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Atomic Structure

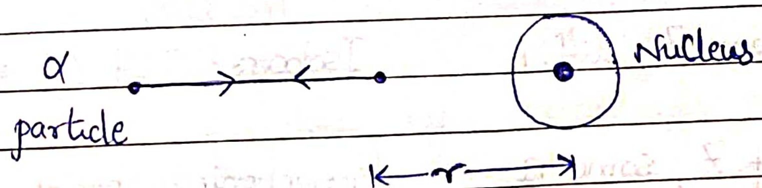
Cathode Rays : from cathode to anode. (−ve) charge. e/m ratio Const. Also called electrons.

Anode Rays : from anode to cathode. (+ve) charge. e/m ratio varies. Due to ionisation of gas.

Specific Charge : Charge per mass. q/m or e/m

	Electron (e^-)	Proton (p)	Neutron (n)
Mass	$9.1 \cdot 10^{-31}$ kg	$1.67 \cdot 10^{-27}$ kg	$1.67 \cdot 10^{-27}$ kg
Charge	$-1.6 \cdot 10^{-19}$ C	$+1.6 \cdot 10^{-19}$ C	0 C

Closest Approach (Rutherford's Experiment) –



At closest dist., intial K.E. of particle = P.E. at closest approach dist.

$\boxed{k = 9 \cdot 10^{9}\ Nm^2C^{-2}}$ ⇒ $$\boxed{\frac{1}{2}mv^2 = \frac{k(2e^-)(Ze^-)}{r}}$$

at. no. of elemet used

Some Imp. Terms –

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1) At. No. (Z) : No. of protons

2) Mass No. (A) : No. of protons + No. of neutrons

$$\boxed{n = A - Z}$$

n = # neutrons
Z = # protons
A = Mass No.

☆ $\boxed{\text{Atom represented by } {}^{A}_{Z}X.}$

Q) An ion with mass no. 37 posses 1unit of (–ve) charge. If ion contains 11.1% more neutron than electron, find ion.

A) We have $A = 37 \Rightarrow n+p = 37 \Rightarrow n+e = 38$

Now, $\left(\frac{n-e}{e}\right) = \left(\frac{11.1}{100}\right) = \left(\frac{1}{9}\right) \Rightarrow 9n = 10e$

$n + e = 38 \Rightarrow 10e + 9e = 342 \Rightarrow e = 18$
$\Rightarrow \boxed{p = 17}$

Ion : ${}^{37}_{17}Cl^{-}$

Isotopes : Same Z, diff. A

Isobars : Diff Z, same A.

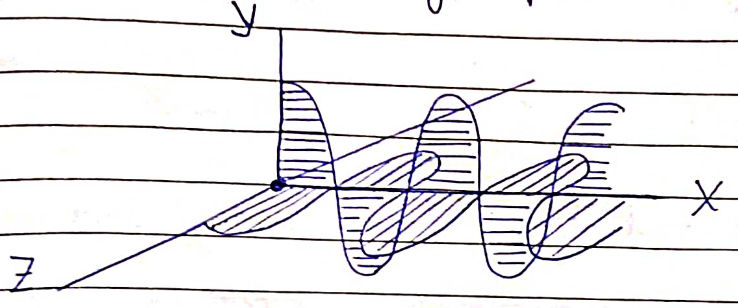
Isotones : Diff. Z, same n

Isoelectronic : Species with same # e^-

Isodiaphers : Diff. Z, same $|n-p|$ or $|A-2p|$

Isosters : Molecules of diff. comp. with same # e^-. & same # atoms

Maxwell's Theory of E.M. radiation –



Y – Electric , Z – Magnetic , X – Propagation

It is form of energy which contains electric & magnetic fields oscillating ⊥ to each other, and both ⊥ to dirxⁿ of propogation of radiation.

38)

Characteristics –

1) Rays are uncharged, carry no charge.

2) Can travel in vaccum, no medium req.

3) Speed independant of source, $= 3 \cdot 10^{8}\ ms^{-1}$ in vaccum.

4) Doesn't deviate by external electrical and magnetic field.

5) Every blackbody (perfect absorber or emitter) only emits radiations of only one wavelength.

#ē

(Later proved wrong)

(6) (Energy of Radiation) $\propto$ (Intensity of light used)

Failure –

1) Blackbody radiation (Proven wrong experimentally)
2) Photoelectric effect
3) Plank's Quantisation Theory

Electromagnetic Spectrum –

If E.M. rays are arranged in inc. order of their wavelength/freq. then a series of spectrum is formed, called E.M. spectrum.

10^{-16} m Cosmic Rays

γ – Rays

U.V. Rays

Visible Rays — V I B G Y O R (4000 Å – 7500 Å)

Infrared Rays

Microwaves

10^{6} m Radiowaves

(λ)

$\lambda \downarrow$

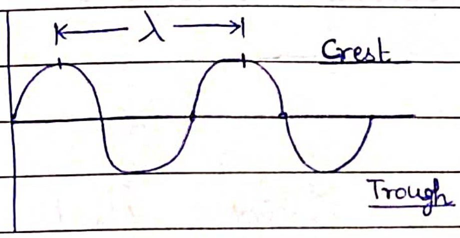
$\nu \uparrow$

Energy $\uparrow$

Characteristics of Wave –

Wave : Mode of energy transmission from one place to another, w/o disp. of matter.

1) **Wavelength (λ)** – Dist. b/w succesive crests or troughs.



1 Å = 10^{-10} m
1 nm = 10^{-9} m
1 pm = 10^{-12} m

2) **Frequency (ν)** – No. of waves passing thru a pt. in 1 s.

☆ $\boxed{\nu\lambda = c}$ Hertz (Hz) $\longleftrightarrow$ s^{-1}

3) **Velocity (c)** – Dist. travelled by wave in 1 s. Unit – ms^{-1}

4) **Wave No. ($\bar{\nu}$)** – No. of waves passing thru unit length.

☆ $\boxed{\bar{\nu} = \left(\frac{1}{\lambda}\right)}$ Unit – m^{-1}

5) Amplitude (A) – Max. height of crest or trough. Unit – m

6) Time Period (T) – Time req. for 1 wave cycle to complete.

☆ $\boxed{T = \left(\frac{1}{\nu}\right)}$

7) Angular ~~Vel~~ freq. (ω) – $\boxed{\omega = 2\pi\nu = \left(\frac{2\pi}{T}\right)}$

Plank's Theory

Any body can emit or absorb energy in discrete qty. (integral multiple of some smallest qty.)

Quantum/ Photon : Small packets/ bundles of energy, which are emitted or absorbed by a body.

Energy of photon directly proportional to freq. of radiation used.

(Energy of 1 photon) $\boxed{E = h\nu}$ — Plank's Constant

$\boxed{E = \left(\frac{hc}{\lambda}\right)}$

$\boxed{E = hc\bar{\nu}}$

☆ $\boxed{h = 6.626 \cdot 10^{-34}\ Js}$

☆ $\boxed{\hbar = h/2\pi}$

Since any body will emit energy in integral multiple of photon.

$$\boxed{E_{Total} = \underbrace{N}_{\text{no. of photons}} h\nu}$$

☆ $$\boxed{\underbrace{E \text{ (in eV)}}_{\text{Energy of 1 photon}} = \left(\frac{12400}{\lambda \text{ (in Å)}}\right)}$$ $$\boxed{1\,eV = 1.6 \cdot 10^{-19}\,J}$$

Q) A bulb emits light of wavelength 4500 Å. Bulb is rated as 150 W, and 8 % of energy is emitted as light. How many photons emitted by bulb per sec.

A) $E = Pt = \left(150\ \frac{J}{s}\right)(1\,s) \Rightarrow E = 150\,J$

$$\Rightarrow \quad E_{photons} = \left(\frac{150}{1.6 \cdot 10^{-19}}\right)\left(\frac{8}{100}\right) eV$$

Also, $E = Nh\nu \Rightarrow E(eV) = \left(\frac{12400}{\lambda\,(Å)}\right) N$

$$\Rightarrow \left(\frac{150}{1.6 \cdot 10^{-19}}\right)\left(\frac{8}{100}\right) = \left(\frac{12400}{4500}\right) N$$

$$\Rightarrow \quad \boxed{N \approx 2 \cdot 10^{19}}$$

Q) A photon of 300 nm wavelength is absorbed by a body which then re-emits $2e^-$. One re-emitted e^- has wavelength of 400 nm. Calc. energy of remitted e^- other

A) $E_{absorbed} = E_{released}$.

$$E_{absorbed} = \left(\frac{12400}{3000}\right) = 4.13\,eV$$

$$E_{released} = \left(\frac{12400}{4000}\right) + \left(\frac{12400}{10\lambda}\right) eV = 3.1\,eV + \frac{1240}{\lambda}$$

(in nm)

$$\Rightarrow \left(\frac{1240}{\lambda}\right) = 1.03 \Rightarrow \boxed{\lambda \approx 1200\text{ nm}}$$

$$E_{photon} = \left(\frac{12400}{10 \cdot 1200}\right) \Rightarrow \boxed{E_{photon} = 1.03\,eV}$$

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Photoelectric Effect —

Phenomeon of emission of e^- takes place when light of suitable freq. falls on metal surface.

☆ This explains particle nature of light. Only particles can transfer momentum. Hence, light acts like particle.

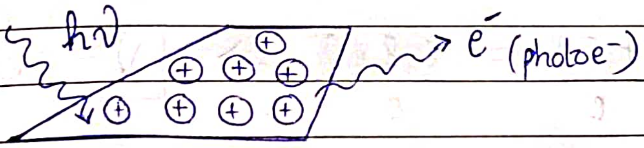
Conclusion :

1) e^- emit only if $\nu > \nu_0$ ← Threshold freq.

