UNIT-1
Structure and Bonding Models

1. What is quantum mechanics?

Answer:
Quantum mechanics is the branch of physics that deals with the behavior of matter and energy at microscopic scales (atomic and subatomic levels), where the classical laws of mechanics fail.

2. What is the Schrödinger wave equation?

Answer:
It is a fundamental equation of quantum mechanics that describes how the wave function (ψ) of a particle evolves in space and time.

$$H^\wedge\psi=E\psi^\wedge$$

where $H^\wedge$ is the Hamiltonian operator and $E^\wedge$ is the energy of the system.

3. What is the significance of ψ (psi)?

Answer:
ψ represents the wave function of a particle and contains all the information about the system's quantum state.

4. What is the significance of ψ^2?

Answer:
ψ^2 (or $|\psi|^2$) represents the **probability density** of finding a particle at a given point in space.

5. What are the boundary conditions for a particle in a 1-D box?

Answer:
For a particle confined between $x = 0$ and $x = L$,

$$\psi(0)=\psi(L)=0$$

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6. What is the expression for energy of a particle in a one-dimensional box?

Answer:

$$E_n = n^2h^2/8mL^2 \qquad n=1, 2, 3.....,$$

Where n is the quantum number, h is Planck’s constant, m is mass, and L is the length of the box.

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7. What does the quantum number 'n' signify in the 1D box model?

Answer:
‘n’ denotes the energy level or the number of half wavelengths fitting inside the box.

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8. What is molecular orbital theory (MOT)?

Answer:
MOT explains bonding by considering the combination of atomic orbitals to form molecular orbitals that extend over the entire molecule.

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9. What is bond order and how is it calculated?

Answer:
Bond order = ½ (Number of bonding electrons – Number of ant bonding electrons)
It indicates bond strength and stability.

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10. What is the bond order of O_2 molecule?

Answer:
Molecular configuration of O_2:

$$(\sigma 1s)^2(\sigma{*}1s)^2(\sigma 2s)^2(\sigma{*}2s)^2(\sigma 2pz)^2(\pi 2px)^2(\pi 2py)^2(\pi{*}2px)^1(\pi{*}2py)^1$$

Bond order = ½ (10 – 6) = **2**.

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11. Why is O_2 paramagnetic?

Answer:
O_2 has two unpaired electrons in π*2p orbitals, making it paramagnetic.

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12. What is the bond order of CO molecule?

Answer:
Electronic configuration of CO:

$$(\sigma 1s)^2(\sigma{*}1s)^2(\sigma 2s)^2(\sigma{*}2s)^2(\sigma 2pz)^2(\pi 2px)^2(\pi 2py)^2$$

Bond order = ½ (10 – 4) = **3**.

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13. Why is CO a stable molecule?

Answer:
Because it has a high bond order (3), indicating a strong triple bond.

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14. What are π molecular orbitals?

Answer:
π-Molecular orbitals form by lateral (sidewise) overlap of p-orbitals, resulting in electron density above and below the internuclear axis.

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15. How many π molecular orbitals are present in 1,3-butadiene?

Answer:
1,3-butadiene (C_4H_6) has **4 π molecular orbitals** formed from 4 p-orbitals.

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16. What is the delocalization in benzene?

Answer:
In benzene, 6 p-orbitals combine to form 6 π molecular orbitals with delocalized electrons spread over the ring.

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17. What is the bond order in benzene?

Answer:
Each C–C bond has a bond order of **1.5** due to delocalization of π electrons.

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18. What is the energy order of molecular orbitals for homonuclear diatomic molecules (Z < 8)?

Answer:

$$\sigma 1s<\sigma *1s<\sigma 2s<\sigma *2s<(\pi 2px=\pi 2py)<\sigma 2pz<(\pi *2px=\pi *2py)<\sigma *2pz$$

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19. What changes in energy order occur for O_2 and F_2 (Z > 8)?

Answer:
For heavier atoms (O_2, F_2):

$$\sigma 1s<\sigma *1s<\sigma 2s<\sigma *2s<\sigma 2pz<(\pi 2px=\pi 2py)<(\pi *2px=\pi *2py)<\sigma *2pz$$

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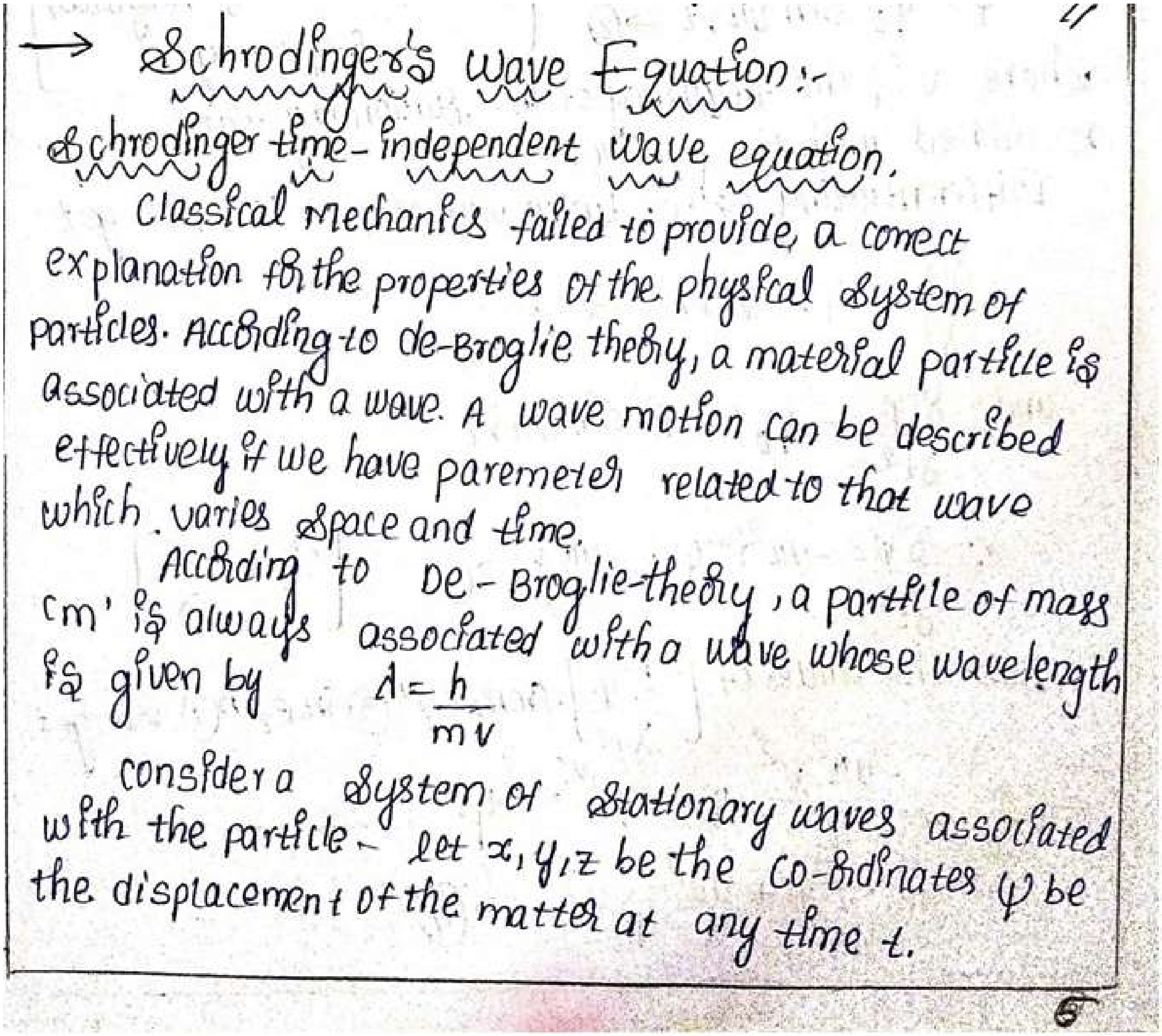
20. What is normalization of a wave function?

Answer:
It means the total probability of finding a particle in all space is

$$\int^{\infty}_{-\infty} |\psi|^2 dx=1$$

EASSAY QUESTIONS

1. Derive the Schrodinger Time-Independent wave equation?



→ Schrodinger's wave Equation:-

Schrodinger time-independent wave equation.

Classical mechanics failed to provide a correct explanation for the properties of the physical system of particles. According to de-Broglie theory, a material particle is associated with a wave. A wave motion can be described effectively if we have paremeter related to that wave which varies space and time.

According to De-Broglie-theory, a particle of mass 'm' is always associated with a wave whose wavelength is given by $\lambda = \frac{h}{mv}$

consider a system of stationary waves associated with the particle. let x, y, z be the co-ordinates ψ be the displacement of the matter at any time t.

The differential equation of a wave function is given

$$\frac{\partial^2 \psi}{\partial t^2} = v^2\left[\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2}\right] = v^2 \nabla^2 \psi \rightarrow ①$$

where, $\nabla^2 = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$, is a laplacian operator,

V = wave velocity.

The solution of equation ① is given by

$$\psi = \psi_0 \sin \omega t$$

$$\psi = \psi_0 \sin 2\pi \nu t \rightarrow ② \quad \left[\because \omega = 2\pi\nu \ \ \omega \text{ is Angular frequency}\right]$$

where ν is the frequency of the stationary wave associated with the particle.

Differentiating eqⁿ ② twice with respect to t, we get

$$\frac{\partial \psi}{\partial t} = \psi_0 (2\pi\nu) \cos 2\pi\nu t$$

and $$\frac{\partial^2 \psi}{\partial t^2} = -\psi_0 (2\pi\nu)^2 \sin 2\pi\nu t$$

$$\because \frac{\partial^2 \psi}{\partial t^2} = -4\pi^2\nu^2 \psi = \frac{-4\pi^2 v^2}{\lambda^2} \rightarrow ③ \quad \left[\because \nu = \frac{c}{\lambda}\right]$$

Sub the values of $\left[\frac{\partial^2 \psi}{\partial t^2}\right]$ from eqⁿ ③ in eqⁿ ① we get

$$\frac{-4\pi^2 \cancel{v^2}}{\lambda} \psi = \cancel{v^2} \nabla^2 \psi$$

$$\nabla^2 \psi + \frac{4\pi^2}{\lambda} \psi = 0 \rightarrow ④$$

from the Debroglie relation, $\lambda = \frac{h}{mv}$

Hence eqn ④ becomes $\nabla^2\psi + \frac{4\pi^2}{h^2} m^2v^2\psi = 0 \rightarrow$ ⑤

If V and E are the potential and total energy of the particle respectively, then it's kinetic energy is given by

Total energy $E = K.E + P.E$

$$E = \frac{1}{2}mv^2 + V$$

$$E - V = \frac{1}{2}mv^2$$

$$2(E - V] = mv^2$$

multiplying 'm' on both sides

$$2m(E-V) = m^2v^2 \rightarrow ⑥$$

Sub eqn ⑥ in eqn ⑤

$$\nabla^2\psi + \frac{4\pi^2}{h^2} 2m(E-V)\psi = 0$$

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-V]\psi = 0 \rightarrow ⑦$$

let $\hbar = \frac{h}{2\pi} \Rightarrow h = \hbar 2\pi$

Sub 'h' value in eqn ⑦

$$\nabla^2\psi + \frac{2\cancel{8}\cancel{\pi^2}m}{\hbar^2\cancel{4\pi^2}}(E-V]\psi = 0$$

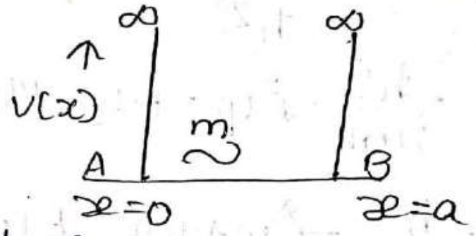
$$\nabla^2\psi + \frac{2m}{\hbar^2}(E-V]\psi = 0$$

∴ This is the Schrodinger time independent wave eqn

2. Derive the Energy equation for particle in one dimensional box and write significance of Ψ and Ψ^2?

Particle in one Dimensional Box :-

let us considera particle of mass 'm' moving along x-axis b/w the two rigid walls A and B at $x=0$ and $x=a$. The particle free to move b/w the walls. The potential energy of the particle b/w the two walls is constant bez no force is acting on the particle.



limit-1 :-

$\psi = 0$ at $x = 0$

limit-2 :-

$\psi = 0$ at $x = a$

let us consider Schrodinger's time independent wave eqn

$$\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0 \rightarrow ①$$

$$\hbar = \frac{h}{2\pi}$$

Sub $\hbar$ value in eqn ①

$$\nabla^2\psi + \frac{2m}{\frac{h^2}{4\pi^2}}(E-V)\psi = 0$$

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0$$

The particle moves in b/w the two walls it's potential energy is 0

$$\therefore V = 0$$

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}(E-0)\psi = 0$$

$$\nabla^2\psi + \frac{8\pi^2 m}{h^2}E\psi = 0$$

Let $\frac{8\pi^2 m}{h^2}E = k^2 \rightarrow ②$

$\nabla^2\psi + k^2\psi = 0 \rightarrow$ ③

The general solution of the equation ③ is $\psi(x)$ =

$$\psi(x) = A\sin kx + B\cos kx \rightarrow ④$$

where A & B are constants. The values of these constants can be determined by applying the boundary conditions of the problem. They are.

$$\psi(x) = 0 \quad at\ x = 0$$

$$0 = A\sin(0) + B(\cos(0))$$

$$0 = 0 + B$$

$$\boxed{B = 0}$$

Replace 'B' value in eqn ④

$$\psi(x) = A\sin kx + 0$$

$$\psi(x) = A\sin kx \rightarrow ⑤$$

Applying the secondary boundary condition. we have

$$\psi(x) = 0 \quad at\ x = a$$

$$0 = A\sin ka$$

$$\sin ka = 0$$

$$ka = \sin^{-1}(0)$$

$$ka = \sin^{-1}(\sin n\pi)$$

$$ka = n\pi$$

$$\boxed{k = \frac{n\pi}{a}} \rightarrow ⑥$$

Replace 'k' value in eqn ⑤

$$\psi(x) = A\sin \frac{n\pi}{a} x$$

Here $\psi(x)$ represents the wave character / properties of the particle.

let $k^2 = \frac{8\pi^2 mE}{\hbar^2}$

$$\frac{n^2\pi^2}{a^2} = \frac{8\pi^2 mE}{h^2}$$

$$\boxed{E = \frac{n^2h^2}{8ma^2}}$$

Case(i):- If $n=1$

$$E_1 = \frac{h^2}{8ma^2}$$

Case(ii):- If $n=2$

$$E_2 = \frac{4h^2}{8ma^2}$$

$$E_2 = 4E_1$$

Case(iii):- If $n=3$

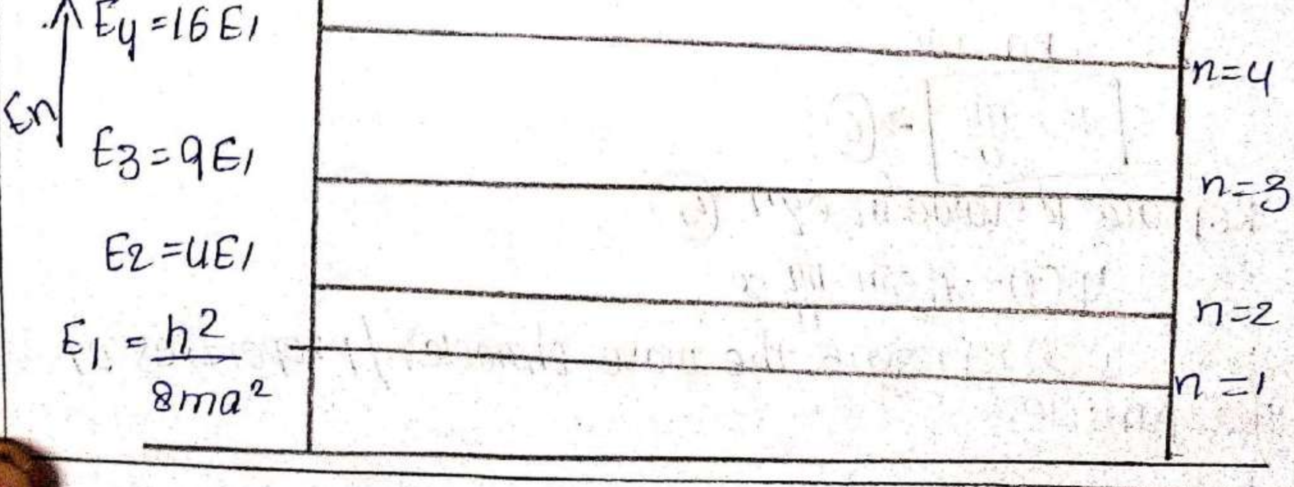
$$E_3 = \frac{9h^2}{8ma^2}$$

$$E_3 = 9E_1$$

Case(iv):- If $n=4$

$$E_4 = 16E_1$$

The energy levels are shown in the figure.



Significance of ψ & ψ^2:-

The value of ψ is called wave function (or) Eigen function of the Schrodinger's wave equation

* The wave function ψ contains all the information we want to know about system

* All the properties of a system can be calculated from it's wave function.

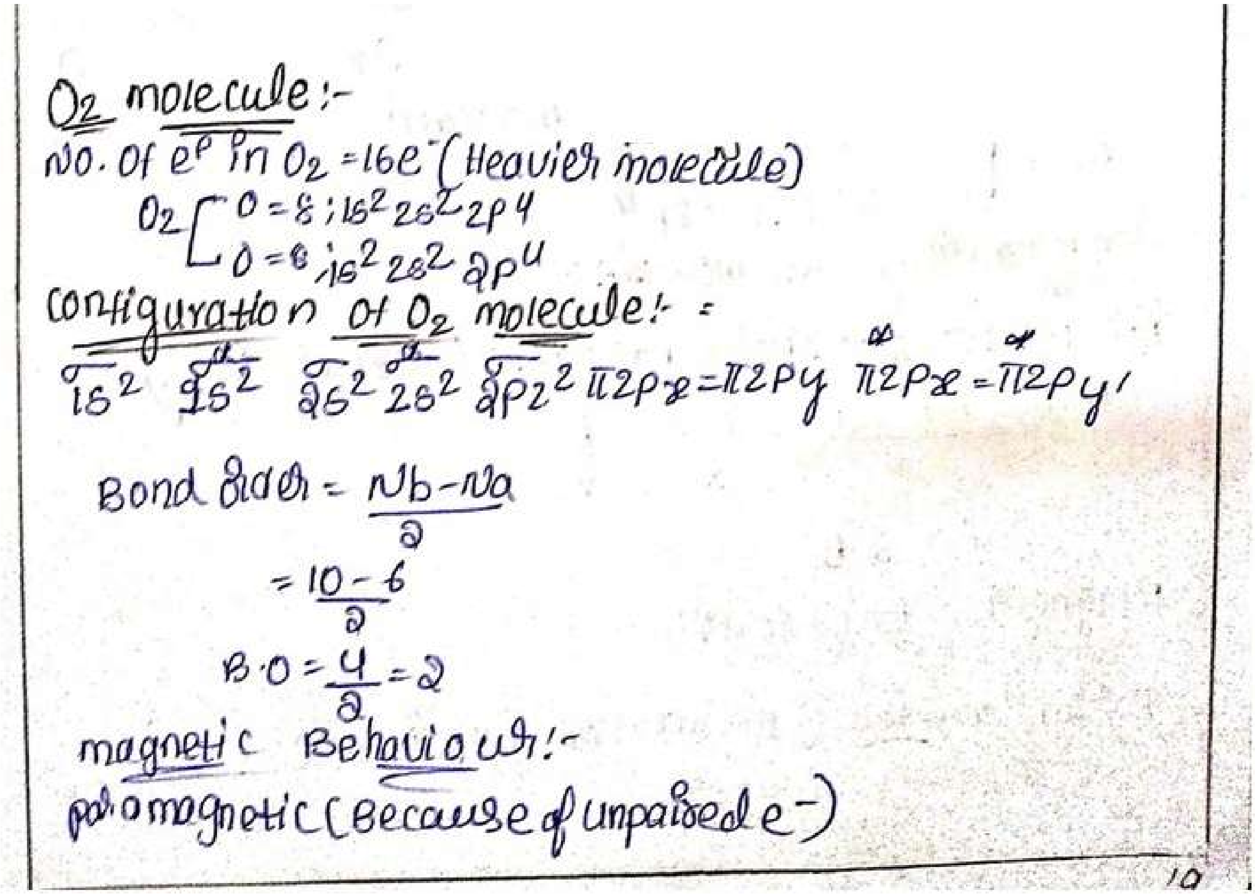
* The wave function ψ in the Schrodinger's eqn represents the amplitude of the e^{ℓ} wave

* The probability of finding an electron at a given point in the 3d space is proportional to ψ^2.

* Hence ψ^2 gives the probility of finding an electron with energy in a given region around the nucleus

* Those places around the nucleus can be detected where the probability of finding the electron is highest

3. Draw the molecular diagrams of O_2 and CO?



O_2 molecule:-

No. of e^- in $O_2 = 16e^-$ (Heavier molecule)

$$O_2 \begin{cases} O = 8;\ 1s^2 2s^2 2p^4 \\ O = 8;\ 1s^2 2s^2 2p^4 \end{cases}$$

configuration of O_2 molecule:-

$\sigma 1s^2\ \sigma^* 1s^2\ \sigma 2s^2\ \sigma^* 2s^2\ \sigma 2p_z^2\ \pi 2p_x = \pi 2p_y\ \pi^* 2p_x = \pi^* 2p_y$

$$\text{Bond order} = \frac{N_b - N_a}{2}$$

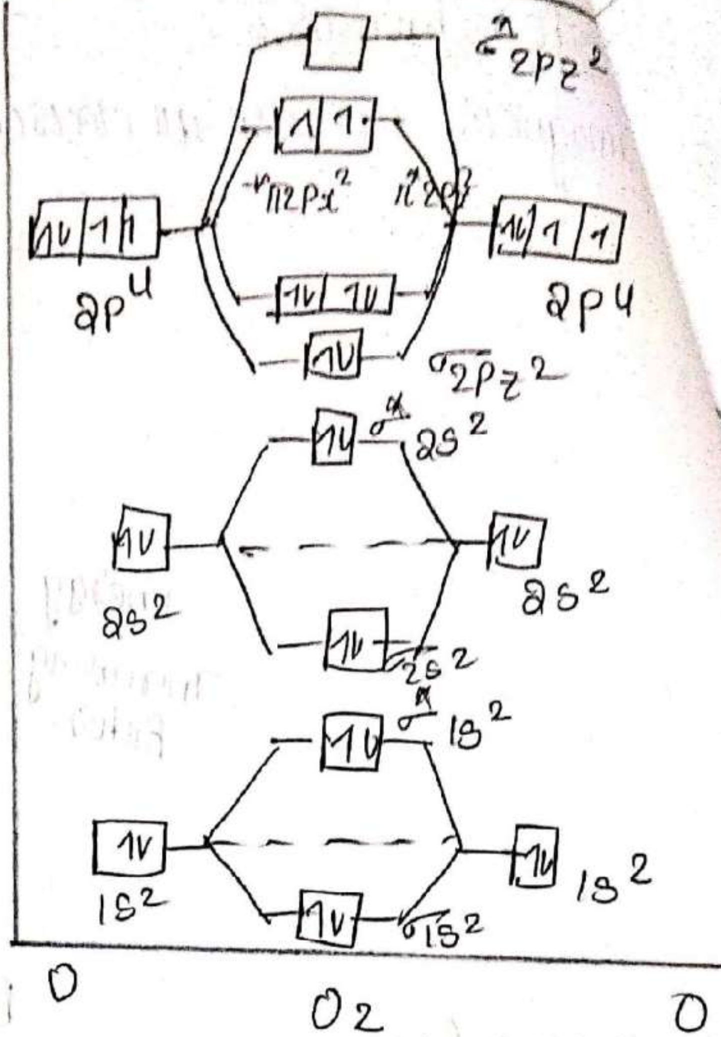
$$= \frac{10-6}{2}$$

$$B.O = \frac{4}{2} = 2$$

magnetic Behaviour:-

paramagnetic (Because of unpaired e^-)

10



Heteronuclear diatomic molecules :-

No. of e^- in NO = 15 e^- (Heavier molecule)

$$NO \begin{cases} N = 7 ;\ 1s^2 2s^2 2p^3 \\ O = 8 ;\ 1s^2 2s^2 2p^4 \end{cases}$$

Configuration of NO molecule :-

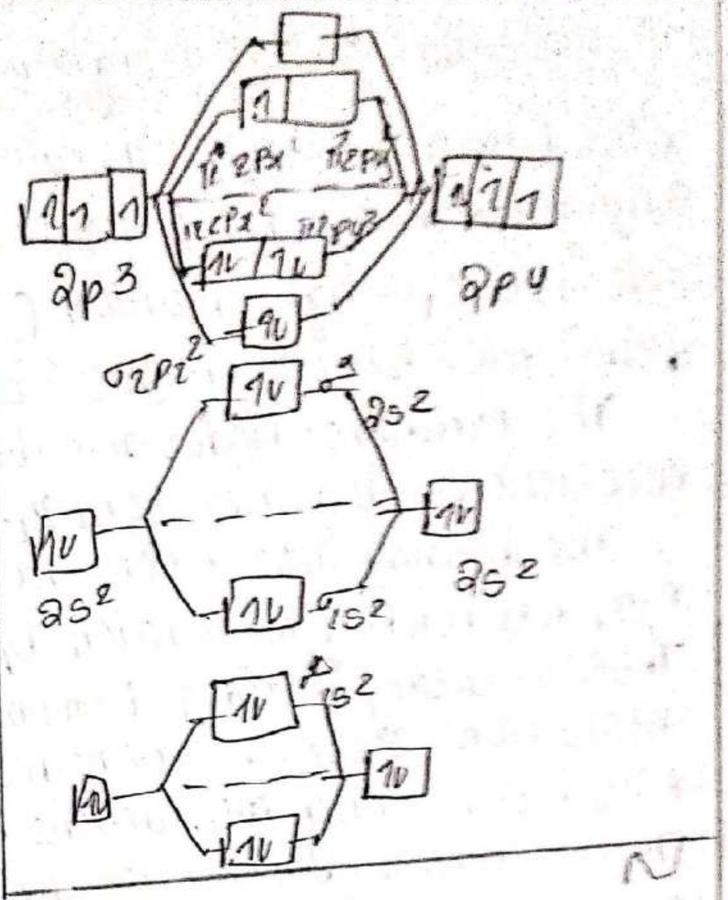
$\sigma 1s^2\ \overset{*}{\sigma} 1s^2\ \sigma 2s^2\ \overset{*}{\sigma} 2s^2\ \sigma 2p_z^2\ \pi 2p_x^2 = \pi 2p_z^2\ \overset{*}{\pi} 2p_x^1 = \overset{*}{\pi} 2p_y$

$$B.O = \frac{Nb - Na}{2} = \frac{10 - 5}{2} = \frac{5}{2}$$

$$= 2.5$$

Magnetic Behaviour :-

paramagnetic (Because of unpaired e^-).



energy
increasing
order.

