) Small size cation.
- ii) Larger size anion.
- iii) high charge on cation/Anion.

for fixed cation, Larger the size of anion, more the magnitude of charge. Hence more is the covalent character.

**Ex**  $\text{NaI} > \text{NaBr} > \text{NaCl} > \text{NaF}$

for fixed anion, the smaller the size of cation, more is the magnitude of charge. Hence more is the covalent character.

**Ex:**  $\text{BeCl}_2 > \text{MgCl}_2 > \text{CaCl}_2 > \text{SrCl}_2 > \text{BaCl}_2$ .

2. Why the stability of carbocation is in order  $3^\circ > 2^\circ > 1^\circ$  ?

**Sol:-** Carbocation  $\Rightarrow$

Any organic species having the positively charge carbon atom, is called as carbocation. It is formed by heterolytic fission of the bond.



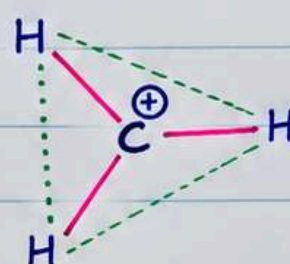
**Structure of carbocation :-**

$$S = (3\sigma + 0 \text{ lp})$$

$$S = 3$$

Hybridisation =  $sp^2$

Geometry : Trigonal planer

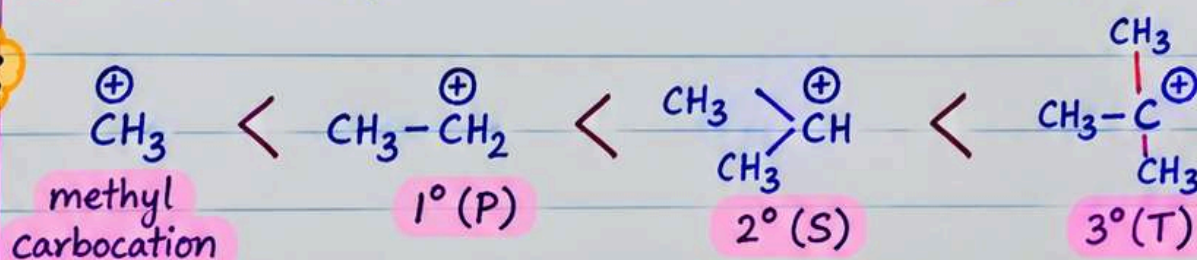


Bond Angle :  $120^\circ$

**Stability order :-**

- (i) +I group increases the stability of carbocation.
- (ii) -I group decreases the stability of carbocation.
- (iii) Hyperconjugation increases the stability of carbocation.

**Ex:**



$\xrightarrow{\text{+I group increases}}$  : Stability Increases

3. Write the difference between Enantiomers and Diastereomers.

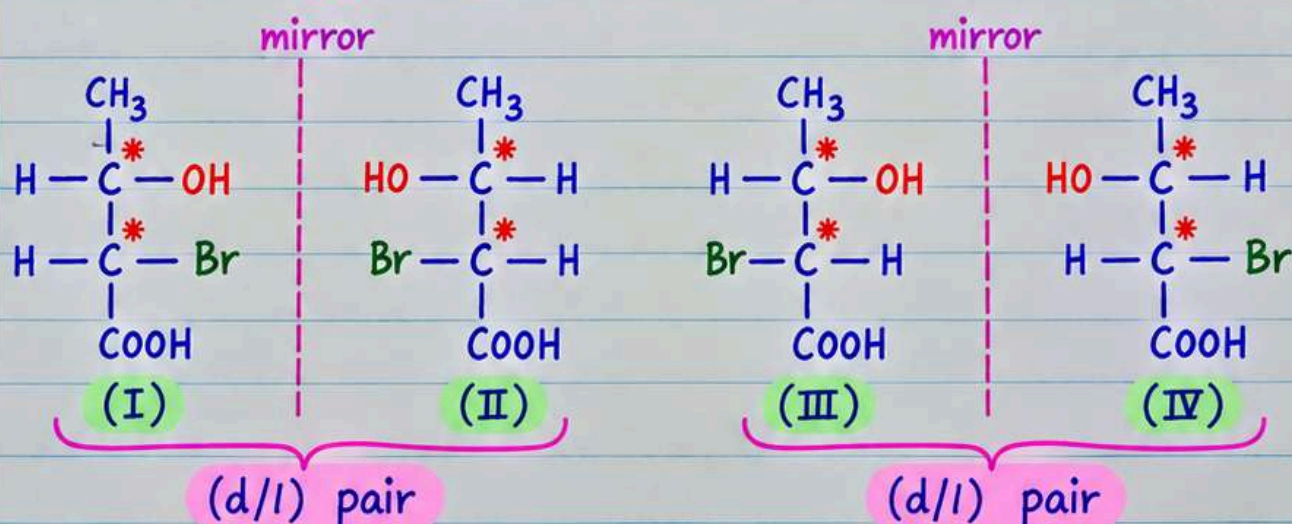
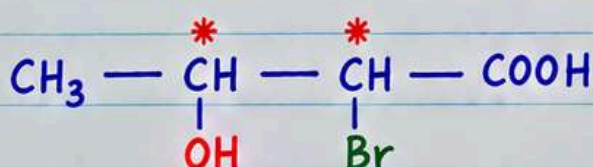
Ans:- Enantiomer pair  $\Rightarrow$

Those stereoisomer pair which has the same molecular formula, mirror image to each other but not superimposable. Such pairs are called Enantiomer pair.

Diastereomer pair  $\Rightarrow$

Those stereoisomers pair which has the same molecular formula, not mirror image to each other and non superimposable. Such pairs are called Diastereoisomers.

Ex:



Enantiomer pair  $\Rightarrow$  (I, II), (III, IV)

Diastereomer pair  $\Rightarrow$  (I, III), (I, IV), (II, III), (II, IV)

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Q. 4

Explain why Formic Acid is a stronger acid than Acetic Acid ?

Ans.:

Acetic Acid ( $\text{CH}_3\text{-COOH}$ )  $\Rightarrow$

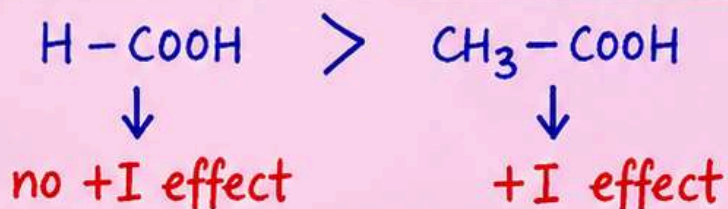
- Acetic acid contains a methyl group ( $-\text{CH}_3$ ), attached directly to the  $-\text{COOH}$  group.
- The  $-\text{CH}_3$  group increases the electron density to  $-\text{COOH}$  group due to **+I effect** (electron donating effect).
- The breaking of O-H bond is hard.

On the other hand —

Formic Acid ( $\text{H-COOH}$ )  $\Rightarrow$

- Formic acid contains a simple H atom, attached directly to  $-\text{COOH}$  group.
- H atom does not show **+I effect**.
- The breaking of O-H bond is easy.

Acidic order  $\Rightarrow$



➔ +I group **decreases** the acidic strength of carboxylic acid.

➔ -I group **increases** the acidic strength of acid.

Q.5

Explain why  $\text{H}_2\text{O}$  is liquid whereas  $\text{H}_2\text{S}$  is a gas ?

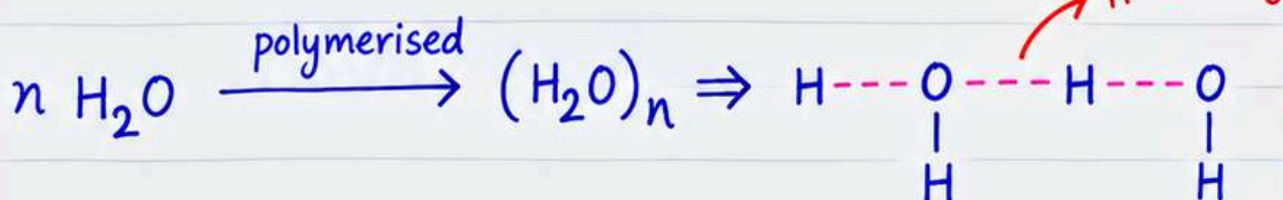
Sol:

**State of  $\text{H}_2\text{O}$  and  $\text{H}_2\text{S}$**   $\Rightarrow$ 

Since O atom is more electronegative than S-atom. Hence the hydrogen bonding is possible in  $\text{H}_2\text{O}$  while it is **absent** in  $\text{H}_2\text{S}$ .



In other words  $\text{H}_2\text{O}$  molecules can **associate** to form a **polymerised molecule**  $(\text{H}_2\text{O})_n$  in which H-atom acts as a bridge between the two O-atoms.



Thus due to the formation of **polymerised  $(\text{H}_2\text{O})_n$**  molecule, **water exist as a liquid.**

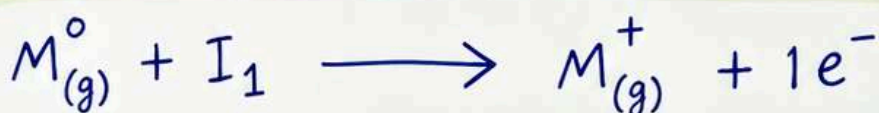
while  $\text{H}_2\text{S}$  in which there is no hydrogen bonding hence **exist as a gas.**



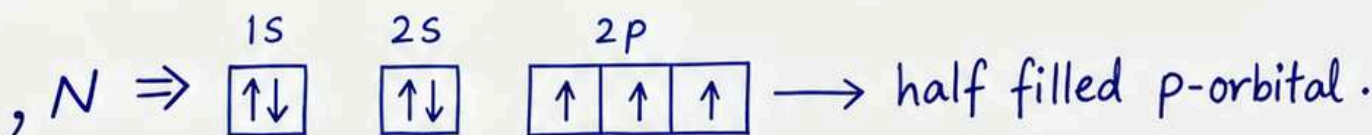
6: Explain, why the first ionisation potential of nitrogen is greater than that of oxygen: ?

Ans: Ionisation Potential  $\Rightarrow$

The amount of Energy required To remove an outermost  $\bar{e}$  from an Isolated neutral gaseous atom to produce a cation, is called its  $I^{st}$ -ionisation potential / ionisation Energy. (I).



The Electronic configuration of N & O-atom are given as-



Due to half filled  $p$ -orbital in case of N-atom, have stable configuration than that of oxygen'.

$\therefore$  it is very difficult to remove an  $\bar{e}$  from N atom than that of oxygen'.

Hence N - have higher ionisation potential than the oxygen atom.

## 7. Differentiate between $\sigma$ and $\pi$ bonds.

### $\sigma$ - Bond

1 This bond is formed by axial or head-on overlapping of atomic orbitals.

2 This bond is strong due to greater extent of overlapping.

3  $e^-$  cloud of  $\sigma$ -bond is symmetrical about the nuclear axis.

4 There are free rotation of bond.

5 This bond is less reactive.

### $\pi$ - Bond

1 This bond is formed by lateral overlapping of atomic orbitals.

2 This is a weak bond due to less extent of overlapping.

3  $e^-$  cloud of  $\pi$ -bond is unsymmetrical.

4 Free rotation is not possible along  $\pi$ -bond.

5 This bond is more reactive.

8.

Write a short note on Internet Applications in Daily life.