2) $\left(\begin{matrix}\text{K.E.}\\ \text{of photoelectron}\end{matrix}\right) \propto (\nu \text{ light used})$.

3) Intensity of light used independent of ν light used.

$$\boxed{(\text{K.E. of photoelectron}) = h\nu - \underbrace{h\nu_0}_{\left(\begin{matrix}\text{Work fx}^n / \text{Binding Energy}\\ \text{Ionisation/Critical Energy}\end{matrix}\right)}}$$

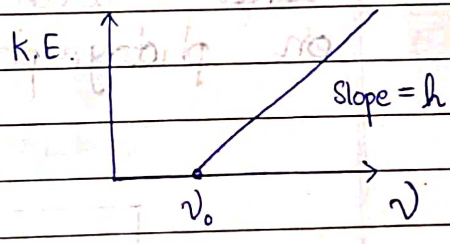


Alkali Metal

Threshold freq. : Min. freq. req. to observe this effect

☆ Threshold freq. & Energy depend on nature of metal.

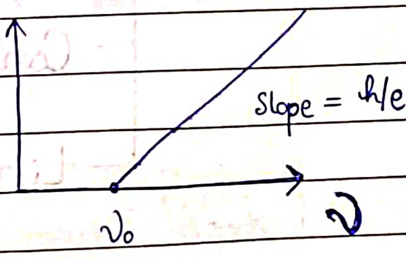
Stopping Potential : Potential ~~Energy~~ req. to stop photoe$^-$.



Stopping Energy : Energy req. to stop photoe$^-$.

Stopping Potential

$$\boxed{V = \frac{h\nu}{e^-} - \frac{h\nu_0}{e^-}}$$



Q) Calc. K.E. of photo e^- (in eV) emmitted by a sodium metal when light of wavelength 400 nm strikes on it. The work fx^n of sodium metal is 2.3 eV. Also calc. stopping potential.

A) $K.E. = h\nu - h\nu_0 = \left(\frac{12400}{4000}\right) - 2.3 \text{ eV}$

$\Rightarrow \boxed{K.E. = 0.8 \text{ eV}}$

Now, $V = \frac{(K.E.)}{e} = \frac{0.8 \text{ eV}}{e} \Rightarrow \boxed{V = 0.8 \text{ V}}$

Spectrum –

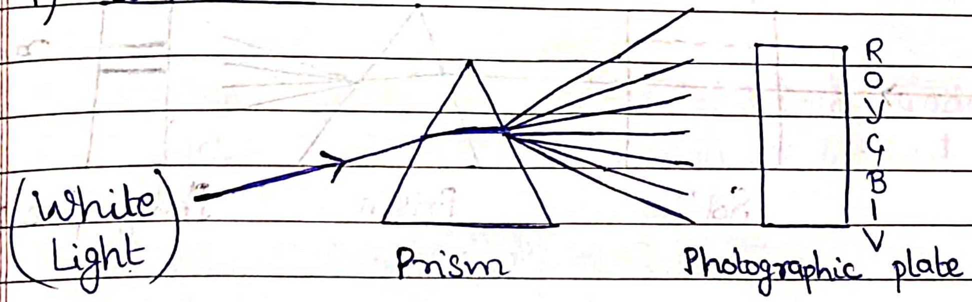
Series of radiations having diff. color bands with diff. wavelength obtained on photographic plate.

- Spectrum
  - Emission
    - Continuous
    - Line
  - Absorption

Emission Spectrum :

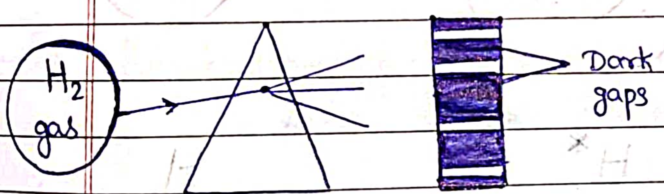
Spectrum obtained on photographic plate after passing radiation from glowing body through a prism.

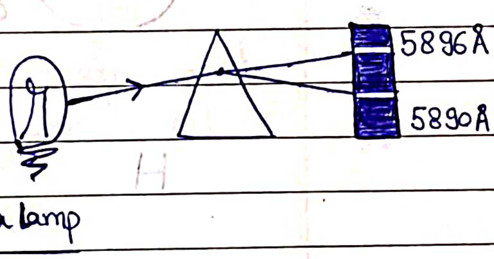
1) Continuous :



All color bands merge with each other.
No line of division b/w 2 colors ; no gaps.

2) Line : (Characteristic of atoms) (fingerprint of element)





When radiation produced by passing electric discharge thru H_2 gas at low pressure, it is passed thru prism and received on photographic plate.

The line spectrum consists of sharp well defined lines which contain dark gaps in b/w them.

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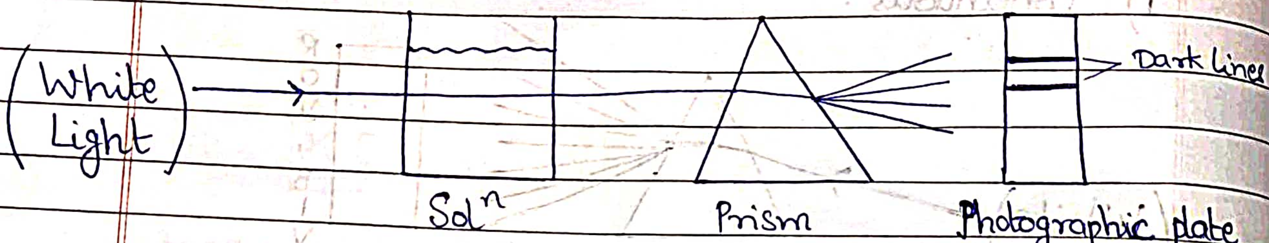
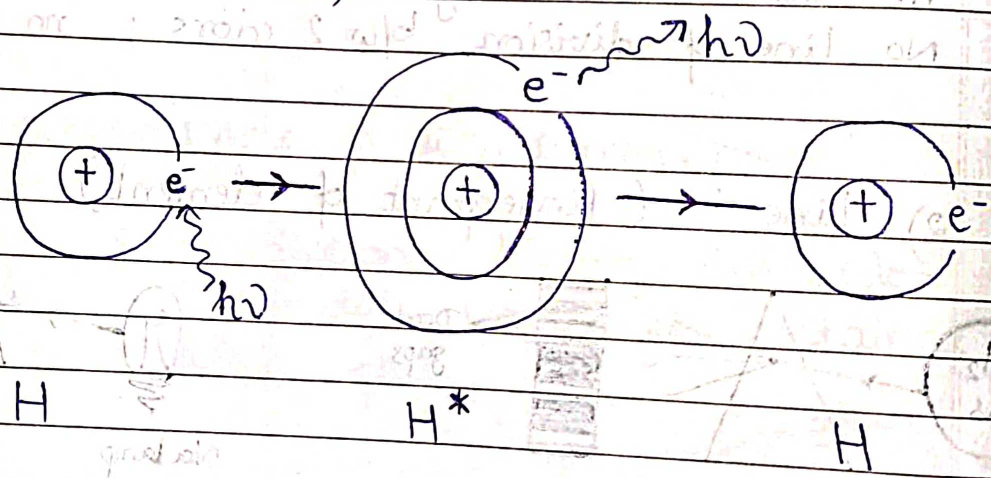
Absorption Spectrum :

White light from any source is first passed thru a sol^n, then analysed by spectroscope it is observed that some dark lines are obtained in otherwise continuous spectrum.



At atomic level,



GOOD WRITE

Bohr Model for Hydrogen like Species —

Hydrogen like Species = 1 e^- species.

Postulates :

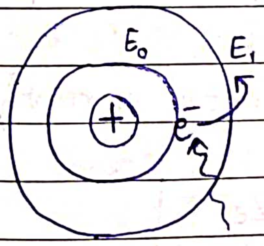
1) Atom consists nucleus, whose size is negligible compared to atom

2) e^- revolve in fixed orbits of fixed radius and fixed vel. and fixed energy, around nucleus.

3) (Practically) Angular Momentum of e^- in orbit is an integral multiple of $\left(\frac{h}{2\pi}\right)$.

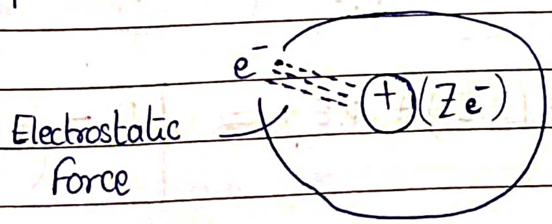
Eg : 1st orbit, $mvr = 1 \cdot h/2\pi$
2nd orbit, $mvr = 2 \cdot h/2\pi$
⋮
nth orbit, $\boxed{mvr = \frac{nh}{2\pi}}$

4) Excitation of e^- : e^- absorbs energy and jumps from lower orbit to higher orbit.



$$\boxed{\Delta E = h\nu = E_1 - E_0}$$

Application of Bohr Model —



Hydrogen like species.