N

NO

CO- Molecule:-

No. of e⁻ in CO = 14e⁻ (lighter mole) N

CO - $\begin{cases} C = 6;\ 1s^2 2s^2 2p^2 \\ O = 8;\ 1s^2 2s^2 2p^4 \end{cases}$

Electronic configuration of CO molecule:-

$\sigma 1s^2\ \overset{*}{\sigma} 1s^2\ \sigma 2s^2\ \overset{*}{\sigma} 2s^2\ \pi 2px^2 = \pi 2py^2\ \sigma 2pz^2$

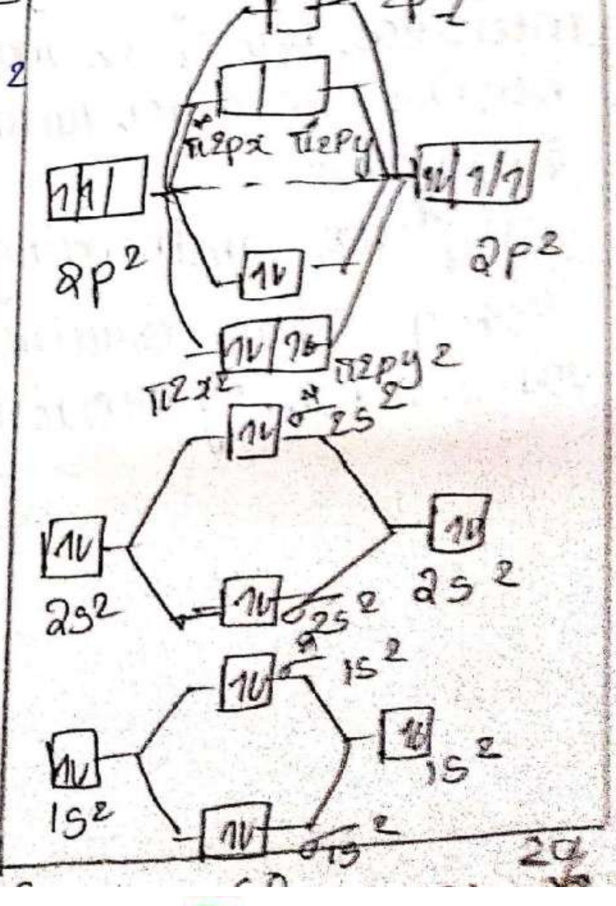
$B.O = \frac{Nb - Na}{2}$

$= \frac{10-4}{2} = \frac{6}{2} = 3$

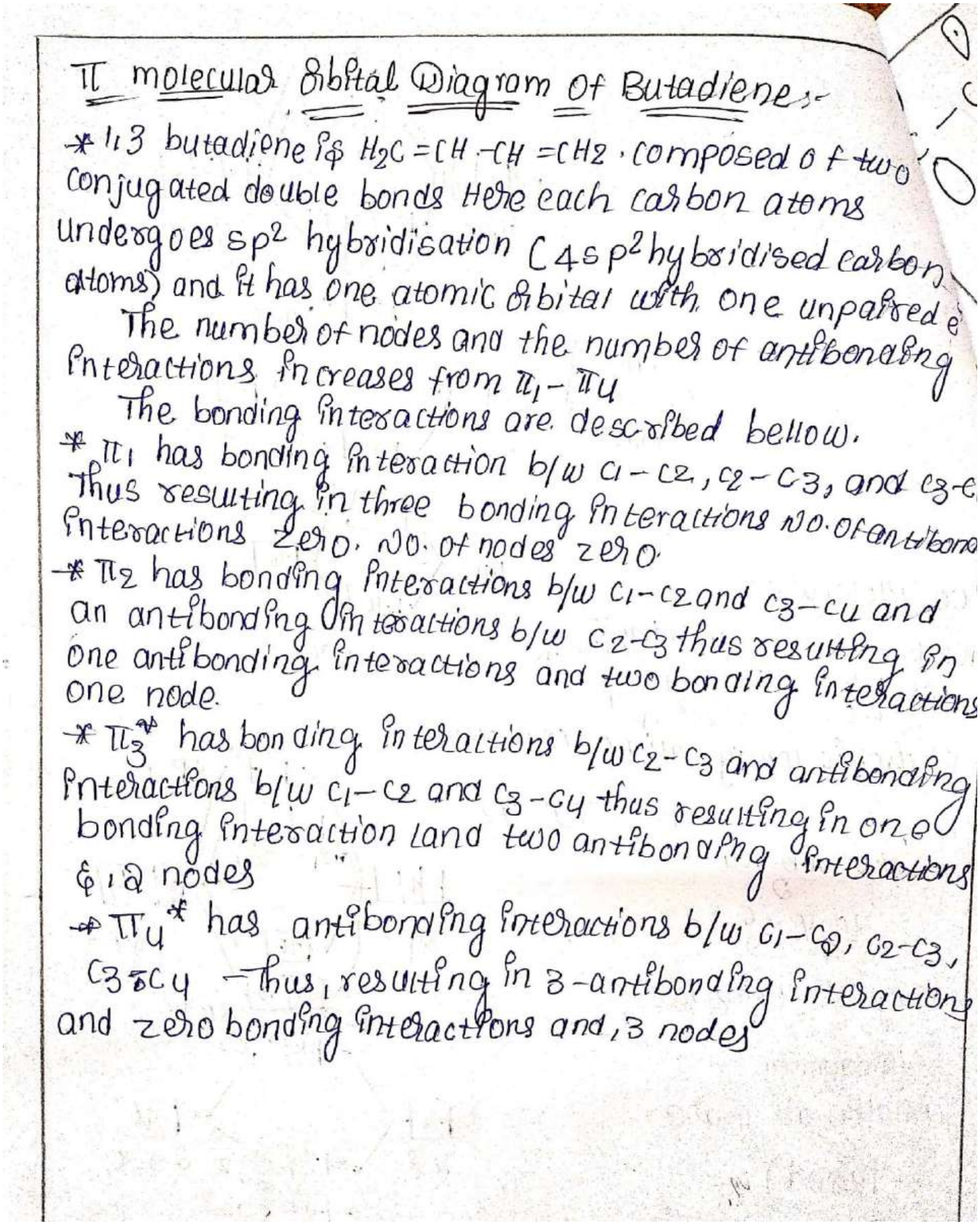
Magnetic Behavior:-

Diamagnetic

(Because all e⁻ are paired).



4. Write the molecular orbital diagrams for 1-3 butadiene and benzene?



π molecular orbital Diagram of Butadiene:-

* 1,3 butadiene is $H_2C=CH-CH=CH_2$. composed of two conjugated double bonds Here each carbon atoms undergoes sp^2 hybridisation (C_4 sp^2 hybridised carbon atoms) and it has one atomic orbital with one unpaired e

The number of nodes and the number of antibonding interactions increases from $\pi_1 - \pi_4$

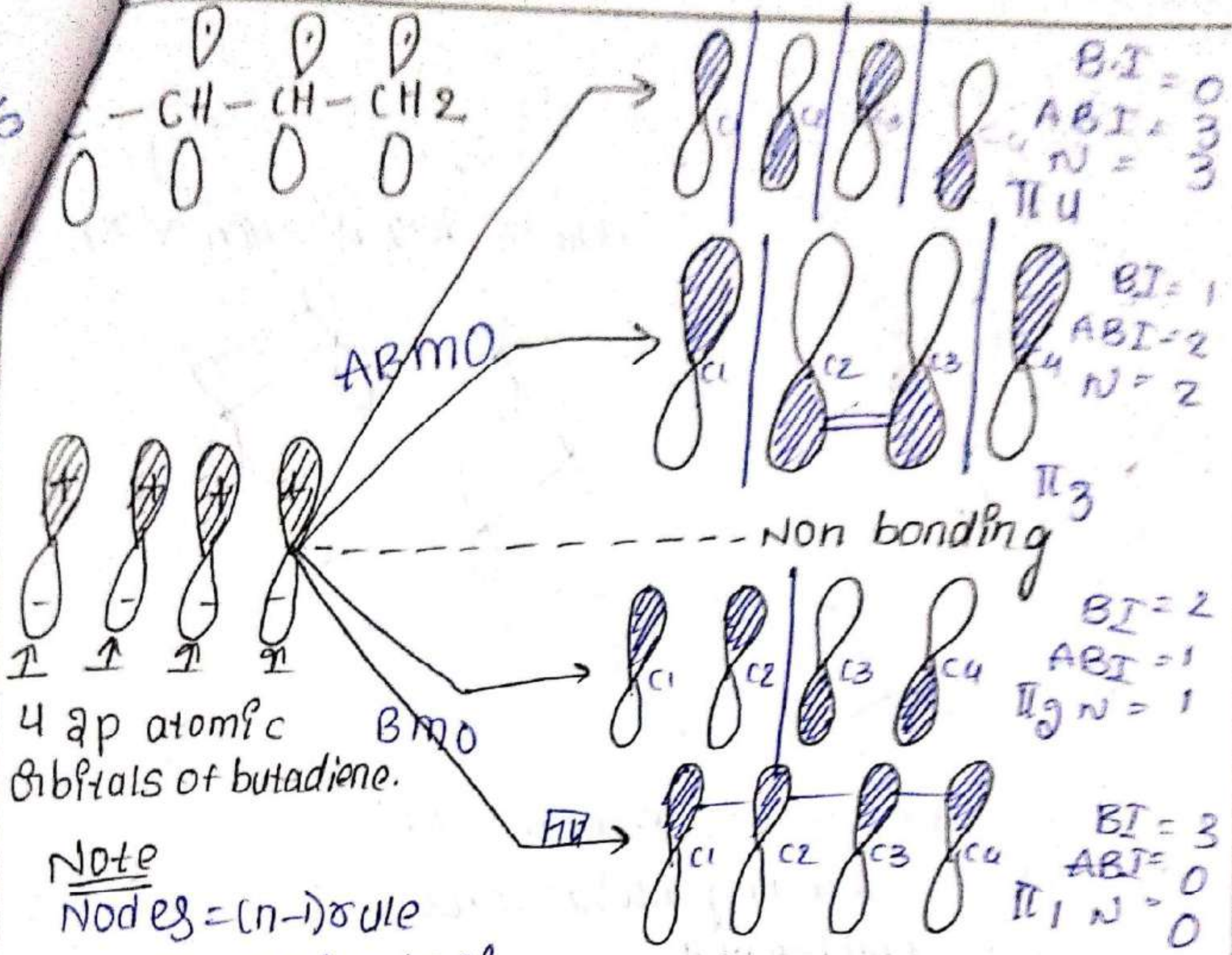
The bonding interactions are described bellow.

* π_1 has bonding interaction b/w C_1-C_2, C_2-C_3, and C_3-C Thus resulting in three bonding interactions no. of antibon interactions zero. no. of nodes zero.

* π_2 has bonding interactions b/w C_1-C_2 and C_3-C_4 and an antibonding interactions b/w C_2-C_3 thus resulting in one antibonding interactions and two bonding interactions one node.

* π_3^* has bonding interactions b/w C_2-C_3 and antibonding interactions b/w C_1-C_2 and C_3-C_4 thus resulting in one bonding interaction and two antibonding interactions & 2 nodes

* π_4^* has antibonding interactions b/w C_1-C_2, C_2-C_3, C_3-C_4 - thus, resulting in 3-antibonding interactions and zero bonding interactions and, 3 nodes



Note

Nodes = (n−1) rule

n = no. of Eenergy level

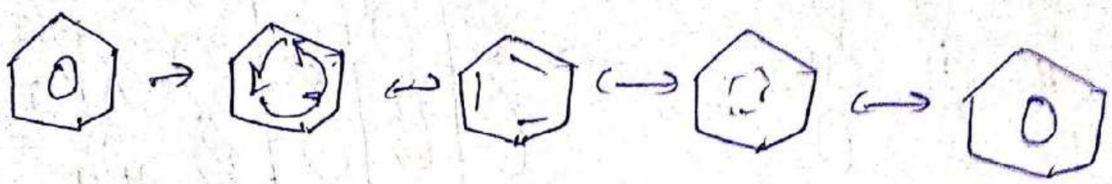
n=1 = 1=1 = 0 nodes
n=2 = 2−1 = 1 nodes
n=3 = 3−1 = 2 nodes
n=4 = 4−1 = 3 nodes

π – Molecular orbital diagram for Benzene:-

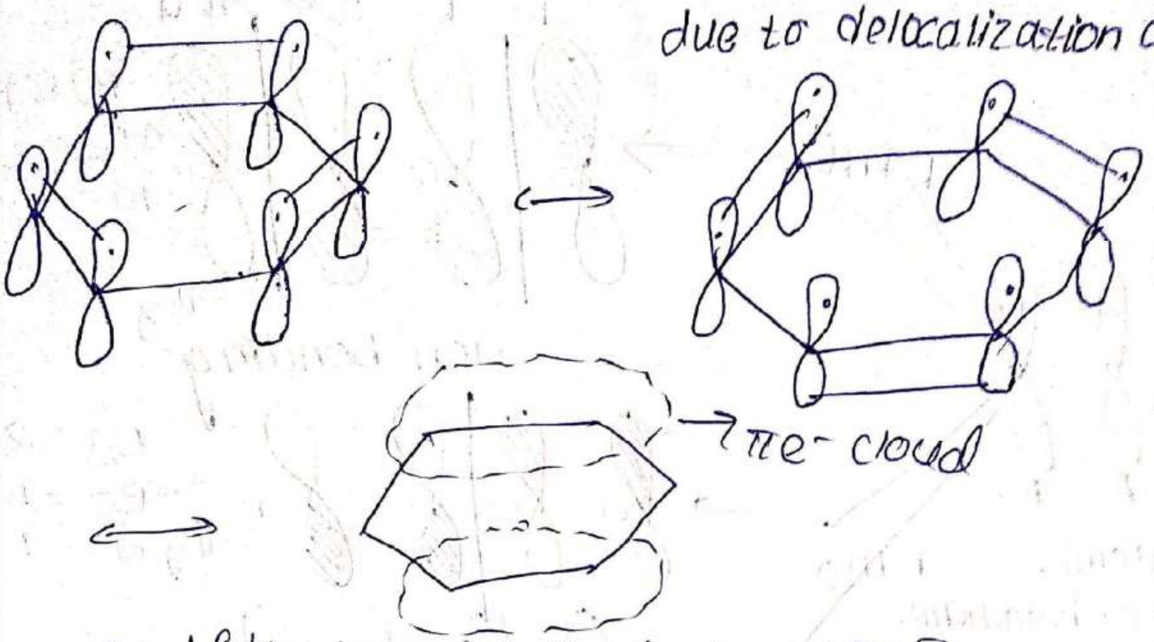
- planar hexagonal cyclic structure
- each carbon atom is sp^2 hybridized
- All carbon carbon bonds are equal in length due to delocalization of π electrons (equivalent bond length)
- stable compound

one hybridized p-orbital is present perpendicularly at each ~~of~~ carbon.

* π_6



due to delocalization of πe^-



Stability due to delocalization of πe^-

* π_1 has all 6-bonding interactions
    zero Anti bonding
    zero node

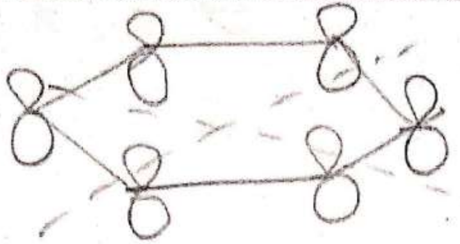
* π_2 has 4 - bonding
    2 - Antibonding
    1 nodel plane
    1 node present

* π_3 has 4 - bonding
    2 A·B
    1 nodel
    1 node present

* π_4^* has 2 Bonding
    4 Anti Bonding
    2 nodel

* π_5^* has 2 bonding
    4 A·B
    2 nodel planes
    2 nodes

π_6^* has No bonding interactions
6 = Anti bonding
3 = Nodel planes
6 = Nodes are present.

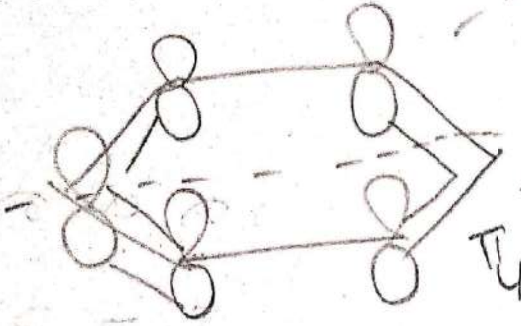


□ π_6

No.of BI = 0

No.of ABI = 6

No.of NodeI = 3

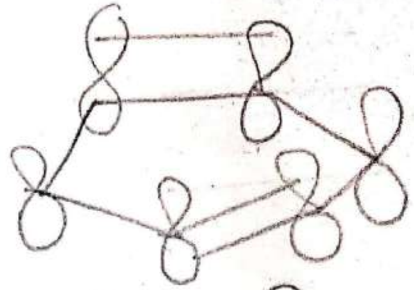


□ π_4

No.of B.I = 2

No.of ABI = 4

No.of Node = 2

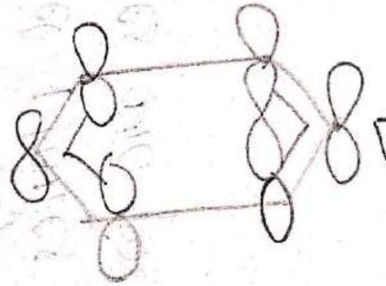


□ π_5

No.of B.I = 2

No.of ABI = 4

No.of Nodes = 2

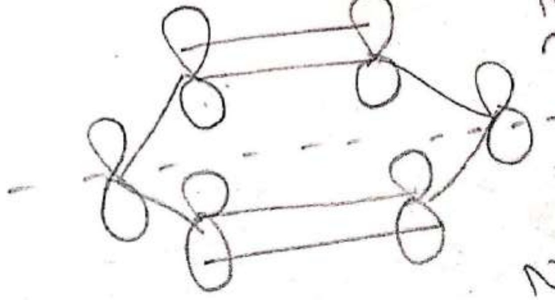


$\boxed{\uparrow\downarrow}$ π_2

No.of B.I = 4

No.of A.B.I = 2

No.of Nodes = 1

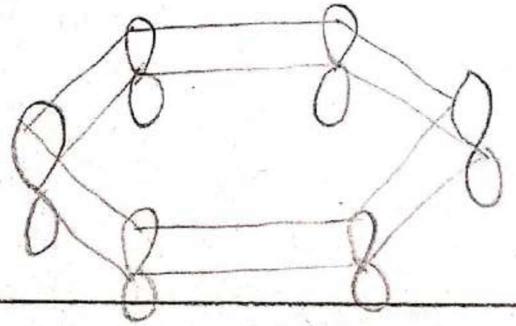


$\boxed{\uparrow\downarrow}$ π_3

No.of B.I = 4

No.of ABI = 2

No.of Nodes = 1



$\boxed{\uparrow\downarrow}$ π_1

No.of B.I = 6

No.of A.B.I = 0

No.of Nodes = 0

MCQs

1. Schrödinger wave equation is a fundamental equation in:

A) Classical mechanics
B) Quantum mechanics
C) Nuclear physics
D) Relativity theory
Answer: B) Quantum mechanics

 It describes the behavior of particles at atomic and subatomic levels.

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2. In the Schrödinger wave equation, the symbol ψ (psi) represents:

A) Energy of the system
B) Wave function of the particle
C) Momentum of the particle
D) Potential energy
Answer: B) Wave function of the particle

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3. The term ψ^2 (psi squared) represents:

A) Kinetic energy
B) Probability of finding the electron
C) Charge density
D) Wave amplitude
Answer: B) Probability of finding the electron

 ψ^2 *gives the probability density function.*

---

4. For a particle in a one-dimensional box, the allowed energy levels are proportional to:

A) n
B) n^2
C) 1/n
D) $1/n^2$
Answer: B) n^2

 $E_n = n^2h^2 / (8mL^2)$

---

5. The lowest energy state of a particle in a box is called the:

A) Excited state
B) Zero energy state
C) Ground state
D) Forbidden state
Answer: C) Ground state

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6. In Molecular Orbital (MO) theory, atomic orbitals combine to form:

A) Hybrid orbitals
B) Molecular orbitals
C) Crystal orbitals
D) Nodal planes
Answer: B) Molecular orbitals

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7. The number of molecular orbitals formed equals:

A) Number of electrons
B) Number of nuclei
C) Number of atomic orbitals combined
D) Twice the number of atomic orbitals
Answer: C) Number of atomic orbitals combined

---

8. In MO theory, bonding molecular orbitals have:

A) Higher energy than atomic orbitals
B) Lower energy than atomic orbitals
C) Same energy as atomic orbitals
D) Zero energy
Answer: B) Lower energy than atomic orbitals

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9. In O_2 molecule, according to molecular orbital theory, the bond order is:

A) 1
B) 2
C) 3
D) 2.5
Answer: B) 2

□ *Bond order = ½ (Nb – Na) = ½ (10 – 6) = 2*

---

10. The magnetic nature of O_2 molecule is:

A) Diamagnetic
B) Paramagnetic
C) Ferromagnetic
D) None of these
Answer: B) Paramagnetic

□ *Due to two unpaired electrons in π*$_2$p orbitals.*

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11. In CO molecule, the bond order is:

A) 1
B) 2
C) 3
D) 2.5
Answer: C) 3

□ *Bond order = ½ (Nb – Na) = ½ (10 – 4) = 3*

---

12. The correct filling order of molecular orbitals up to O_2 is:

A) σ1s, σ*1s, σ2s, σ*2s, π2p, σ2p, π*2p, σ*2p
B) σ1s, σ2s, σ*2s, π2p, σ*2p
C) σ1s, σ*1s, σ2s, π2p, σ*2s
D) π2p, σ1s, σ2p, σ*2s*
***Answer:** A) σ1s, σ*1s, σ2s, σ*2s, π2p, σ2p, π*2p, σ*2p

---

13. In 1,3-butadiene, π molecular orbitals are formed by the combination of:

A) 2 p-orbitals
B) 3 p-orbitals
C) 4 p-orbitals
D) 6 p-orbitals
Answer: C) 4 p-orbitals

□ *Each carbon contributes one p-orbital → 4 total π-MOs.*

---

14. The number of π molecular orbitals in benzene is:

A) 3
B) 6
C) 12
D) 2
Answer: B) 6

□ *One from each of the six* sp^2 *carbons.*

---

15. The delocalized π-electron system in benzene contributes to:

A) Its instability
B) Its high reactivity
C) Its aromatic stability
D) Its ionic character
Answer: C) Its aromatic stability

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16. The bond order between two atoms can be calculated using the formula:

A) (Nb + Na)/2
B) (Nb – Na)/2
C) (Nb × Na)/2
D) (Nb / Na)
Answer: B) (Nb – Na)/2

□ *Nb = number of electrons in bonding MOs, Na = in antibonding MOs.*

---

17. In the O_2^- **ion, the bond order is:**

A) 1.5
B) 2
C) 2.5
D) 3
Answer: C) 2.5

□ *Extra electron enters* π2p → bond order = ½ (10–5) = 2.5.*

---

18. In the O_2^{2-} ion (peroxide), the bond order is:

A) 1
B) 1.5
C) 2
D) 2.5
Answer: A) 1

---

19. Which molecule is isoelectronic with CO?

A) N_2
B) O_2
C) NO
D) CN^-
Answer: D) CN^-

□ *Both CO and CN^- have 14 electrons.*

---

20. The π–π^* transition in conjugated molecules like butadiene occurs at:

A) Very low energy (long λ)
B) Very high energy (short λ)
C) Infinite energy
D) No transition possible
Answer: A) Very low energy (long λ)

□ *Because the HOMO–LUMO gap decreases as conjugation increases.*

UNIT-II
MODERN ENGINEERING MATERIALS

SEMICONDUCTORS

1. What is a semiconductor?

A semiconductor is a substance whose electrical conductivity lies between that of a conductor and an insulator.
Example: Silicon (Si), Germanium (Ge).

2. What are the types of semiconductors?

- **Intrinsic semiconductor:** Pure semiconductor (e.g., Si, Ge).
- **Extrinsic semiconductor:** Doped with impurities to increase conductivity.
  - **n-type:** Doped with pentavalent element (P, As).
  - **p-type:** Doped with trivalent element (B, Al).

3. What is the band gap in semiconductors?

It is the small energy gap (about 1 eV) between the valence band and conduction band.

4. Give two applications of semiconductors.

- Used in diodes, transistors, and integrated circuits (ICs).
- Used in solar cells and LEDs.

⚡SUPERCONDUCTORS

1. What is superconductivity?

It is the phenomenon in which a material shows **zero electrical resistance** and **expulsion of magnetic field (Meissner effect)** below a critical temperature.

2. What is the critical temperature (Tc)?

The temperature below which a material becomes superconducting.

3. Give examples of superconductors.

- Mercury (Hg)
- Niobium (Nb)
- $YBa_2Cu_3O_7$ (Yttrium barium copper oxide – high-Tc superconductor)

4. Mention two applications of superconductors.

- Magnetic Resonance Imaging (MRI) machines.
- Maglev (magnetic levitation) trains.
- Superconducting power cables.

□□ SUPERCAPACITORS

1. What is a supercapacitor?

A supercapacitor (ultracapacitor) is an energy storage device that stores electrical energy **between a capacitor and a battery**, with higher energy density than conventional capacitors.

2. What is the basic concept?

Supercapacitors store charge either by **electrostatic double-layer formation** or **fast surface redox reactions.**

3. What are the types (classification) of supercapacitors?

- **Electrochemical Double Layer Capacitors (EDLCs)** – charge stored electrostatically.
- **Pseudocapacitors** – charge stored by redox reactions.
- **Hybrid supercapacitors** – combination of both.

4. Give two applications of supercapacitors.

- Energy storage in electric vehicles (EVs).
- Power backup in electronic devices and renewable energy systems.

⍰ NANOMATERIALS

1. What are nanomaterials?

Materials having at least one dimension in the nanometer range (1–100 nm).

2. What are the classifications of nanomaterials?

- **Zero-dimensional (0D):** Nanoparticles, quantum dots.
- **One-dimensional (1D):** Nanowires, nanotubes.
- **Two-dimensional (2D):** Graphene sheets.
- **Three-dimensional (3D):** Nanocomposites.

3. What are the important properties of nanomaterials?

- High surface area to volume ratio.
- Enhanced mechanical strength.
- Improved electrical and optical properties.

4. What are Fullerenes?

Fullerenes are spherical carbon molecules (C_{60}, buckyballs) composed of pentagons and hexagons.

5. What are Carbon Nanotubes (CNTs)?

CNTs are cylindrical fullerenes with high tensile strength and conductivity.
Types: Single-walled (SWCNT) and multi-walled (MWCNT).