Ans:

Internet Application in Daily life ⇒

The Internet has become an important part of our daily life. It helps us communicate, learn, work, shop and entertain ourselves. The major applications are as –



1) **Communication** ⇒ we can send Emails, messages and make video calls using the Internet.



2) **Education** ⇒ Students can Attend online classes, watch educational video, read E-books ..etc.



3) **Online Banking** ⇒ Internet Banking allows us to Transfer money, pay bills, check Bank Accounts from home.



4) **Shopping** ⇒ we can buy clothes, books, groceries and other products through online shopping website.



5) **Entertainment** ⇒ Access to movies, music, games ..etc.



6) **Information** ⇒ search for news, weather update ..etc.

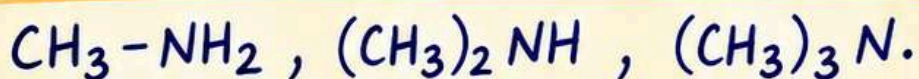


7) **Online Services** ⇒ Filling forms, ticket booking, making Appointment ..etc.



9.

Which is more basic and why ?

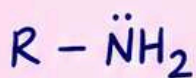


Ans:

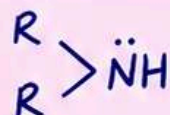
Amines are the derivatives of Ammonia -



Ammonia



1° (1) Amine



2°(s) Amine



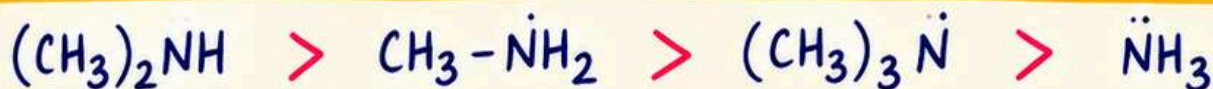
3°(t) Amine.

→ Amines are basic due to presence of lone pair of  $e^-$  on the N-atom.

→ Aliphatic Amines are stronger bases than  $\text{NH}_3$  due to +I effect of Alkyl group.

→ +I ( $e^-$  donating group) increases the probability of lone pair on the N-atom, increases the basic character.

→ In aqueous ( $\text{H}_2\text{O}$ ) solution, the order of basicity of Amine is -



2° (s)

1° (p)

3° (t)

Ammonia

→ In the non aqueous solution, the order of basicity is



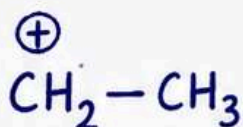
10.

out of  $(\text{CH}_3)_3\text{C}^+$  and  $(\text{CH}_3)_2\text{CH}^+$  carbocations which is more stable and why. ?

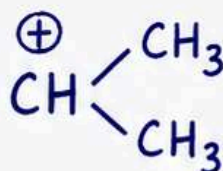
**Sol:**  $\Rightarrow$  Carbocation  $\Rightarrow$  having the +ve charge on C-atom.



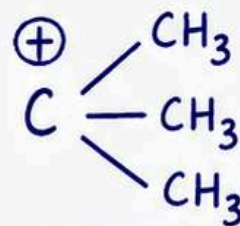
methyl cation,



$1^\circ (\text{P})$



$2^\circ (\text{S})$

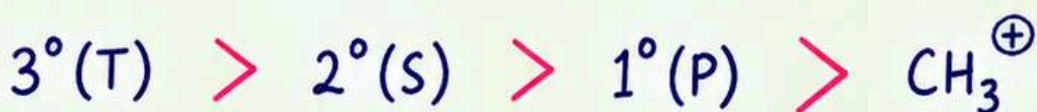


$3^\circ (\text{T})$

$\xrightarrow{\text{+I group increases.}}$

$\Rightarrow$  +I ( $\bar{e}$  donating group) group increases the stability of carbocation.

$\therefore$  Stability order of Carbocation is –



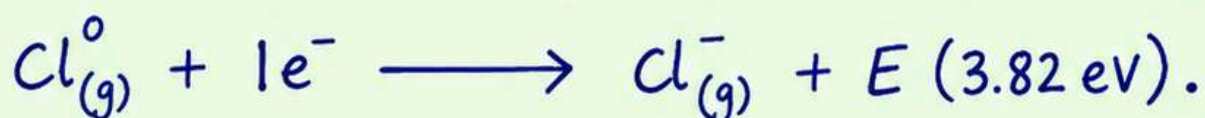
$\therefore (\text{CH}_3)_3\text{C}^+$  is more stable than  $(\text{CH}_3)_2\text{CH}^+$

11.

Distinguish between electron affinity and electronegativity.

(a) **Electron Affinity**  $\Rightarrow$

The amount of Energy released when an electron is added to an neutral gaseous atom in its ground state to produce an anion.



(b) **Electronegativity**  $\Rightarrow$

The tendency of an atom to attract the shared pair of  $e^-$  towards itself in a covalent bond, is called as electronegativity of that atom.

$\Rightarrow$  F is most electronegative elements in the Periodic Table having value 4.0,

$\Rightarrow$  The value of electronegativity of an elements is not constant. But it is different in different oxidation state of elements.

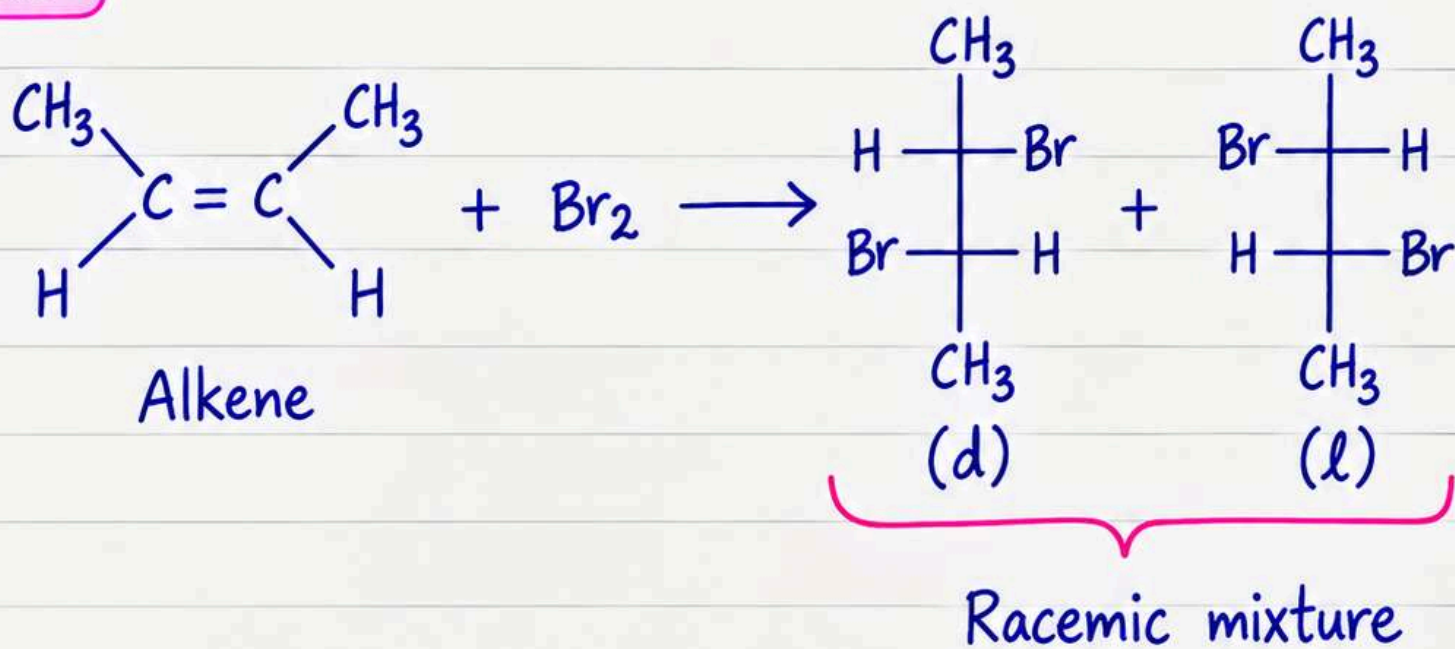
12.

What is a Racemic mixture ? Describe one method of its resolution.

**Ans :** Racemic mixture  $\Rightarrow$

: A mixture containing two enantiomers in equal amount (50% d + 50% l), will have zero optical rotation because the rotation of one Isomer will be cancelled out by the rotation of other Isomer. Such a mixture is called Racemic mixture.

**Ex :**



13.

Write a short Note on Electrophile and Nucleophile.

(a) Electrophile ( $E^+$ )  $\Rightarrow$

- I Electron pair acceptor .
- II electron deficient species .
- III +ve charge / neutral ( $e^-$  deficient)

Ex :  $\text{NO}_2^+$  ,  $\text{BF}_3$  ,  $\text{AlCl}_3$  ,  $\text{H}^+$  , etc .

(b) Nucleophile ( $\text{Nu}^-$ )  $\Rightarrow$

- I electron pair donor species .
- II electron rich system .
- III -ve charge / lone pair present on species .

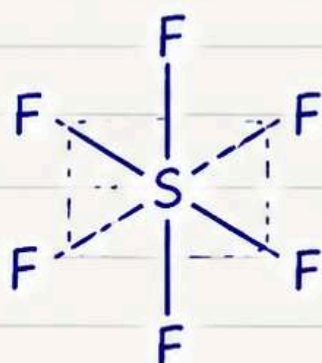
Ex :  $\text{CN}^-$  ,  $\text{OH}^-$  ,  $\text{Cl}^-$  ,  $\text{NH}_3$  , etc .

14.

On the basis of hybridisation, explain shapes of the following molecules -  
 $\text{SF}_6$ ,  $\text{H}_2\text{O}$ ,  $\text{XeF}_4$ .