Since, electrostatic force acts as centripetal force.

$$\left|\frac{Kq_1q_2}{r_{n,z}^2}\right| = \left|\frac{mv_{n,z}^2}{r_{n,z}}\right| \Rightarrow \frac{K(e)(Ze)}{r_{n,z}^2} = \frac{mv_{n,z}^2}{r_{n,z}}$$

$$\Rightarrow KZe^2 = mv_{n,z}^2 r_{n,z}$$

By Bohr's model, $mv_{n,z}r_{n,z} = \left(\frac{nh}{2\pi}\right)$

$$\Rightarrow \boxed{v_{n,z} = (Ke^2)\left(\frac{2\pi}{h}\right)\left(\frac{Z}{n}\right)} \text{ (Vel.)}$$

$$\Rightarrow \boxed{v_{n,z}(m/s) = (2.18 \cdot 10^6)\left(\frac{Z}{n}\right)}$$

$$\boxed{\underset{(\text{Å})}{r_{n,z}} = (0.529)\left(\frac{n^2}{Z}\right)}$$

$$\Rightarrow \boxed{r_{n,z} = \left(\frac{h^2}{4\pi^2 mKe^2}\right)\left(\frac{n^2}{Z}\right)} \text{ (Radius)}$$

Now, $T_{n,z} = \frac{2\pi r_{n,z}}{v_{n,z}} \propto \left(\frac{r_{n,z}}{v_{n,z}}\right) \propto \frac{(n^2/Z)}{(Z/n)}$

(Time Period) (Freq.)

$$\Rightarrow \boxed{T_{n,z} \propto \left(\frac{n^3}{Z^2}\right)} \Rightarrow \boxed{\nu_{n,z} \propto \left(\frac{Z^2}{n^3}\right)}$$

Now, $K.E. = \frac{1}{2}mv_{n,z}^2$ and $KZe^2 = mv_{n,z}^2 r_{n,z}$

$$\Rightarrow \boxed{K.E. = \left(\frac{KZe^2}{2r_{n,z}}\right)}$$

Now, $P.E. = \left(\frac{Kq_1q_2}{r}\right) = \frac{K(-e)(Ze)}{r_{n,z}} \Rightarrow \boxed{P.E. = \left(\frac{-KZe^2}{r_{n,z}}\right)}$

Now, (Total Energy) = (K.E.) + (P.E.) $\Rightarrow \boxed{E = \left(\frac{-KZe^2}{r_{n,z}}\right)}$

$$\boxed{E = (-K.E.) = \left(\frac{P.E.}{2}\right)}$$

$$\boxed{E_{n,z} = (-2.18 \cdot 10^{-18})(Z/n)^2 \text{ (J/atom)}}$$

$$\Rightarrow \boxed{E_{n,z} = \left(\frac{-K^2 e^4 m}{h^2}\right)(2\pi^2)\left(\frac{Z^2}{n^2}\right)}$$

$$\boxed{E_{n,z} = \left(\frac{-m}{2}\right)\left(\frac{Ke^2}{\hbar}\right)^2\left(\frac{Z}{n}\right)^2}$$

$$\Rightarrow \boxed{E_{n,z}(\text{eV/atom}) = (-13.6)\left(\frac{Z^2}{n^2}\right)}$$

$$\boxed{v_{n,z} = \left(\frac{Ke^2}{\hbar}\right)\left(\frac{Z}{n}\right)}$$

$$\Rightarrow \boxed{E_{n,z}(\text{kJ/mol}) = (-1312)\left(\frac{Z^2}{n^2}\right)}$$

$$\boxed{r_{n,z} = \left(\frac{(\hbar)^2}{mKe^2}\right)\left(\frac{n^2}{Z}\right)}$$

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For H atom,

Orbit	Radius (Å)	Velocity (ms^{-1})	Total Energy (eV)	K.E (eV)	P.E. (eV)
1st	0.529	$2.18 \cdot 10^6$	−13.6	13.6	−27.2
2nd	$(0.529)(2^2)$	$(2.18 \cdot 10^6)/2$	$(-13.6)/2^2$	$(13.6)/2^2$	$(-27.2)/2^2$
3rd	$(0.529)(3^2)$	$(2.18 \cdot 10^6)/3$	$(-13.6)/3^2$	$(13.6)/3^2$	$(-27.2)/3^2$
4th	$(0.529)(4^2)$	$(2.18 \cdot 10^6)/4$	$(-13.6)/4^2$	$(13.6)/4^2$	$(-27.2)/4^2$

For H atom,

Orbit	1	2	3	4
Total Energy (eV)	−13.6	−3.4	−1.51	−0.85

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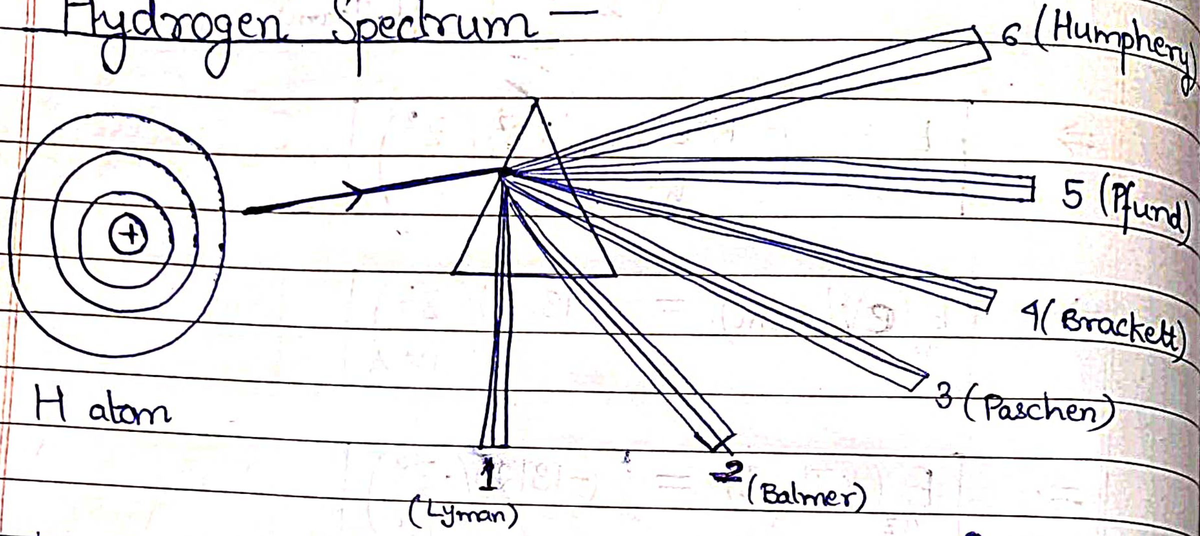
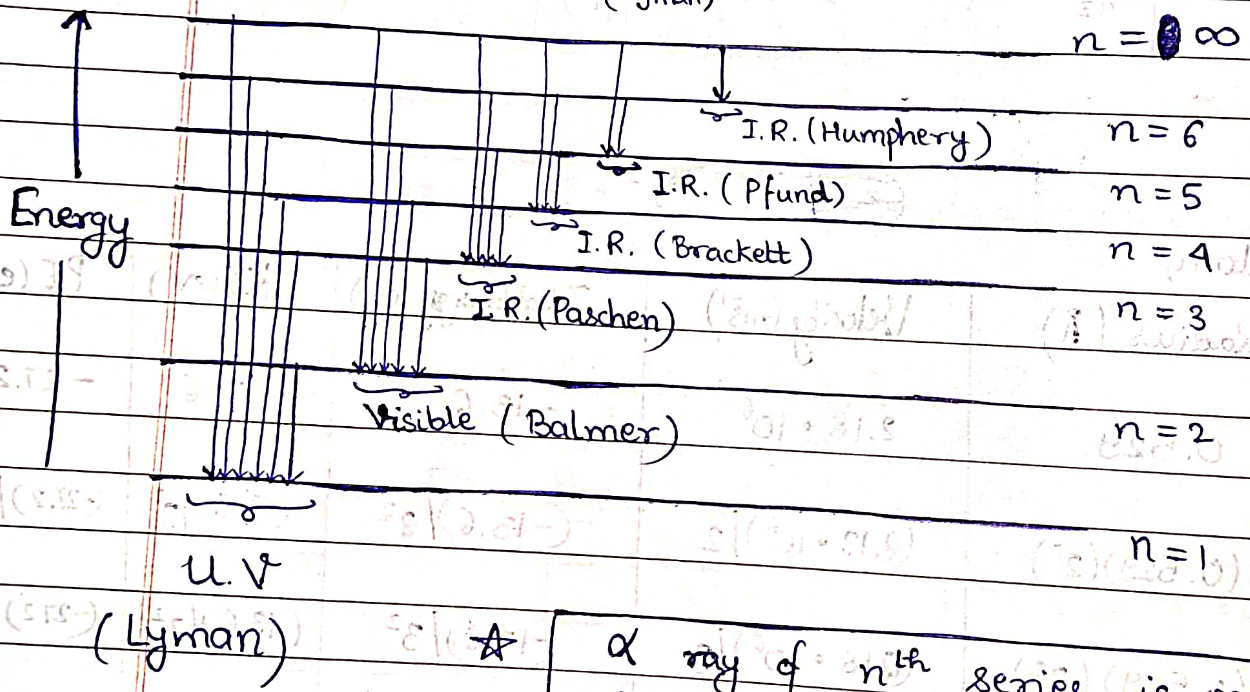
Hydrogen Spectrum —





☆ $\boxed{\text{$\alpha$ ray of n^{th} series is radiation when e^- transition from $(n+1)$ orbit to (n) orbit.}}$

✓ nth Series : e^- falls from ANY orbit (in ANY atom) to nth orbit
Rays obtained form nth series.