6. What is Graphene?

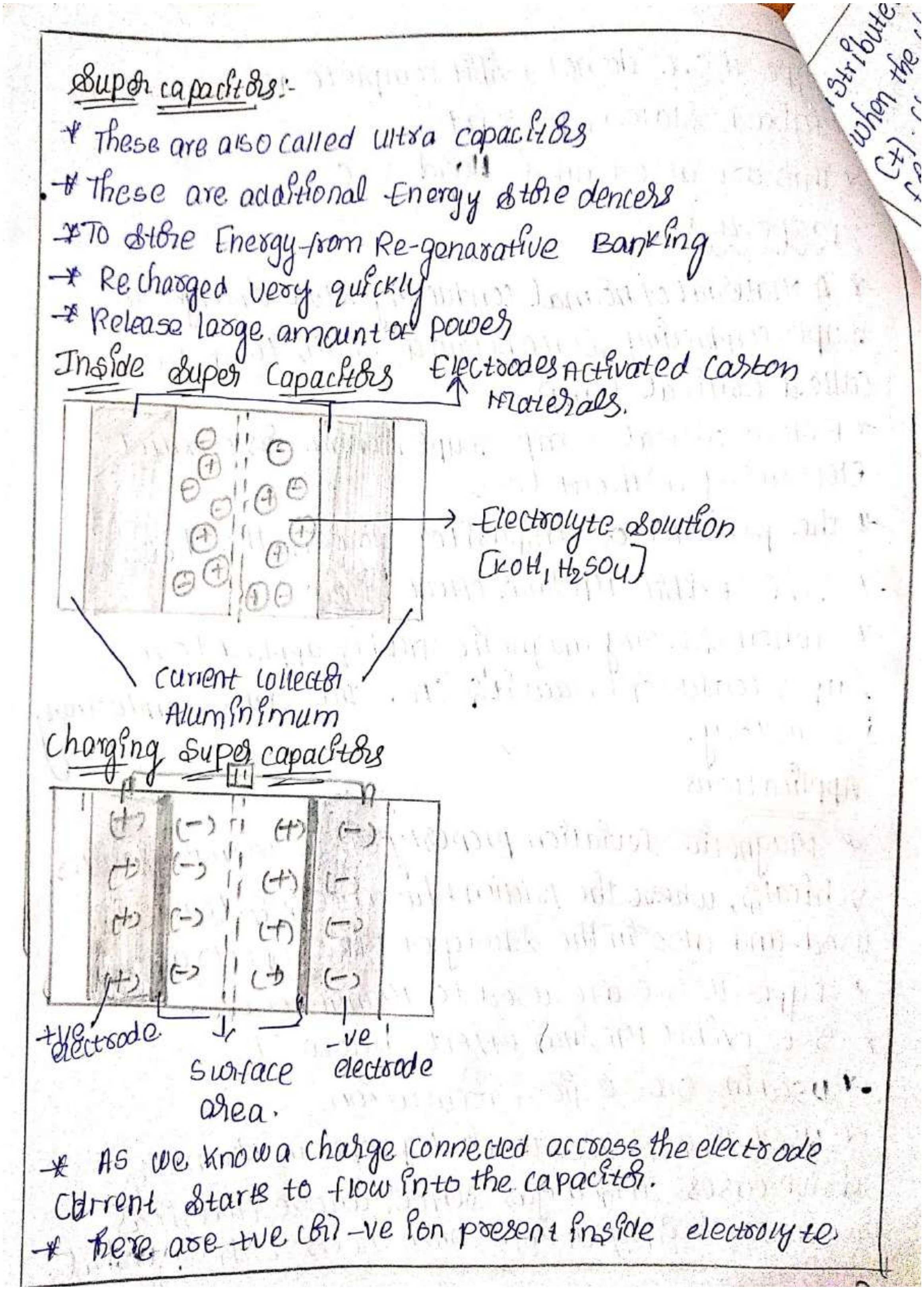
Graphene is a single layer of carbon atoms arranged in a hexagonal lattice; it has excellent electrical, thermal, and mechanical properties.

7. Mention applications of nanomaterials.

- Drug delivery and biosensors.
- Nanoelectronics and solar cells.
- Strengthening materials (nanocomposites).
- Catalysts and coatings.

EASSAY QUESTIONS

1. Write about super capacitors and classification applications of super capacitors?



Super capacitors:-

- * These are also called ultra capacitors
- * These are additional Energy store dencers
- * To store Energy from Re-genarative Banking
- * Re charged very quickly
- * Release large amount of power

Inside super capacitors

Charging super capacitors

- * As we know a charge connected accross the electrode current starts to flow into the capacitor.
- * here are +ve (or) −ve ion present inside electrolyte

istributed randomly accross it.

*when the chargor starts to charges the (+) electrode with (+). charge it starts to attract (-) ions from electrolyte. forming layer.

* Similarly the (-) electrode is charge with (-) ions and attract the (+) ions from electrolyte forming another layer accross it.

* The forcess of attraction b/w electrode & Electrolyte is Electrostatic force so the Alignment of (+) & (-) charges accross the boundary of Electrode Soln cause Electric double layer.

* And this is Responsible for stores Electrical charges

* Then capacitor known as Double layer capacitor

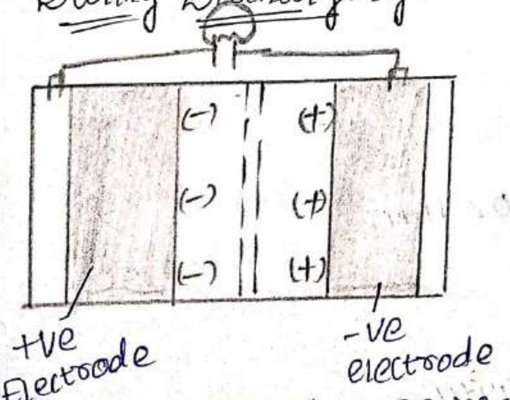
* The capacitor (C1) formed along with the another capacitor (C2) which act as they are connected as series

$C_1 \propto \frac{A}{d}$ | $C_2 \propto \frac{A}{d}$ ⇒ A = high surface area of Electrodes

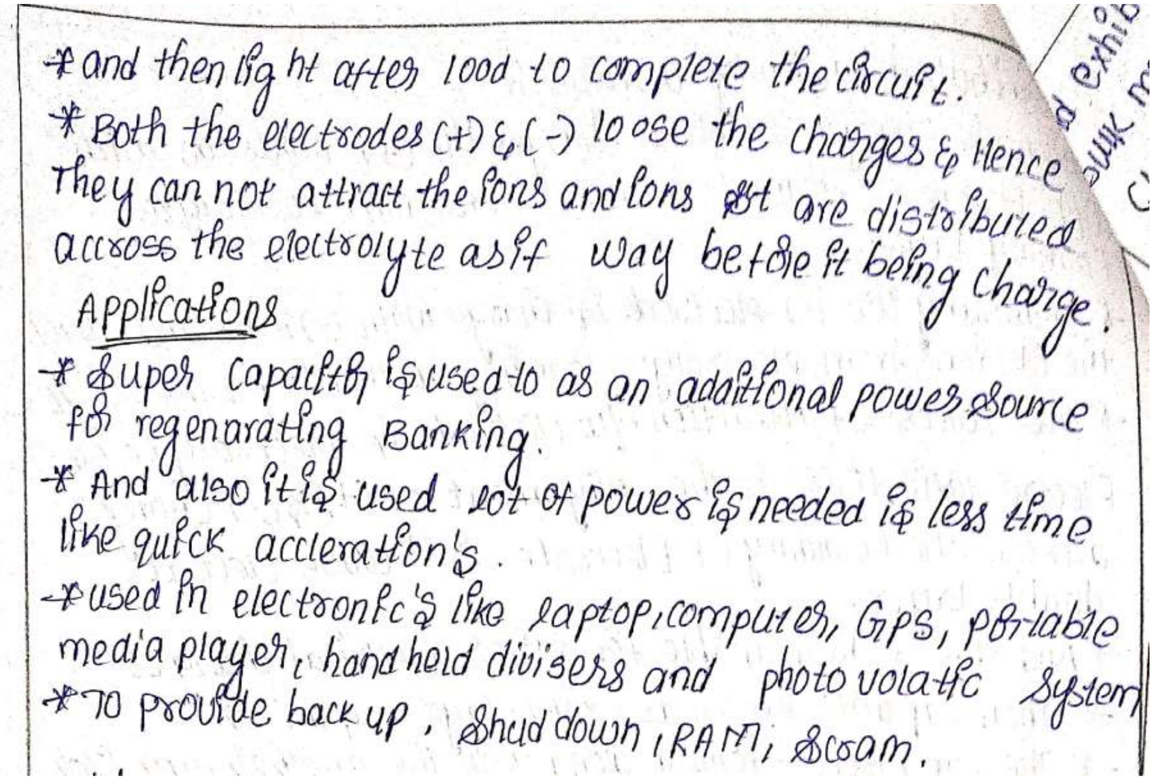
d = small distance b/w plates

$C' \text{ total} = \frac{C1 \cdot C2}{C1 + C2}$

During Discharging



* load connected to accross the electricity and the Electrode starts to lose the charge and charge flows the external circuits



* and then light after load to complete the circuit.

* Both the electrodes (+) & (-) loose the charges & Hence They can not attract the ions and ions ~~it~~ are distributed accross the electrolyte as it way before it being charge.

<u>Applications</u>

* Super capacitor is used to as an additional power source for regenarating Banking.

* And also it is used lot of power is needed is less time like quick accleration's.

* used in electronic's like laptop, computer, GPS, portable media player, hand held divisers and photo volatic system

* To provide back up, Shud down, RAM, Sram.

2. Write about Nano materials classification properties and applications of Carbon nano tubes and Fullerenes?

Nano Materials

The materials like metals, ceramics, polymeric materials/composite materials with dimensions and tolerance in the range of 1nm to 100nm are called ~~n~~ Nanomaterials

- one billonth (10^{-9}) of a meter.
- 1 m = 39 inches

$1 NM = 10^{-9} m$
$1 M = 10^{9} Nm$

Eg: ~~1NM =~~ $H = 0.1nm$, $H_2O < 1nm$

Significance

- Due to their small size
- M.P, reaction rates, conductivity, colour
- A nanoparticle is defined as a small object that behaves as a whole unit in terms of it's transport

d. exhibit a number of special properties relative to bulk materials. (1nm-100nm).

Classification (Based on Dimensions)

1D 2D 3D

1D :- Two dimension reduced to nanorange & one D is remains large. movement of e- is along these direction

Eg :- Nanowires

2D : 1D reduced to nanorange, 2D are large. movement of e- is along 2 directions

Eg :- Nanowells, Nanofilms

3D : There is no confinement in nanorange. movement of e- along 3 directions

Eg :- Bulk N.m, nano powders.

Based on composition :-

1] Organic n.m :- composed with carbon with different forms

Eg :- CNT, fullerenes

2] Inorganic n.m :- composed with metal & metal oxide in different forms

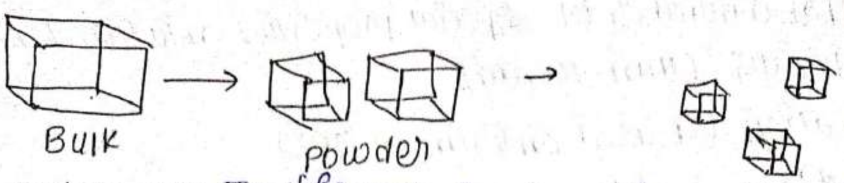
Eg :- Au, Fe, Pt, Al

3] Hybrid n.m :- exhibit combination of organic & inorganic n.m (O-O, O-I, I-I).

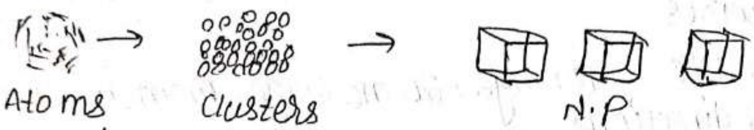
Eg :- polymers

Preparation of N.M :-

1. Top-down :- In this method bulk materials are converted to nanoparticles by making use of lithographic methods.

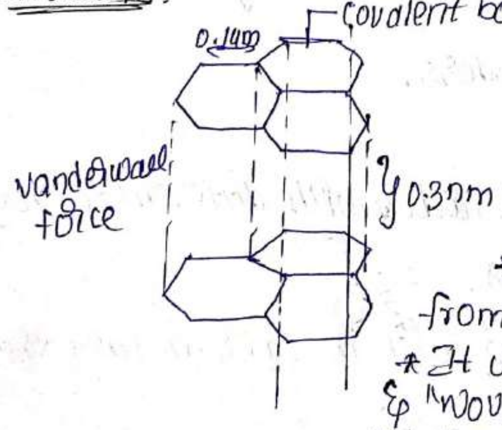


Bottom-up:- In this very small particle N.P like individual molecules are assembled to get clusters which in turn are aggregated with N.P



Graphene:-

Structure:-



* Graphene is an allotrope of 'c' consisting of a single layer of atoms arranged in a hexagonal monostructure.
* Graphene is dervied word from Graphite
* It was invented by "Andre Geim" & "Novoselov" in 2004 & received Nobel prize in 2010

properties:-

* It is exhibit in 2D form
* Graphene is stronger than Diamond
* It is Tough & highly flexible.
* weight of graphen 1000 lesser than a paper
* It has Excellet fire resistance
* Having high flexibility up to 25%
* It has more durability & stiffness.

pplications

- * used in optical electronic system
- * used in ultra filtration
- * used in photo voltaic cells solar cells
- * used as sensors
- * used as super capacitors
- * used in nuclear reactors
- * used in preparation of power banks, mobile & display
- * mixed in concrete to increase strength of cement in buliding constructions.

* Carbon Nano tubes (CNT) :-

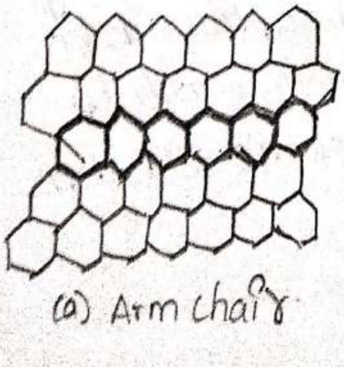
Carbon nano tubes are shocts of graphite about 0.4nm in diameter rolled up to make a tube of few nm in diameter

* CNT's are also called "buckytubes".

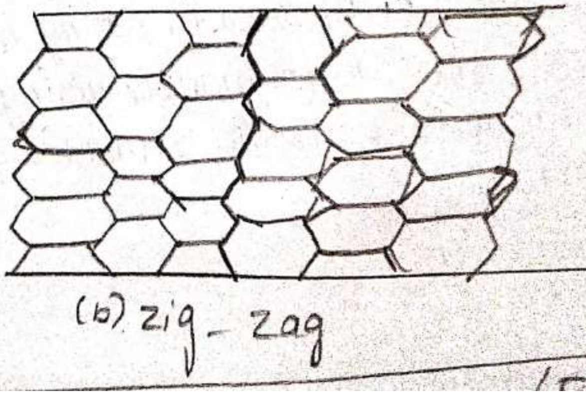
Depending on arrangement these are 2-types.

1] Single walled NTs :- a. $n=m$ - Arm, chair, b. $m=0$, zig-zag, c. $n \neq m$, chirol.

2] Multiwalled NT'S :- consists multi layers of graphite, Distance b/w 2 graphite layers is 3.3A°

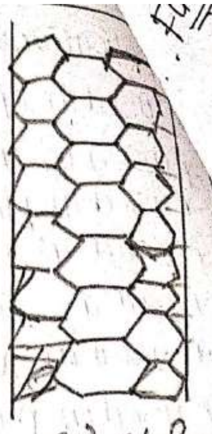


(a) Arm chair



(b) zig - zag

properties of CNT :-



(c) Chiral

- CNT's are high thermal conductivity
- CNT's have high Electrical conductivity
- CNT's have high tensile strength
- CNT's are highly flexible with out damage
- Have law thermal expansion coefficient
- CNT posses Toxicity.
- CNT's have unique optical obsorption properties and differ from in bulk materials

Applications

- CNT's are used to make space elevators, stab-proof
- CNT's are recently used for making electrical cables & wires bcz of high conductivity.

paper batteries :- use a paper-thin sheet of cellulose infused with CNT - Here CNT act as electrode.

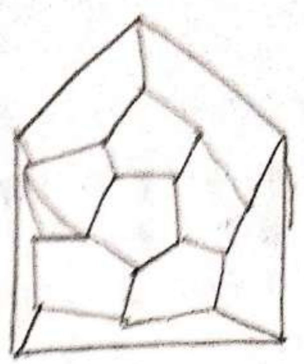
Hydrogen storage :- CNT can be store hydrogen to be used as a fuel source

Medical :- * used as drug delivery materias
* used as tumaur targeting material in human body

Textile :- CNT's used for coating & absorption on the surface of fibre for manufacturing fabric which is antibacterial electronic conductive, flame retardant etc.

Fullerenes :

C_{60}



C_{20}

- Fullerenes are allotropes of carbon
- It can be prepared by vaporasing rod in the Atmosphere
- carbon atoms in fullerenes are connected by single and double bonds and forms closed mesh network.
- The shape of fullerene may be a hallow sphere.

C_{60} fullerenes

- As structur like soccer ball
- each carbon atom is sp_2 hybridised and trigonally linked (each carbon atom is linked with other 3 carbon atoms)
- It has polyhedral Network
- It has 60 vertices & 32 faces
- out of 32 faces 12 are pentagonal & 20 are hexagonal rings.

properties

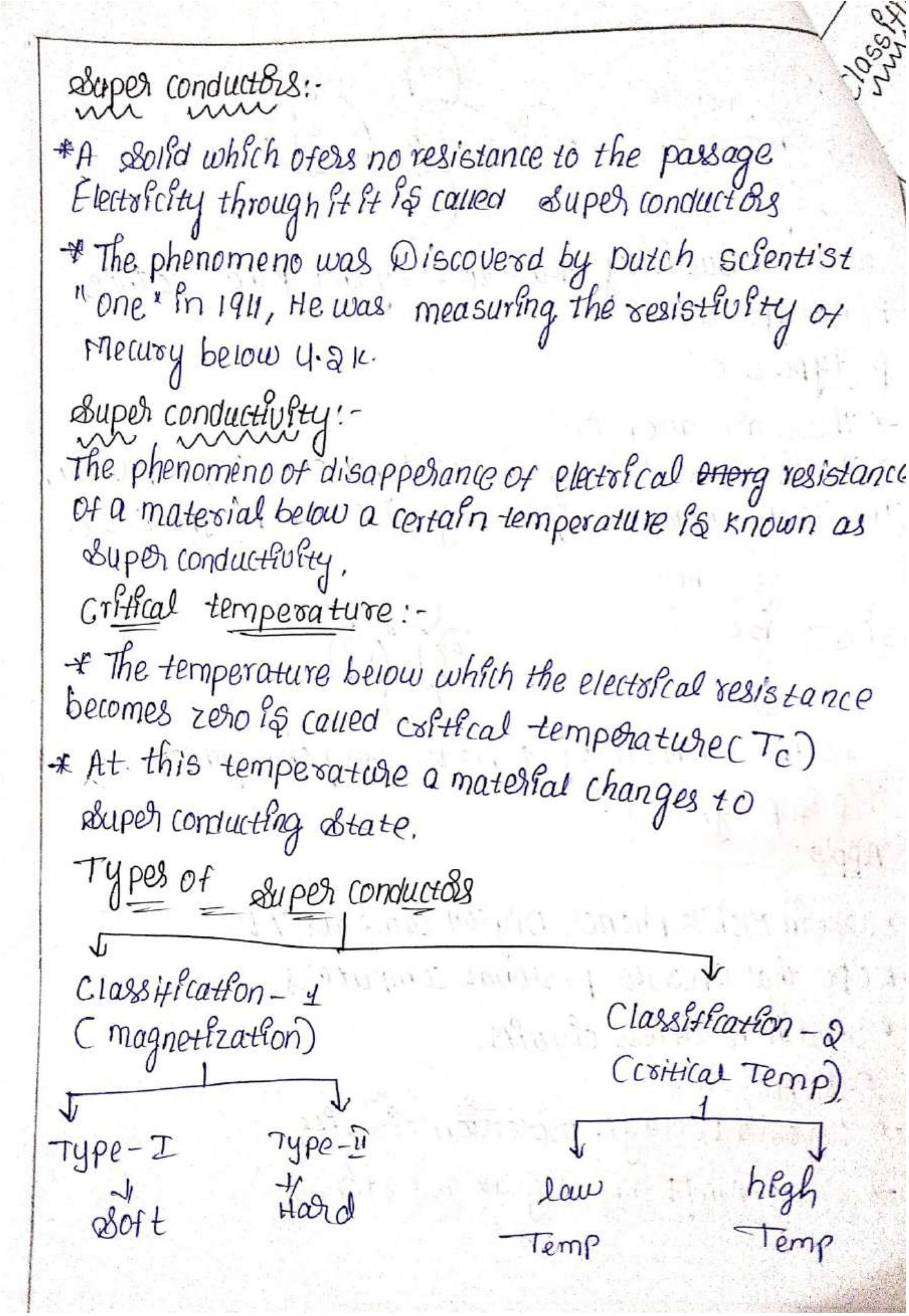
* It can be compressed up 30% of it's volume.
* It is thermally stable up to 60°c
* It is soluble in Benzene solution.
* It has good tensil strength.

Applications

* used as charge carries in Battriey.
* Alkali metal fullerences are used as super conductors
* It is used as lubricant due to spherical shape.
* used to controlgrowth of HN-I virus
* used to make hydrogen fuel
* used to making cosmetic related materials

== × ==

3. Define super conductor and discuss about their classification and applications?



Super conductors:-

*A solid which ofers no resistance to the passage Electricity through it it is called super conductors

* The phenomeno was Discoverd by Dutch scientist "one" in 1911, He was measuring the resistivity of Mecury below 4.2k.

Super conductivity:-

The phenomeno of disapperance of electrical ~~energ~~ resistance Of a material below a certain temperature is known as super conductivity.

Critical temperature:-

* The temperature below which the electrical resistance becomes zero is called critical temperature(T_C)

* At this temperature a material changes to super conducting state.

Types of super conductors

- Classification - 1 (magnetization)
  - Type-I → Soft
  - Type-II → Hard
- Classification - 2 (critical Temp)
  - low Temp
  - high Temp

Classification's

Based on super conducting transition the super conductors are following to two types

1] law temperature
2] High temperature.

1] law Tem:-

* Super conductors with law T_c are known as law temperature Super conductors
* Useually the T_c of law Temp S.C is less than 20K
* The other name is Elemental S.C

Eg:- Hg = 4.2K.

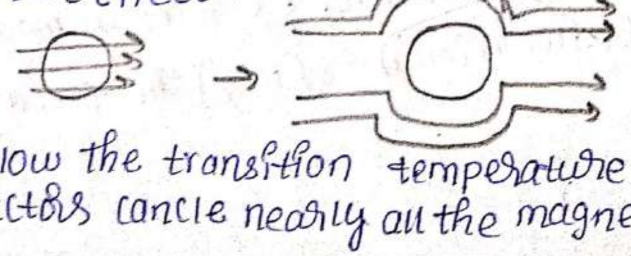
High temperature:-

* Super conductors with high temperature are knocon as High temperatur S.C
* usually the T_c is $< 20K$

Eg:- Metalic alloys.

Misinar Effect :-

* An Explusion of a magnetic field from a S.C during it's to the super conducting state is called misinar effect



* Below the transition temperature the super conductors cancle nearly all the magnetic field inside

→

Classification – I

* Based on Magnatisation Behaviour Super conductors are divided into two types

1. Type – I S.C
2. Type – II S.C

1. Type. I Super conductors :-

* Example pure metals, conductors , Hg, Pb
* In type-I Super conductors the magnetic field is totally expeld from the interer of the material below a certain magnitization field (Hc)
* At H_C the material losses it's magnitization sudenly
* This type of super conductors exibits misinar effect.

2. Type-II S.C :-

* Examples allays, metals
* In type-II super conductors the magnitization is last gradually rather than suddeny
* there are two magnetic field.
* lower critical magnetic field [H_{c1}] & upper critical magnetic field [H_{c2}].
* Below H_{c1} the super conductor excludes all magnetic field lines in between (H_{c1}) & [H_{c2}] the field becomes to enter.

Type-II S.C do not exibit complete misinar effect

- * Mixed state is present
- * This are also called Hard S.C.

Properties

- * A material of normal conducting state changes to super conducting state below a certain temp is called critical temp
- * Below critical temp super conductors conduct electricity without loss.
- * The presence of Impurites lower's the T_c
- * S.C exibit Misinar effect below T_c
- * when strong magnetic field is applied to a super conductor below it's T_c. The super conductivity is distroy.

Applications

- * Magnetic leviation property of S.C to make trains, vehicals, where the friction b/w wheels & tracks is used. and also in the study of MRI spectra
- * Type-II S.C are used to manufactures
- * S.C exibit Misinar effect below T_c
- * used in S.C logic calculation
- * used as a sencer to find people in drunk & drive cases. It is a gas sencer whose electrical resistance sharply changes when meets with Alkohal.

4. Define semi conductor and discuss various types and applications of semi conductor?

Semi Conductors

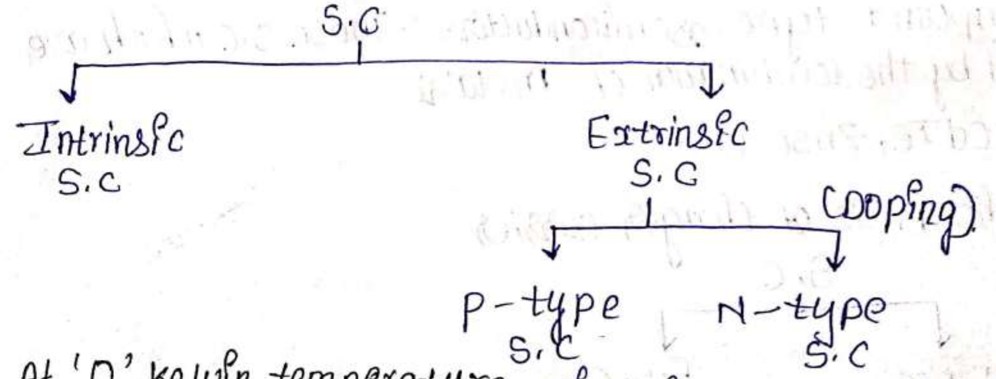
* Between the valence band and the conduction band in a semiconductor, there is a slight energy difference of around

* This band gap is also known as Forbidden energy gap

* Those substances which do not conduct electricity at law temperature but an increasing the temperature it conduct electricity called semiconductors". Eg: si/Ge.

* S.C are materials which have conductivity b/w conductors & Insulators, so they have law conductivity. To Increase conductivity of S C we are adding impurities to it. Eg: si/Ge

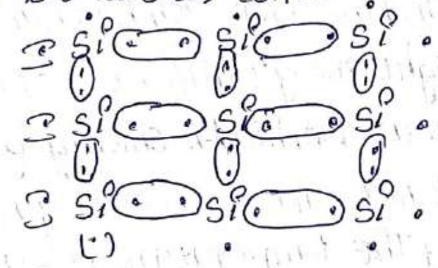
Then S.C are classified into



At 'O' kelvin temperature :- There is no free electron as all the valence electron are involved in bonding so that zero kelvin temp S.C behave as an Insulator.