Ans :

(i)  $\text{SF}_6 \Rightarrow$



Steric No (S) = No. of  $\sigma$  bond + lone pair

$$S = (6 \text{ bp} + 0 \text{ lp})$$

$$S = 6$$

Hybridisation =  $sp^3d^2$

Geometry / Shape = octahedral

Bond Angle =  $90^\circ$

(ii)  $\text{H}_2\text{O} \Rightarrow$



$$S = 2 \text{ bp} + 2 \text{ lp}$$

$$S = 4$$

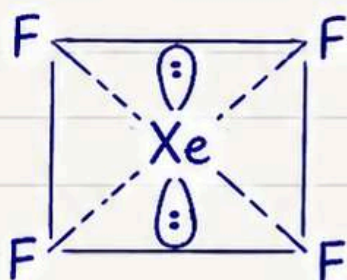
Hybridisation =  $sp^3$

Geometry = Tetrahedral

Shape = Bent / V-shape

Bond Angle =  $104.5^\circ$

(iii)  $\text{XeF}_4 \Rightarrow$



$$S = (4 \text{ bp} + 2 \text{ lp})$$

$$S = 6$$

Hybridisation =  $sp^3d^2$

Geometry = octahedral

Shape = square planar

Bond Angle =  $90^\circ$

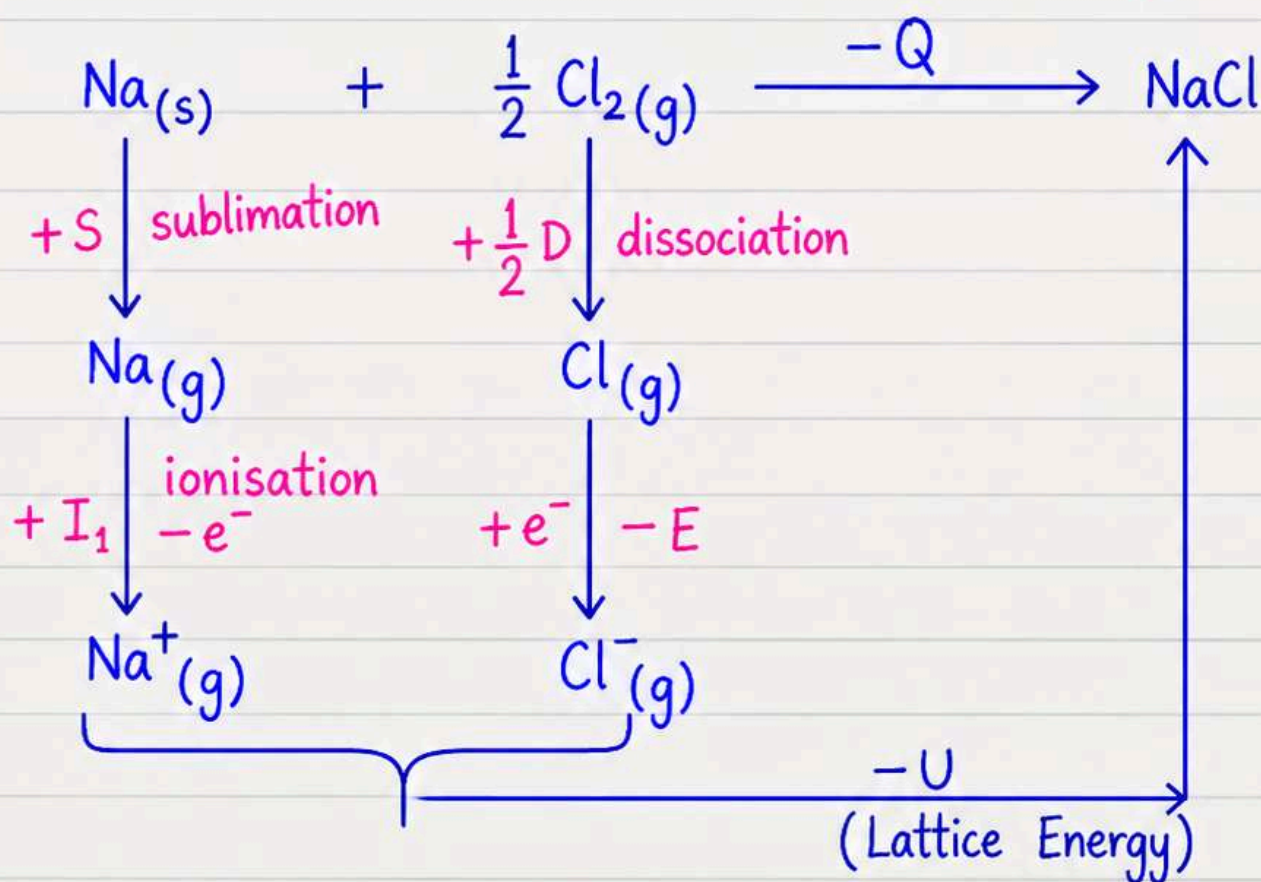
15.

Define Born-Haber cycle ?

Ans: Born-Haber cycle  $\Rightarrow$ 

This cycle is based on the fact that one mole of an ionic crystal may be formed either by the direct combination of elements or by an alternative process which involve many steps.

Ex: Formation of NaCl takes place in two ways -



Acc. to Hess law -

$$-Q = +S + \frac{1}{2}D + I_1 - E - U$$

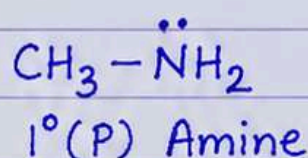
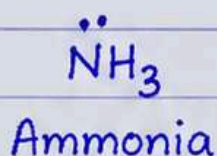
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**16.** Explain why methyl amine is stronger base than Ammonia ?

**Ans.** Amines are the derivative of Ammonia .



- ⇒ Ammonia is a basic, due to presence of lp  $e^-$  on N-atom.
- ⇒ +I (electron donating) group increases the probability of lp  $e^-$  on N-atom, increases the basic strength.
- ⇒ due to +I effect of methyl group in  $1^\circ(\text{P})$  Amine, it is more basic than  $\text{NH}_3$ .

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**18.** Discuss the molecular structure and hybridisation of the following ?

(i) methane      (ii) acetylene.

**Ans.**

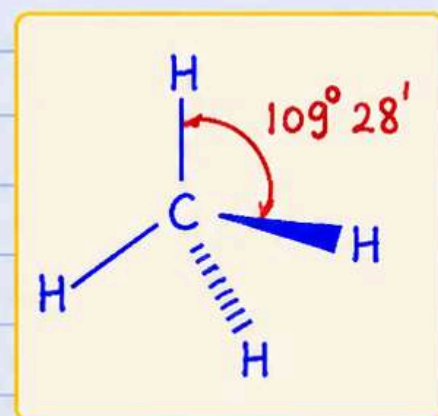
(i) Methane :  $\text{CH}_4$

→ Steric no. (S) =  $4 \text{ bp} + 0 \text{ lp} = 4$

→ Hybridisation =  $\text{sp}^3$

→ Geometry / shape = Tetrahedral

→ Bond angle =  $109^\circ 28'$



(ii) Acetylene :  $\text{H} - \text{C} \equiv \text{C} - \text{H}$

→ Steric no. of C-atom =  $2 \text{ bp} + 0 \text{ lp} = 2$

→ Hybridisation =  $\text{sp}$

→ Geometry / shape = Linear

→ Bond angle =  $180^\circ$



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19.

Write the full form of the following ?  
VDU , ALU , CPU , RAM , CU , ROM .

Ans.

VDU  $\Rightarrow$  Visual Display Unit

ALU  $\Rightarrow$  Arithmetic Logic Unit

CPU  $\Rightarrow$  Central Processing Unit

RAM  $\Rightarrow$  Random Access Memory

CU  $\Rightarrow$  Control Unit

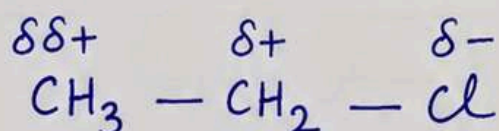
ROM  $\Rightarrow$  Read Only Memory

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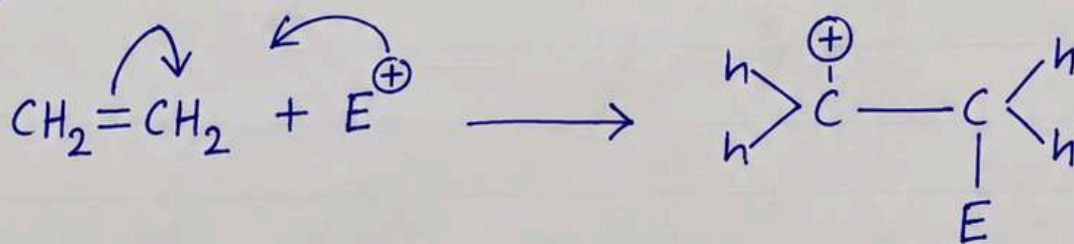
20. what is the difference between Inductive and Electomeric Effect ?

sol<sup>n</sup>:

(a) Inductive Effect  $\Rightarrow$  The polarisation of carbon-carbon single bond due to adjacent polar group, is called as Inductive Effect and The group which is responsible for polarisation, is called Inductive ~~effect~~ group. It is a permanent Effect and decreases as the distance from source Increases.



(b) Electomeric Effect  $\Rightarrow$  polarisation of carbon-carbon multiple bond due to Incoming group (Electrophile / Nucleophile), is called Electomeric Effect ; it is a Temporary Effect and depends upon The Attacking reagent.



Expt. No. ....

Date : .....

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21. Explain difference between Atomic and Ionic radius ?

Ans. **Atomic Radius :**

Atomic radius measures the size of a neutral atom. It is defined as -

"The distance between the nucleus of an atom and the  $e^-$  cloud of the outermost shell".

It is obtained by X-ray and measured in  $\text{\AA}^\circ$ .

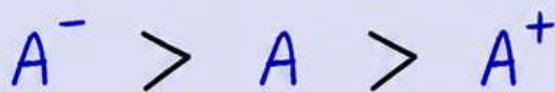
**Ionic Radius :**

The ionic radius measures the size of an atom that gained or lost electrons to become a -ve or +ve ion.

⇒ The value of ionic radii depends upon the +ve as well as -ve ions.

⇒ Radius of -ve ion is larger than the corresponding neutral atom.

Ex.



Teacher's Signature : \_\_\_\_\_

22. Write the Aufbau principle with Example ?

Sol. Aufbau is a German word which means "Built up".  
Acc. to this principle - "The orbitals are filled in order of increasing Energy level." as .

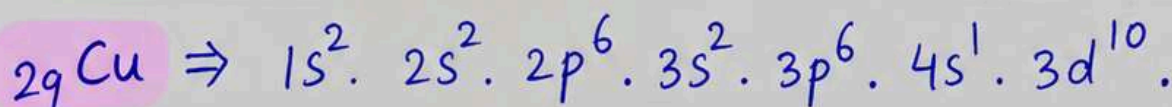
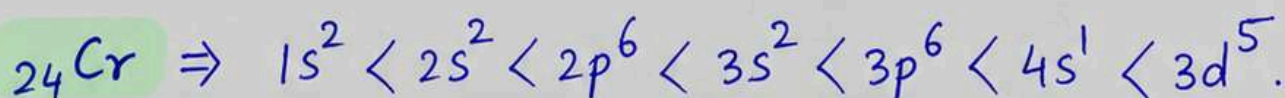
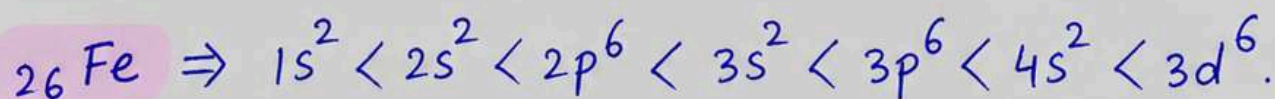


This order can be explain with the help of  $(n+l)$  Rule.

$(n+l)$  Rule  $\Rightarrow$

- i) a new  $\bar{e}$  can Enter into the orbital for which  $(n+l)$  is minimum.
- ii) if  $(n+l)$  has same value for Two orbitals then the new  $\bar{e}$  can Enter into the orbital for which  $n$  is minimum.

Ex.