☆ $\boxed{\text{Limiting line of nth series is ray when e^- transit from ∞ orbit to n orbit}}$

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For H,

Series	Region	Lowest Energy Level	Highest Energy Level
Lyman	U.V.	$n=1$	$n=2,3,\ldots$
Balmer	Visible	$n=2$	$n=3,4,\ldots$
Paschen	I.R.	$n=3$	$n=4,5,\ldots$
Brackett	I.R.	$n=4$	$n=5,6,\ldots$
Pfund	I.R.	$n=5$	$n=6,7,\ldots$
Humphery	I.R.	$n=6$	$n=7,8,\ldots$

✓ Energy released/absorbed in transition.

$$\Delta E = (13.6)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] Z^2$$

$$\Rightarrow \boxed{\left(\frac{1}{\lambda}\right) = (R_H)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] Z^2}$$ (when e^- transit from n_1 to n_2)

(Rydberg Const.) $R_H = 1.1 \cdot 10^7\ m^{-1}$

✓ Max. no. of spectral lines (if ∞ atoms) $\left[{}^{n_2-n_1+1}C_2\right]$

$$\boxed{\left(\begin{matrix}\text{Max. no. of}\\ \text{spectral lines}\end{matrix}\right) = \frac{(n_2-n_1+1)(n_2-n_1)}{2}}$$

Q) Calc. the min. & max. λ for Balmer Series

A) For Balmer series, $n_2 = 2$

For λ_{min}, $E_{max.}$ $\Rightarrow$ $\left(\frac{1}{\lambda_{min}}\right) = (R_H)\left(\frac{1}{\infty^2} - \frac{1}{2^2}\right)$

$\Rightarrow$ $|\lambda_{min}| = \left(\frac{4}{R_H}\right)$ ($\lambda < 0 \Rightarrow$ Energy released)

For λ_{max}, E_{min} $\Rightarrow$ $\left(\frac{1}{\lambda_{max}}\right) = (R_H)\left(\frac{1}{3^2} - \frac{1}{2^2}\right)$

$\Rightarrow$ $|\lambda_{max}| = \left(\frac{36}{5R_H}\right)$ ($\lambda < 0 \Rightarrow$ Energy released)

Q) The energy of H in excited state is -0.85eV. What will be energy of photon emitted, when e^- returns to ground state.

A) $E_{photon} = E_{i,1} - E_{n,1} = (-13.6) - (0.85)$

$\Rightarrow$ $|E_{photon}| = 12.75$ eV ($E<0 \Rightarrow$ Energy released)

Q) What transition in H spectrum would have same wavelength as Balmer transition from $n=4$ to $n=2$ of He^{+} spectrum

A) $(R_H)\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)(1^2) = (R_H)\left(\frac{1}{4^2} - \frac{1}{2^2}\right)(2^2)$

$\Rightarrow (1/n_1)^2 - (1/n_2)^2 = (-3/4) \Rightarrow (2/n_2)^2 - (2/n_1)^2 = 3$

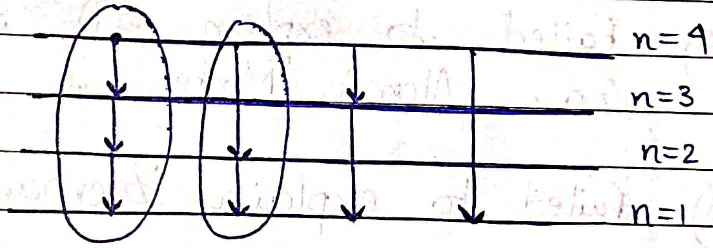
$\Rightarrow (2/n_2) = 2$ & $(2/n_1) = 1 \Rightarrow n_2 = 1, \; n_1 = 2$

Transition : $n=2$ to $n=1$

Q) Two hydrogen atoms present in 3rd excited state, find max. no. of possible emission lines.

A) For max. emission lines, e^- returns to ground state.

In atoms,



For max. no. of lines, 1st atom : 3 transitions
2nd atom 2 transitions.

$\Rightarrow$ $\boxed{\text{(Distinct) Max. no. of lines} = 4}$

Q) For a hypothetical atom, potential energy $U = \left(\frac{-Ke^2}{r^3}\right)$, where r is dist. b/w particles. If Bohr's model of quantisation applies, find velocity of particle.

A) $U(r) = \left(\frac{-Ke^2}{r^3}\right) \Rightarrow \left(-\frac{dU(r)}{dr}\right) = F = \left(\frac{-3Ke^2}{r^4}\right)$

Since circular motion, $\left(\frac{mv^2}{r}\right) = \left(\frac{3Ke^2}{r^4}\right)$

We know, $mvr = n\hbar$ (Bohr's quantisation model)

$$\Rightarrow \frac{(mv^2)}{(n\hbar/mv)} = \frac{(3Ke^2)}{(n\hbar/mv)^4} \Rightarrow \boxed{v = \left(\frac{n^3h^3}{24Ke^2\pi^3m^2}\right)}$$

Drawbacks of Bohr's Atomic Model -

1) Only valid for H & H-like species. It can't explain spectra of multi e^- system.

2) Failed to explain 3D structure of atom. Bohr's Atomic Model is a Planar Model.

3) Failed to explain Zeeman & Stark Effect.

Zeeman Effect: Splitting of spectral lines in magnetic field.

Stark Effect: Splitting of spectral lines in electric field.

4) Failed to account for
   - Heisenberg's Uncertainity Principle
   - De-Broglie Concept
   - Dual nature of matter

5) Could only explain particle nature of e^-.

6) Could NOT explain size, shape & properties of molecules.

De-Broglie Concept –

For electromagnetic radiation acc. to Plank's Theory,

$$E = h\nu \Rightarrow \boxed{E = \frac{hc}{\lambda}} \quad — (1)$$

$\nu, \lambda \longrightarrow$ Wave Nature

Acc. to Einstein's theory of Relativity,

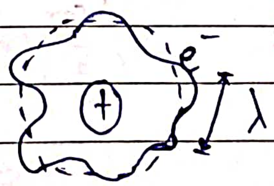
$$\boxed{E = mc^2} \quad — (2)$$

$$(1) = (2) \Rightarrow \frac{hc}{\lambda} = mc^2 \Rightarrow \lambda = \left(\frac{h}{mc}\right) \Rightarrow \overbrace{\boxed{\lambda = \frac{h}{p}}}^{\text{Wavelength}}$$

Rel^n b/w λ & p $\Rightarrow$ Dual nature of light.

Acc. to Einstein the eq^n of De Broglie wavelength applies to all.

Eg : If e^- wave $\Rightarrow$



$n\lambda = 2\pi r$ (if n waves)

$$\Rightarrow n\left(\frac{h}{p}\right) = 2\pi r \Rightarrow \left(\frac{nh}{mv}\right) = (2\pi r)$$

$$\Rightarrow \boxed{mvr = \left(\frac{nh}{2\pi}\right)}$$

☆ In nth orbit, e^- makes n waves.
$\Rightarrow \boxed{2\pi r = n\lambda}$

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E.M. Wave	Matter Wave
Associated with Electric & Magnetic field.	NOT associated with Electric & Magnetic field.
Vel. = c (in Vaccum)	Vel. < c
$\boxed{\lambda = \left(\frac{c}{\nu}\right)}$	$\boxed{\lambda = \left(\frac{h}{mv}\right)}$ De-Broglie wavelength.

Significance of De-Broglie Eq^n :

1. Altough it is valid for whole material particle, it is sig. fig. for microscopic bodie

Eg : λ_{car} for 4000 kg car moving at 20 ms^{-1} is $\approx 10^{-38}$ m, which is negligble.

Imp. Rel^{n}s :

$$\boxed{\lambda = \frac{h}{\sqrt{2m(K.E.)}}}$$

$$\boxed{\lambda = \frac{h}{\sqrt{2mqV}}}$$

V : potential diff.

☆ For e^-, (Starting from rest) $\boxed{\lambda(\text{Å}) = \sqrt{\frac{150}{V}}}$

Q) For a Hydrogen like species, if De-Broglie wavelength in nth orbit is $\lambda_{n,Z}$.
If $\lambda_{n+1,Z} + \lambda_{n-1,Z} = 3\lambda_0$, then find n and species.
(λ_0 = De-Broglie wavelength of H atom in ground state)

A) $\lambda_{n,Z} \propto \left(\frac{1}{V_{n,Z}}\right) \propto \left(\frac{n}{Z}\right) \Rightarrow \left(\frac{n+1}{Z}\right) + \left(\frac{n-1}{Z}\right) = 3\left(\frac{1}{1}\right)$

$\Rightarrow 2n/Z = 3 \Rightarrow Z/n = 2/3 \Rightarrow Z = 2, n = 3$

Species: He^{2+}

Q) Narendra Avasthi, At. Strctr, L-2, Q-29.

A) $\lambda = \left(\frac{h}{mv}\right) = \left(\frac{h}{m}\right)\left(\frac{\hbar}{Ke^2}\right)\left(\frac{n}{Z}\right) \Rightarrow \lambda = (2\pi)\left(\frac{n}{Z}\right)\left(\frac{\hbar^2}{mKe^2}\right)$

We are given, $3.4 = (13.6)\left(\frac{Z}{n}\right)^2 \Rightarrow n/Z = 2$

$\Rightarrow \lambda = (2\pi)(2)(0.529\ \text{Å}) \Rightarrow \boxed{\lambda \approx 6.66\ \text{Å}}$

Heisenberg Uncertainity Principle –

It is impossible to simultaneously measure exact posⁿ. and exact momentum of a particle.

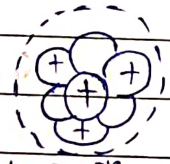
$$\boxed{(\Delta x)(\Delta p) \geqslant \left(\frac{h}{4\pi}\right)}$$

Δx = Uncertainity in Posⁿ.
Δp = Uncertainity in Momentum.

Applications :

1) Proves that e^- doesn't exist in nucleus of atom.