At temperature above then zero :- On increasing temp more thermal energy are available due to which atom is a crystal start vibrating due to which same of the covalent bond break and some free e° are generated so there s.c acts as conductors.

intrins // *pure



At zero kelvin Temperature

Classification :-

1. On the basis of chemical composition.

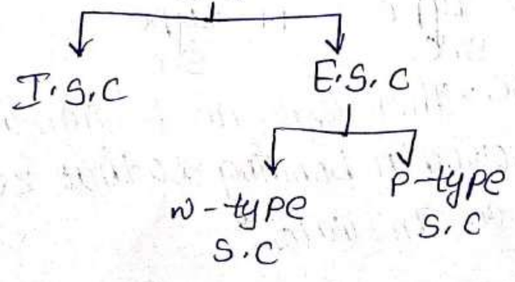
a) Element type semiconductors :- Those s.c are available in natural form.

Eg:- silicon & Germanium

b) Compound type semiconductors :- Those s.c which are formed by the combination of metals

Eg:- CdTe, ZnSe etc.

2) On the basis of Charges carries



Intrinsic semiconductors :-

* pure form of S.C are called I.S.C
Eg:- Si, Ge.

* Impurities do not effect it's electrical behaviour hence are also called undopped / S.C

* It has equal no. of e^- & holes(+ve).

* This S.C pentavalent impurities are added that acts as N-type S.C & Trivalent are added.

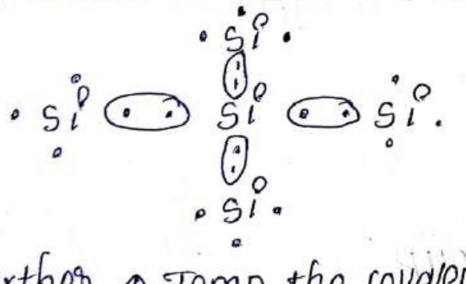
working:-

* W.K.T Electronic configuration of both the elements Si/Ge have $4e^-$ in it's valence cell.

$Si\ (14) = 2, 8, 4 - 1s^2 2s^2 2p^6 3s^2 3p^2$

$Ge\ (32) = 2, 18, 18, 4 - 1s^2 2s^2 2p^6, 3s^2 3p^6 4s^2 3d^{10} 4p^2$

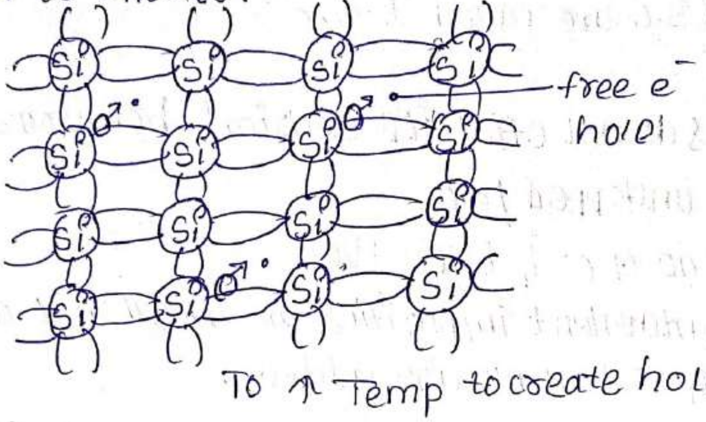
* As ↑ Temp it behaves like an insulator at zero K 7l temp above zero, act as conductor.



* further ↑ Temp the covalent band is broken and the e^- is free. The position from which the e^- gets dislodged has a hole.

* The hole is occupied by a free e^- as a result of which vaccant position becomes a hole

* This way the hole/+ve charge is transfered from one position to another.



TO ↑ Temp to create hole

Extrinsic S.C:-

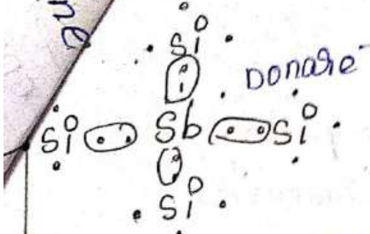
* E.S.C are formed by the doping of pure s.c with certain specific impurity atom.
* So it is also known as impure & Dopped s.c
* No. of e^- ~~#~~ ≠ N.o. of holes
* Electric conductivity is high

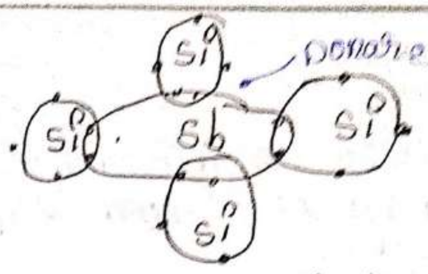
Depending on Doping E.S.C are 2 types.

1] N-type E.S.C
2] P-type E.S.C

N- type E.S.C:-

* It is also called Donar group
* In this S.C pentavalent impurity atoms i.e, P, AS, Sb, Bi etc are added to pure si/Ge crystal is called, N-type E.S.C.
* The conductivity of si/Ge is ↑ by the process of Doping.

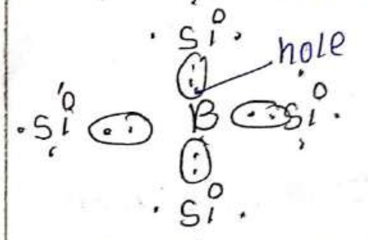


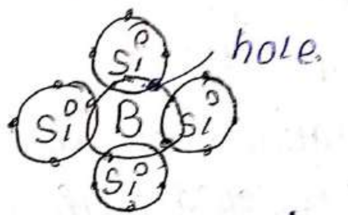


So the conductivity ↑ due to -vely charged e^- so this is n-type S.C.

p-type S.C

- * These are acceptors
- * In this S.C trivalent impurity atoms i.e, B, Al, Ga, In, Tl are added to Si/Ge crystal called p-type E.S.C.





So the conductivity ↑ due to +vely charged ion. So this is p-type S.C.

App's:-

- * used in Mobile phones, Digital cameras, TV.
- * CPU that operate personal computers
- * used in rectifiers circuits
- * for AC-DC.
- * In over voltage. protection circuits
- * In Am/Fm signal detectors

MCQs

1. **Substances whose conductivity lies between conductors and insulators are called:**

A) Conductors
B) Semiconductors
C) Superconductors
D) Insulators
Answer: B) Semiconductors

2. **In an *intrinsic semiconductor*, conduction is due to:**

A) Electrons only
B) Holes only
C) Electrons and holes both
D) Impurities
Answer: C) Electrons and holes both

3. **Example of an intrinsic semiconductor:**

A) Silicon (Si)
B) Copper (Cu)
C) Germanium (Ge)
D) Both A and C
Answer: D) Both A and C

4. **In *n-type* semiconductors, the majority charge carriers are:**

A) Holes
B) Electrons
C) Protons
D) Neutrons
Answer: B) Electrons

5. **In *p-type* semiconductors, the majority carriers are:**

A) Holes
B) Electrons
C) Ions
D) Protons
Answer: A) Holes

6. The process of adding impurities to increase conductivity is called:

A) Polarization
B) Doping
C) Deionization
D) Magnetization
Answer: B) Doping

7. A common application of semiconductors is:

A) Transformers
B) Diodes and Transistors
C) Heating elements
D) Capacitors
Answer: B) Diodes and Transistors

8. Band gap of silicon at room temperature is approximately:

A) 1.1 eV
B) 2.2 eV
C) 0.7 eV
D) 3.2 eV
Answer: A) 1.1 eV

⚡2️⃣ Superconductors – Concepts and Applications

9. A superconductor is a material which shows:

A) Infinite resistance
B) Zero resistance
C) High resistance
D) Variable resistance
Answer: B) Zero resistance

10. The temperature below which a material becomes superconducting is called:

A) Transition temperature (Tc)
B) Critical temperature
C) Both A and B
D) Melting temperature
Answer: C) Both A and B

---

11. The Meissner effect is related to:

A) Thermal expansion
B) Magnetic field expulsion
C) Photoelectric emission
D) Electrolysis
Answer: B) Magnetic field expulsion

☐ *Superconductors expel magnetic flux below Tc.*

---

12. Which of the following is a high-temperature superconductor?

A) Mercury
B) $YBa_2Cu_3O_7$ (Yttrium barium copper oxide)
C) Tin
D) Lead
Answer: B) $YBa_2Cu_3O_7$

---

13. One major application of superconductors is in:

A) Transformers
B) Magnetic levitation (Maglev) trains
C) Electric irons
D) LEDs
Answer: B) Magnetic levitation (Maglev) trains

---

14. The property lost by a superconductor above Tc is:

A) Conductivity
B) Diamagnetism
C) Luster
D) Elasticity
Answer: B) Diamagnetism

⚡3️⃣ Supercapacitors – Concepts, Classification & Uses

---

15. **Supercapacitors are also called:**

A) Chemical capacitors
B) Ultracapacitors
C) Quantum capacitors
D) Power capacitors
Answer: B) Ultracapacitors

---

16. **Supercapacitors store energy mainly by:**

A) Chemical reaction
B) Electrostatic charge separation
C) Magnetic induction
D) Nuclear reaction
Answer: B) Electrostatic charge separation

---

17. **Supercapacitors are classified mainly as:**

A) Electrochemical double-layer capacitors (EDLCs)
B) Pseudocapacitors
C) Hybrid capacitors
D) All of the above
Answer: D) All of the above

---

18. **Which of the following is *used as electrode material* in supercapacitors?**

A) Graphite
B) Activated carbon
C) Silicon
D) Copper
Answer: B) Activated carbon

---

19. **An important application of supercapacitors is in:**

A) Long-term energy storage
B) Fast charge/discharge backup systems
C) Food preservation
D) Light emission
Answer: B) Fast charge/discharge backup systems

4️⃣ Nanomaterials – Concepts, Types, Properties, and Applications

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20. **Nanomaterials have at least one dimension in the range of:**

A) 1–100 µm
B) 1–100 nm
C) 1–10 cm
D) 0.1–1 mm
Answer: B) 1–100 nm

---

21. **Fullerenes are:**

A) Allotropes of sulfur
B) Allotropes of carbon
C) Allotropes of silicon
D) None of these
Answer: B) Allotropes of carbon

---

22. **The most famous fullerene molecule is:**

A) C_{60}
B) C_{70}
C) C_{80}
D) C_{120}
Answer: A) C_{60}

Known as Buckminsterfullerene (buckyball).

---

23. Carbon nanotubes (CNTs) are formed by:

A) Folding graphite sheets into cylinders
B) Melting diamond
C) Polymerizing carbon monoxide
D) Heating hydrocarbons in air
Answer: A) Folding graphite sheets into cylinders

---

24. Graphene is a:

A) 0D nanomaterial
B) 1D nanomaterial
C) 2D nanomaterial
D) 3D nanomaterial
Answer: C) 2D nanomaterial

---

25. The electrical conductivity of graphene is due to:

A) Localized π-electrons
B) Delocalized π-electrons
C) σ-bonds
D) Ionic bonds
Answer: B) Delocalized π-electrons

---

26. Nanoparticles have unique properties mainly due to:

A) High surface-to-volume ratio
B) High temperature
C) Bulk density
D) Crystal defects only
Answer: A) High surface-to-volume ratio

---

27. An important application of carbon nanotubes is in:

A) Bulletproof vests
B) Nanoelectronics and sensors
C) Cement manufacture
D) Paints
Answer: B) Nanoelectronics and sensors

---

28. Fullerenes are used in:

A) Drug delivery and lubricants
B) Nuclear reactors
C) Fertilizers
D) None of these
Answer: A) Drug delivery and lubricants

29. Graphene is used in:

A) Transparent conductive displays
B) Electrical insulators
C) X-ray tubes
D) Glass polishing
Answer: A) Transparent conductive displays

30. Nanomaterials are widely used in:

A) Medicine
B) Electronics
C) Energy storage
D) All of the above
Answer: D) All of the above

UNIT III
ELECTROCHEMISTRY AND APPLICATIONS

1. Electrochemical Cell

Q1. What is an electrochemical cell?
A: An electrochemical cell converts chemical energy into electrical energy or vice versa through redox reactions. It consists of two electrodes (anode and cathode) and an electrolyte.

Q2. Differentiate between galvanic and electrolytic cells.
A:

- **Galvanic cell:** Spontaneous redox reaction, generates electricity.
- **Electrolytic cell:** Non-spontaneous reaction, electricity is supplied to drive the reaction.

---

2. Nernst Equation

Q3. What is the Nernst equation?
A: It relates the cell potential to the concentration of ions:

$$E=E0-0.0591/n \log Q$$

Where E = cell potential, E_0= standard potential, n = electrons, Q = reaction quotient.

Q4. Numerical example:
For the cell: $Zn|Zn2+||Cu2+|Cu$, $[Cu2+]=0.01M$, $E0=1.10$ V

$$E=1.10-0.0591\log[Cu2+]/[Zn2+]$$

$$=1.10-0.0591\log 0.1/0.01$$

$$=1.10-0.0591(1)\approx 1.041V$$

---

3. Potentiometry & Titrations

Q5. What is potentiometry?
A: Measurement of the voltage of an electrochemical cell without current to determine analyte concentration.

Q6. What is a potentiometric titration?
A: A titration in which the potential of the solution is measured as a function of titrant volume. Example: redox titration of Fe^{2+} with Ce^{4+}.

---

4. Conductivity & Conductometric Titrations

Q7. What is conductivity?
A: The ability of a solution to conduct electric current due to the presence of ions.

Q8. Conductivity cell:
A device with electrodes immersed in solution to measure conductivity.

Q9. Conductometric titration:
Titration based on changes in conductivity.

- **Example:** Strong acid vs. strong base (HCl vs. NaOH). Conductivity decreases till equivalence point, then increases.

---

5. Electrochemical Sensors

Q10. Potentiometric sensor example:

- **P^H meter** using glass electrode, measures potential due to H^+ concentration.

Q11. Amperometric sensor example:

- **Glucose biosensor**, current proportional to glucose concentration via enzymatic reaction.

---

6. Primary Cells

Q12. Example of primary cell:

- **Zinc-air battery**
  Reaction:
- Anode: $Zn \rightarrow Zn^{2+} + 2e^-$
- Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
- Characteristics: Non-rechargeable, high energy density.

---

7. Secondary Cells

Q13. Example of secondary cell:

- **Lithium-ion battery**
  Reaction:
- Charging: $LiCoO_2$+ C→$Li_{1-x}CoO_2$+LiC_6
- Discharging: Reverse reaction.
- Characteristics: Rechargeable, high energy density, long cycle life.

---

8. Fuel Cells

Q14. Hydrogen-Oxygen Fuel Cell:

- **Anode:** $H_2 \rightarrow 2H^+ + 2e-$
- **Cathode:** $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
- Converts chemical energy directly to electrical energy, clean.

Q15. Polymer Electrolyte Membrane Fuel Cell (PEMFC):

- Uses **proton-conducting polymer membrane** as electrolyte.
- **Working:** H_2 at anode → H^+ moves through membrane, electrons via circuit; O_2 at cathode reacts with H^+ → water.

EASSAY QUESTIONS

1. **Write about Potentiometric titrations and discuss various types and write about conductometric titrations?**

Potentiometric titrations:

The potential of electrode depends upon the concentration of the ions to which it is reversible in accordance with Nernst equation. Thus in a titration, the potential of an electrode is measured by the change in ionic concentration.

The potentiometric titrations are those titrations which involve the measurement of electrode potentials with the addition of the titrant. The end point is detected by measuring the changes in the potential of a suitable electrode during the course of reaction. No indicator is used in this titrations. The end point of the reaction is indicated by a sharp change in the potential of the system.

(i) ACID BASE TITRATIONS:

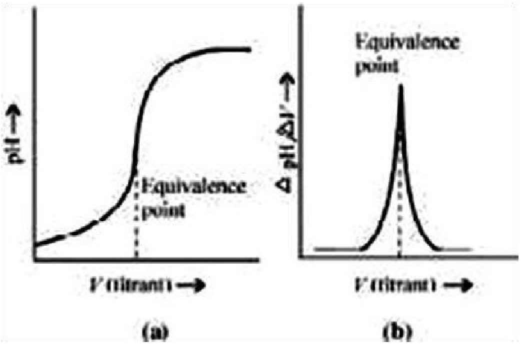
The acid solution whose strength has to be determined is taken in a beaker and the hydrogen electrode and calomel electrode were dipped in the solution. The electrodes were connected to the potentiometer and the E.M.F is measured. A known volume of standard alkali solution is added from a burette and stirred and the EMF of the cell is recorded. Like this 10-15 readings are recorded by repeating the procedure of the addition of standard alkali. On adding alkali solution (NaOH) from the burette, the H^+ concentration goes on decreases, i.e. pH of the solution goes on increases and hence the EMF of the cell goes on increases gradually, but at the end point the rate of change of potential will be suddenly quite large. After the end point, further addition of NaOH produces very little change in the H^+ ion concentration and hence there is very little change in the EMF of the cell.

The complete cell may be represented as

Pt, H_2 (1atm) / H^+ (unknown) //KCl (sat. sol^n) / Hg_2Cl_2.Hg

The emf of the indicator electrode (hydrogen electrode) is given as $E_{H2/H+} = E^o_{H2/H+} + 0.0591 \log_{10} [H^+]$

A graph is plotted by taking volume of alkali added against EMF observed. A sigmoid curve is obtained and the steepest portion of the curve indicates the equivalence point of the titration



From the graph, we draw the conclusion that the EMF increases with the decrease in concentration of hydrogen ions because electrode potential of indicator electrode depends on the concentration of H^+ ions.

(ii) OXIDATION- REDUCTION TITRATIONS:

The procedure adopted for oxidation titration is the same as in acid-base titration; the only difference is that the electrode reversible to hydrogen ions is replaced by a bright platinum electrode. The EMF of the electrode is determined by the activity of ratio of the substance being oxidized or reduced. For E.g.; Fe^{2+} titrated against $K_2Cr_2O_7$. The Fe^{2+} solution is taken in the beaker, treated with dil.H_2SO_4 and Pt electrode and calomel electrodes are dipped. The electrodes are connected to the potentiometer and EMF of the solution after the addition of $K_2Cr_2O_7$ is recorded. On addition of $K_2Cr_2O_7$ from the burette, EMF of the cell increase first slowly, but at the equivalence point there will be sudden jump in potential, since change in ratio of Fe^{2+}/Fe^{3+} ion concentration. A graph is plotted with EMF and volume of $K_2Cr_2O_7$. A sigmoid curve is obtained and the steepest portion of the curve indicates the end point of the titration.

(iii) PRECIPITATION REACTION:

In precipitation reaction also an electrode reversible to one of the ions involved is made use of, for **e.g:** titration of $AgNO_3$ with NaCl, where AgCl precipitates out, Ag- electrode is used along with calomel electrode. The silver nitrate is placed in the micro burette and added to sodium chloride taken in the beaker, containing electrodes. The EMF of the cell is measured and plotted against volume of silver nitrate added. The steep rise in the curve shows the end point of the titration.

1. Real life applications

Potentiometry represents a powerful technique with a myriad of different applications in biology, physics as well as chemistry. It was also used for the respiratory gas analysis in the hospitals consisting of respired gas samples from the patients undergoing anesthesia. It can also be used for the genomic studies with potential applications for clinical medicine. Due to its speed and sensitivity, potentiometry has played a pivotal role in space related applications, drug discovery, geologic research for petroleum composition measurements, carbon dating and some other research endeavors. Three most interesting uses of potentiometry in real life are as follows:

- **Food industry:** Titration is a method or the process of determining the concentration of a dissolved substance in terms of the smallest amount of a reagent of known concentration required to bring about a given effect in reaction with a known volume of the test solution.
- **Paper manufacturing:** Atmospheric emissions from the pulp and paper manufacturing industry can be determined by the potentiometric measurements.
- **Pharmaceutical industry:** To determine the pH of given chemical

agents and also in the detection of end point in potentiometry titration of certain drugs like amoxicillin, propranolol.

Example: Determination of pH of blood for diagnosis of acidosis or alkalosis

Example: Determination of NO_3, NO_2 in meat preservatives.

Example: To determine the NaCl content in meat, fish, dairy products and fruit juice **Example:** To determine the Ca content in dairy products, beer, wines and brewing solutions **Example:** To determine the K content in fruit juices, beer and wines.

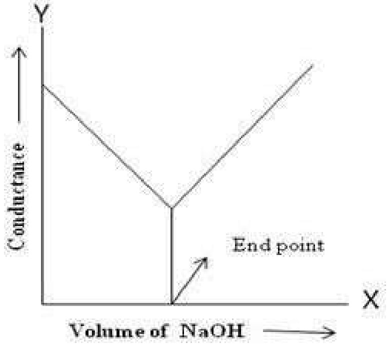
CONDUTOMETRIC TITRATIONS: Titrations involving conductivity measurements of electrolytes to get endpoint are called conductometric titrations. The end point is generally found out by plotting the conductance values on y-axis against the volume of electrolyte on x-axis. The electrical conductance of an aqueous solution depends up on:

1. The number of free ions in the solution containing an electrolyte.
2. The charge on the free ions.
3. The mobility of the ions.

1. Strong acid Vs Strong base titrations:

In an acid–base titration, acid is taken in the conical flask and base is added through the burette. Consider the titration of strong acid (HCl) with strong base (NaOH). Before the addition of NaOH, the conductivity is mainly due to the H^+ ions; hence the conductivity is high. On the gradual addition of NaOH from the burette, the fast moving H^+ ions of acid are replaced by OH^- ions. The conductivity of the solution decreases progressively by the addition of NaOH till the equivalence point is reached. The conductance again increases after the equivalence point.

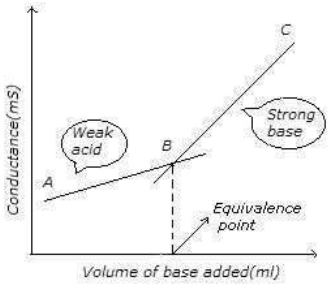
$$HCl + NaOH \rightarrow NaCl + H_2O$$



2. Weak acid Vs Strong base titration:

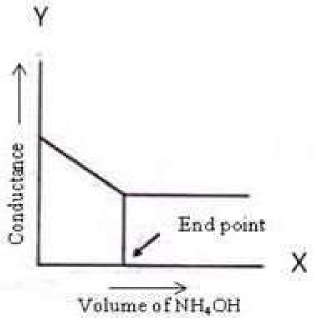
When weak acid is titrated with strong base, the conductance of the solution is low in the beginning, since the dissociation of weak acid is very low. On addition of base, highly dissociated sodium acetate is formed. Due to the common ion effect, the acetate ion tends to suppress the ionization of acetic acid. Later the conductivity begins to increase due to the conductivity power of the highly ionized salt exceeds that of weak acid. After end point, the addition of NaOH contributes sharp increase in the conductivity of the solution. The point of intersection of the two cures gives the end point of the titration.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$



3. Strong acid Vs weak base titrations: When strong acid is titrated against a weak base, the conductance of the solution first decrease due to the replacement of fast moving H^+ ions with slow moving NH_4^+ ions. After the end point, the addition of excess of NH_4OH will not result in any appreciable change in the conductivity.

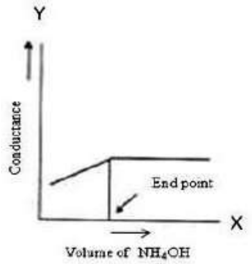
$$HCl + NH_4OH \rightarrow NH_4Cl + H_2O$$



4. Weak acid Vs weak base Titration:

Consider the titration of acetic acid against ammonium hydroxide. The titration of weak acid with weak base does not give sharp end point by volumetric titrations. The initial conductance of the solution is low due to the poor dissociation of weak acid, but starts raising as CH_3COONH_4 is formed. After the equivalent point, the conductivity remains almost constant because the free base NH_4OH is weak electrolyte. The end point is quite sharp by conductometric titrations

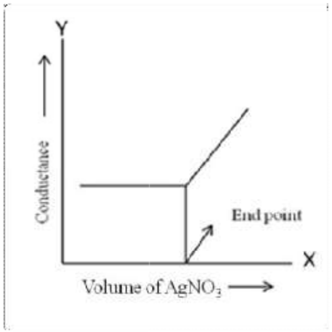
$$CH_3COOH + NH_4OH \rightarrow CH_3COONH_4 + H_2O$$



5. Precipitation titrations:

In precipitation titrations, sharp endpoint is obtained, e.g. The titration of KCl against $AgNO_3$. There is no sharp increase in conductance after the addition of $AgNO_3$, because the mobility of K^+ and Ag^+ is one and the same. After the end point, there is a sharp increase in conductance due to an increase in the number of free ions in the solution.

$$KCl + AgNO_3 \rightarrow KNO_3 + AgCl \text{ (ppt)}$$



Advantages of conductometric titrations:

1. The results obtained by conductometric titrations are more accurate because the end point is obtained graphically.
2. The titrations of a weak acid with a weak base do not give a sharp end point with indicator in volumetric titrations. Accurate results are

obtained in conductometric titrations.

3. Colored solutions where no indicator is found to work satisfactorily can be successfully titrated.
4. Conductometric titrations can be used even in case of polybasic acids.

Precautions:

1. The temperature must be kept constant throughout the experiment.
2. In acid–base titration, the titrant should be about 10 times stronger than the solution to be titrated so that the volume change is as little as possible.

2. **Define primary and secondary cells? Write about construction and working of lithium-ion battery with neat diagram?**

Primary cells are the ones which cannot be recharged and have to be discarded after the expiration of the lifetime.

Secondary cells need to be recharged when the charge gets over.

Both the types of battery are used extensively in various appliances and these cells differ in size and material used in them.