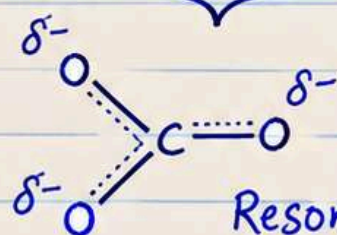
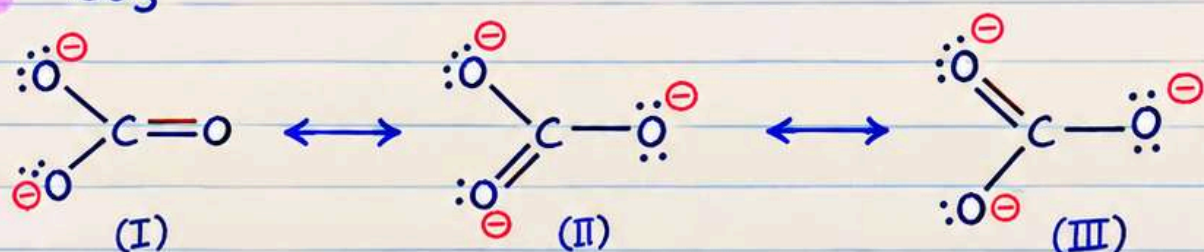


**Q.23** What is meant by resonance ? Explain with suitable example.

**Sol.** Resonance Effect  $\Rightarrow$

The delocalisation of  $\pi$ -electrons are called Resonance. Resonance is a hypothetical state of chemical species in which the electronic structure of molecule can be represented by two or more than two resonating/canonical forms. The real structure is inbetween these resonating forms which is called Resonance Hybrid Structure.

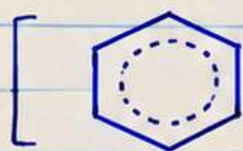
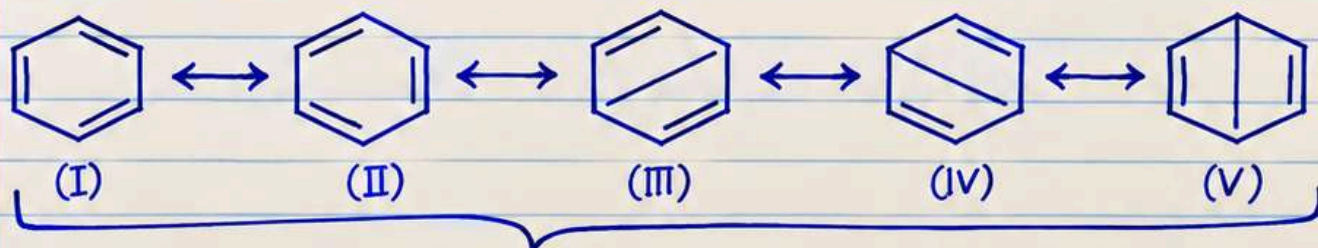
**Ex:**  $\text{CO}_3^{2-}$



Bond order = 1.33

Resonance Hybrid Str. of  $\text{CO}_3^{2-}$

**Ex:** Benzene



Resonance Hybrid Str. of Benzene

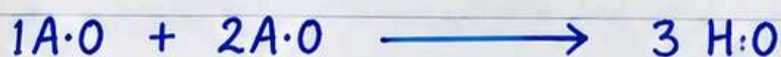
## Q. 24 Define hybridisation. How it is classified ?

### Hybridisation $\Rightarrow$

Before the overlapping, the mixing of atomic orbitals of central atom (having approximately same energy) to form new hybrid orbitals of same energy. Then this process is called as **hybridisation**.

$\Rightarrow$  Hybridisation is **not a physical process** but it is only **hypothetical**, which is used to explain the shape and geometry of simple molecules that can not be explained by VBT.

Atomic orbital + Atomic orbital  $\xrightarrow{\text{mixed}}$  Hybrid orbitals



No. of atomic orbitals taken part in mixing  $\Rightarrow$  No. of hybrid orbitals formed.

### Types of Hybridisation $\Rightarrow$

- (ii)  $sp$  - hybridisation
- (iii)  $sp^2$  - hybridisation
- (iii)  $sp^3$  - hybridisation
- (iv)  $sp^3d$  - hybridisation
- (v)  $sp^3d^2$  - hybridisation
- (vii)  $sp^3d^3$  - hybridisation

Ques. 25. what do you understand by optical Activity ?

Sol. optical Activity  $\Rightarrow$

Those molecule which rotate the plane polarised light (PPL) Towards clock wise or Anticlock wise direction, are called optically Active molecules.

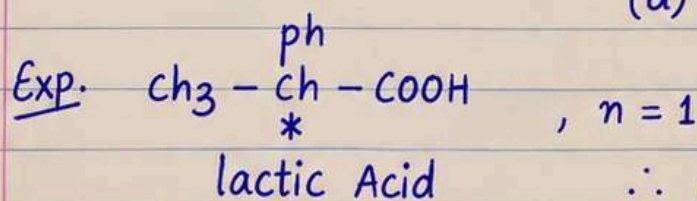
and Those molecules which does not rotate the PPL, are called optically Inactive molecules.

$\Rightarrow$  Therefore, the primary condition for optical Activity of molecule is Presence of chiral centre.

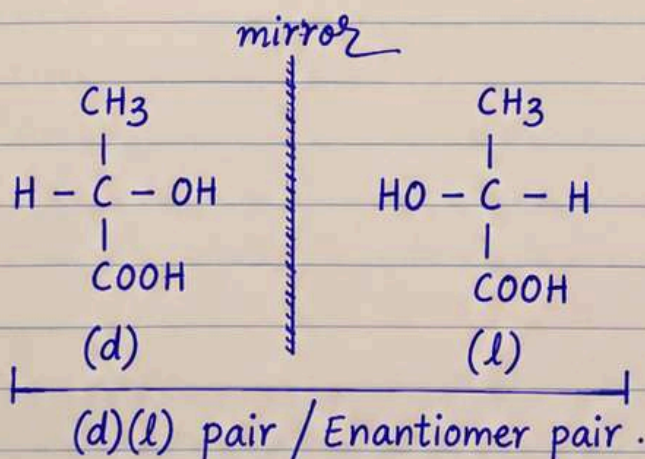
$\Rightarrow$  If a molecule have a chiral/Asymmetric carbon then it is optically Active!

$\therefore$  No. of optical Isomer =  $2^n$ ,  $n$  = no. of chiral centre.

$\swarrow$   $\searrow$   
 (d) (l)



$\therefore$  Optical Isomer =  $2^1 \begin{cases} 1(d) \\ 1(l) \end{cases}$



Ques. 26. What is free radicals ? Discuss its stability.

Sol. Free radicals  $\Rightarrow$

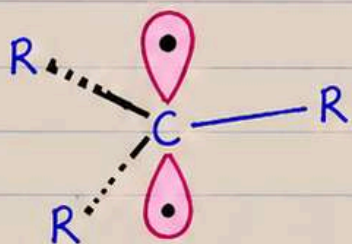
Any species in which carbon atom have an unpaired electron, is called as free radical. It is formed by the homolytic fission of the bond.

$\Rightarrow$  Radicals are paramagnetic and more reactive.

Ex.:  $\cdot\text{CH}_3$  /  $\cdot\text{CR}_3 \rightarrow$  Steric No.(S) = (3 bp + 0 lp)

Hybridisation =  $sp^2$

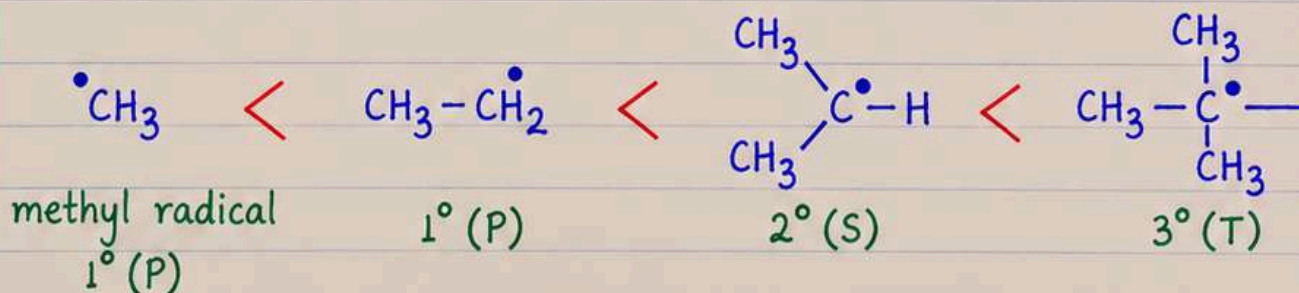
Shape / Geo  $\Rightarrow$  Trigonal planer.



Stability order of radicals  $\Rightarrow$

- (i) +I group increases the stability of radicals.
- (iii) -I group decreases the stability of radicals.
- (iiii) Hyperconjugation increases the stability of radicals.

$\therefore$



$\xrightarrow{\hspace{10em}}$   
+I effect increases, stability increases.

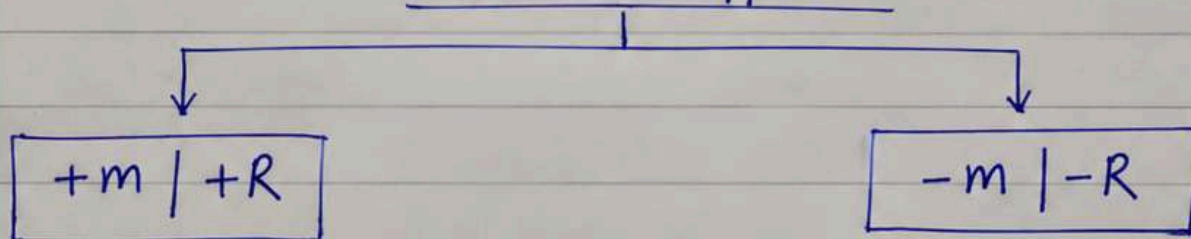
Ques. 27. Explain the mesomeric Effect :-

Sol. mesomeric Effect  $\Rightarrow$

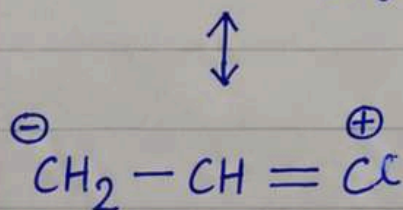
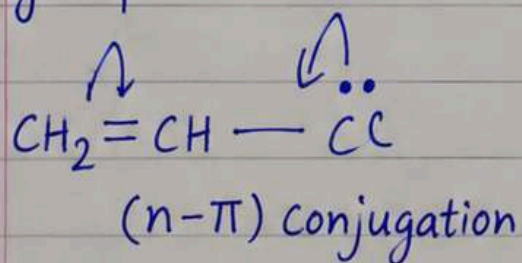
polarisation of Carbon-carbon double bond due to adjacent group, is called as mesomeric Effect. it is a permanent Effect of polarisation.

$\Rightarrow$  mesomeric Effect operate Along the conjugated system ( $\pi-\pi$ ) or ( $n-\pi$ ). if conjugation Break, mesomeric  $\&$  stop.

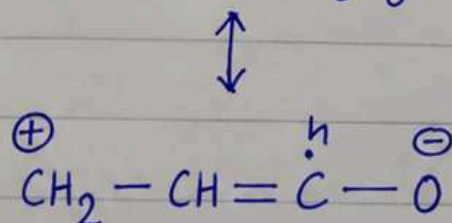
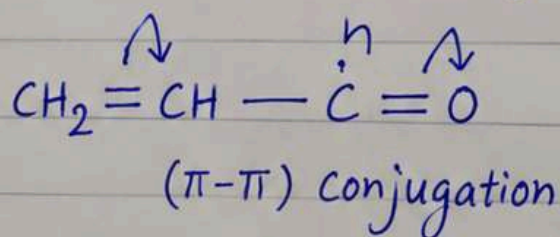
### mesomeric Effect



when the displacement of  $\bar{e}$  away from the group.



when the displacement of  $\bar{e}$  Towards the group.



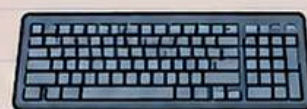
**Ques. 28.** What are the three basic components of which a computer system is made up of?