Proof: If e^- in nucleus $\Rightarrow$ $\Delta x \approx 2 \cdot 10^{-14}$ m



$\leftarrow 2 \cdot 10^{-14} \rightarrow$

$$(\Delta x)(\Delta p) \geqslant \left(\frac{h}{4\pi}\right)$$

$$\Rightarrow \Delta v \geqslant \frac{6.6 \cdot 10^{-34}}{(4\pi) \cdot (2 \cdot 10^{-14}) \cdot (9.1 \cdot 10^{-31})}$$

$$\Rightarrow \Delta v \geqslant 3 \cdot 10^{9} \text{ ms}^{-1}$$

Since error has to be < c.

Hence, contradiction $\Rightarrow$ e^- outside nucleus.

2) Proves that $(\Delta E)(\Delta t) \geq h/4\pi$

Proof: $(\Delta x)(\Delta p) \geq \frac{h}{4\pi} \Rightarrow \underbrace{(\Delta x)\left(\frac{\Delta p}{\Delta t}\right)}_{\text{Work/Energy}}(\Delta t) \geq h/4\pi$

$\Rightarrow \boxed{(\Delta E)(\Delta t) \geq \left(\frac{h}{4\pi}\right)}$

3) Proves that $(\Delta x)(\Delta \lambda) \geq \lambda^2/4\pi$

Proof: $\lambda = \left(\frac{h}{p}\right) \Rightarrow \Delta\lambda = \left|-\frac{h}{p^2}(\Delta p)\right|$

(we only care about magnitude)

$\Rightarrow (\Delta\lambda) = \left(\frac{h}{p^2}\right)(\Delta p)$

$\Rightarrow (\Delta x)(\Delta\lambda) = \left(\frac{1}{h}\right)\left(\frac{h}{p}\right)^2(\Delta x)(\Delta p) = \left(\frac{\lambda^2}{h}\right)(\Delta x)(\Delta p) \geq \left(\frac{\lambda^2}{4\pi}\right)$

$\Rightarrow \boxed{(\Delta x)(\Delta\lambda) \geq \lambda^2/4\pi}$

4) Proves that $(\Delta KE)(\Delta x) \geq \left(\frac{hv}{4\pi}\right)$

Proof: $K.E. = \left(\frac{p^2}{2m}\right) \Rightarrow (\Delta KE) = \left(\frac{2p\,\Delta p}{2m}\right) = (\underline{v})(\Delta p)$

$(\Delta KE)(\Delta x) = v(\Delta x)(\Delta p) \Rightarrow \boxed{(\Delta KE)(\Delta x) \geq \left(\frac{hv}{4\pi}\right)}$

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Wave Mechanical Model –

This model explains stability of atom by considering Heisenberg's Uncertainity Principle & De Broglie Concept.

Schrodinger Time Independent Wave Eqn

Derivation –

ψ – Amplitude of e^- wave (NOT a physical thing)

$$\left(\frac{\partial^2 \psi}{\partial x^2}\right) = \left(\frac{1}{v^2}\right)\left(\frac{\partial^2 \psi}{\partial t^2}\right)$$

ω – Angular Freq.

In 3D form,

$$\left(\frac{\partial^2 \psi}{\partial x^2}\right) + \left(\frac{\partial^2 \psi}{\partial y^2}\right) + \left(\frac{\partial^2 \psi}{\partial z^2}\right) = \left(\frac{1}{v^2}\right)\left(\frac{\partial^2 \psi}{\partial t^2}\right)$$

$$\Rightarrow \boxed{\nabla^2 \psi = \left(\frac{1}{v^2}\right)\left(\frac{\partial^2 \psi}{\partial t^2}\right)}$$

Laplacion

Now, $\psi = \psi_0 e^{-i\omega t}$ (Soln of Wave)

$$\Rightarrow \left(\frac{\partial^2 \psi}{\partial t^2}\right) = (-\omega^2)(\psi_0 e^{-i\omega t})$$

$$\Rightarrow \boxed{\left(\frac{\partial^2 \psi}{\partial t^2}\right) = (-\omega^2)\psi}$$

Now, $\omega = 2\pi\nu = \left(\frac{2\pi v}{\lambda}\right) \Rightarrow \boxed{\omega = \left(\frac{2\pi v}{h}\right) p}$

$\{\lambda = h/p\}$

Substituting,

$$\boxed{\left(\frac{\partial^2 \psi}{\partial t^2}\right)} = -\left(\frac{2\pi v}{h} p\right)^2 \psi = \boxed{(-\psi)\left(\frac{v \cdot mv}{h}\right)^2}$$

Substituting,

$$\boxed{\nabla^2 \psi} = \left(\frac{1}{v^2}\right)(-\psi)\left(\frac{v \cdot mv}{h}\right)^2 = \boxed{(-\psi)\left(\frac{m^2 v^2}{h^2}\right)}$$

Now, Total Energy = K.E. + P.E.

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

$$\Rightarrow \quad E = \left(\frac{m^2 v^2}{2m}\right) + V \Rightarrow \boxed{m^2 v^2 = (2m)(E-V)}$$

Substituting, $\nabla^2 \psi = (-\psi)\left(\frac{2m(E-V)}{h^2}\right)$

$$\Rightarrow \boxed{\left(\frac{\partial^2 \psi}{\partial x^2}\right) + \left(\frac{\partial^2 \psi}{\partial y^2}\right) + \left(\frac{\partial^2 \psi}{\partial z^2}\right) + \frac{2m(E-V)\psi}{h^2} = 0}$$

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

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Schrodinger Time Dependent Wave Eq^n

Derivation -

- $\psi = \psi_0 e^{i\omega t} \Rightarrow \left(\frac{\partial \psi}{\partial t}\right) = (-i\omega)\psi_0 e^{-i\omega t}$

$$\Rightarrow \boxed{\left(\frac{\partial \psi}{\partial t}\right) = (-i\omega)\psi}$$

Now, $E = h\nu = \frac{h\omega}{2\pi} \Rightarrow \boxed{\omega = \left(\frac{E}{\hbar}\right)}$

Substituting, $\left(\frac{\partial \psi}{\partial t}\right) = (-i)\left(\frac{E}{\hbar}\right)\psi$

$$\Rightarrow \boxed{E\psi = \hbar i\left(\frac{\partial \psi}{\partial t}\right)}$$

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

$$\Rightarrow E\psi = V\psi - \left(\frac{\hbar^2}{2m}\right)\nabla^2\psi$$

$$\Rightarrow \boxed{\hbar i\left(\frac{\partial \psi}{\partial t}\right) = V\psi - \left(\frac{\hbar^2}{2m}\right)(\nabla^2\psi)}$$

$$\Rightarrow \boxed{E\psi = \hat{H}\psi} \qquad \left(\hat{H} = V - \left(\frac{\hbar^2}{2m}\right)\nabla^2\right)$$

Hamilton's Eq^n

Hamiltonian Operator

(ψ has no physical significance as it is a complex no.)

In 1927, Schrodinger described behaviour of e^- using his wave eq^{n}s.

The term ψ^2 (sq. of magnitude of ψ) has physical significance. It gives Probability Density of finding an e^- per unit volume.

Orbital – Space where probability of finding e^- is max. (> 90%)

(Acc. to Bohr) Orbit / Shell	Orbital (acc. to Schrodinger)
Circular region in which e^- revolves.	Space where probab. of finding e^- max. (>90%)
Shape is circular	Shapes are complex.
Max. no. of $e^- = 2n^2$	Max. no. of $e^- = 2$
Doesn't account for De Broglie Concept & Uncertainity Principle.	Accounts for De Broglie Concept & Uncertainity Principle.

By solving Schrodinger Wave eq^n we get 3 Quantum Nos. l, m, n.

[Bohr's Orbit = Shell in Wave Mech Model]

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Quantum Nos.

(I) 4 qtys. which give complete info. of an e^- present in an atom.

It gives, info. like Post., Energy, Angular Momentum, etc

1) Principal (n) – Info. about shell of an e^- & Energy associated with it.

Eg:

n	1	2	3
Shell	K	L	M

2) Azimuthal (l) – Info. about subshell and Orbital Angular Momentum.

$$\boxed{0 \leq l \leq n-1}$$

Eg: $n=1$, $l=0$ 1s subshell
$n=2$, $l=0$ 2s subshell
$l=1$ 2p subshell
$n=3$, $l=0$ 3s subshell
$l=1$ 3p subshell
$l=2$ 3d subshell

☆ $$\boxed{\begin{pmatrix}\text{Orbital Angular} \\ \text{Momentum}\end{pmatrix} = \left(\frac{h}{2\pi}\right)\sqrt{l(l+1)}}$$

3) Magnetic (m) — Info. about orbital
(Subsidary Qntm. No.)

$$\boxed{-l \leq m \leq l}$$

n	l	m	(Orbital) ~~Subshell~~
1	0	0	1s
2	0	0	2s
2	1	-1	$2p_x$
2	1	0	$2p_z$
2	1	1	$2p_y$

☆ For $m = \{-1, 0, -1\}$

p_x / p_y p_z

For $m = \{-2, 2, -1, 1, 0\}$

$d_{x^2-y^2} / d_{xy}$ d_{yz} / d_{xz} d_{z^2}

☆ No. of orbitals in 'n' shell $= n^2$

No. of orbitals in 'l' subshell $= 2l+1$

No. of subshell in 'n' shell $= n$

4) Spin (s) - Info. about orientation of e^-

Acc. to this, $2e^-$ in an orbital always spin in opp. dirx^n.