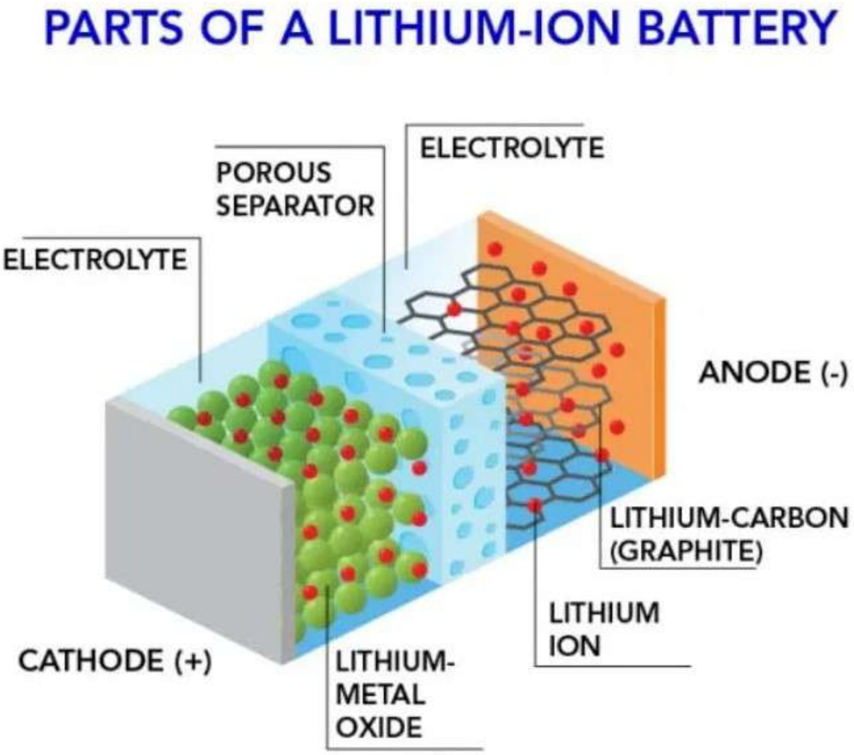
Difference between Primary Cell and Secondary Cell	
Primary Cell	**Secondary Cell**
Have high energy density and slow in discharge and easy to use	They have smaller energy density
There are no fluids in the cells hence it is also called as dry cells	These are made up of wet cells (flooded and liquid cells) and molten salt (liquid cells with different composition)
It has high internal resistance	It has a low internal resistance
It has an irreversible chemical reaction	It has a reversible chemical reaction
Its design is smaller and lighter	Its design is more complex and heavier
Its initial cost is cheap	Its initial cost is high

A lithium-ion (Li-ion) battery is a type of **rechargeable battery** that uses lithium ions as the main component of its electrochemical cells. It is **characterised** by **high energy density**, fast charge, long cycle life, and wide temperature range operation. Lithium-ion batteries have been **credited** for revolutionising communications and transportation, enabling the rise of super-slim smartphones and electric cars with a practical range such as portable electronics and electrified transportation.

M. Stanley Whittingham, John B. Goodenough, and Akira Yoshino received the **Nobel Prize in Chemistry** for their contributions to the development of the **modern Li-ion battery in 2019.**

Lithium-ion Battery Structure

A lithium-ion battery consists of an **anode** (negative electrode), **cathode** (positive electrode), separator, electrolyte, and two current collectors (positive and negative).



Cathode: The cathode of a lithium-ion battery is typically made of a lithium metal oxide, such as **lithium cobalt oxide ($LiCoO_2$), lithium manganese oxide ($LiMn_2O_4$), or lithium iron phosphate ($LiFePO_4$).**

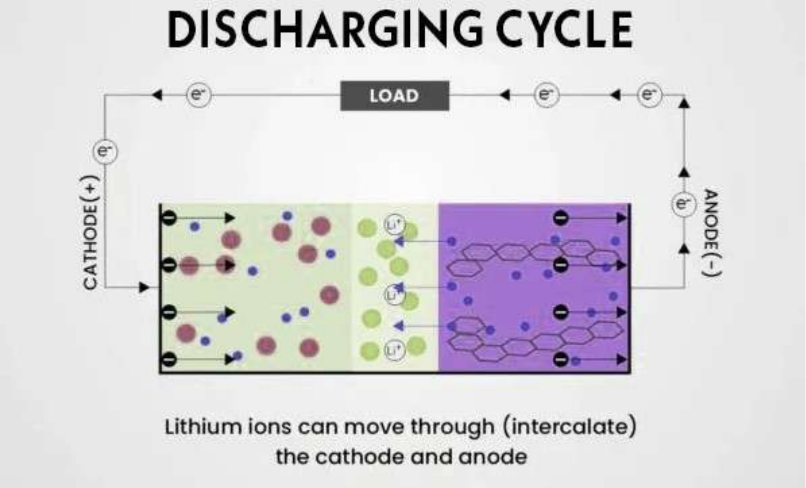
The choice of cathode material influences the performance characteristics of the battery.

- **Anode:** The anode is usually composed of **graphite**. During discharge, **lithium ions** move from the **anode to the cathode** through the electrolyte, and during **charging,** they **move back to the anode.**
- **Electrolyte:** The electrolyte is a **conductive medium** that allows the flow of lithium ions between the cathode and anode.
  - It is typically a **lithium salt** dissolved in a solvent.
- **Separator:** The separator is a **permeable membrane** that keeps the cathode and anode apart to prevent a short circuit while allowing the passage of lithium ions.
- **Rechargeability:** One of the key advantages of lithium-ion batteries is their rechargeability.

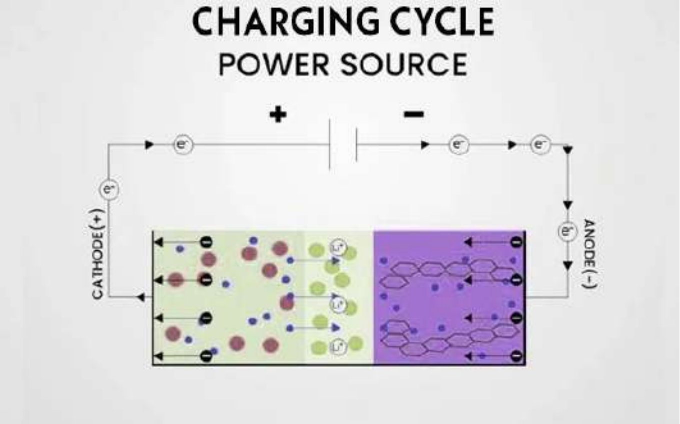
   - They can be recharged hundreds to thousands of times, depending on the specific chemistry and use conditions such as **overcharging** or **undercharging.**

Working of Lithium-ion Battery

Working principle of Lithium-ion Battery based on **electrochemical reaction.** Inside a lithium-ion battery, **oxidation-reduction (Redox)** reactions take place which sustain the charging and discharging cycle.



- **Discharging:**
   - During this cycle, **lithium ions** form from the ionization of lithium atoms in the anode.
      - **Oxidation reaction** takes place: $LiC_6 \rightarrow C_6 + Li^+ + e^-$
   - The lithium ions move from the anode and pass through the electrolyte until they reach the cathode, where they recombine with their electrons and electrically neutralise.
   - The lithium ions are small enough to be able to move through a **micro-permeable separator** between the anode and cathode.
   - **Li-ion batteries** are capable of having a very **high voltage** and **charge storage** per unit mass and unit volume owing to the small size of lithium.



- **Charging cycle:**
    - **During the charging cycle,** the process is exactly the opposite of the discharging cycle. The lithium ions return to the anode from the cathode and electrons are transferred from the anode to the cathode.
    - Lithium ions flow from the cathode to the anode, and electrons flow from the **anode to the cathode,** as the battery is charging.
    - There is a **steady flow of electrons** as long as lithium ions are making their way from one electrode to the next.
    - **Reduction** takes place at the cathode -$CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$ (Cobalt oxide combines with lithium ions to form lithium-cobalt oxide ($LiCoO_2$).

Lithium-ion Battery Significance

The excellent electrochemical properties of lithium such as highly reactive properties give Lithium the potential for high-density batteries, enhanced standby power, complacent design, etc.

- **High charge density**: Since lithium is the most electropositive element, it has a high charge density, and can give a lot of energy without being very heavy. This means they can store a significant amount of energy for their size and weight.
    - **Electropositivity** is a measure of how easily an element can produce positive ions or how easily an element can produce energy.
- **Compact design:** They can store a large amount of energy in a relatively small and lightweight package.
- **Low self-discharge rate**: They also exhibit a relatively low self-discharge rate when compared to other rechargeable batteries, allowing them to hold their charge for extended periods.
- **High-scale current:** Lithium-ion batteries can deliver large amounts of current for high-power applications.
    - **For example-** Lithium-ion battery cells can deliver up to **3.6 Volts, 3 times greater** than any present technology.
- **No memory effect:** Lithium-ion batteries have no memory effect, a detrimental process where repeated partial discharge/charge cycles can cause a battery to **'remember'** a lower capacity.
- **Free-form toxic materials:** These batteries do not contain toxic cadmium, which makes them easier to dispose of than **Ni-Cd batteries.**
- **Fossil Fuel-free society:** Modern society is completely dependent on fossil fuels, and lithium-ion batteries have great potential to replace the **internal combustion engine** and **store solar energy, and wind energy,** which will reduce dependency on fossil fuels by providing sustainable renewable energy.

Lithium-ion Battery Application

The versatility and performance characteristics of lithium-ion batteries make them a preferred choice in a wide range of applications, such as **aerospace, electric vehicles, electronics industries, etc.**

- **Portable electronic devices:** Lithium-ion batteries are predominantly used in various portable electronic devices such as **smartphones** and **laptops** etc.
- **High-end application:** It can also be employed to power electrical systems for aerospace applications and submarines.
    - For Example**, Aircraft-Boeing 787,** where weight is a significant cost factor.
- **Hybrid electric vehicles:** Lithium-ion technology so far has the best option for potential applications in battery-powered **vehicles** with a practical range **thereby reducing dependency on fossil fuels.**
- **Example-** Tesla's Model S cars are using a P85 battery consisting of 18,650 Li-ion cells, with an energy output of 80-90 kWh.
- **Defence:** Various submarines are using lithium-ion batteries as a source of power back in emergency and enhanced stealth operation.
- **Medical devices:** They are used in cardiac pacemakers and other implantable devices.

Lithium-ion Battery Disadvantages

Despite several promising applications of lithium-ion batteries, they have certain limitations:

- **Highly Inflammable:** The batteries tend to overheat and can face insulation failure at high voltages.
    - In some cases, this can lead to thermal runaway and combustion.
- **Performance constraints:** Lithium-ion batteries face the situation of increased weight and **limited performance** in some cases due to the requirement of safety mechanisms to limit voltage and internal pressures.
- **Low self-life:** Lithium-ion batteries are also subject to ageing, meaning that they can lose capacity and frequently fail after some years.
- **Heavily dependent on imports**: Another factor limiting their widespread adoption is their uneven geographical distribution of lithium leading to higher cost, which is around **40% higher than Ni-Cd.**

3. **Define Fuel cells? Write about construction and working of H_2-O_2 fuel cell and polymeric electrolyte membrane fuel cell with neat diagram?**

FUEL CELLS

Definition: A fuel cell is an electrochemical which converts chemical energy contained in readily available fuel oxidant system into electrical energy.

Principle: The basic principle of fuel cell is as same as that of an electrochemical cell. The fuel cell operates like a galvanic cell. The only difference is that the fuel and the oxidant are stored outside the cell. Fuel and oxidant are supplied continuously and separately to the electrodes at which they undergo redox reaction. Fuel cells are capable of supplying current as long as reactants are replenished.

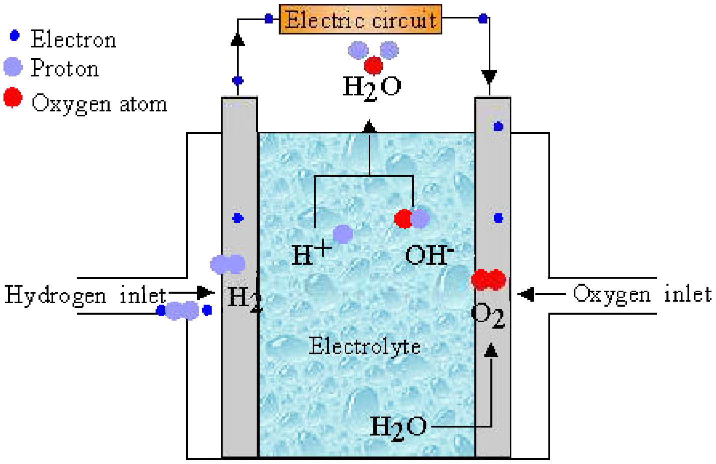
Fuel + Oxidant → Oxidation products + Electric Energy

Examples: 1. H_2-O_2 fuel cell

2. CH_3OH-O_2 fuel cell

Hydrogen oxygen fuel cell:

This cell is a common type of fuel cell. Similar to a galvanic cell, fuel cell also have two half cells. Both half cells have porous graphite electrode with a catalyst (platinum, silver or a metal oxide). The electrodes are placed in the aqueous solution of NaOH or KOH which acts as an electrolyte. Hydrogen and oxygen are supplied at anode and cathode respectively at about 50 atmospheric pressure, the gases diffuse at respective electrodes. The two half-cell reactions are as follows;



At anode: $2H_2$ (g) + $4OH^-$ (aq)

→ $4H_2O$ (l) + $4e^-$ **At cathode:** O_2

(g) + $2H_2O$ (l) + $4e^-$ → $4OH^-$

(aq) **The net reaction:** $2H_2$ (g) +

O_2 (g) → $2H_2O$ (l)

The EMF of this cell is measured to be 1.23V. A number of such fuel cell are stacked together in series to make a battery.

Advantages:

1. The energy conversion is very high (75-82%).
2. Fuel cell minimizes expensive transmission lines and transmission losses.
3. It has high reliability in electricity generation.
4. The byproducts are environmentally acceptable.
5. Maintenance cost is low for these fuels.
6. They save fossil fuels.
7. Noise and thermal pollution are very low.
8. They have low maintenance cost.
9. They have quick start system.

Disadvantages:

1. The major disadvantage of the fuel cell is the high cost and the problems of durability and storage of large amount of hydrogen.
2. The accurate life time is also not known.

APPLICATIONS:

1. The most important application of a fuel cell is its use in space vehicles, submarine or military vehicles.
2. The product H_2O is valuable source of fresh water by the astronauts.
3. It is hoped that fuel cell technology will bring a revolution in the area of energy production.
4. Fuel cell batteries for automotive will be a great boom for the future.

Limitations:

1. The life time of fuel cells is not accurately known
2. It cannot store electricity
3. Electrodes are expensive ad short lived.
4. Storage and handling of H_2 gas is dangerous because it is inflammable.

4. **Derive Nernest equation and numerical problems?**

Derivation of Nernst equation: Nernst found that the single electrode potential varies with the change in concentration of ions and temperature and hence the EMF of the cell also varies. He derived a mathematical relationship between the standard electrode potential, temperature and the concentration of ions. This relationship is known as the Nernst equation.

Consider the redox reaction: $M^{n+} + ne^- \rightleftarrows M$

In the above reversible reaction the free energy change (G) and its equilibrium constant (K) are related by the following equation which is popularly known as Van't Hoff reaction isotherm.

$$\Delta G = RT \ln K + RT\ln \frac{\text{product}}{\text{reactant}}$$

$$\Delta G = \Delta G^0 + RT\ln \frac{\text{product}}{\text{reactant}}$$

When ΔG^0 is the standard free energy change

The free energy change is equivalent to the electrical

energy $-nFE$ Where n = valency

F = Faraday

(96500

coloumbs)

E =

Electrode

potential

$R = 8.314$ Joules K^{-1}

$mole^{-1}$(Gas constant) T

= Temperature (K)

$$-nFE = -nFE^0 + RT\ln([M])/([M^{n+}]) \quad \text{(Concentration of M is unity)}$$

$$-nFE = -nFE^0 - RT\ln [M^{n+}]$$

$$= -nFE^0 - RT2.303 \log_{10} [M^{n+}]$$

Dividing the equation by – nF

$$E = E^{0+} + \frac{2.303RT}{nF} \log_{10} [M^{n+}]$$

$$\boxed{E = E^0 + \frac{0.0591}{n} \log_{10} [M^{n+}]}$$

APPLICATIONS OF NERNST EQUATION:

4. It can be used to study the effect of electrolyte concentration on electrode potential. $E = E^{o} – RT/nF \ln[1/M^{n+}]$
5. It can also be used for the calculation of the potential of a cell under non-standard conditions.

MCQs

1. In a galvanic cell, which of the following statements is correct?
A) Oxidation occurs at the cathode
B) Reduction occurs at the anode
C) Electrons flow from cathode to anode
D) Oxidation occurs at the anode

☑**Answer:** D
Explanation: In a galvanic cell, oxidation takes place at the anode and reduction at the cathode.

---

2. The standard electrode potential of Zn^{2+}/Zn and Cu^{2+}/Cu are –0.76 V and +0.34 V respectively. The EMF of the cell $Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$ is:
A) 0.10 V
B) 0.42 V
C) 1.10 V
D) 1.50 V

☑**Answer:** C
Explanation: $Ecell=E_{cathode}−E_{anode}=0.34−(−0.76)=1.10V$

□ NERNST EQUATION & CELL POTENTIAL

3. The Nernst equation for a half-cell reaction is given by:
A) $E=E°+RTnF \ln Q$
B) $E=E°−RT/nF \ln Q$
C) $E=E°+nF \ln Q$
D) $E=E°−RT/Nf\ Q$

☑**Answer:** B

---

4. For the cell reaction:
$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$,

if [Zn^{2+}] = 0.1 M and [Cu^{2+}] = 1 M, the EMF at 25°C is approximately:
A) 1.10 V
B) 1.12 V
C) 1.08 V
D) 1.00 V

✅**Answer:** C
Explanation:
$E_{cell}=E_{cathode}-E_{anode}$

- $E_{Cu2+/Cu}=+0.34$ V
- $E_{Zn2+/Zn}=-0.76$ V
- Ecell $=0.34-(-0.76)=1.10$ V

  $E=1.10-20.0591\ \log(0.1)$

  $\log(0.1)=-1$

  $E=1.10-20.0591\times(-1)$

  $E=1.10+0.02955$

  $E\approx1.1295\ V\approx1.13\ V$

□□ POTENTIOMETRY

5. Potentiometry is based on the measurement of:
A) Current at constant potential
B) Potential at zero current
C) Resistance at constant current
D) Conductance at constant potential

✅**Answer:** B
Explanation: Potentiometric measurements involve determining potential differences under zero current flow conditions.

---

6. Which electrode is commonly used as a reference electrode in potentiometry?
A) Glass electrode
B) Calomel electrode
C) Silver electrode
D) Platinum electrode

✅**Answer:** B
Explanation: The saturated calomel electrode (SCE) is a common reference electrode.

---

7. In potentiometric **redox titration**, the potential change is due to:
A) pH variation
B) Change in ion concentration
C) Electron transfer between oxidant and reductant
D) Change in temperature

☑**Answer:** C

□ CONDUCTIVITY & CONDUCTOMETRIC TITRATIONS

8. The unit of specific conductivity (κ) is:
A) Ω cm
B) Ω^{-1} cm^{-1}
C) S m
D) mho cm

☑**Answer:** B
Explanation: Conductivity (κ) has the unit Siemens per centimetre (S cm^{-1} or Ω^{-1} cm^{-1}).

---

9. Molar conductivity (Λm) increases with dilution because:
A) Ion concentration increases
B) Ion mobility increases
C) Ion-pair formation increases
D) Temperature decreases

☑**Answer:** B
Explanation: On dilution, interionic attraction decreases → ion mobility increases → Λm increases.

---

10. In conductometric acid–base titration, the end point is determined by:
A) Sharp potential change
B) Minimum conductance
C) Maximum conductance
D) Constant temperature

☑**Answer:** B
Explanation: Conductance decreases, then increases — the minimum point corresponds to the equivalence point.

□□ ELECTROCHEMICAL SENSORS

11. A glass electrode is an example of a:
A) Amperometric sensor
B) Conductometric sensor
C) Potentiometric sensor
D) Optical sensor

✅**Answer:** C
Explanation: Glass electrode measures pH via potential difference → a potentiometric sensor.

---

12. The **Clark oxygen electrode** is an example of:
A) Potentiometric sensor
B) Amperometric sensor
C) Conductometric sensor
D) Optical biosensor

✅**Answer:** B
Explanation: Clark electrode measures current produced by oxygen reduction at a cathode (amperometric principle).

---

13. Amperometric sensors operate at:
A) Constant voltage, measuring current
B) Constant current, measuring voltage
C) Variable resistance
D) Constant power

✅**Answer:** A
Explanation: They maintain a fixed potential and measure the resulting current due to redox reactions.

---

14. Which of the following is used in glucose biosensors?
A) Glass electrode
B) Clark oxygen electrode
C) pH electrode
D) Silver–silver chloride electrode

✅**Answer:** B
Explanation: Glucose oxidase enzyme reacts with glucose producing oxygen changes detected by Clark electrode.

---

15. Conductivity cell constant depends on:
A) Concentration of electrolyte
B) Geometry of electrodes
C) Nature of solvent
D) Applied voltage

✅**Answer:** B
Explanation: Cell constant = distance between electrodes / area of electrodes.

Electrochemical Cells MCQs

1. Primary Cells – Zinc–Air Battery

1. Zinc–air battery is a type of:
A) Primary cell
B) Secondary cell
C) Fuel cell
D) Electrolytic cell
✅**Answer:** A) Primary cell

2. In a zinc–air cell, the **anode** is made of:
A) Carbon
B) Zinc
C) Nickel
D) Platinum
✅**Answer:** B) Zinc

3. The **cathode reaction** in a zinc–air cell involves:
A) Reduction of Zn^{2+} ions
B) Oxidation of O_2 gas
C) Reduction of O_2 gas
D) Oxidation of H_2O
✅**Answer:** C) Reduction of O_2 gas

4. The **overall reaction** in a zinc–air battery is:
A) $Zn + \frac{1}{2}O_2 \rightarrow ZnO$
B) $Zn + O_2 \rightarrow ZnO_2$
C) $Zn + O_2 \rightarrow ZnO$
D) $Zn \rightarrow Zn^{2+} + 2e^-$
✅**Answer:** C) $Zn + O_2 \rightarrow ZnO$

5. Zinc–air batteries are **non-rechargeable** because:
A) Zinc electrode gets corroded
B) Electrolyte dries up
C) Reaction is irreversible

D) All of the above
✅**Answer:** D) All of the above

---

2. Secondary Cells – Lithium-Ion Batteries

6. Lithium-ion batteries are:
A) Primary cells
B) Secondary cells
C) Fuel cells
D) Voltaic cells
✅**Answer:** B) Secondary cells

7. The **anode** in a Li-ion cell is usually made of:
A) Lithium metal
B) Graphite
C) Nickel
D) Zinc
✅**Answer:** B) Graphite

8. The **cathode** in a Li-ion battery is commonly made of:
A) Lithium cobalt oxide ($LiCoO_2$)
B) Zinc oxide
C) Manganese dioxide
D) Nickel-cadmium
✅**Answer:** A) Lithium cobalt oxide ($LiCoO_2$)

9. The **overall cell reaction** during discharge of Li-ion battery:
A) Li^+ moves from cathode → anode
B) Li^+ moves from anode → cathode
C) Electrons move through electrolyte
D) Lithium ions are not involved
✅**Answer:** B) Li^+ moves from anode → cathode

10. The **electrolyte** in lithium-ion cells is usually:
A) KOH solution
B) H_2SO_4
C) $LiPF_6$ in organic solvent
D) NaCl aqueous solution
✅**Answer:** C) $LiPF_6$ in organic solvent

---

3. Fuel Cells – Hydrogen–Oxygen Fuel Cell

11. Hydrogen–oxygen fuel cell is an example of:
A) Primary cell
B) Secondary cell

C) Fuel cell
D) Dry cell
✅**Answer:** C) Fuel cell

12. In a hydrogen–oxygen fuel cell, **electrolyte** used is:
A) Concentrated H_2SO_4
B) KOH solution
C) NaCl solution
D) HCl solution
✅**Answer:** B) KOH solution

13. The **anode reaction** in hydrogen–oxygen fuel cell:
A) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
B) $2H_2 \rightarrow 4H^+ + 4e^-$
C) $H_2 + O_2 \rightarrow H_2O$
D) $O_2 \rightarrow 2O^{2-}$
✅**Answer:** B) $2H_2 \rightarrow 4H^+ + 4e^-$

14. The **cathode reaction** in hydrogen–oxygen fuel cell:
A) $4H^+ + O_2 + 4e^- \rightarrow 2H_2O$
B) $2H_2 \rightarrow 4H^+ + 4e^-$
C) $O_2 + 2H_2O \rightarrow 4OH^-$
D) $O_2 \rightarrow 2O^{2-}$
✅**Answer:** A) $4H^+ + O_2 + 4e^- \rightarrow 2H_2O$

15. The **overall cell reaction** is:
A) $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$
B) $H_2 + O_2 \rightarrow 2H_2O$
C) $2H_2 + O_2 \rightarrow 2H_2O$
D) $H_2O \rightarrow H_2 + \frac{1}{2}O_2$
✅**Answer:** C) $2H_2 + O_2 \rightarrow 2H_2O$

---

4. Polymer Electrolyte Membrane Fuel Cell (PEMFC)

16. The **electrolyte** in a PEM fuel cell is:
A) Aqueous KOH
B) Phosphoric acid
C) Solid polymer membrane (Nafion)
D) Molten carbonate
✅**Answer:** C) Solid polymer membrane (Nafion)

17. The **working temperature** of PEM fuel cell is typically:
A) 1000°C
B) 600°C
C) 80°C
D) 25°C
✅**Answer:** C) 80°C

18. The **anode reaction** in a PEMFC is:
A) $H_2 \rightarrow 2H^+ + 2e^-$
B) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
C) $2H_2 + O_2 \rightarrow 2H_2O$
D) $H_2O \rightarrow H_2 + \frac{1}{2}O_2$
✅**Answer:** A) $H_2 \rightarrow 2H^+ + 2e^-$

19. The **cathode reaction** in a PEMFC is:
A) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
B) $2H_2 \rightarrow 4H^+ + 4e^-$
C) $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$
D) $H_2O \rightarrow H_2 + \frac{1}{2}O_2$
✅**Answer:** A) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

20. The main **advantage** of PEM fuel cells is:
A) High operating temperature
B) Fast start-up, compact design
C) Use of molten electrolytes
D) Low efficiency
✅**Answer:** B) Fast start-up, compact design

5. Conceptual & Application-Based

21. Which cell is rechargeable?
A) Zinc–air cell
B) Lithium-ion cell
C) Dry cell
D) Fuel cell
✅**Answer:** B) Lithium-ion cell

22. Which of the following directly converts chemical energy to electrical energy **continuously** as fuel is supplied?
A) Primary cell
B) Secondary cell
C) Fuel cell
D) Electrolytic cell
✅**Answer:** C) Fuel cell

23. In fuel cells, **electrodes are**:
A) Consumed in reaction
B) Permanent catalysts
C) Made of zinc only
D) Replaced after each use
✅**Answer:** B) Permanent catalysts

24. The byproduct of hydrogen–oxygen fuel cell is:
A) CO_2

B) SO_2
C) H_2O
D) H_2S
✅**Answer:** C) H_2O

25. The **efficiency** of a hydrogen–oxygen fuel cell is approximately:
A) 10–20%
B) 25–35%
C) 50–60%
D) 90–100%
✅**Answer:** C) 50–60%

UNIT IV

POLYMER CHEMISTRY

1. Introduction to Polymers

Q: What is a polymer?
A: A polymer is a large molecule composed of repeating structural units called monomers, linked by covalent bonds.