**Sol.** A computer system is made up of three basic components :  
 (1) Input Unit (2) Central Processing Unit (CPU) (3) Output Unit.

### 1. Input Unit

- The input unit is used to enter data and instructions into the computer.
- It converts the information into a form (binary form) that the computer can understand.
- **Examples :** Keyboard, Mouse, Scanner, Microphone, etc.

#### Input Devices



Keyboard



Mouse



Scanner

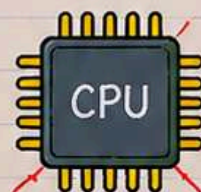


Microphone

### 2. Central Processing Unit (CPU)

- The CPU is the brain of the computer.
- It processes the data and instructions according to the given program.
- It controls and coordinates the activities of all other units.
- It consists of two main parts :
  - (i) **Arithmetic Logic Unit (ALU)** – performs arithmetic and logical operations.
  - (ii) **Control Unit (CU)** – controls the working of all units.

#### CPU



CPU

**ALU**  
Arithmetic  
and Logical  
Operations

**CU**  
Controls  
the working  
of all units



### 3. Output Unit

- The output unit is used to give the processed result to the user.
- It converts the processed data from binary form to a form that humans can understand.
- **Examples :** Monitor, Printer, Speaker, etc.

#### Output Devices



Monitor



Printer

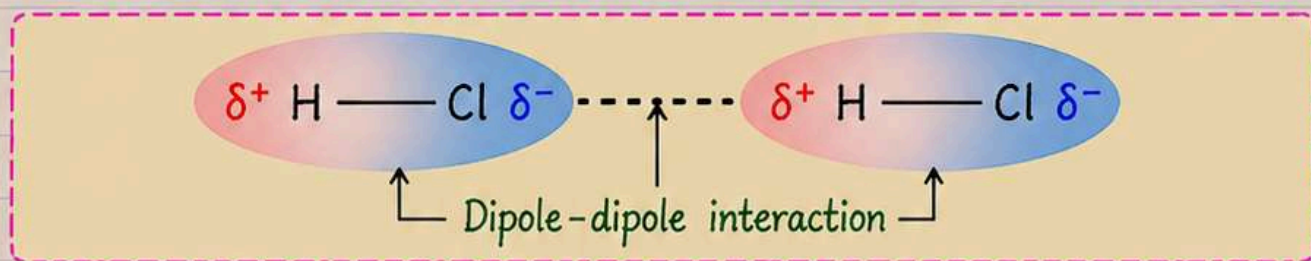


Speaker

Ques. 29. Explain the dipole-dipole interaction.

Sol. **Dipole - Dipole Interaction  $\Rightarrow$**

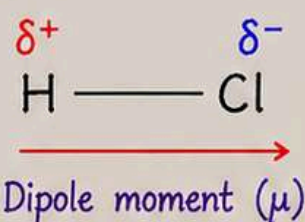
- Dipole-dipole interaction is a type of intermolecular force of attraction that occurs between **permanent dipoles** of polar molecules.
- In a polar molecule, due to difference in electronegativity, one end becomes partially positive ( $\delta^+$ ) and the other end becomes partially negative ( $\delta^-$ ), producing a dipole.
- The partially positive end ( $\delta^+$ ) of one molecule is attracted towards the partially negative end ( $\delta^-$ ) of a neighbouring molecule. This **electrostatic attraction** is called dipole-dipole interaction.



### Characteristics :

- Occurs only between **polar molecules** having permanent dipole moments.
- Weaker than covalent and ionic bonds, but stronger than London dispersion forces.
- The strength of dipole-dipole interaction depends on the **magnitude of the dipole moment** and the **distance** between the molecules.

#### Permanent dipole



### Examples :

- 1 HCl molecules show dipole-dipole interaction.
- 2 Other examples: HF, HBr,  $\text{SO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{CH}_3\text{Cl}$ , etc.

#### HCl molecules



Ques. 30. Explain Clathrates with example.

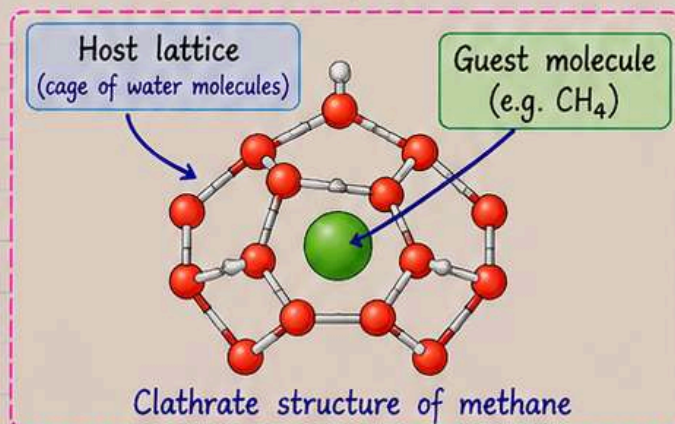
Sol.

## Clathrates

- Clathrates are **inclusion compounds** in which molecules of one substance (**guest molecules**) are physically trapped inside the cavities of another substance (**host lattice**) without forming a chemical bond.
- The host molecule forms a cage-like structure with hollow cavities, and small molecules of a suitable size get trapped inside these cavities.
- The trapped molecules are held by weak **van der Waals forces**, so clathrates are non-stoichiometric and can release the guest molecules easily on heating or applying pressure.

### Structure of Clathrates :

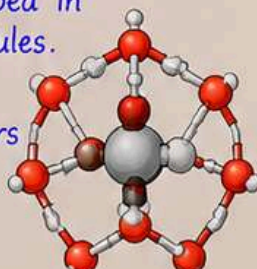
- Host lattice has a cage-like network of molecules (generally water or urea).
- Guest molecules are enclosed in the cavity.
- No chemical bond is formed between host and guest molecules.



### Examples of Clathrates :

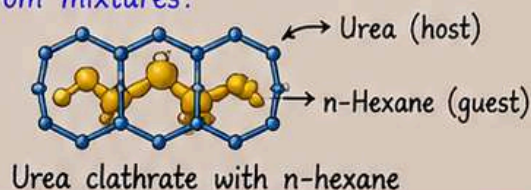
#### 1. Methane clathrate (Natural ice)

- Methane molecules are trapped in the cavities of water molecules.
- Formula** :  $\text{CH}_4 \cdot 5.75 \text{H}_2\text{O}$
- Occurs naturally in ocean floors and permafrost regions.



#### 2. Urea clathrate

- Urea forms clathrates with n-alkanes (e.g. n-hexane, n-heptane).
- Example** : **Urea · n-hexane**
- Used for separation of n-alkanes from mixtures.



### Conclusion :

Clathrates are inclusion compounds in which guest molecules are trapped inside the cavities of a host lattice by weak van der Waals forces.  
**Example** : Methane clathrate ( $\text{CH}_4 \cdot 5.75 \text{H}_2\text{O}$ ) and Urea · n-hexane.

## Ques.31. Explain the Charge Transfer Complexes.

### Charge Transfer Complexes :

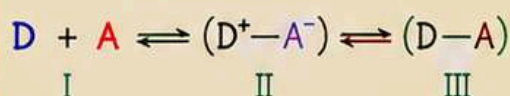
- A charge transfer complex (or CT complex) is a **molecular complex** formed by the association of two or more molecules in which a **fraction of electron charge** is **transferred** from a **donor molecule** (electron rich) to an **acceptor molecule** (electron deficient).
- It is an **electron-donor-acceptor complex**, held together by **electrostatic attraction** arising from this partial electron transfer (not by a normal covalent bond).
- The attraction is much weaker than a covalent bond and is mainly due to **van der Waals forces** (dipole-dipole, ion-dipole and dipole-induced dipole forces).

### General representation



D = electron donor (electron rich)      A = electron acceptor (electron deficient)

### Resonance forms



Form I (D—A) contributes most to the actual compound.

### Origin of Colour :

- The electron transfer leads to a **new electronic transition (charge-transfer band)** in the visible region of the spectrum. As a result, charge transfer complexes show **intense colours**.
- These bands are called **charge-transfer bands** or **CT bands** and are used in spectroscopic identification of such complexes.

### Structure :

- The donor and acceptor molecules are held at a distance of about **3 Å** (greater than a normal covalent bond length).
- The  $\pi$ -orbitals of the two molecules overlap only partially, so the bond is **weak and non-stoichiometric**. These complexes can exist in solids, liquids and even gases.

### Examples :

#### 1. Iodine-starch complex :

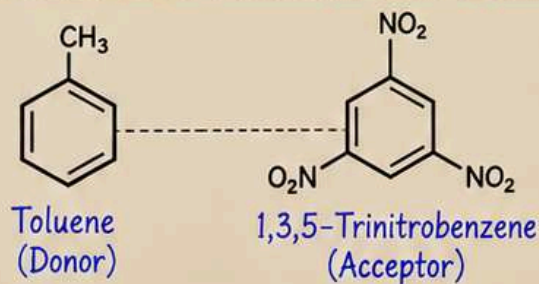
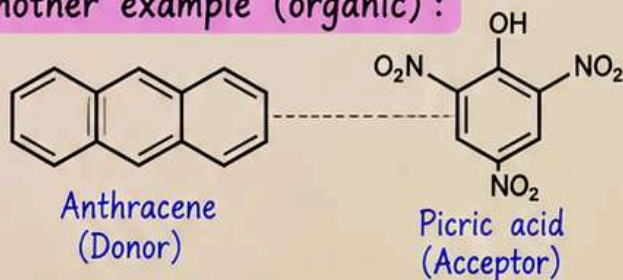
- Iodine and starch form an intense **purple coloured** charge transfer complex. It is widely used for testing starch and in identifying counterfeit currency.



#### 2. Tetracyanoquinodimethane (TCNQ) complex :

- TCNQ is a strong electron acceptor and forms charge transfer complexes with donors such as TTF (tetrathiafulvalene). These complexes show **high electrical conductivity** (first organic conductor).

### Another example (organic) :



### Conclusion :

Charge transfer complexes are **weak, non-stoichiometric, electron-donor-acceptor complexes** characterised by **intense colours** due to charge transfer bands. They are important in both inorganic and organic systems and have wide applications.

**Ques! 32.** Write short note on factorials.**Factorial :**

The factorial of a non-negative integer  $n$  (written as  $n!$ ) is the product of all positive integers from 1 to  $n$ .

$$n! = 1 \times 2 \times 3 \times \dots \times n$$

By definition,  $0! = 1$ .

**Examples :**

- 1  $4! = 1 \times 2 \times 3 \times 4 = 24$
- 2  $5! = 1 \times 2 \times 3 \times 4 \times 5 = 120$
- 3  $0! = 1$  (by definition)
- 4  $1! = 1$
- 5  $6! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 = 720$

**Values of  $n!$  for small  $n$  :**

| $n$ | $n!$ |
|-----|------|
| 0   | 1    |
| 1   | 1    |
| 2   | 2    |
| 3   | 6    |
| 4   | 24   |
| 5   | 120  |
| 6   | 720  |

**Properties of Factorials :**

- 1  $n!$  is defined only for non-negative integers (0, 1, 2, 3, ...).
- 2  $0! = 1$  and  $1! = 1$ .
- 3  $n! = n \times (n-1)!$  for  $n \geq 1$ .
- 4  $(n+1)! = (n+1) \times n!$
- 5 Factorials grow very rapidly as  $n$  increases.