Sign Convention : e^- (anticlockwise) $\Rightarrow +1/2$

e^- (clockwise) $\Rightarrow -1/2$

- $\boxed{S = \left(\frac{n}{2}\right)}$ n = no. of unpair e^-
- S (Spin Multiplicity) $= 2\left(\frac{n}{2}\right)+1$ n = no. of unpaired e^-
- $\boxed{(\text{Spin magnetic Moment}) = \sqrt{4S(S+1)}\ \text{B.M.}}$ B.M. = Bohr magneton
- $\boxed{1\ \text{BM} = \left(\frac{eh}{4\pi m}\right) = 9.27 \cdot 10^{-24}}$
- $\boxed{(\text{Magnetic Moment}) = \sqrt{n(n+2)}\ \text{B.M.}}$

☆

for any shell (n)	# Subshell	# Orbitals	# e^-s
n	n	n^2	$2n^2$

for any subshell	# Orbitals	# e^-s
l	$(2l+1)$	$2(2l+1)$

Q) Find no. of e^- in —

i) $n = 5$ ii) $n = 4,\ l = 2$ iii) $n = 6,\ l = 4,\ m = 2$

iv) $n = 3,\ l = 0,\ m = 0,\ s = -1/2$

A) i) $\# e^- = 2n^2 = 50$

ii) $\# e^- = 2(2l+1) = 10$

iii) $\# e^- = 2$

iv) $\# e^- = 1$

Q) Find no. of e^- in —

i) $n = 5,\ m = 1$ ii) $n = 3,\ |m| = 1$

iii) $n = 4,\ s = 1/2$ iv) $n = 3,\ |m| = 1,\ s = -1/2$

A) i) $l = \{0, 1, 2, 3, 4\}$; $m \in [-l, l]$

$l = 1$, $m = \{-1, 0, 1\}$ $\Rightarrow$ $\# e^- = 2$

$l = 2$, $m = \{-2, -1, 0, 1, 2\}$ $\Rightarrow$ $\# e^- = 2$

⋮

$l = 4$, $m = \{-4, \ldots, 1, \ldots, 4\}$ $\Rightarrow$ $\# e^- = 2$

$\Rightarrow$ $\boxed{\text{Total } \# e^- = 8}$

ii) $l = \{0, 1, 2\}$; $m \in [-l, l]$

$l = 1$, $m = \{-1, 0, 1\} \Rightarrow \# e^- = 4$
$l = 2$, $m = \{-2, -1, 0, 1, 2\} \Rightarrow \# e^- = 4$

$\Rightarrow$ $\boxed{\text{Total no. } e^- = 8}$

iii) Half e^- have $s = +1/2$ & the others have $s = -1/2$

$\Rightarrow \# e^- = \left(\frac{2 \cdot 4^2}{2}\right) \Rightarrow \boxed{\# e^- = 16}$

iv) $l = \{0, 1, 2\}$; $m \in [-l, l]$

$l = 1$, $m = \{-1, 0, 1\} \Rightarrow \# e^- = 2$
$l = 2$, $m = \{-2, -1, 0, 1, 2\} \Rightarrow \# e^- = 2$

$\Rightarrow$ $\boxed{\text{Total no. of } e^- = 4}$

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Electronic Configuration

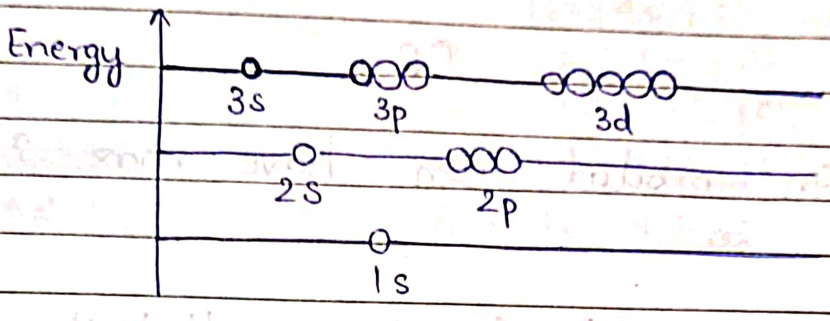
1) Aufbau's Principle –

e^- fill in subshell in inc. order of energy.

[Orbitals with same Energy ⇒ Degenerate]

C-1 : for H like atoms ($1e^-$ system),

Energy depends only on 'n'.



C-2 : for multi e^- system,

Energy depends ~~only~~ on '$n+l$'.
If '$n+l$' same, then $n\uparrow \Rightarrow$ Energy $\uparrow$

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d

(1+0) (2+0) (2+1) (3+0) (3+1) (4+0) (3+2) (4+1) (5+0)
1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s

[School School Public School Public School Delhi Public School
Delhi Public School Free Delhi Public School Free Delhi Public]

[1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p]

2) Pauli's Exclusion Principle -

No 2 e^- can have all 4 quantum same nos

OR

An orbital can have max. 2 e^-s with opp. spin

3) Hund's Rule of Max. multiplicity -

e^- don't pair until all degenerate orbitals are half filled with e^- with // spin.

Eg: 2p $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ ✓ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\downarrow}$ X

Electronic Config. of Elements upto Z=30

H = $1s^1$

He = $1s^2$

Li = [He] $2s^1$

Be = [He] $2s^2$

B = [He] $2s^2 2p^1$

C = [He] $2s^2 2p^2$

N = [He] $2s^2 2p^3$

O = [He] $2s^2 2p^4$

F = [He] $2s^2 2p^5$

Ne = [He] $2s^2 2p^6$

Na = [Ne] $3s^1$

Mg = [Ne] $3s^2$

Al = [Ne] $3s^2 3p^1$

Si = [Ne] $3s^2 3p^2$

$P = [Ne]\ 3s^2\ 3p^3$

$S = [Ne]\ 3s^2\ 3p^4$

$Cl = [Ne]\ 3s^2\ 3p^5$

$Ar = [Ne]\ 3s^2\ 3p^6$

$K = [Ar]\ 4s^1$

$Ca = [Ar]\ 4s^2$

$Sc = [Ar]\ 4s^2\ 3d^1$

$Ti = [Ar]\ 4s^2\ 3d^2$

$V = [Ar]\ 4s^2\ 3d^3$

☆ $Cr = [Ar]\ 4s^1\ 3d^5$

$Mn = [Ar]\ 4s^2\ 3d^5$

$Fe = [Ar]\ 4s^2\ 3d^6$

$Co = [Ar]\ 4s^2\ 3d^7$

$Ni = [Ar]\ 4s^2\ 3d^8$

☆ $Cu = [Ar]\ 4s^1\ 3d^{10}$

$Zn = [Ar]\ 4s^2\ 3d^{10}$

☆ Exceptional E.C. —

$Cr = [Ar]\ 4s^1\ 3d^5$

$Cu = [Ar]\ 4s^1\ 3d^{10}$

$Nb = [Kr]\ 5s^1\ 4d^4$

$Mo = [Kr]\ 5s^1\ 4d^5$

$Ru = [Kr]\ 5s^1\ 4d^7$

$Rh = [Kr]\ 5s^1\ 4d^8$

$Pd = [Kr]\ 4d^{10}$

$Ag = [Kr]\ 5s^1\ 4d^{10}$

$La = [Xe]\ 6s^2\ 5d^1$

$Pt = [Xe]\ 6s^1\ 5d^9$

$Au = [Xe]\ 6s^1\ 5d^{10}$

$Ac = \cancel{[Xe]}\ [Rn]\ 7s^2\ 6d^1$

$Th = [Rn]\ 7s^2\ 5f^0\ 6d^2$

$Ce = [Xe]\ 6s^2\ 4f^1\ 5d^1$

$Gd = [Xe]\ 6s^2\ 4f^7\ 5d^1$

Reason for exceptional E.C. of Cr & Cu

Cr : [Ar] $4s^2\ 3d^4$ (Expectation) [Ar] $4s^1\ 3d^5$ (Reality)

Cu : [Ar] $4s^2\ 3d^9$ (Expectation) [Ar] $4s^1\ 3d^{10}$ (Reality)

---

1) Symmetric E.C. —

Eg :

4s	3d	3d	3d	3d	3d	
↑↓	↑	↑	↑	↑		NOT symmetric
↑	↑	↑	↑	↑	↑	Symmetric

---

2) Exchange Energy —

is

Energy released when e^- in degenerate orbitals try to pair up/exchange. Pairing/exchange of e^- releases energy.

Eg :

A	B	C	D	E
↑	↑	↑	↑	

A can go in B, C, D
B can go in C, D
C can go in D

\# Exchanges = 6 <

A	B	C	D	E
↑	↑	↑	↑	↑

A can go in B, C, D, E
B can go in C, D, E
C can go in D, E
D can go in E

\# Exchanges = 10

$\begin{pmatrix}\text{No. of} \\ \text{Exchanges}\end{pmatrix} = {}^{n}C_2 + {}^{m}C_2$; n = no of $\uparrow e^-$ in degenerate orbitals, m = no. of $\downarrow e^-$ in degenerate orbitals

Q) Write E.C of the following species –

i) Fe^{2+} ii) Fe^{3+} iii) Cr^{3+}

iv) Cu^{2+} v) Zn^{2+} vi) H^-

A) i) $Fe = [Ar]\, 4s^2\, 3d^6$

$Fe^{2+} = [Ar]\, 3d^6$ ✓ $Fe^{2+} = [Ar]\, 4s^2\, 3d^4$ ✗

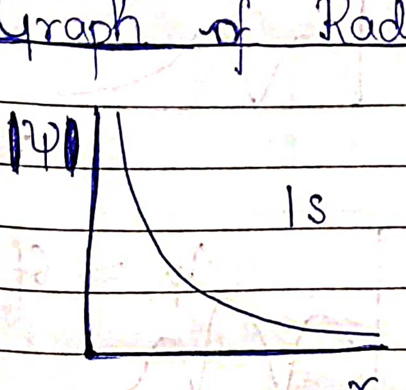
☆ e^- ALWAYS removed from last shell (largest n). If shell same, the e^- remove from largest energy subshell.