Q: Give examples of natural and synthetic polymers.
A:

- Natural: Cellulose, rubber, proteins
- Synthetic: Polyethylene (PE), Nylon-6,6, Polystyrene (PS)

---

2. Functionality of Monomers

Q: What is the functionality of a monomer?
A: Functionality is the number of reactive sites on a monomer molecule that can form bonds during polymerization.

Q: Give an example.
A: Ethylene (C_2H_4) has a functionality of 2 (one double bond), allowing it to form polyethylene.

---

3. Polymerization Methods

A. Chain Growth Polymerization

Q: What is chain growth polymerization?
A: Polymerization where monomers add to an active site on a growing chain, e.g., free radical polymerization.

Q: Example and mechanism.
A: Polyethylene (PE)

- Initiation: Formation of radical by decomposing initiator (e.g., benzoyl peroxide)
- Propagation: Radical reacts with monomer → chain grows
- Termination: Two radicals combine → polymer chain ends

B. Step Growth Polymerization

Q: What is step growth polymerization?

A: Polymerization where monomers with two or more reactive groups react stepwise to form dimers, trimers, and eventually high molecular weight polymer.

Q: Example and mechanism.
A: Nylon-6,6

- Monomers: Hexamethylenediamine + Adipic acid
- Mechanism: Condensation reaction with release of water → amide bond formation

---

C. Coordination Polymerization
Q: What is coordination polymerization?
A: Polymerization using metal catalysts (e.g., Ziegler–Natta catalyst) to control polymer structure and stereochemistry.

Q: Example.
A: Polypropylene – isotactic polypropylene produced via Ziegler-Natta catalysis.

---

4. Plastics

Q: Differentiate thermoplastics and thermosetting plastics.
A:

- **Thermoplastics:** Soften on heating, can be reshaped (e.g., PVC, Teflon)
- **Thermosetting:** Harden permanently on heating, cannot be reshaped (e.g., Bakelite, epoxy)

Q: Examples, preparation, and uses:**

- **PVC (Polyvinyl Chloride):** Chain growth polymerization; pipes, flooring
- **Teflon (PTFE):** Free radical polymerization of tetrafluoroethylene; non-stick coatings
- **Bakelite:** Phenol + formaldehyde; thermosetting; electrical insulators
- **Nylon-6,6:** Step growth condensation; fibers, textiles
- **Carbon fibers:** Pyrolysis of polyacrylonitrile; high strength, aerospace

---

5. Elastomers

Q: What are elastomers?**
A: Polymers that can stretch and recover their original shape.

Q: Examples:**

- **Buna-S:** Copolymer of butadiene and styrene; tires, shoes
- **Buna-N:** Copolymer of butadiene and acrylonitrile; oil-resistant gaskets

---

6. Conducting Polymers

Q: What are conducting polymers?**
A: Polymers that conduct electricity due to conjugated double bonds.

Q: Examples and conduction mechanism:**

- **Polyacetylene:** Doping with halogens increases conductivity
- **Polyaniline:** Protonation/doping enhances conductivity
  Applications: Flexible electronics, sensors, batteries

---

7. Biodegradable Polymers

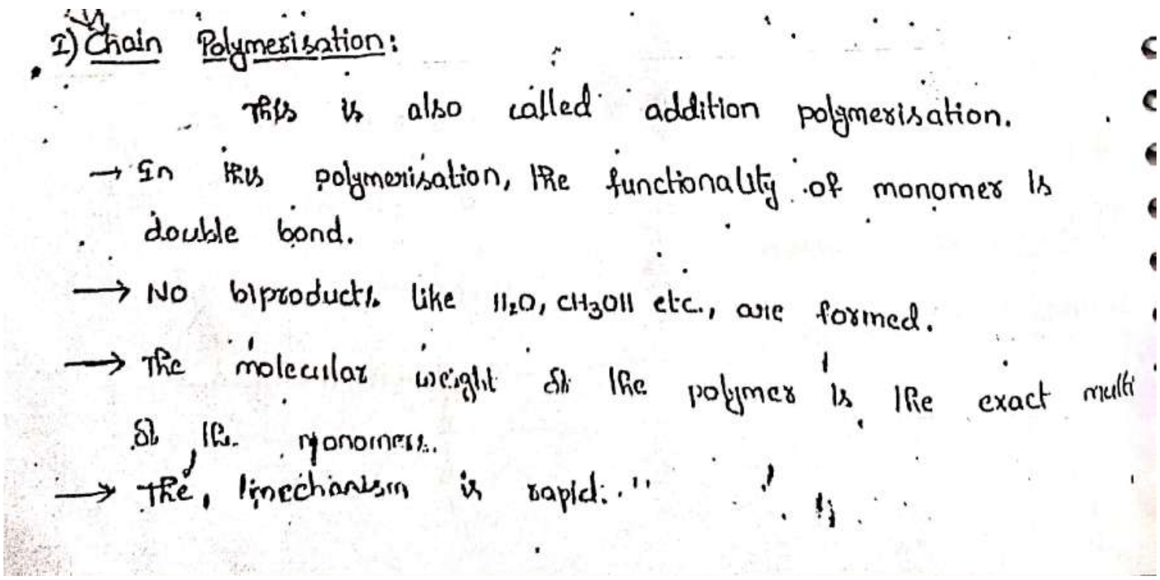
Q: Examples of biodegradable polymers:**
A:

- **Poly Glycolic Acid (PGA):** Sutures, tissue engineering
- **Poly Lactic Acid (PLA):** Packaging, biomedical devices

Q: Why are they biodegradable?
A: They can hydrolyze or be metabolized into non-toxic products in the environment.

EASSAY QUESTIONS

1. Write the addition polymerization and condensation polymerization? Write specific examples with mechanisms?



1) Chain Polymerisation:

This is also called addition polymerisation.

→ In this polymerisation, the functionality of monomer is double bond.

→ No biproducts like H_2O, CH_3OH etc., are formed.

→ The molecular weight of the polymer is the exact multi of the monomers.

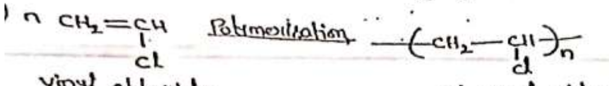
→ The mechanism is rapid.

The compounds containing double bonds undergo chain polymerisation.

For example: i) olefins ii) vinyl iii) allyl and iv) dienes.

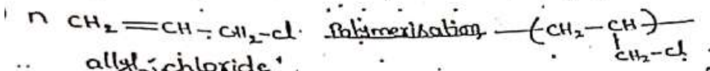
$n CH_2=CH_2 \xrightarrow{\text{Polymerisation}} -(CH_2-CH_2)_n-$

ethylene Polyethylene



$n CH_2=\underset{Cl}{\underset{|}{C}H} \xrightarrow{\text{Polymerisation}} -(CH_2-\underset{Cl}{\underset{|}{C}H})_n$

vinyl chloride Poly vinyl chloride



$n CH_2=CH-CH_2-Cl \xrightarrow{\text{Polymerisation}} -(CH_2-\underset{CH_2-Cl}{\underset{|}{C}H})-$

allyl chloride Poly allyl chloride

$n CH_2=CH-CH=CH_2 \xrightarrow{\text{Polymerisation}} -(CH_2-CH=CH-CH_2)_n$

Butadiene Polybutadiene

The mechanism is carried out in three steps, i.e., initiation, propagation and termination.

An initiator is required to start the polymerisation reaction

Addition polymerisation can be done by the following three methods :

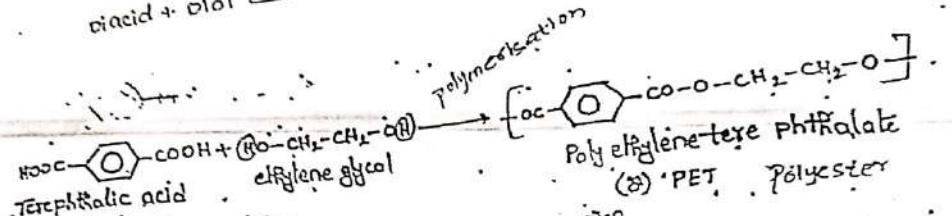
2) C.P. Polymerisation (or) Condensation Polymerisation:

This type of polymerisation takes place by condensation reactions of the functional groups of the monomers. Hence, known as condensation polymerisation.

example:

i) Formation of Polyester:

diacid + Diol ⟶ Polyester + water

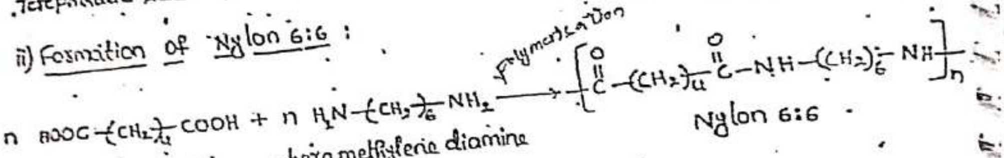


$HOOC-C_6H_4-COOH + HO-CH_2-CH_2-OH \xrightarrow{polymerisation} [OC-C_6H_4-CO-O-CH_2-CH_2-O]$

Terephthalic acid   ethylene glycol

Poly ethylene tere phthalate (or) PET Polyester

ii) Formation of Nylon 6:6 :



$n\ HOOC-(CH_2)_4-COOH + n\ H_2N-(CH_2)_6-NH_2 \xrightarrow{polymerisation} [\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-NH-(CH_2)_6-NH]_n$

Adepic acid   hexamethylene diamine   Nylon 6:6

Characteristics of condensation Polymerisation:

a) The monomers contain functional groups like $-OH$, $-COOH$, $-NH_2$ etc.

b) This polymerisation is accompanied by the elimination of biproducts like HCl, H_2O, NH_3, CH_3OH etc.

c) The functionality of the monomer must be two or more than two.

d) The molecular weight of the polymer is not the sum of the molecular weights of the monomers.

1) Free radical mechanism:

This mechanism involves the following steps:

1) Initiation step   2) Propagation step   3) Termination step

1) Initiation step: This step takes place by two reactions. The first is the production of free radicals, the second the addition of this radical to the first monomeric molec to produce the chain initiating species $\dot{M}_1$.

$$\underset{\text{initiator}}{I} \longrightarrow \underset{\text{free radicals}}{2\dot{R}}$$

$$\underset{\text{free radical}}{\dot{R}} + \underset{\text{monomer}}{M} \longrightarrow \underset{\text{chain initiating species}}{\dot{M}_1}$$

example: $\dot{R} + CH_2{=}CH_2 \longrightarrow R{-}CH_2{-}\dot{C}H_2$

2) Propagation step: This step involves successive addition of large number of monomer molecules

$$\left.\begin{array}{l} \dot{M}_1 + M \longrightarrow \dot{M}_2 \\ \dot{M}_2 + M \longrightarrow \dot{M}_3 \\ \dot{M}_3 + M \longrightarrow \dot{M}_4 \\ \cdots\cdots\cdots \\ \dot{M}_{n-1} + M \longrightarrow \dot{M}_n \end{array}\right\}$$

example:

$$R{-}CH_2{-}\dot{C}H_2 + (n-1)CH_2{=}CH_2 \longrightarrow R{-}(CH_2{-}CH_2)_{n-1}{-}\dot{C}$$

3) Chain Termination: chain termination takes place either by coupling reaction, or disproportionation reaction.

coupling:

$$R\!-\!(CH_2-CH_2)_{n-1}-CH_2-\dot{C}H_2 + \dot{C}H_2-CH_2-(CH_2-CH_2)_{m-1}-R$$

$$\xrightarrow{\text{coupling}} R-(CH_2-CH_2)_n-(CH_2-CH_2)_m-R$$

Disproportionation:

$$R-(CH_2-CH_2)_{n-1}-CH_2-\dot{C}H_2 + \dot{C}H_2-CH_2-(CH_2-CH_2)_{m-1}-R$$

$$\xrightarrow{\text{disproportionation}} \underset{\text{saturated}}{R-(CH_2-CH_2)_{n-1}-CH_2-CH_3} + \underset{\text{unsaturated}}{CH_2=CH-(CH_2-CH_2)_{m-1}-R}$$

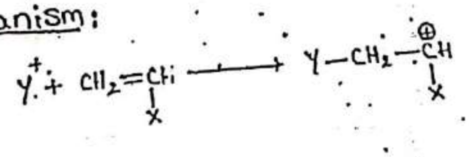
ii) Ionic Mechanism:

Ionic mechanism is again classified into 2 types.

A) Cationic mechanism B) Anionic mechanism.

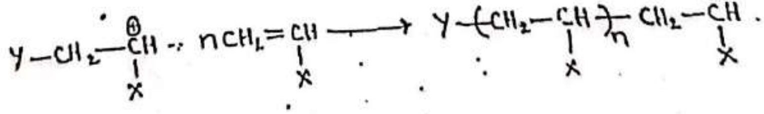
A) Cationic Mechanism:

1) Initiation:



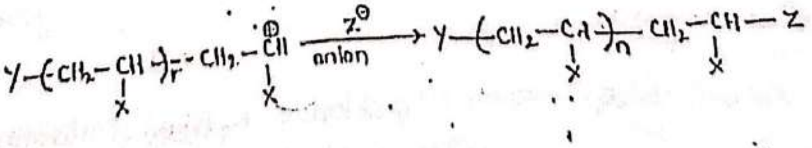
$$\overset{+}{Y} + \underset{X}{CH_2=CH} \longrightarrow Y-CH_2-\underset{X}{\overset{\oplus}{C}H}$$

2) Propagation:



$$Y-CH_2-\underset{X}{\overset{\oplus}{C}H} + n\,\underset{X}{CH_2=CH} \longrightarrow Y-(CH_2-\underset{X}{CH})_n-CH_2-\underset{X}{\overset{\oplus}{C}H}$$

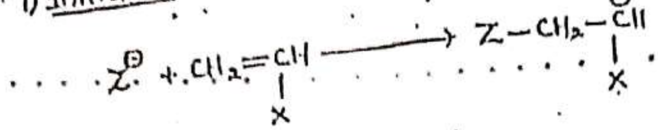
3) Termination:



$$Y-(CH_2-\underset{X}{CH})_r-CH_2-\underset{X}{\overset{\oplus}{C}H} \xrightarrow[\text{anion}]{Z^{\ominus}} Y-(CH_2-\underset{X}{CH})_n-CH_2-\underset{X}{CH}-Z$$

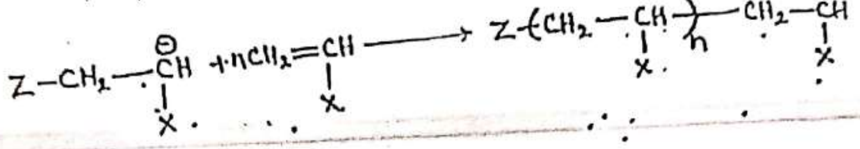
B) Anionic mechanism:

1) Initiation:



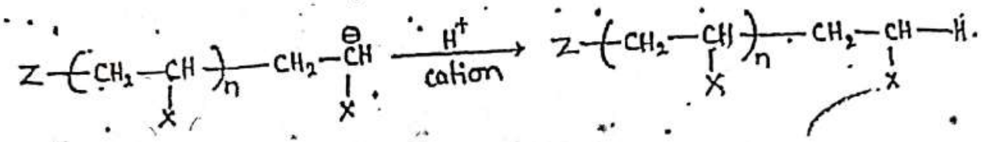
$$Z^{\ominus} + CH_2{=}\underset{X}{\underset{|}{CH}} \longrightarrow Z-CH_2-\underset{X}{\underset{|}{\overset{\ominus}{CH}}}$$

2) Propagation:



$$Z-CH_2-\underset{X}{\underset{|}{\overset{\ominus}{CH}}} + nCH_2{=}\underset{X}{\underset{|}{CH}} \longrightarrow Z{-}\!\left(CH_2-\underset{X}{\underset{|}{CH}}\right)_n\!-CH_2-\underset{X}{\underset{|}{\overset{\ominus}{CH}}}$$

3) Termination:



$$Z{-}\!\left(CH_2-\underset{X}{\underset{|}{CH}}\right)_n\!-CH_2-\underset{X}{\underset{|}{\overset{\ominus}{CH}}} \xrightarrow[\text{cation}]{H^+} Z{-}\!\left(CH_2-\underset{X}{\underset{|}{CH}}\right)_n\!-CH_2-\underset{X}{\underset{|}{CH}}-H.$$

2. Write the coordination polymerization? Write specific examples with mechanisms?

iii) Co-ordination polymerisation mechanism:

This mechanism is suggested by Zeigler and Natta. In this mechanism, a combination of transition metal halide and trialkyl aluminium is used as catal

This catalyst is called zeiglar Natta catalyst. So, this mechanism is also called zeiglar Natta catalysis.

one example for the Zeiglar-Natta catalyst combination is

"Titanium Tetrachloride + Triethyl aluminium"

$TiCl_4 + (C_2H_5)_3Al$

These two compounds react with each other and form a [illegible] complex.

(11)

This complex of catalyst is active catalyst in the mechanism.

The mechanism of polymerisation is given below:

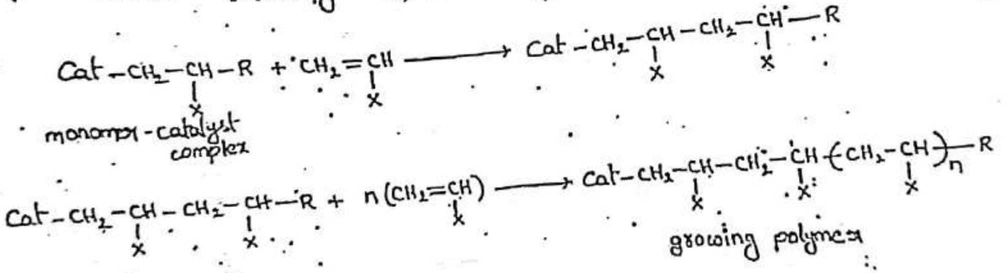
a) Initiation:

The catalyst form monomer catalyst complexes by reacting with monomer molecule.

$$\underset{\text{complex of catalyst}}{Cat-R} + \underset{\text{monomer}}{CH_2=\underset{X}{\underset{|}{CH}}} \longrightarrow \underset{\text{monomer-catalyst complex}}{Cat-CH_2-\underset{X}{\underset{|}{CH}}-R}$$

b) Propagation:

The monomer catalyst complex reacts with fresh monomers resulting the chain growth.

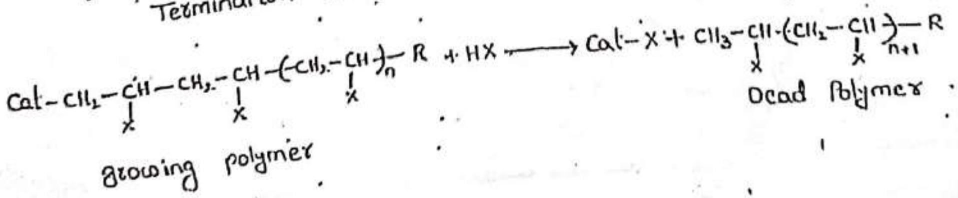


$$\underset{\text{monomer-catalyst complex}}{Cat-CH_2-\underset{X}{\underset{|}{CH}}-R} + CH_2=\underset{X}{\underset{|}{CH}} \longrightarrow Cat-CH_2-\underset{X}{\underset{|}{CH}}-CH_2-\underset{X}{\underset{|}{CH}}-R$$

$$Cat-CH_2-\underset{X}{\underset{|}{CH}}-CH_2-\underset{X}{\underset{|}{CH}}-R + n(CH_2=\underset{X}{\underset{|}{CH}}) \longrightarrow \underset{\text{growing polymer}}{Cat-CH_2-\underset{X}{\underset{|}{CH}}-CH_2-\underset{X}{\underset{|}{CH}}(CH_2-\underset{X}{\underset{|}{CH}})_n-R}$$

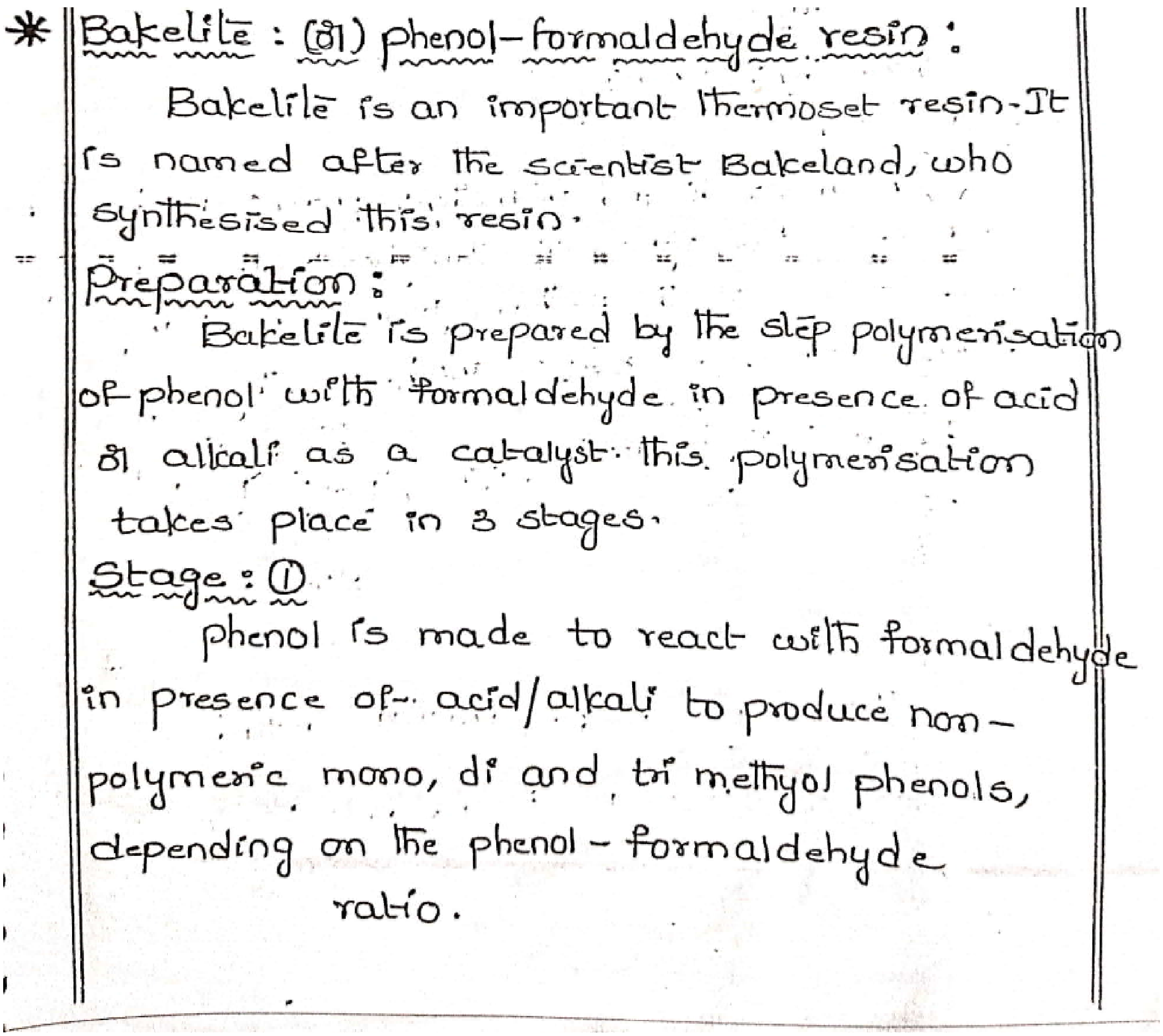
c) Termination:

Termination is carried out with an active halogen compound.



$$\underset{\text{growing polymer}}{Cat-CH_2-\underset{X}{\underset{|}{CH}}-CH_2-\underset{X}{\underset{|}{CH}}-(CH_2-\underset{X}{\underset{|}{CH}})_n-R} + HX \longrightarrow Cat-X + \underset{\text{Dead Polymer}}{CH_3-\underset{X}{\underset{|}{CH}}-(CH_2-\underset{X}{\underset{|}{CH}})_{n+1}-R}$$

3. Write the Preparations of following Polymers
    a) BUNA-S b) BUNA-N c) Bakelite d) Nylon 6,6 e) Teflon



* Bakelite : (or) phenol-formaldehyde resin :

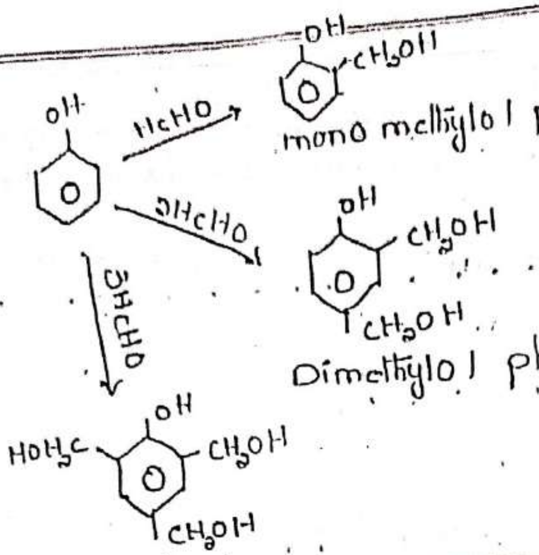
Bakelite is an important thermoset resin. It is named after the scientist Bakeland, who synthesised this resin.

Preparation :

Bakelite is prepared by the step polymerisation of phenol with formaldehyde in presence of acid or alkali as a catalyst. this polymerisation takes place in 3 stages.

Stage : ①

phenol is made to react with formaldehyde in presence of acid/alkali to produce non-polymeric mono, di and tri methyol phenols, depending on the phenol-formaldehyde ratio.