**Uses :**

- Used in permutations and combinations.
- Used in probability and binomial theorem.
- Used in series expansions such as  $e^x$ ,  $\sin x$  and  $\cos x$ .
- Used in many areas of mathematics, physics and computer science.

**Conclusion :**

Factorial is a simple but very important concept in mathematics. It represents the product of the first  $n$  natural numbers and has wide applications in different fields.

## Ques. 33. Write short note on permutation and combination.

### Permutation :

- A permutation is an arrangement of objects in a **definite order**.
- It tells us in how many ways **r** objects can be selected from **n** objects and **arranged**.
- The number of permutations of **n** distinct objects taken **r** at a time is given by :

### Formula :

$${}^n P_r = \frac{n!}{(n-r)!}$$

where  $0 \leq r \leq n$

### Example :

In how many ways can 3 students be arranged out of 5 students ?

$$\begin{aligned} {}^5 P_3 &= \frac{5!}{(5-3)!} \\ &= \frac{5!}{2!} = 5 \times 4 \times 3 \\ &= 60 \text{ ways} \end{aligned}$$

### Combination :

- A combination is a selection of objects **without considering their order**.
- It tells us in how many ways **r** objects can be chosen from **n** objects.
- The number of combinations of **n** distinct objects taken **r** at a time is given by :

### Formula :

$${}^n C_r = \frac{n!}{r!(n-r)!}$$

where  $0 \leq r \leq n$

### Example :

In how many ways can a committee of 3 students be chosen from 5 students?

$$\begin{aligned} {}^5 C_3 &= \frac{5!}{3!(5-3)!} \\ &= \frac{5!}{3!2!} = \frac{5 \times 4}{2 \times 1} \\ &= 10 \text{ ways} \end{aligned}$$

### Some important cases :

1.  ${}^n P_0 = 1, {}^n C_0 = 1$
2.  ${}^n P_1 = n, {}^n C_1 = n$
3.  ${}^n P_n = n!, {}^n C_n = 1$
4.  ${}^n C_r = {}^n C_{n-r}$  (Symmetry property)
5.  ${}^n P_r = {}^n C_r \times r!$

### Example : Find ${}^6 P_2$ and ${}^6 C_2$ .

#### Permutation :

$$\begin{aligned} {}^6 P_2 &= \frac{6!}{(6-2)!} \\ &= \frac{6!}{4!} = 6 \times 5 \\ &= 30 \end{aligned}$$

#### Combination :

$$\begin{aligned} {}^6 C_2 &= \frac{6!}{2!(6-2)!} \\ &= \frac{6!}{2!4!} = \frac{6 \times 5}{2 \times 1} \\ &= 15 \end{aligned}$$

### Key differences :

| Basis   | Permutation ( ${}^n P_r$ )     | Combination ( ${}^n C_r$ )       |
|---------|--------------------------------|----------------------------------|
| Meaning | Arrangement of objects         | Selection of objects             |
| Order   | Order is important             | Order is not important           |
| Formula | ${}^n P_r = \frac{n!}{(n-r)!}$ | ${}^n C_r = \frac{n!}{r!(n-r)!}$ |
| Example | Arranging 3 students out of 5  | Choosing 3 students out of 5     |

### Conclusion :

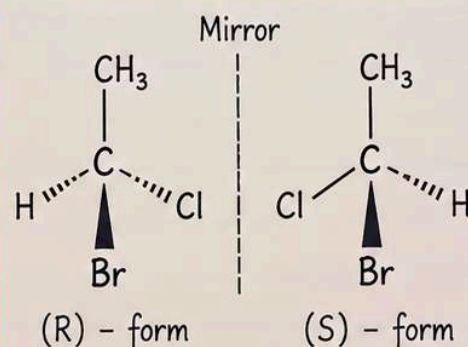
Permutation and combination are important tools in counting problems. Permutation is used when the **order of arrangement matters**, while **combination** is used when only the **selection of objects** is considered.

### Ques. 33. Explain the chirality.

#### Chirality :

- A molecule is said to be **chiral** if it is **not superimposable** on its **mirror image**.
- Such molecules exist in two non-superimposable mirror image forms called **enantiomers**.
- Chirality usually arises due to the presence of a **stereogenic (asymmetric) carbon atom**, i.e. a carbon attached to **four different groups**.
- These mirror image forms have **identical physical and chemical properties** in achiral environment, but **rotate plane-polarised light** in **equal magnitude and opposite directions**.

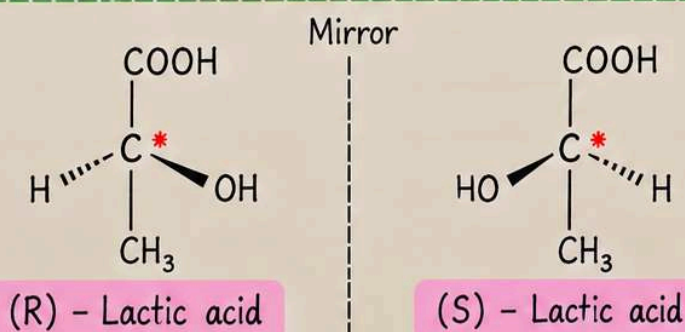
#### Mirror image relationship



These two are non-superimposable mirror images (**enantiomers**).

#### Example :

- **Lactic acid** ( $\text{CH}_3\text{-CH(OH)-COOH}$ ) has a chiral carbon atom (marked \*) attached to **four different groups** -  $\text{CH}_3$ , H, OH and  $\text{COOH}$ .
- It exists as two enantiomers, which are non-superimposable mirror images.



#### Significance :

- Chirality is very important in biological systems because enantiomers can show **different biological activities**.
- For example, one enantiomer of a drug may be therapeutic, while the other may be inactive or even harmful.

Q.34.

Explain the integration with example.

### Integration :

Integration is a process in calculus which is the reverse of differentiation. It is used to find an original function (antiderivative) whose derivative is a given function. The result of integration is called an integral.

### Notation :

The integral of a function  $f(x)$  is written as

$\int f(x) dx$ , where  $dx$  represents the variable of integration.

### Types of Integrals :

- ① Indefinite Integral - It gives a family of functions and contains an arbitrary constant ( $C$ ).
- ② Definite Integral - It gives a definite numerical value over a given interval.

### Examples :

#### Example 1 :

Find  $\int x^2 dx$ .

Solution :

$$\begin{aligned}\int x^2 dx &= \frac{x^{2+1}}{2+1} + C \\ &= \frac{x^3}{3} + C\end{aligned}$$

$$\therefore \int x^2 dx = \frac{x^3}{3} + C$$

#### Example 2 :

Find  $\int \frac{1}{x} dx$ .

Solution :

$$\int \frac{1}{x} dx = \ln|x| + C$$

$$\therefore \int \frac{1}{x} dx = \ln|x| + C$$

#### Example 3 :

Find  $\int (2x+3) dx$ .

Solution :

$$\begin{aligned}\int (2x+3) dx &= \int 2x dx + \int 3 dx \\ &= 2 \left( \frac{x^2}{2} \right) + 3x + C \\ &= x^2 + 3x + C\end{aligned}$$

$$\therefore \int (2x+3) dx = x^2 + 3x + C$$

**Q.35.**

**Explain the differentiation with example.**

### Differentiation :

Differentiation is a process in calculus which is the reverse of integration. It is used to find the derivative of a function, which represents the rate of change of the function with respect to its independent variable.

### Definition :

If  $y = f(x)$  is a function of  $x$ , then the derivative of  $y$  with respect to  $x$ , denoted by  $\frac{dy}{dx}$  or  $f'(x)$ , is defined as

$$\frac{dy}{dx} = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

### Notation :

The derivative of a function  $f(x)$  is written as  $f'(x)$ ,  $\frac{dy}{dx}$  or  $D(f)$ .

### Geometric Meaning :

The derivative  $\frac{dy}{dx}$  at a point gives the slope of the tangent to the curve  $y = f(x)$  at that point.

### Examples :

#### Example 1 :

Find the derivative of  $f(x) = x^2$ .

**Solution :**

$$\begin{aligned} f(x) &= x^2 \\ \Rightarrow f'(x) &= \frac{d(x^2)}{dx} \\ &= 2x \end{aligned}$$

$$\therefore \frac{d(x^2)}{dx} = 2x$$

#### Example 2 :

Find the derivative of  $f(x) = \sin x$ .

**Solution :**

$$\begin{aligned} f(x) &= \sin x \\ \Rightarrow f'(x) &= \frac{d(\sin x)}{dx} \\ &= \cos x \end{aligned}$$

$$\therefore \frac{d(\sin x)}{dx} = \cos x$$

#### Example 3 :

Find the derivative of  $f(x) = 3x + 5$ .

**Solution :**

$$\begin{aligned} f(x) &= 3x + 5 \\ \Rightarrow f'(x) &= \frac{d(3x+5)}{dx} \\ &= 3 \frac{d(x)}{dx} + 5 \frac{d(1)}{dx} \\ &= 3 \times 1 + 5 \times 0 \\ &= 3 \end{aligned}$$

$$\therefore \frac{d(3x+5)}{dx} = 3$$

Q.36.

## What is Walden inversion ?

### Walden Inversion :

Walden inversion is the inversion of configuration at a chiral carbon atom during a nucleophilic substitution reaction, usually occurring by the  $S_N2$  mechanism.

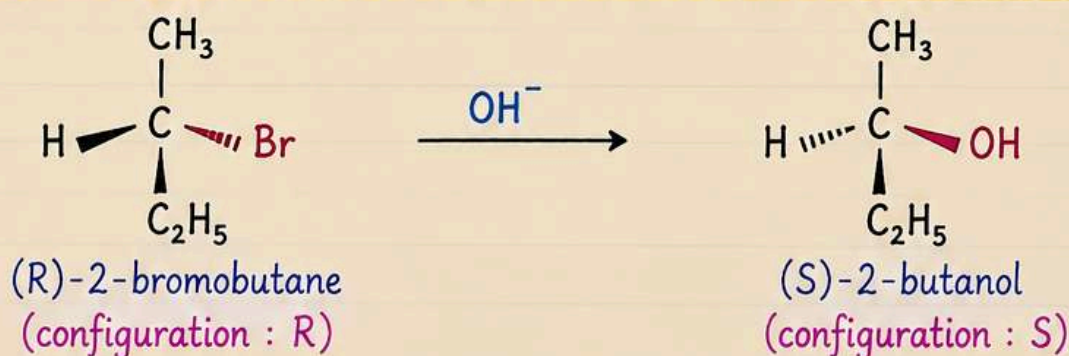
In this process, the incoming nucleophile attacks the chiral carbon from the side opposite to the leaving group (**backside attack**), which results in the inversion of the spatial arrangement of the groups around the chiral carbon. This is also called **inversion of configuration** or **Walden inversion**.

### Mechanism :

- The nucleophile approaches the chiral carbon from the side opposite to the leaving group.
- A transition state is formed in which both the nucleophile and leaving group are partially bonded.
- The product is formed with inversion of configuration (the spatial arrangement of groups is reversed).

### Example :

Nucleophilic substitution of (R)-2-bromobutane with hydroxide ion ( $\text{OH}^-$ ).



### Conclusion :

- Walden inversion results in a change from one enantiomer to the other (e.g.,  $R \rightarrow S$  or  $S \rightarrow R$ ).
- It is a characteristic feature of  $S_N2$  reactions.
- This occurs due to the backside attack of the nucleophile.