ii) $Fe = [Ar]\, 4s^2\, 3d^6 \Rightarrow Fe^{3+} = [Ar]\, 3d^5$

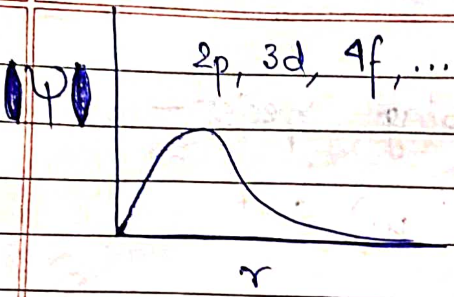
iii) $Cr = [Ar]\, 4s^1\, 3d^5 \Rightarrow Cr^{3+} = [Ar]\, 3d^3$

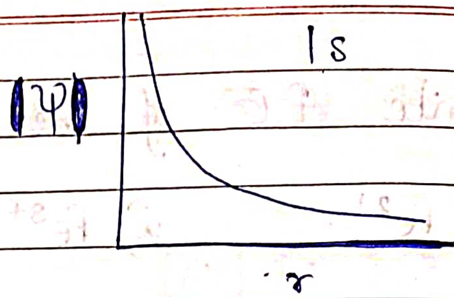
iv) $H = 1s^1 \Rightarrow H^- = 1s^2$

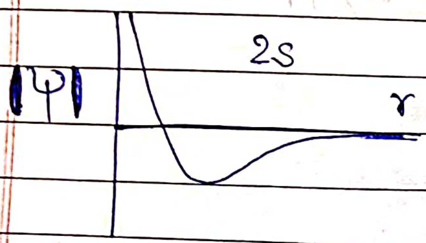
Graph of Radial / Wave fx^n (ψ) –

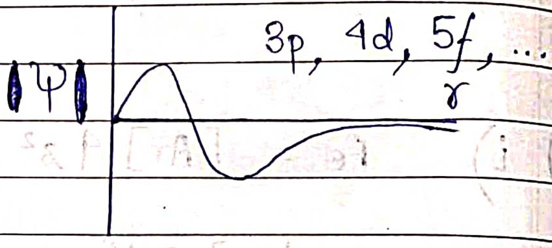


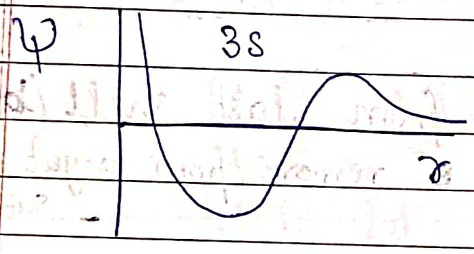
r = Radial dist (Dist. from Nucleus)

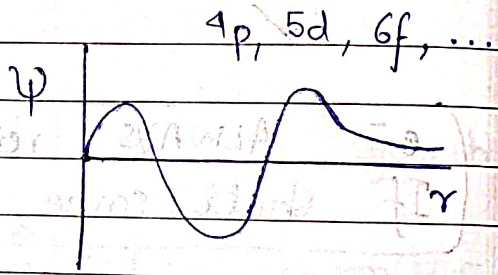

|ψ|
2p, 3d, 4f, ...
r

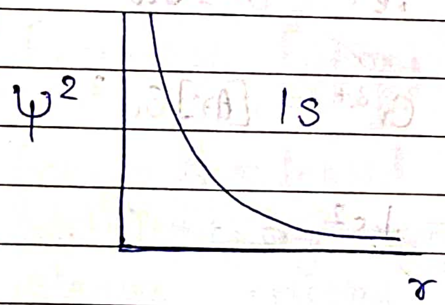

|ψ|
1s
r

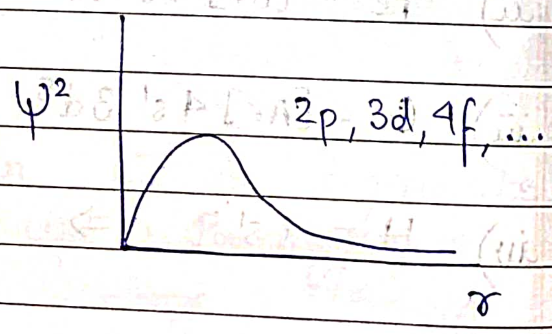

|ψ|
2s
r

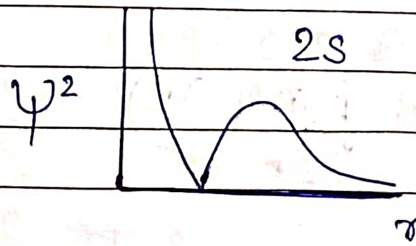

|ψ|
3p, 4d, 5f, ...
r

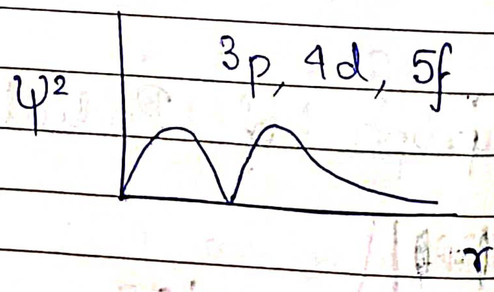

ψ
3s
r

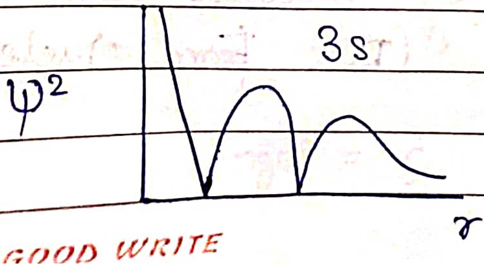

ψ
4p, 5d, 6f, ...
r

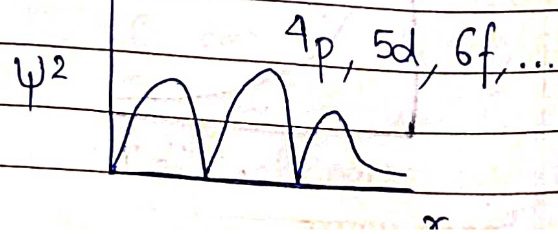

ψ²
1s
r


ψ²
2p, 3d, 4f, ...
r

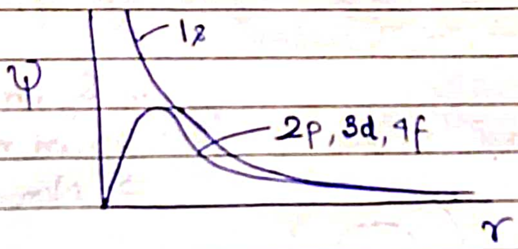

ψ²
2s
r


ψ²
3p, 4d, 5f
r

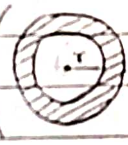

ψ²
3s
r


ψ²
4p, 5d, 6f, ...
r

Note: In all graphs portion starting from origin in p, d, f graph is BELOW s graph

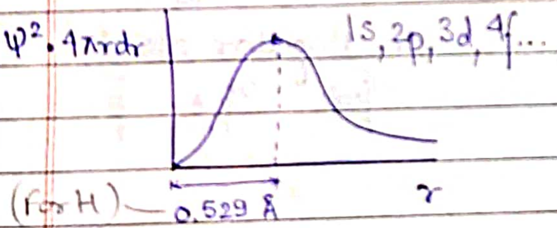


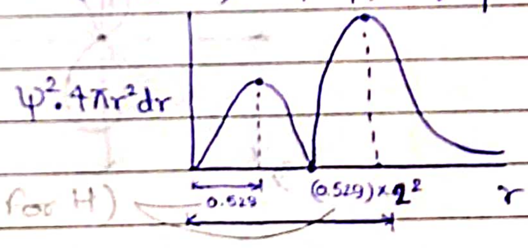
$$\boxed{\text{Probability (in small vol.)} = \psi^2 \cdot 4\pi r^2 \, dr}$$

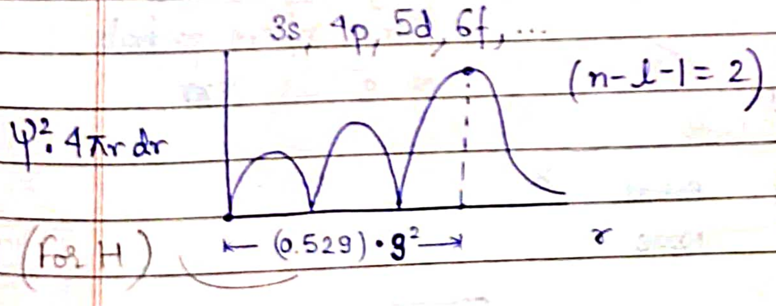


(Probab. of finding e^- b/w r & r+dr dist.)