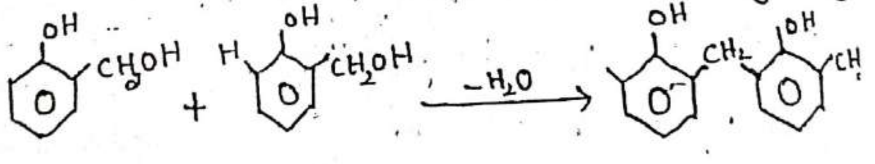
mono methylol phenol

Dimethylol phenol

Trimethylol phenol

Stage : ②

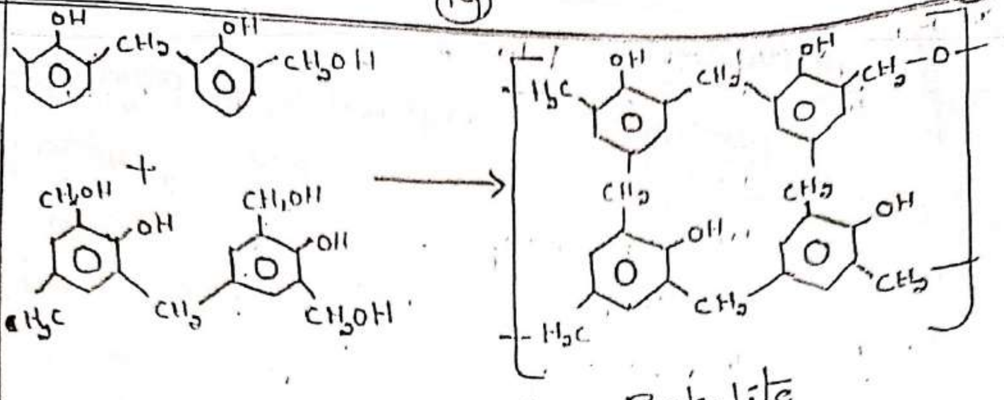
The mono di and tri methylol phenols are he
to produce two types of straight chain resin
condensation of the methyol group with hydrog
atom of benzene ring or another methylol gr



NOVOLAC

Stage : ③

this stage of preparation includes heating of Novolac, to produce Bakel



Bakelite

Properties:

1. It is hard, rigid and strong
2. starch and water resistant
3. Good chemical resistant.
4. Excellent electrical insulator
5. Very good adhesive;
6. Good corrosion and atmospheric resistance

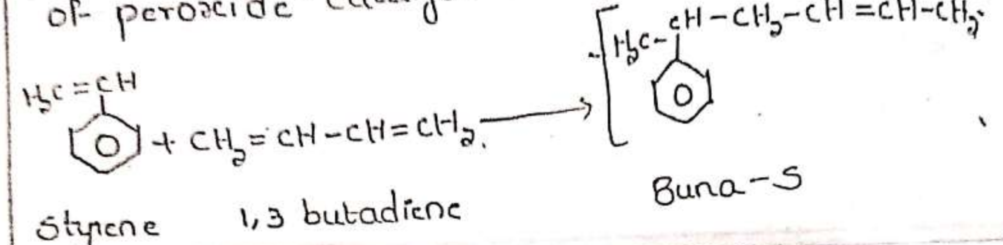
Engineering Applications:

Bakelite has wide range of applications.

1. Used to make electrical insulator parts like Switches, Switch boards, heater handles
2. Used to make telephone parts, radio & Tv cabinets
3. Good anion exchange resin.

1. Buna-S :

Preparation : It is prepared by co-polymerisatio of 75% 1,3 butadiene and 25% styrene in prese of peroxide catalyst at 50°C . . .



Properties :

i. High abrasion resistant

ii High loading capacity.

iii. poor resilience property

iv. It swells in oils and solvents

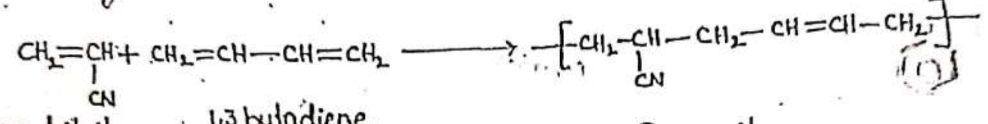
v. Low oxidation resistant, specially with traces of ozone.

Uses :

Used for motor pipes, shoe sols, foot wear, gaskets, adhesives, insulating cable wires, tank lin carpet backing, electrical insulation etc---

⑧ Buna – N : (Nitrile Rubber)

Preparation: It is prepared by polymerisation of acryl nitrile with 1,3-butadiene in presence of H_2O_2 catalyst.



$$CH_2{=}\underset{\displaystyle CN}{\underset{|}{CH}} + CH_2{=}CH{-}CH{=}CH_2 \longrightarrow \left[CH_2{-}\underset{\displaystyle CN}{\underset{|}{CH}}{-}CH_2{-}CH{=}CH{-}CH_2\right]$$

acrylnitrile 1,3 butadiene Buna – N

Properties :

i). Excellent resistance to oils

ii) High abrasion resistance and good tensile strength

iii) Excellent resistance to heat, sunlight and acids

iv) It is less resistant to alkalies because of CN group.

Uses :

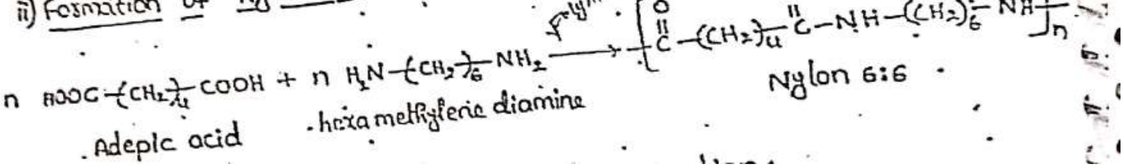
→ Gaskets, adhesives, conveyer belts

→ Used in oil resistant foams

→ Tank linings

→ Aircraft components

ii) Formation of Nylon 6:6 :



$$n\ HOOC{-}(CH_2)_4{-}COOH + n\ H_2N{-}(CH_2)_6{-}NH_2 \xrightarrow{\text{polymerisation}} \left[\overset{\displaystyle O}{\overset{\|}{C}}{-}(CH_2)_4{-}\overset{\displaystyle O}{\overset{\|}{C}}{-}NH{-}(CH_2)_6{-}NH\right]_n$$

Adepic acid hexa methylene diamine Nylon 6:6

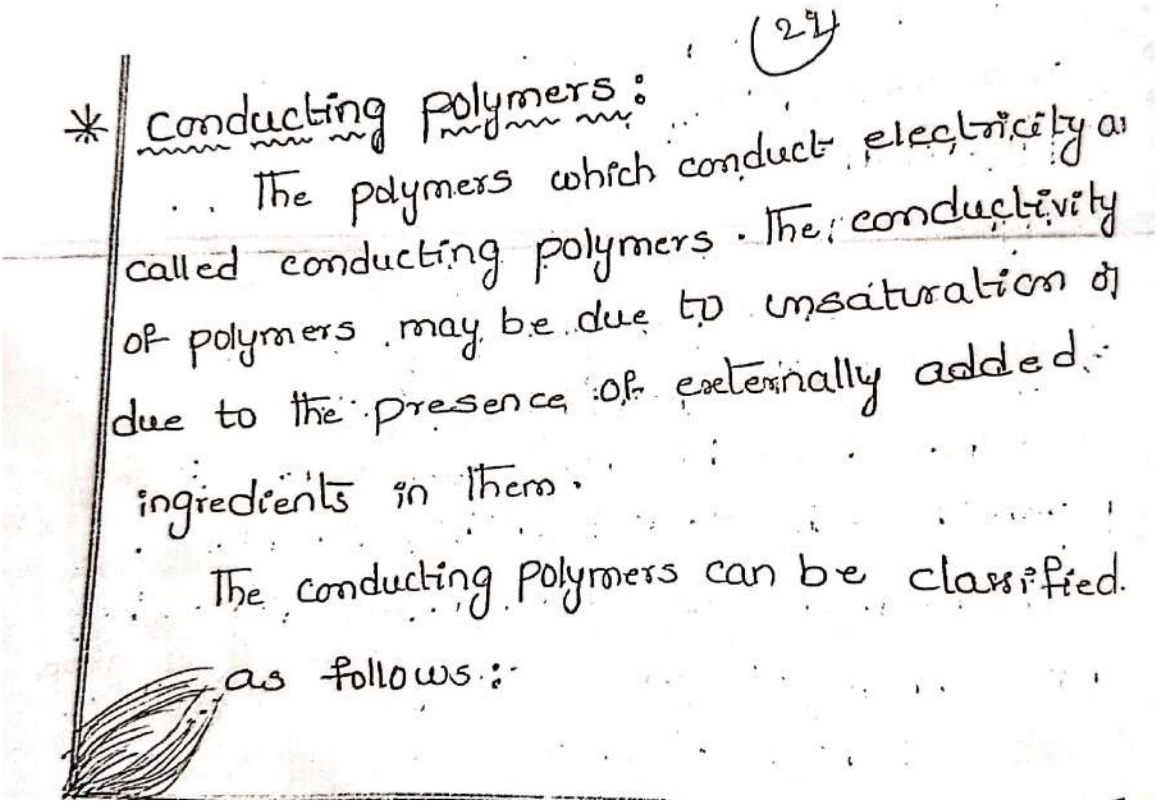
Polytetrafluoroethylene (Teflon)

Teflon is manufactured by free-radical polymerization of tetrafluoroethylene. The catalyst used is per sulphate at high pressure. The reaction is given as:

$$n\ F_2C{=}CF_2 \rightarrow -(F_2C{-}CF_2)_n-$$

Teflon is hydrophobic and is inert in nature. It is used in making a non-stick coating for cookware and also as a lubricant in machinery to reduce friction.

4. **What are Conducting Polymers and discuss various examples and mechanism of conduction?**

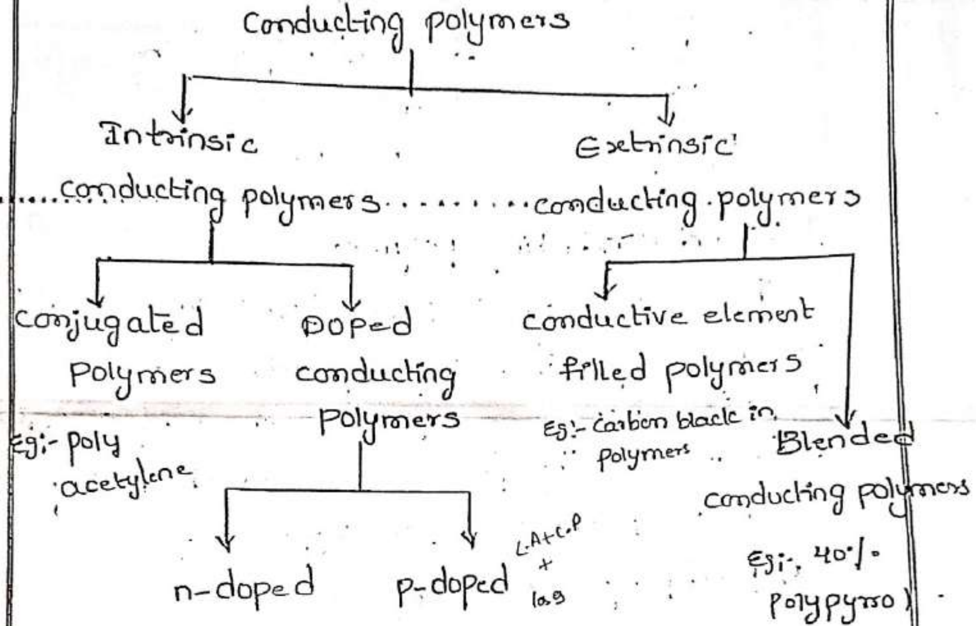


(27)

* Conducting polymers:

The polymers which conduct electricity a
called conducting polymers. The conductivity
of polymers may be due to unsaturation o
due to the presence of externally added
ingredients in them.

The conducting polymers can be classified
as follows:



Intrinsic conducting polymers :

These polymers having conjugation in the backbone of the polymer. Again these are two types.

1. Conjugated conducting polymers :

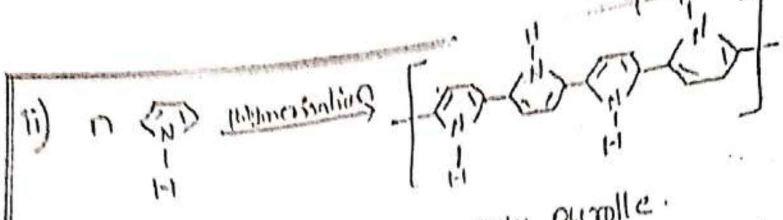
these polymers have conjugated double bonds in the backbone the polymer. Their conductivity is due to π - electrons.

Examples :-

1) acetylene : $n\,CH \equiv CH \xrightarrow{Polymerisation} \left(CH = CH \right)_n$

poly acetylene.

(2,4)

ii) 

Pyrole poly pyrolle.

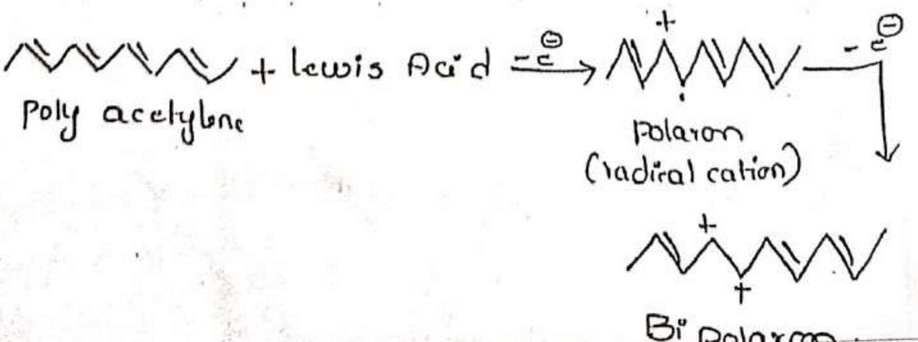
2: Doped conducting polymers :-

The conductivity of conjugated polymers can be enhanced by introducing a positive charge or negative charge on polymer backbone by Oxidation or reduction. This process is called doping.

Doping is again two types.

a) p-doping b) n-doping.

a) **p-doping** : p-doping is done by Oxidation of a conjugated polymer with a Lewis acid. During this process, removal of π-electron from Polymer backbone leads to the formation of a radical cation (or) polaron. The second Oxidation of polaron forms bipolaron.

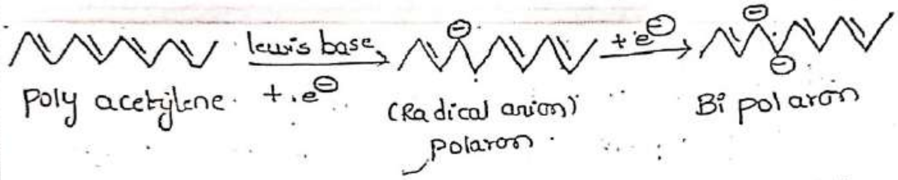


Poly acetylene

Polaron (radical cation)

Bi Polaron

b) n-doping : n-doping is done by reduction of a conjugated (reduction) polymer with a Lewis base. During this process, addition of $e^{\ominus}$ to the polymer backbone leads to the formation of a radical anion (or) polaron. The second reduction of Polaron forms bipolaron.



II) Extrinsic conducting polymers:

The conductivity of these polymers is due to the presence of externally added ingredients in them.

3- Conductive element filled polymers:

The polymer acts as a binder to hold the conducting element such as metallic fibre carbon black etc-----

Minimum amount of conducting filler is added so that the polymer starts conducting. This minimum amount is called percolation threshold.

Normal polymer - Conductional polymer

Advantages:

i) These are low cost polymers
ii) These are light weight and mechanically durabl
iii) These are strong
iv) They can be fabricated very easily.

4- Blended mixed conducting polymers:

The conventional polymer is blended with a conducting polymer to improve physical, chemical, electrical and mechanical properties.

Ex:- polypyrrole is a conducting polymer an if it is present 40% in a normal conventional polym Then the impact strength increases. These blend polymers are used in electromagnetic shieldin

Applications of conducting polymers:

1. conducting polymers are used in rechargable batteries.
2. In analytical sensors for p^H, O_2, NO_2, SO_2, NH_3 and glucose.
3. The conducting polymers are used for making ion exchangers.
4. In electronic displays and optical fibres
5. In photovoltaic devices.

MCQs

1. Which of the following statements about polymers is TRUE?

A) Polymers are always natural.
B) Polymers are made up of repeating structural units called monomers.
C) All polymers are biodegradable.
D) Polymers cannot be synthesized artificially.

☑**Answer:** B
Explanation: Polymers are large molecules formed by repeating monomer units through polymerization.

☐ 2. The functionality of a monomer refers to:

A) Its ability to conduct electricity
B) The number of reactive sites present in the monomer
C) Its molecular weight
D) Its chemical stability

☑**Answer:** B
Explanation: Functionality = number of bonding sites that can form covalent links during polymerization.
Example: Ethylene ($CH_2=CH_2$) has functionality 2.

☐ 3. Which of the following polymerization reactions involves free radicals, cations, or anions?

A) Step-growth polymerization
B) Chain-growth polymerization
C) Condensation polymerization
D) Coordination polymerization

☑**Answer:** B
Explanation: Chain-growth polymerization proceeds via active centers like free radicals, cations, or anions.

☐ 4. Nylon-6,6 is prepared by condensation of:

A) Adipic acid and hexamethylene diamine
B) Caprolactam
C) Maleic acid and ethylene glycol

D) Phthalic acid and glycerol

✅**Answer:** A
Explanation: Nylon-6,6 = condensation polymer of adipic acid + hexamethylene diamine → amide linkages.

☐ **5. Which of the following is an example of coordination polymerization?**

A) Polymerization of ethylene using Ziegler–Natta catalyst
B) Condensation of glycerol with phthalic acid
C) Polymerization of formaldehyde
D) Vulcanization of rubber

✅**Answer:** A
Explanation: Coordination polymerization uses transition metal catalysts (e.g., $TiCl_4$ + $Al(C_2H_5)_3$).

☐ **6. PVC (Polyvinyl Chloride) is formed by the polymerization of:**

A) Vinyl chloride
B) Ethylene
C) Tetrafluoroethylene
D) Styrene

✅**Answer:** A
Explanation: PVC is obtained by addition polymerization of vinyl chloride ($CH_2{=}CHCl$).

☐ **7. Teflon is known chemically as:**

A) Polyethylene
B) Polytetrafluoroethylene (PTFE)
C) Polypropylene
D) Polyacrylonitrile

✅**Answer:** B
Explanation: Teflon = PTFE, obtained by polymerizing tetrafluoroethylene.

☐ **8. Bakelite is a thermosetting plastic formed by condensation of:**

A) Phenol and formaldehyde
B) Ethylene and benzene
C) Styrene and butadiene
D) Adipic acid and glycerol

✅**Answer:** A
Explanation: Bakelite = phenol + formaldehyde → cross-linked phenol-formaldehyde resin.

□ **9. Which of the following is a thermoplastic polymer?**

A) Bakelite
B) Melamine
C) Teflon
D) Urea–formaldehyde resin

✅**Answer:** C
Explanation: Teflon (PTFE) softens on heating → thermoplastic.
Bakelite & urea-formaldehyde → thermosetting.

□ **10. Buna-S rubber is obtained by copolymerization of:**

A) Styrene and butadiene
B) Styrene and acrylonitrile
C) Butadiene and acrylonitrile
D) Isoprene and butadiene

✅**Answer:** A
Explanation: Buna-S = butadiene + styrene → synthetic rubber.

□ **11. Buna-N is prepared by copolymerization of:**

A) Butadiene and acrylonitrile
B) Styrene and butadiene
C) Ethylene and propylene
D) Isoprene and butadiene

✅**Answer:** A
Explanation: Buna-N = butadiene + acrylonitrile → oil-resistant rubber.

□ **12. Conducting polymer among the following is:**

A) Polyethylene
B) Polyaniline
C) PVC
D) Nylon-6,6

✅**Answer:** B
Explanation: Polyaniline and polyacetylene conduct electricity due to delocalized π-electrons.

□ **13. Mechanism of conduction in polyacetylene involves:**

A) Ionic conduction
B) Electron delocalization through conjugated double bonds
C) Proton conduction
D) Hole conduction only

✅**Answer:** B
Explanation: Polyacetylene conducts through delocalized π-electrons along conjugated C=C bonds.

□ **14. Which of the following polymers is biodegradable?**

A) PVC
B) Polythene
C) Poly(lactic acid) (PLA)
D) Nylon-6,6

✅**Answer:** C
Explanation: PLA and PGA are biodegradable polyesters used in medical sutures.

□ **15. Poly Glycolic Acid (PGA) is used mainly for:**

A) Electrical insulation
B) Biodegradable surgical sutures
C) Textile fibers
D) Rubber materials

✅**Answer:** B
Explanation: PGA is a biodegradable polymer used for absorbable sutures and implants.

☐ **16. Thermoplastics differ from thermosetting plastics in that:**

A) They soften on heating and harden on cooling
B) They are cross-linked
C) They cannot be reshaped after molding
D) They have high rigidity permanently

✅**Answer:** A
Explanation: Thermoplastics can be remolded; thermosets cannot due to cross-linking.

☐ **17. Carbon fibers are made from:**

A) Polyacrylonitrile (PAN)
B) Polystyrene
C) Polyethylene
D) Nylon

✅**Answer:** A
Explanation: PAN is pyrolyzed to form carbon fibers—lightweight, strong materials.

☐ **18. Step-growth polymerization is also called:**

A) Addition polymerization
B) Condensation polymerization
C) Radical polymerization
D) Ionic polymerization

✅**Answer:** B
Explanation: Step-growth involves condensation with elimination of small molecules (e.g., H_2O, HCl).

☐ **19. In chain-growth polymerization, molecular weight increases:**

A) Gradually throughout
B) Only at the end
C) Rapidly at the beginning and then levels off
D) After all monomers react

✅**Answer:** C
Explanation: Chain-growth polymerization forms high molecular weight early in the

reaction.

□ **20. The monomer of Teflon is:**

A) $CF_2=CF_2$
B) $CH_2=CHCl$
C) $CH_2=CH_2$
D) $C_6H_5CH=CH_2$

✅**Answer:** A
Explanation: $CF_2=CF_2$ → polytetrafluoroethylene (Teflon).

UNIT V
INSTRUMENTAL METHODS AND APPLICATIONS

Electromagnetic Spectrum

Q1. What is the electromagnetic spectrum?
A1. It is the range of all types of electromagnetic radiation, ordered by wavelength or frequency, including gamma rays, X-rays, UV, visible light, IR, microwaves, and radio waves.

Q2. Which region of the electromagnetic spectrum is used in UV-Visible spectroscopy?
A2. The UV (200–400 nm) and visible (400–800 nm) regions.

Absorption of Radiation & Beer-Lambert Law

Q3. What is absorption of radiation?
A3. It is the process where molecules absorb specific wavelengths of radiation, causing electronic or vibrational transitions.

Q4. State the Beer-Lambert law.
A4. A=ε c lA = \varepsilon \, c \, lA=εcl
Where AAA = absorbance, ε\varepsilonε = molar absorptivity, ccc = concentration, lll = path length.

Q5. What is the significance of the Beer-Lambert law?
A5. It allows determination of concentration of a solution by measuring absorbance.

UV-Visible Spectroscopy

Q6. What is UV-Visible spectroscopy?
A6. It is a technique that measures absorption of UV or visible light by molecules, causing electronic transitions from ground to excited states.

Q7. What are common electronic transitions in UV-Vis spectroscopy?
A7. $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$, and $d \rightarrow d$ transitions.

Q8. Name main components of a UV-Vis spectrophotometer.
A8. Light source, monochromator, sample holder (cuvette), and detector.

IR Spectroscopy

Q9. What is IR spectroscopy used for?
A9. To identify functional groups in molecules by measuring vibrational transitions.

Q10. What are fundamental vibrational modes?
A10. Stretching and bending (scissoring, rocking, wagging, twisting).

Q11. State the selection rule for IR absorption.
A11. A vibration is IR active if it causes a change in the dipole moment of the molecule.

Q12. Components of an IR spectrometer?
A12. IR source, sample holder, monochromator or interferometer, detector.

Chromatography

Q13. What is chromatography?
A13. A technique for separating components of a mixture based on differential partitioning between stationary and mobile phases.

Q14. Name types of chromatography.
A14. Paper, thin-layer (TLC), column, gas (GC), and high-performance liquid chromatography (HPLC).

Q15. What is the basic principle of chromatography?
A15. Components move at different rates due to differences in adsorption or solubility between stationary and mobile phases, leading to separation.

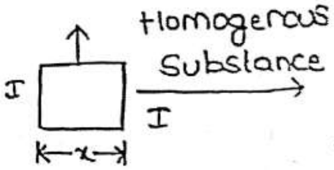
EASSAY QUESTIONS

1. **Write about the UV Spectroscopy with applications?**

Absorption laws :-

There are two laws which are the absorption of light by the molecules. they are lambert's law, beer's law.

Lambert's law :



It is applied to solids.

When a beam of monochromatic radiation pass through a homogenous absorbing medium the rate of decrease of intensit of radiation with thickness of absorbing medium is proportio o the Intensity of the incident light.

Mathematically the law is expressed as

$$-\frac{dI}{dx} \propto I_0$$

$$-\frac{dI}{dx} = KI_0 .$$

(7.) ①

Where,

I = Intensity of radiation after passing through a thickness (x) for the medium.

dI = Small decrease in the intensity.

$-\frac{dI}{dx}$ = rate of decrease of intensity of radiation with thickness of the absorbing medium.

K = proportionality constant. Its value depends upon the nature of absorbing medium.

Let 'I_0' be the intensity of radiation entering the absorbing medium $x=0$.

Then 'I' is the Intensity of radiation after passing through any thickness x (x) of the medium can be calculated as

$$\int_{I_0}^{I} \frac{dI}{I_0} = \int_{x=0}^{x=x} -K\,dx$$

$$\log \frac{I_t}{I_0} = -Kx + C \quad [\because C = \text{constant}]$$

$$\frac{I}{I_0} = e^{-Kx+C} \Rightarrow \boxed{I = I_0 e^{-Kx+C}}$$

The intensity of radiation absorbed I_{abs} is given by

$$\begin{aligned} I_{abs} &= I_0 - I \\ &= I_0 - I_0 e^{-Kx+C} \\ &= I_0 [1 - e^{-Kx+C}]. \end{aligned}$$

Beer's law :

It is applied to liquids.

when a beam of monochromatic radiations passed th solution of absorbing medium substance. the rate o decrease of intensity of radiation with thickness o absorbing solute is proportional to the incident radia as well as the concentration of the solution. Mathem it is represented as

$$-\frac{dI}{dx} \propto C I_0$$

$$-\frac{dI}{dx} = K'CI_0$$

where C = concentration of the solution in moles per liter

K' = molar absorption coefficient.

