Structure Of Atom

- **Fundamental Particles**
  - electron ($_{-1}e^0$)
  - Proton ($_1H^1$ / $_1P^1$)
  - neutron ($_0n^1$)
- **Atomic Models**
  - Earlier Model
    - Thomson's model (1897)
    - Rutherford's Model (1911)
  - Recent Model
    - Bohr's Model (1913)
    - Quantum Mechanical model
- **Quantum Numbers**
  - Principle Quantum no. (n)
  - Azimuthal or Orbital Angular Quantum no. (l)
  - Magnetic orbital Quantum Number (m_l)
  - Spin Quantum Number (m_s)
- **Electronic Configuration**
  - Bohr-Bury's rule or (n+l)
  - Auf-Bau principle
  - Pauli's Exclusion principle
  - Hund's Rule of Maximum Multiplicity

Discovery of –
(i) electron by J.J. Thomson
(ii) proton by Goldstein
(iii) neutron by Jame Chadwick

Dalton's atom → (n, P, e) → Rutherford's α-scattering experiment (Discovery of Nucleus) → Failure of Rutherford's Model

(Classical mechanics) Bohr's Concept (Discovery of orbits)

orbits — nucleus (P+n) — Bohr's Atomic model

Sommerfeld's model (Concept of suborbits) — K, N, n, (P+n)

Quantum Mechanical Concept — concept of orbital & quantum numbers

nth orbit (P+n) → Orbit → Subshell → Orbital → Suborbital

Electronic Configuration → The distribution of electron in different orbitals.

Cathode Ray Tube / Gas discharge tube

Thomson's Cathode Ray Experiment (C.R.T.)

q_+ ←— d —→ q_-

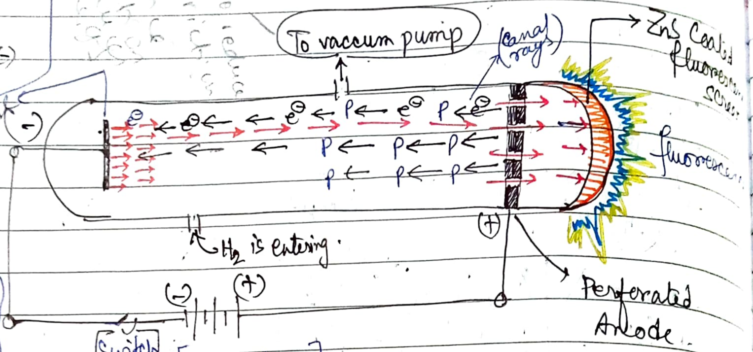
$F_{attraction} \propto \frac{q_{(+)} q_{(-)}}{d^2}$

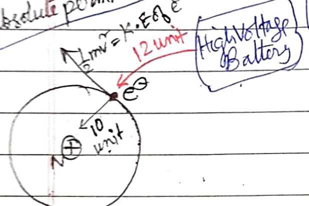
$F_{attract} = K \cdot \frac{q_+ q_-}{d^2}$

Coulombic force of attraction between 2 oppositely charged ions

where K = dielectric constant $= \frac{1}{4\pi\epsilon^{\circ}}$

ϵ° = absolute permittivity





$e^{\ominus}$ → H —($e^{\ominus}$)→ H —($e^{\ominus}$)→ H —$e^{\ominus}$→ H →

$H^{\oplus}$ ← $H^{\oplus}$ ← $H^{\oplus}$ ← $H^{\oplus}$ (P)

ionisation of Hydrogen gas kept inside the CRT

Energy = Work done

Electrical work = Charge × potential

$W = V \times q$

* In S.I system, values of K (Kappa) $= 9 \times 10^9$ Nm^2/C^2

C.G.S system, values of K = 1

∴ Cathode rays are nothing but highly energetic −vely charge beam of electron flow.