Graph of Probability Distribution Curve:







☆ $\boxed{(\#\text{ Radial Nodes}) = (n-l-1)}$

- Probability = 0 ⇒ Radial node
  (Region where probab of finding e^- = 0)

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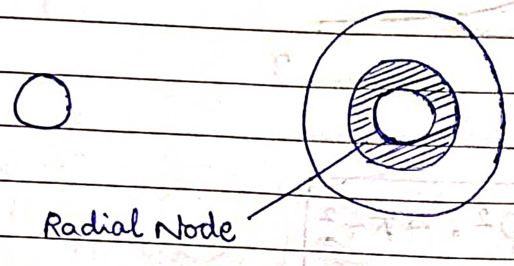
Shapes of Atomic Orbitals —

1) S orbital : (+ and − give sign of ψ in the region)

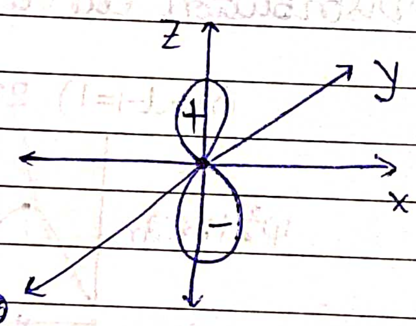
1s   2s

✓ Symmetrical in nature
⇒ Non directional



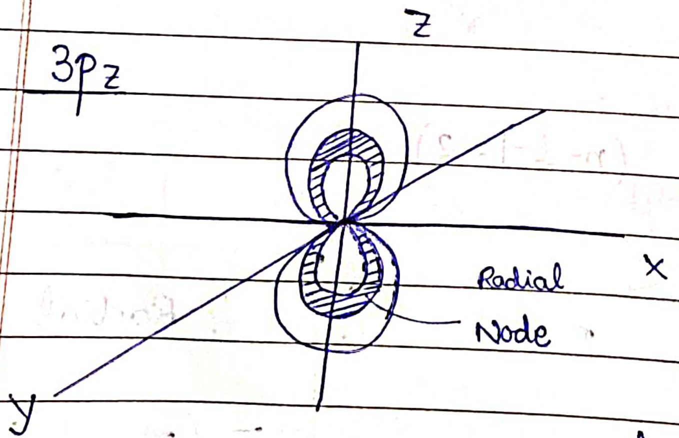
2) p orbital :

2pz



xy plane is Nodal Plane or Angular Node for 2pz

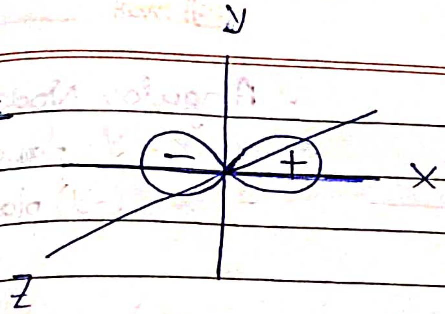
3pz



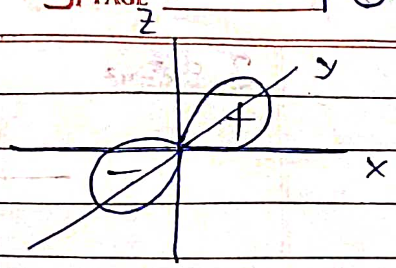
Angular Node : Plane where probab. of e^- is zero.

☆ $\boxed{(\#\text{Angular Node}) = l}$

$2p_x$



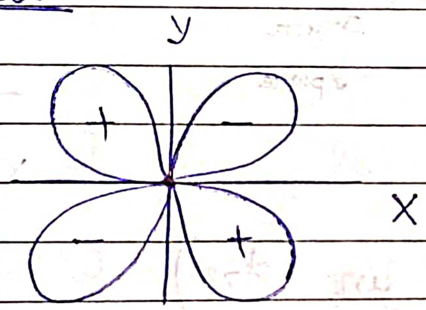
$2p_y$



✓ Dumbell shape ✓ Directional in nature

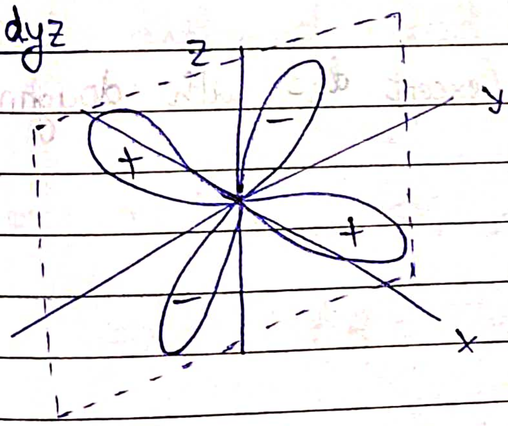
3) d orbital :

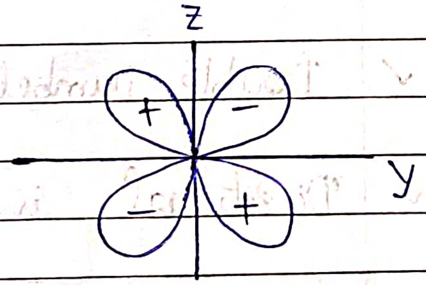
$3d_{xy}$



✓ Angular Nodes –
- YZ plane (X=0)
- XZ plane (Y=0)

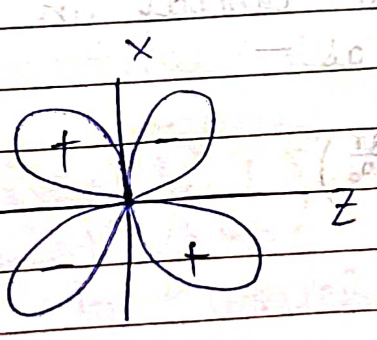
$3d_{yz}$





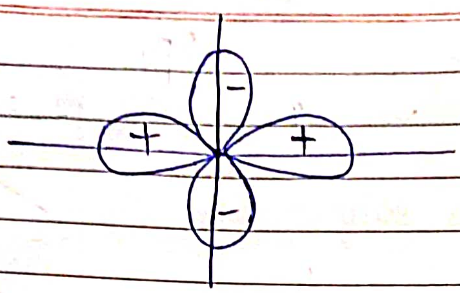
✓ Angular Nodes –
- XZ plane (Y=0)
- XY plane (Z=0)

$3d_{zx}$



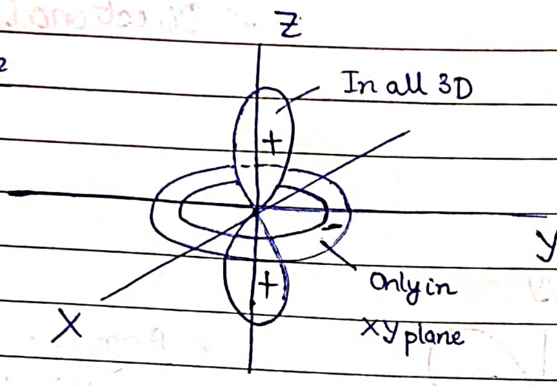
✓ Angular Nodes –
- XY plane (Z=0)
- YZ plane (X=0)

$3d_{x^2-y^2}$

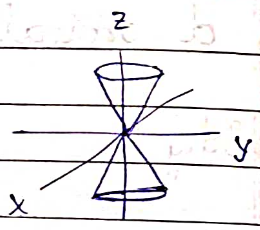


✓ Angular Nodes –
– $x = y$ plane
– $x = (-y)$ plane

$3d_{z^2}$



✓ Angular Nodes –
– 2 cones.



☆ No Nodal plane in d_{z^2}

✓ Double Dumbell Shape (except d_{z^2} with doughnut shape)

✓ Directional in nature

☆ Q) Find dist. at which probab. of finding e^- is max. for 1s orbital in He atom. ψ for orbital given as –

$$\psi = \left(\frac{4}{a_0^{3/2}}\right)\left(e^{\frac{-2r}{a_0}}\right)$$

A) $\psi^2 = \left(\frac{16}{a_0^3}\right)\left(e^{-\frac{4r}{a_0}}\right) \Rightarrow P(r) = 4\pi r^2 \cdot \psi^2$

$$\Rightarrow \left(P(r)\right) = \left(\frac{64\pi}{a_0^3}\right) r^2 e^{-4r/a_0}$$

$$\Rightarrow \left(\frac{dP(r)}{dr}\right) = \left(\frac{64\pi}{a_0^3}\right)\left[2r e^{-4r/a_0} - \left(\frac{4}{a_0}\right) r^2 e^{-4r/a_0}\right] = 0$$

(for max.

$$\Rightarrow \boxed{r = a_0/2}$$

Q) Consider ψ for 2s orbital of H atom as

$$\psi = \left(\frac{1}{4\sqrt{2\pi}}\right)\left(\frac{1}{a_0^{3/2}}\right)\left[2 - \frac{r}{a_0}\right] e^{-r/2a_0}$$

Find dist. of radial node.

A) For radial node, $\psi = 0$, $\psi^2 = 0$,

$$\Rightarrow \left(2 - r/a_0\right) = 0 \Rightarrow \boxed{r = 2a_0}$$

Q) If an orbital is represented by $\left\{\sigma = \frac{2r}{a_0}\right\}$

$$\psi = \left(\frac{2}{3}\right)\left(\frac{1}{3a_0}\right)^{3/2}(\sigma - 1)(\sigma^2 - 8\sigma + 12)\sigma e^{-\sigma/2}\cos(\theta)$$

belongs to which orbital.

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A) 1) Since ϕ is not present, it can only be Z purely.

2) If ϕ is present, Z is NOT totally ~~absent~~ present

3) To find no. of radial nodes, $\psi = 0$ or $\psi^2 = 0$.

4) Take highest common factor of r or σ out of bracket. Its power = (# Angular Nodes)

Now, (# Radial) = $n - l - 1$ = 3 $\left((\sigma-1)(\sigma^2 - 8\sigma + 12)\right)$

(# Angular) = l = 1 (σ^1)

$\Rightarrow$ $n = 3$, $l = 1$ $\Rightarrow$ $\boxed{3p_z \text{ orbital}}$

Imp. Pts. —

1) Even if 1 e^- unpaired $\Rightarrow$ Paramagnetic.

If all e^- paired $\Rightarrow$ Diamagnetic.

GOOD WRITE