Q.37.

## Explain the CIP sequence and R/S nomenclature with examples.

### CIP Sequence (Cahn-Ingold-Prelog sequence) :

The CIP sequence is a set of rules used to assign priority to the groups attached to a chiral (stereogenic) carbon atom. It is used to determine the R/S configuration of an asymmetric centre.

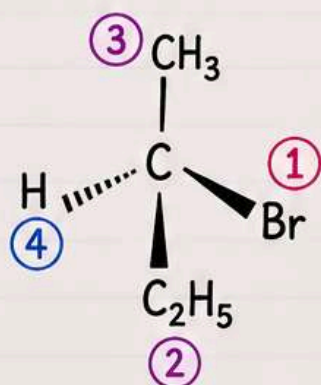
### Rules for assigning CIP priority :

- ① The atom directly attached to the chiral carbon with higher atomic number gets higher priority.
- ② If the directly attached atoms are the same, compare the next set of atoms along the chain until a point of difference is found.
- ③ Multiple bonds are treated as if the atom is bonded to the equivalent number of duplicate atoms.
- ④ Arrange the groups in decreasing order of priority ( $1 > 2 > 3 > 4$ ).

### R/S Nomenclature :

- After assigning the priorities using CIP rules, the molecule is viewed with the lowest priority group (4) pointing away from the observer (usually shown by a dashed bond).
- If the sequence  $1 \rightarrow 2 \rightarrow 3$  is clockwise, the configuration is R (from Latin rectus, right).
- If the sequence  $1 \rightarrow 2 \rightarrow 3$  is anticlockwise, the configuration is S (from Latin sinister, left).

### Example 1 : (R)-2-bromobutane



#### Solution :

**Step 1 :** Assign CIP priorities.

Br ( $Z = 35$ )  $>$   $C_2H_5$  ( $Z = 6$ )  $>$   $CH_3$  ( $Z = 6$ )  $>$  H ( $Z = 1$ )

**Priority order :** 1 (Br)  $>$  2 ( $C_2H_5$ )  $>$  3 ( $CH_3$ )  $>$  4 (H).

**Step 2 :** The lowest priority group (H) is already pointing away from the observer (dashed bond).

**Step 3 :** Trace the sequence  $1 \rightarrow 2 \rightarrow 3$  (Br  $\rightarrow$   $C_2H_5 \rightarrow$   $CH_3$ ). The sequence is **clockwise**.

$\therefore$  Configuration = **R** (R)-2-bromobutane

### Key Points :

- CIP priority depends on atomic number, not on mass.
- In case of isotopes, the one with higher mass number gets higher priority.
- If there is a tie, compare the next atoms along the chain.
- R means rectus (right, clockwise) and S means sinister (left, anticlockwise).
- The lowest priority group must be pointing away from the observer while determining R or S configuration.

**Q.38****Explain the maxima and minima.****Maxima and minima :**

Let  $y = f(x)$  be a function. To find the maxima or minima, we use the first and second derivative tests.

A point  $x = a$  is a stationary point if  $\frac{dy}{dx} = 0$  at  $x = a$ . We then use the second derivative to determine whether it is a maximum or minimum.

① If  $\frac{dy}{dx} = 0$  and  $\frac{d^2y}{dx^2}$  is negative at  $x = a$ , then  $y$  is maximum at  $x = a$ .

② If  $\frac{dy}{dx} = 0$  and  $\frac{d^2y}{dx^2}$  is positive at  $x = a$ , then  $y$  is minimum at  $x = a$ .

**Example 1 (Maxima) :** Find the maximum value of  $y = 4x - x^2$ .

**Solution :**

Step 1 : Differentiate w.r.t.  $x$ .

$$\frac{dy}{dx} = 4 - 2x$$

Step 2 : Put  $\frac{dy}{dx} = 0$  to find the stationary point.  $4 - 2x = 0 \Rightarrow 2x = 4 \Rightarrow x = 2$

Step 3 : Find the second derivative.

$$\frac{d^2y}{dx^2} = -2$$

Step 4 : At  $x = 2$ ,  $\frac{d^2y}{dx^2} = -2$  which is negative.  
Hence,  $y$  is maximum at  $x = 2$ .

Step 5 : Find the maximum value.

$$y = 4(2) - (2)^2 = 8 - 4 = 4$$

Therefore, the maximum value is 4 at  $x = 2$ .

**Example 2 (Minima) :** Find the minimum value of  $y = x^2 - 6x + 5$ .

**Solution :**

Step 1 : Differentiate w.r.t.  $x$ .

$$\frac{dy}{dx} = 2x - 6$$

Step 2 : Put  $\frac{dy}{dx} = 0$  to find the stationary point.  $2x - 6 = 0 \Rightarrow 2x = 6 \Rightarrow x = 3$

Step 3 : Find the second derivative.

$$\frac{d^2y}{dx^2} = 2$$

Step 4 : At  $x = 3$ ,  $\frac{d^2y}{dx^2} = 2$  which is positive.  
Hence,  $y$  is minimum at  $x = 3$ .

Step 5 : Find the minimum value.

$$y = (3)^2 - 6(3) + 5 = 9 - 18 + 5 = -4$$

Therefore, the minimum value is -4 at  $x = 3$ .

### Q.39.

## Explain the dipole moment with example.

### Dipole moment :

The product of magnitude of partial charge developed on any two covalently bonded atoms and the distance between them is called dipole moment.

$$\mu = q \times d$$

$d$  = distance between two atoms (Å or cm)

$q$  = magnitude of charge on the atoms (in esu)

It is a vector quantity having both magnitude and direction.  
Its unit is Debye (D).

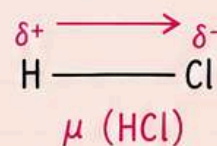
### Unit :

$\mu \rightarrow$  Debye (D)

1 Debye =  $1 \times 10^{-18}$  esu·cm

### Direction :

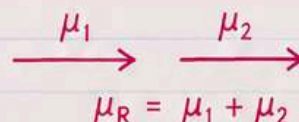
The dipole moment is directed from the less electronegative atom (positive end) towards the more electronegative atom (negative end).



### Resultant dipole moment :

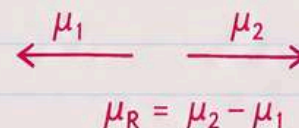
- ① When two dipoles are in the same direction ( $\theta = 0^\circ$ ), the resultant dipole moment is

$$\mu_R = \mu_1 + \mu_2$$



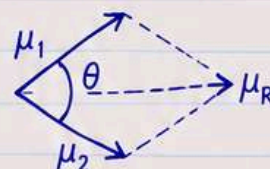
- ② When two dipoles are in opposite direction ( $\theta = 180^\circ$ ), the resultant dipole moment is

$$\mu_R = \mu_2 - \mu_1 \quad (\mu_2 > \mu_1)$$



- ③ When two dipoles are inclined at an angle  $\theta$ , the resultant dipole moment is

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

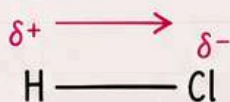


### Factors affecting dipole moment :

- Dipole moment increases with increase in electronegativity difference.
- It increases with increase in bond length.
- It depends on the geometry (symmetry) of the molecule.
- In symmetrical molecules, the resultant dipole moment may be zero.

### Examples :

- ① HCl :



Non-zero dipole moment due to electronegativity difference.

- ②  $\text{NH}_3$  (Trigonal pyramidal):



Resultant dipole moment is non-zero ( $\mu \neq 0$ ).

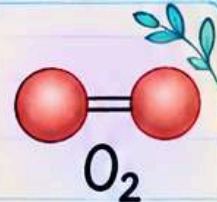
- ③  $\text{NF}_3$  (Trigonal pyramidal):



Resultant dipole moment is smaller than  $\text{NH}_3$  because F is more electronegative ( $\mu_{\text{NF}_3} < \mu_{\text{NH}_3}$ ).

Q.40.

Draw the molecular orbital energy level diagram of  $O_2$  molecule and explain its magnetic property.

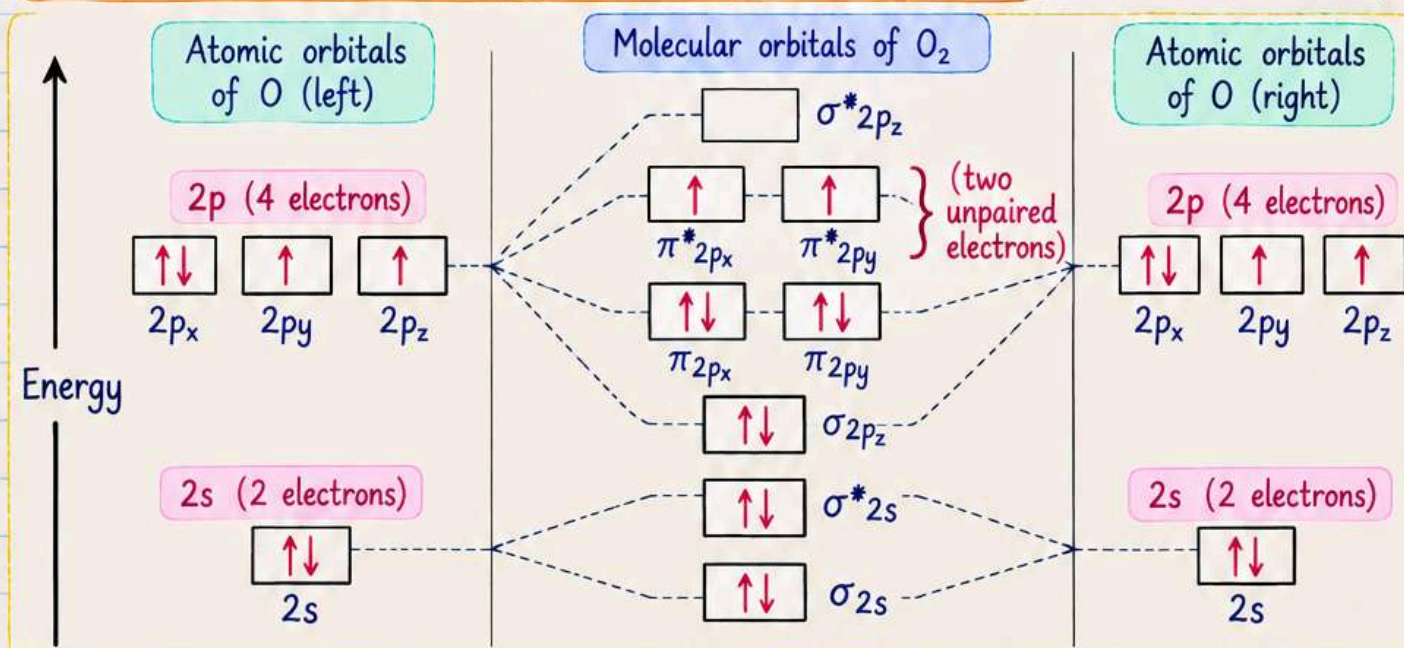


### Introduction :

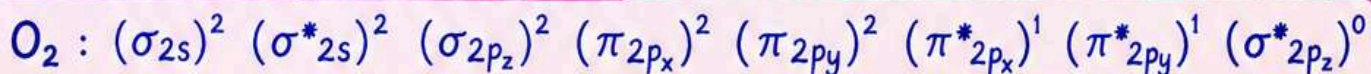
- Each oxygen atom ( $Z = 8$ ) has the electronic configuration  $1s^2 2s^2 2p^4$ .
- In  $O_2$  molecule, the  $1s$  and  $2s$  orbitals form bonding and antibonding molecular orbitals which are completely filled and do not affect the magnetic property.
- The magnetic behaviour of  $O_2$  is determined by the  $2p$  molecular orbitals.
- For  $O_2$  (and  $F_2$ ), the energy order of  $2p$  molecular orbitals is:

$$\sigma_{2s} < \sigma_{2s}^* < \sigma_{2p_z} < \pi_{2p_x} = \pi_{2p_y} < \pi_{2p_x}^* = \pi_{2p_y}^* < \sigma_{2p_z}^*$$

### Molecular orbital energy level diagram of $O_2$ :



### Electronic configuration of $O_2$ :



### Bond order :

$$\begin{aligned} \text{Bond order} &= \frac{1}{2} (N_b - N_a) \\ &= \frac{1}{2} (10 - 6) \\ &= \frac{1}{2} (4) \\ &= 2 \end{aligned}$$

$N_b$  = number of electrons in bonding MOs = 10

$N_a$  = number of electrons in antibonding MOs = 6

### Magnetic property :

- $O_2$  has two unpaired electrons in the degenerate antibonding molecular orbitals  $\pi_{2p_x}^*$  and  $\pi_{2p_y}^*$ .
- Therefore,  $O_2$  is **paramagnetic**.
- The unpaired electrons are parallel and occupy separate degenerate orbitals (Hund's rule).
- This makes  $O_2$  attracted by an external magnetic field.
- In contrast,  $N_2$  has all electrons paired and is diamagnetic.