Suppose I_0 be the intensity of radiation before entering medium($x=0$) then the intensity of the radiation 'I' aft Passing through the thickness x of the medium can be ca as

$$\int_{I_0}^{I} \frac{dx}{I_0} = -\int_{x=0}^{x} K'C\,dx$$

$$\int_{I_0}^{I} dI/I_0 = \int_{x=0}^{x} kc\,dx$$

$$\ln I/I_0 = -kcx$$

$$\ln \frac{I}{I_0} = -K'Cx$$

$$\frac{I}{I_0} = e^{-K'Cx}$$

$$\boxed{\therefore I = I_0 e^{-K'Cx}}$$

The intensity of radiation absorbed is given by

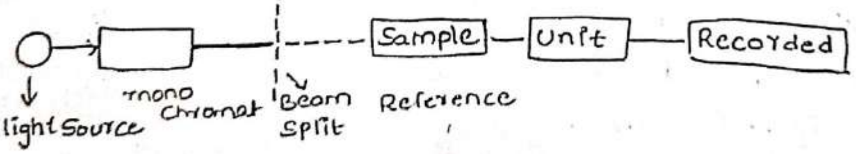
$$I_{abs} = I_0 - I$$
$$= I_0 - Ie^{-k'cx}$$
$$= I_0[1 - e^{-k'cx}]$$

The above beer's law can also be written by changing the natural logarithm to base

$$I = I_0 - 10^{-a'cx} \quad \left[\because a' = \frac{k'}{2.803}\right]$$

Instrumentation:

In visible-UV spectrometer, a beam of light is split into two equal half. One-half of the beam (the sample beam) is directed through a transparent cell containing a solution of the compound being analyzed and one-half (The reference bear is directed through an identical cell that contains only the solvent. The instument is so-designed that it can compare the intensities of the two beams at each above length of the region



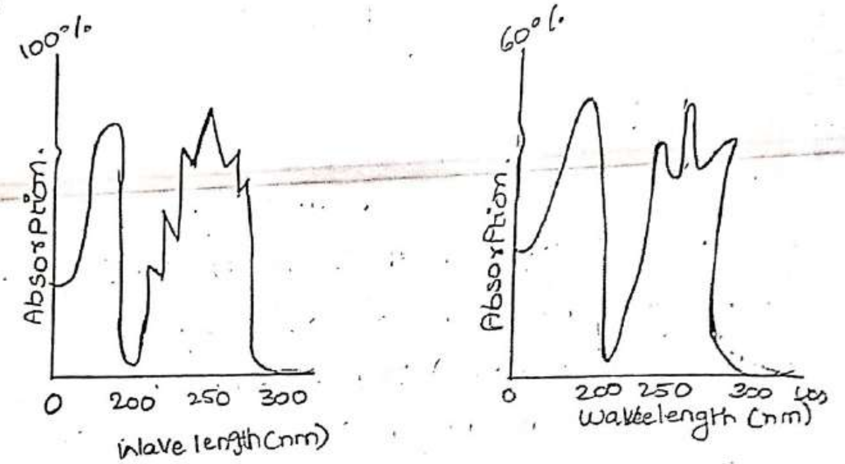
If the compound absorbs light at a particular wave length, the intensity of the sample beam (I) will be less than that of the references beam (I₀). The instrument gives output graph-a Plot the wavelength of the entire region versus the absorbance (A) of the light at each wavelength, where absorbance

$$(A) = \log\left(\frac{I_0}{I}\right).$$

Such a graph is known as an absorption spectrum.

Example of Visible-UV spectroscopy :—

(i) Spectrum of arenes: Arenes are organic compounds th contain one or more benzene rings. The electrons in these are spread around the hexagonal rings of carbon atom. fig a&b. shows UV spectro of benzene and napthalene.

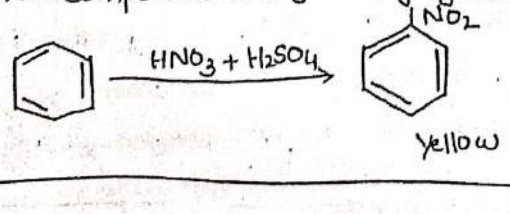


Chromophore :—

All those compounds which absorbs light of wave length between 400 – 800 mμ appear coloured to the human eye. exact colour depends upon the wavelength of light absorb by the compound.

" A chromophore was considered by substance which is respon-sible for imparting colour to the compound".

Eg: Nitro compounds are generally yellow in colour.



(u) (u)

Auxochrome :—

An Auxochrome can be defined as "any group which does not itself acts as a chromophore" but whose presence brings about a shift of the absorption bond towards the out end of the spectrum.

→ The Absorption of longer wave length is due to the combination of chromophore and an auxochrome to give raise to another chromophore.

→ An Auxochromic group is called colan exchanging group.

→ Auxochrome is a functional group which does not absorb UV and it represents a saturated group with non-bonded electrons which are attached to a chromophore alters both wavelength as well as absorption maximum(ϵ_{max})

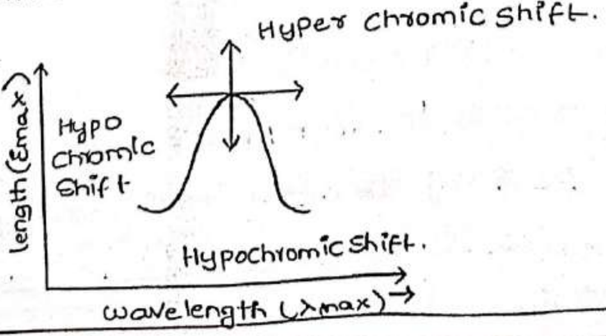
→ Auxochromic group do not show the characteristic absorption above 200.

Eg: $-\ddot{O}H$, $-\dot{N}H_2$, $-SH$, $-\ddot{Cl}:$, $-\ddot{O}R$, $-\dot{N}O_2$, $-CN$ etc.,

Intensity Shifts :

These are Two Types. they are;

1. Hyperchromic Shift
2. Hypochromic Shif.



(i) Hyperchromic Shift :-

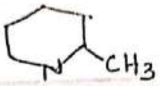
It is an effect due to which the intensity of absorption max-mum increases (Emax). This is called "Hyper chromic shi

* The introduction of an auxochromic usually increases intensity of absorption.

Eg: The band for pyridine of 257nm [Emax = 2750] is shifted to 262 nm [Emax - 3650] for 2-methyl pyridine.

λmax = 257nm

[Emax = 2750]



λmax -262nm

[Emax = 3650]

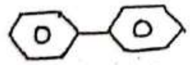
(ii) Hypochromic Shift :

It is an effect due to which the two intensity of absorption maximum decreases.

* i.e., extinction coefficient [Emax] decreases.

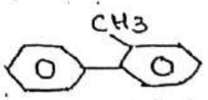
* The introduction of group which distorts the geometry of the molecule causes" Hypochromic shif".

Eg:



Bi phenyl

λmax = 250nm [Emax=19000]



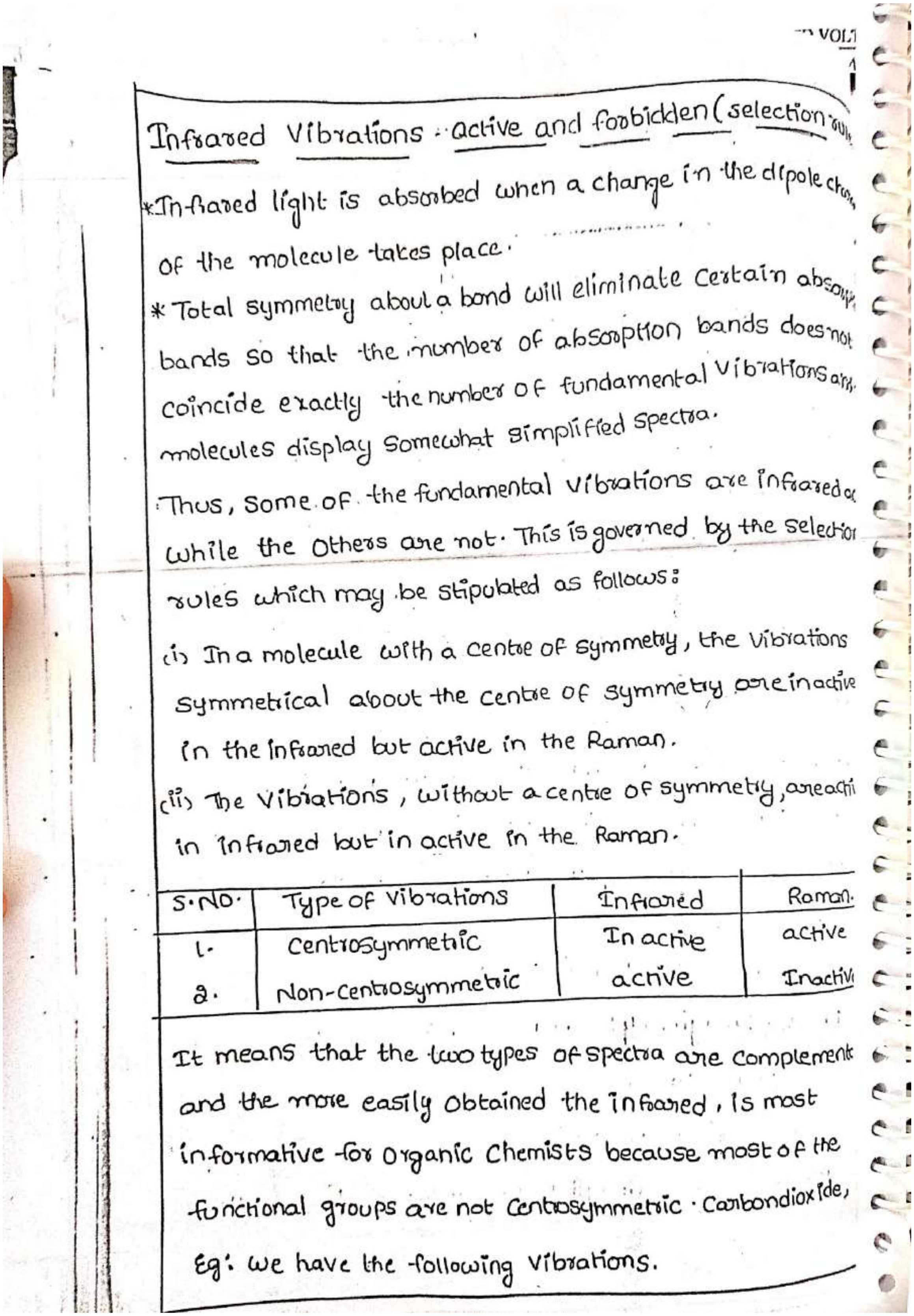
2-methyl Bi phen

λmax = 237 nm

[Emax = 10,250

Bi-phenyl absorbs at 250nm [Emax = 19,000]. where as 2-methy Bi-phenyl absorbs of 273nm [Emax = 10,250]. It is due to the distortion caused by the methyl group in 2-methyl Bi-phenyl.

2. Write about the IR Spectroscopy with applications?



VOL.1

Infrared Vibrations : active and forbidden (selection rules)

* Infrared light is absorbed when a change in the dipole change of the molecule takes place.

* Total symmetry about a bond will eliminate certain absorption bands so that the number of absorption bands does not coincide exactly the number of fundamental vibrations are. molecules display somewhat simplified spectra.

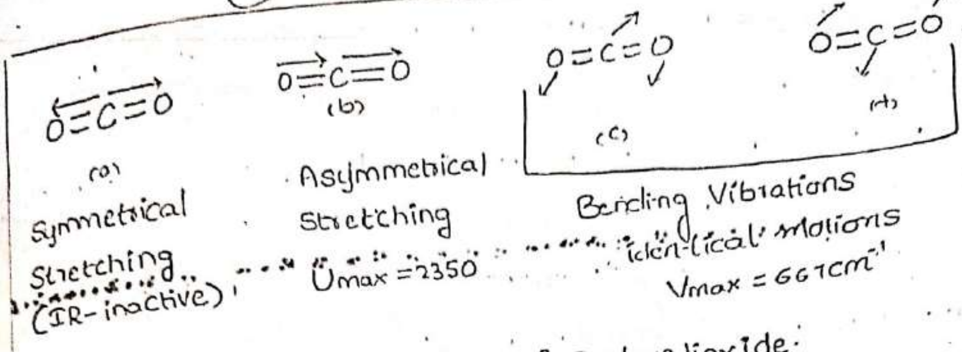
Thus, some of the fundamental vibrations are infrared ac while the others are not. This is governed by the selection rules which may be stipulated as follows:

(i) In a molecule with a centre of symmetry, the vibrations symmetrical about the centre of symmetry are inactive in the infrared but active in the Raman.

(ii) The vibrations, without a centre of symmetry, are acti in infrared but inactive in the Raman.

S.NO.	Type of Vibrations	Infrared	Raman.
1.	Centrosymmetric	Inactive	active
2.	Non-centrosymmetric	active	Inactiv

It means that the two types of spectra are complement and the more easily obtained the infrared, is most informative for organic chemists because most of the functional groups are not centrosymmetric. Carbondioxide, Eg: we have the following vibrations.



Fundamentals Vibration of Carbondioxide.

* These four vibrations (a-d) are the fundamental vibration of Carbondioxide. The symmetric C=O streching vibration (a) of carbon dioxide does not give rise to a change in the dipole moment of the molecule and consequently remains inactive. However, in the Asymmetric stretching (b) the two C=O bonds are of different length and hence the molecule has a net change in the dipole character (infrared active) and consequently absorbs at 2350 cm⁻¹.

* The Bending of O=C=O bonds (c and d) are identical motions but they occur in perpendicular. Planes. Such vibrations are called degenerate and appear in the same position in the spectrum. Thus, the two bands at 2350 cm⁻¹ and 667 cm⁻¹ pertaining to asymmetric stretching (b) and bending vibrations (c and d) constitute the fundamental spectrum of Carbondioxide.

Intensity and position of Infrared absorption bands:

The intensity of a particular fundamental absorption depends upon the difference between the dipole moments of the molecule in the ground state and the vibrational excited state. The greater the difference in these dipole moments, the more intense the absorption. If no change in the dipole moment accompanies the vibrations then the mode is infrared inactive.

The intensity of absorption bonds in infrared spectroscopy cannot be measured with the same accuracy as in ultraviolet, spectroscopy. It is usually sufficient for an organic chemist to know that a bond is of strong, medium, weak or variable intensity. This may be classified / estimated by assigning the most-intense peak in the infrared spectrum ; a relative intensity of 100%.

Functional Group and Fingerprint regions :

The Region of the infrared spectrum from $4800 cm^{-1}$ to $1400 cm^{-1}$ exhibits absorption bonds assignable to a number of functional groups and called functional group region.

* These bonds are useful diagnostically but more usually they supplement the region below $1400 cm^{-1}$.

* The region from $1400 cm^{-1}$ to $900 cm^{-1}$ is complex because it contains apart from fundamental streching and bending vibrations, many bonds resulting from the sum or difference of their vibrational frequencies.

* Specific vibrational assignments in these region are therefore, very difficult. Thus, this part of the spectrum is characteristic of a compound is called fingerprint region. Similar compounds may show very similar spectra in functional group region but certainly exhibit discrible difference in fingerprint region.

Absorption of Infrared radiation & molecular Vibrations:

(i) Absorption of Infiared radiation:—

* The absorption of Infrared radiation corresspords to energy Changes in the range from 2 to 10 kcal/mol.

* Radiation in this energy range, corresponds to the range encompassing the streching and bending vibrational frequencies of the bands in most Covalent molecules.

* Infrared light is absorbed when oscillating dipole moment inleracts with the oscillating electric vector of infrared beam.

* These vibrations absorb light at certain quantized frequency given rise to characterstics bands. when infrared light of that frequency is incident on the molecule, energy is absorbed and the Amplitude of that vibration is increased.

(ii) Molecular Vibrations:

A molecule may be regarded as a system of balls(atoms) and springs(bonds. when it absorbs infrared radiation. It is Set into vibrations resulting in exclation of bond deformations, streching and bending.

→ Streching Vibrations: During streching vibrations the distance between 2 atoms increases or decreases but the atoms remain in the same bond axis.

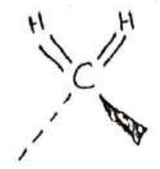
Types of Streching vibrations:

streching vibrations require high energy and occur at higher frequency. They are two types.

(i) Symmetrical stretching:

In this Stretching mode both the atoms move in and out simultaneously.

Eg: for example, symmetrical streching of $=CH_2$ group



Asymmetrical Streching :

In Asymmetrical Streching one atom moves in while the oth moves out.

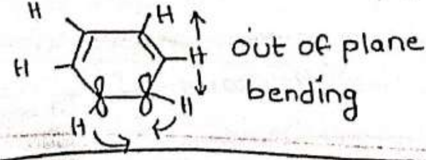
Bending Vibration : During bending vibrations, the dista b/w the atoms remains constant but the position of the atoms changes relative to the original bond axis.

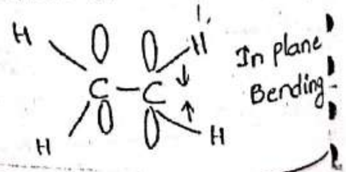
* Bending vibrations require lower energy and occur at low frequency. They are divided in to two types.

a) In plane bending (b) Out-of plane bending.

(a) In-plane Bending Vibrations:

A bending vibrational mode in which the atoms remain the same plane as the nodal plane of the system, is ca in-plane bending vibration. The in-plane bending vibra in olefin or aromatic ring as shown.





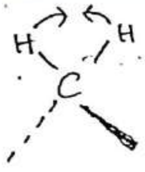
Types of in-plane bending vibrations :-

They are of two types · (i) In-plane scissoring deformation ·
(ii) In plane rocking deformation ·

(i) In-plane scissoring deformation:

In the scissoring deformation mode, the atoms swing in concert toward opposite directions as represented for $>CH_2$ group

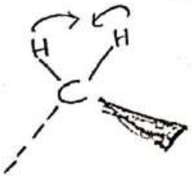
* Imagine carbon as the pivot and the hydrogens as the points of a scissors, then there is a plane passing all the atoms and the motion is in-plane.



In-plane bending (scissoring).

(ii) In-plane rocking deformation :

In this deformation mode, both the atoms swing to the same side then both to the other side. This is shown for the CH_2 group.



Imagine a person (c) sitting on a rocking chair of Hydrogen (H) as 'tips of' the rockers. Then there is a plane passing through all the atoms. This is a poor group frequency as all the atoms move

(b) Out-of plane bending:

When the atoms bond out of the nodal plane, the bending is called out-of-plane bending. The Out-of-plane bend. vibrations in olefin or aromatic ring.

Types of Out-of-plane bending Vibrations:

Out-of plane bending vibrations are of two types

(i) Wagging deformations (ii) Twisting deformations.

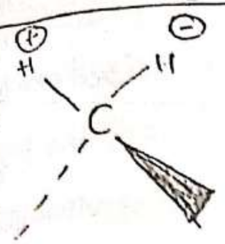
(i) out-of-Plane wagging deformation:

In this deformation mode both the atoms swing up and out of the paper in unison. This is illustrated for the ci group.

Suppose (C) represents the body of a dog and Hydrogen (H) i tail. When the dogs wags its tail, the motion is from si to side and out of the plane of the dog.

(ii) Out-of-plane Twisting Deformation:

In twisting deformation one atom swings up and the ot swings down related to the plane of paper. The ⊕ or signs signify the movement of hydrogens in a direction -dicular to the plane of paper.



election Rules :

change in Dipole moment :

or a vibrational mode to be observed in the IR spectrum, here must be a change in the molecule's dipole moment during the vibration.

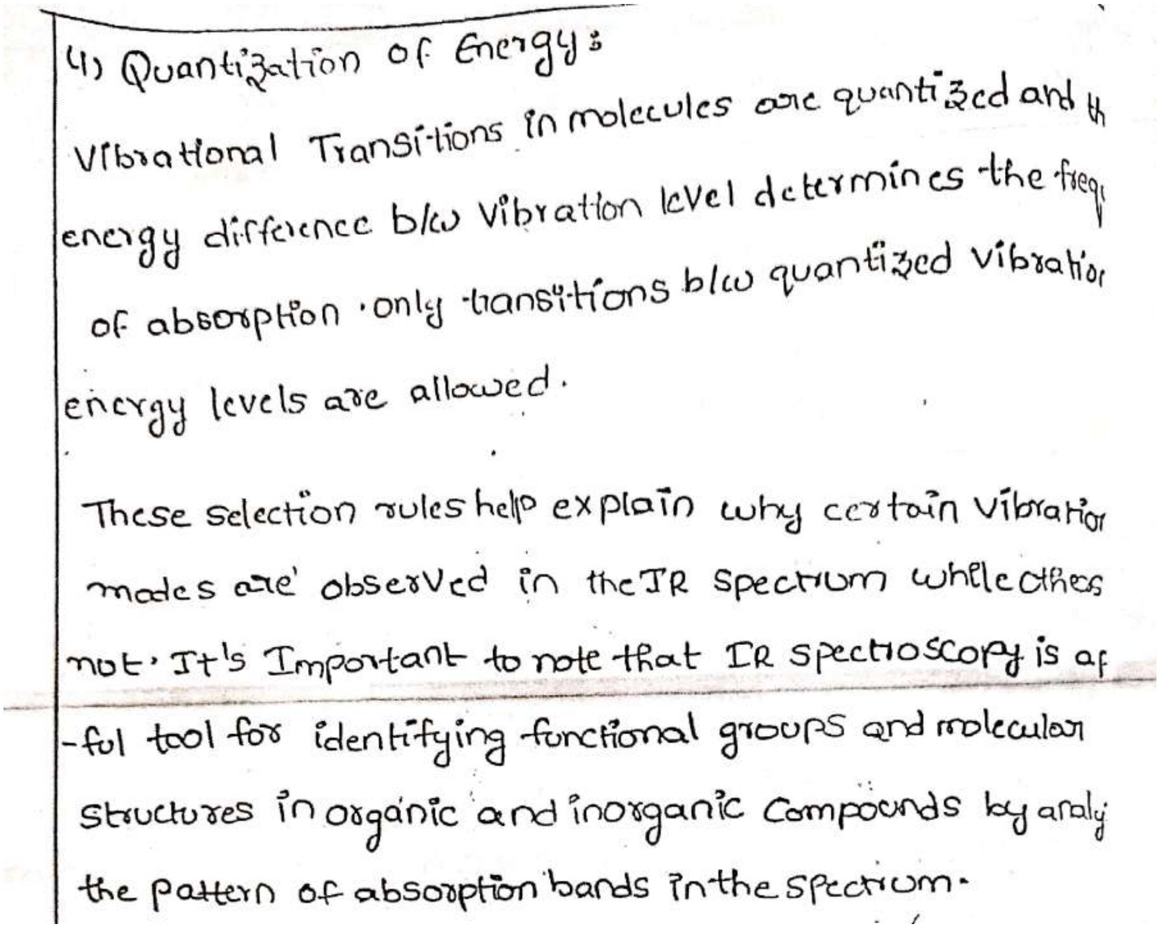
→ The molecule must go from a non-polar state to polar state or vice versa during the vibration.

· Non-Centrosymmetric molecules :

In centrosymmetric molecules, such as diatomic gases like like N_2 or O_2 no net changes in the dipole moment occurs during vibration because; they have a center of inversion symmetry. As a result they do not exhibit IR absorption.

3) Intensity factors :

The intensity of an IR absorption band depends on the magnitude of the change in dipole moment during the vibration. Vibrations with larger dipole moment changes will have stronger absorption bands.



4) Quantization of Energy:

Vibrational Transitions in molecules are quantized and th energy difference b/w Vibration level determines the freq of absorption. only transitions b/w quantized vibratio energy levels are allowed.

These selection rules help explain why certain Vibratior modes are observed in the IR spectrum while others not. It's Important to note that IR spectroscopy is a -ful tool for identifying functional groups and molecular structures in organic and inorganic compounds by analy the pattern of absorption bands in the spectrum.

MCQs

Electromagnetic Spectrum & Absorption of Radiation

1. Which of the following has the *shortest wavelength*?
A) Infrared
B) Ultraviolet
C) Visible
D) Microwave
✓**Answer:** B) Ultraviolet
Explanation: Wavelength decreases from IR → Visible → UV → X-ray → Gamma.

---

2. The relationship between energy and wavelength is given by:
A) $E=hc*\lambda$
B) $E=hc/\lambda$
C) $E=hc\lambda$
D) $E=h\lambda c^2$
✓**Answer:** B)

---

3. Beer-Lambert's law is represented as:
A) A=εcl
B) A=cε/l
C) A=ε+cl
D) A=1/εcl
✅**Answer:** A) A=εcl
Explanation: Absorbance (A) is directly proportional to molar absorptivity (ε), concentration (c), and path length (l).

---

4. Deviation from Beer-Lambert's law occurs due to:
A) High concentration of solute
B) Monochromatic radiation
C) Constant temperature
D) Dilute solution
✅**Answer:** A) High concentration of solute
Explanation: At high concentration, molecular interactions alter linearity.

☀️ UV-Visible Spectroscopy

5. In UV-Visible spectroscopy, transitions involve:
A) Rotational energy levels
B) Vibrational energy levels
C) Electronic energy levels
D) Nuclear energy levels
✅**Answer:** C) Electronic energy levels

---

6. π → π* transitions are observed in:
A) Alkanes
B) Alkenes
C) Alkynes
D) Alkanols
✅**Answer:** B) Alkenes
Explanation: π → π* transitions occur in compounds with C=C bonds.

---

7. Which component is used for wavelength selection in a UV-Vis spectrophotometer?
A) Detector
B) Grating or prism
C) Lamp

D) Sample holder
✅**Answer:** B) Grating or prism
Explanation: Monochromators (grating/prism) select specific wavelengths.

---

8. A common light source for UV spectroscopy is:
A) Tungsten lamp
B) Deuterium lamp
C) Sodium lamp
D) Mercury lamp
✅**Answer:** B) Deuterium lamp

⍰□ IR Spectroscopy

9. IR spectroscopy deals with transitions between:
A) Electronic energy levels
B) Vibrational energy levels
C) Nuclear spin levels
D) Translational energy levels
✅**Answer:** B) Vibrational energy levels

---

10. The stretching vibration involves:
A) Change in bond angle
B) Change in bond length
C) Both
D) None
✅**Answer:** B) Change in bond length

---

11. A molecule will show IR absorption only if:
A) It has a change in dipole moment
B) It has a change in mass
C) It has π electrons
D) It contains hydrogen
✅**Answer:** A) It has a change in dipole moment

---

12. The fundamental region in IR spectroscopy is:
A) 400–4000 cm^{-1}
B) 4000–10000 cm^{-1}
C) 40–400 cm^{-1}

D) 10000–40000 cm^{-1}
✅**Answer:** A) 400–4000 cm^{-1}

13. The IR spectrometer uses which radiation source?
A) Tungsten lamp
B) Nernst glower or Globar
C) Mercury vapor lamp
D) Sodium lamp
✅**Answer:** B) Nernst glower or Globar

⍰ Chromatography – Basic Principle

14. Chromatography is based on:
A) Difference in solubility
B) Difference in adsorption
C) Difference in partition
D) All of the above
✅**Answer:** D) All of the above
Explanation: Depending on the type—adsorption, partition, or ion exchange—different principles apply.

15. The stationary phase in paper chromatography is:
A) Paper itself
B) Water trapped in paper
C) Mobile solvent
D) Ink
✅**Answer:** B) Water trapped in paper

16. The term *Rf value* represents:
A) Ratio of distance moved by solute to solvent front
B) Distance moved by solvent
C) Ratio of solvent to solute concentrations
D) Retardation factor
✅**Answer:** A) Ratio of distance moved by solute to solvent front

17. In gas chromatography, the mobile phase is:
A) Gas
B) Liquid

C) Solid
D) Supercritical fluid
✅**Answer:** A) Gas

---

18. The main use of chromatography is:
A) Quantitative analysis
B) Qualitative analysis
C) Both
D) None
✅**Answer:** C) Both

---

19. In thin layer chromatography (TLC), the stationary phase is often:
A) Silica gel or alumina
B) Paper
C) Mercury
D) Glass beads
✅**Answer:** A) Silica gel or alumina

---

20. The main principle behind HPLC is:
A) Partition
B) Adsorption
C) Both A and B
D) Electrophoresis
✅**Answer:** C) Both A and B