### Conclusion :

$O_2$  has bond order 2 and is paramagnetic due to two unpaired electrons in  $\pi_{2p_x}^*$  and  $\pi_{2p_y}^*$  molecular orbitals.

## Q.41.

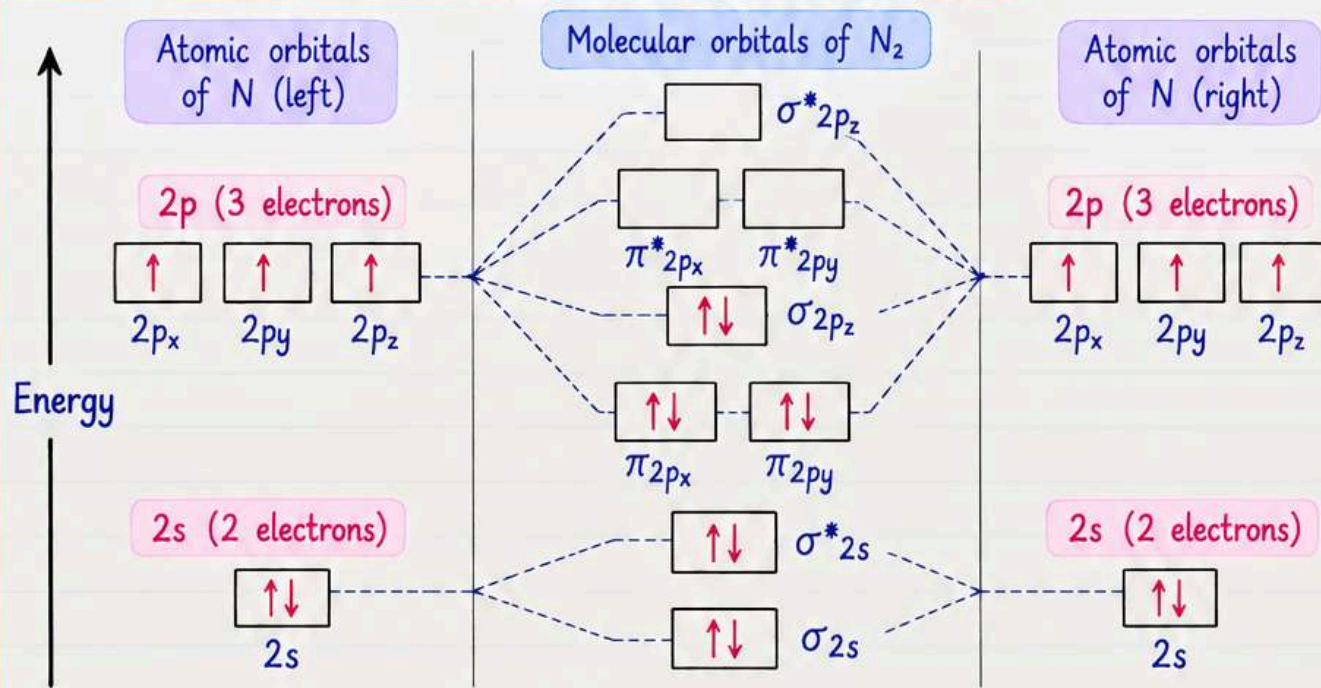
Draw the molecular orbital energy level diagram of  $N_2$  molecule and explain its magnetic property and bond order.

### Introduction :

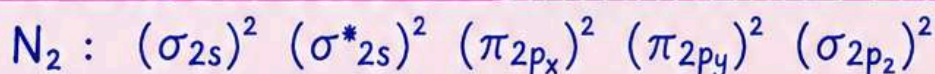
- Each nitrogen atom ( $Z = 7$ ) has the electronic configuration  $1s^2 2s^2 2p^3$ .
- In  $N_2$  molecule,  $1s$  and  $2s$  orbitals form bonding and antibonding molecular orbitals which are completely filled and do not affect the magnetic property.
- For  $N_2$  (and molecules up to  $N_2$ ), the order of  $2p$  molecular orbitals is :

$$\sigma_{2s} < \sigma_{2s}^* < \pi_{2p_x} = \pi_{2p_y} < \sigma_{2p_z} < \pi_{2p_x}^* = \pi_{2p_y}^* < \sigma_{2p_z}^*$$

### Molecular orbital energy level diagram of $N_2$ :



### Electronic configuration of $N_2$ :



### Magnetic property :

- All the electrons in  $N_2$  molecule are paired in the molecular orbitals.
- Therefore,  $N_2$  is **diamagnetic** (i.e., not attracted by an external magnetic field).

### Bond order :

$$\begin{aligned} \text{Bond order} &= \frac{1}{2} (N_b - N_a) \\ &= \frac{1}{2} (10 - 4) \\ &= \frac{1}{2} (6) \\ &= 3 \end{aligned}$$

$N_b$  = number of electrons in bonding MOs = 10

$N_a$  = number of electrons in antibonding MOs = 4

### Conclusion :

$N_2$  has bond order 3 and is diamagnetic as all the electrons are paired.

Q.41.

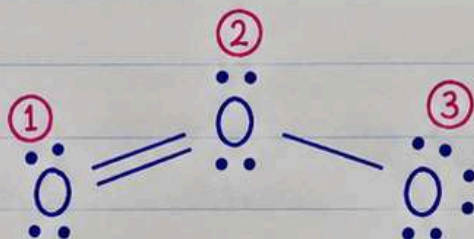
Explain the formal charge with example.

### Formal charge :

Formal charge mainly regarded as charge that one atom in a molecule would have if all of the atoms have same nearly electronegativity.

$$\text{FC} = \text{Total no. of outermost } e^- \text{ in free state} - \text{No. of lone pair } e^- \text{ s} - \frac{1}{2} (\text{Total no. of bonded } e^- \text{ s})$$

Ex.  $\text{O}_3$



① Formal charge on  $\text{O}_1$  :

$$\begin{aligned} \text{FC for } \text{O}_1 &= 6 - 4 - \frac{1}{2} \times 4 \\ &= 6 - 4 - 2 = \underline{\underline{0}} \end{aligned}$$

② Formal charge on  $\text{O}_2$  :

$$\begin{aligned} \text{FC for } \text{O}_2 &= 6 - 2 - \frac{1}{2} \times 6 \\ &= 6 - 2 - 3 = \underline{\underline{+1}} \end{aligned}$$

③ Formal charge on  $\text{O}_3$  :

$$\begin{aligned} \text{FC for } \text{O}_3 &= 6 - 6 - \frac{1}{2} \times 2 \\ &= 6 - 6 - 1 = \underline{\underline{-1}} \end{aligned}$$

Q.42.

Explain the VSEPR theory with example of  $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$ .

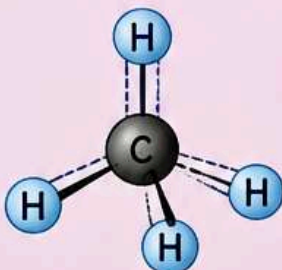
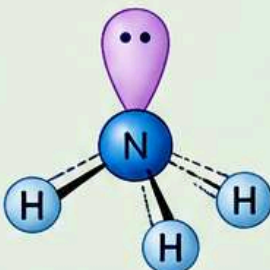
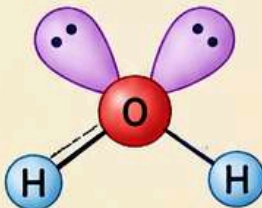
### VSEPR Theory :

- VSEPR stands for **V**alence **S**hell **E**lectron **P**air **R**epulsion theory.
- It states that the electron pairs (bonding or lone pairs) around a central atom repel each other and arrange themselves as far apart as possible to minimize repulsion.
- The shape of a molecule depends on the number of bonding pairs and lone pairs around the central atom.
- Lone pairs repel more strongly than bonding pairs, so they reduce the bond angle.

### Order of repulsion :

Lone pair – Lone pair  
>  
Lone pair – Bond pair  
>  
Bond pair – Bond pair

### Examples :

| Molecule                                   | $\text{CH}_4$                                                                                      | $\text{NH}_3$                                                                                              | $\text{H}_2\text{O}$                                                                                    |
|--------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Lewis structure                            | $\begin{array}{c} \text{H} \\   \\ \text{H} - \text{C} - \text{H} \\   \\ \text{H} \end{array}$    | $\begin{array}{c} \cdot\cdot \\ \text{H} - \text{N} - \text{H} \\   \\ \text{H} \end{array}$               | $\begin{array}{c} \cdot\cdot \\ \text{H} - \text{O} - \text{H} \\ \cdot\cdot \end{array}$               |
| Total electron pairs (around central atom) | 4 bonding pairs<br>0 lone pair<br>(total = 4)                                                      | 3 bonding pairs<br>1 lone pair<br>(total = 4)                                                              | 2 bonding pairs<br>2 lone pairs<br>(total = 4)                                                          |
| Electron pair geometry                     | Tetrahedral<br>(4 electron pairs)                                                                  | Tetrahedral<br>(4 electron pairs)                                                                          | Tetrahedral<br>(4 electron pairs)                                                                       |
| Molecular shape                            | <br>Tetrahedral | <br>Trigonal pyramidal | <br>Bent (Angular) |
| Bond angle                                 | $109.5^\circ$                                                                                      | $\sim 107^\circ$<br>(less than $109.5^\circ$ )                                                             | $\sim 104.5^\circ$<br>(less than $107^\circ$ )                                                          |

### Conclusion :

- All the three molecules ( $\text{CH}_4$ ,  $\text{NH}_3$  and  $\text{H}_2\text{O}$ ) have tetrahedral electron pair geometry because each has 4 electron pairs around the central atom.
- The actual molecular shape and bond angle differ due to the number of lone pairs. Lone pairs cause greater repulsion and reduce the bond angle.