- Anode (canal rays) are +vely charged particle movement.

if 'W' work has to be done to bring a +q Coulomb charge from infinity,

∴ q coulomb is brought by performing 'W' work

1 coulomb is " " " $\frac{W}{q} = V$, potential

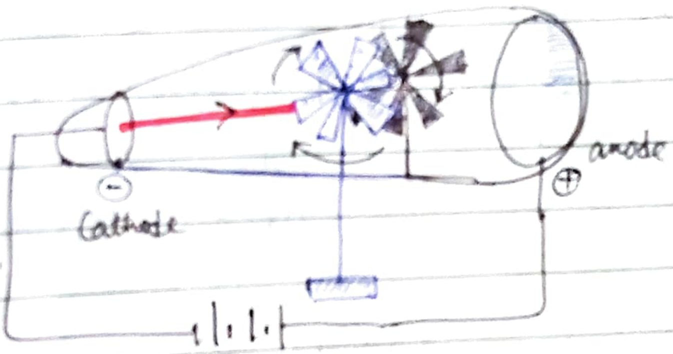
$\boxed{W = V \times q}$

(work done) (volt (potential)) (charge) Coulomb

- Cathode rays are same of all gases kept in the discharge tube but anode rays are different from gas to gas.

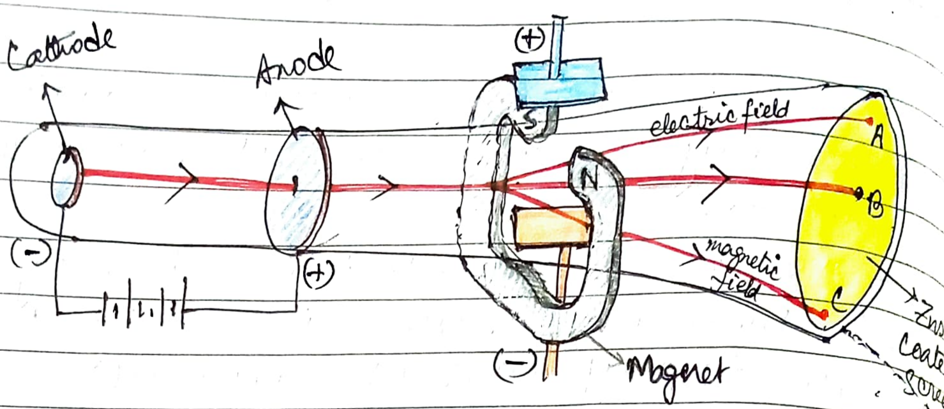
CHARACTERISTICS OF CATHODE RAYS:

- starts from cathode and move towards anode.
- These rays are invisible but cause fluorescent materials.
- In the absence of electric and magnetic field, these rays travel in straight lines.
- Cathode rays cast shadows of an object placed in its path and produces mechanical effects on a small paddle wheel.



- These rays consist of -vely charged particles (fast moving) & are deflected by electrical & magnetic fields.
- Characteristics of cathode rays donot depend on the nature of electrode or nature of the gas present in it.
- Cathode rays penetrate through thin sheets of Al and other metals.
- They affect photographic plates.
- Charge to mass ratio (e/m) is universal constant for cathode rays.

$$\boxed{e/m = (-)1{\cdot}76 \times 10^{11}\ C\,Kg^{-1}}$$



Electric force = Magnetic force

$$e^{-} \times E = B e^{-} v$$

Charge of e^-

Strength of electric field

velocity of electron

Charge of electron

Strength of Magnetic field or Magnetic flux density

$$E = Bv \quad \text{--- (1)}$$

velocity of e^-, $v = \frac{E}{B} \Rightarrow \boxed{B = \frac{E}{v}}$

Suppose the e^- is moving with the velocity v, travels on a circular arc of radius "r" then

$$Bev = \frac{mv^2}{r} \quad \text{--- (11)}$$

it's the Centripetal force

$$\frac{e}{m} = \frac{v}{Br}$$

$$= \frac{1}{Br} \cdot \frac{E}{B}$$

$$\boxed{\frac{e}{m} = \frac{E}{B^2 r}}$$

Charge by mass ratio of e^- can be calculated

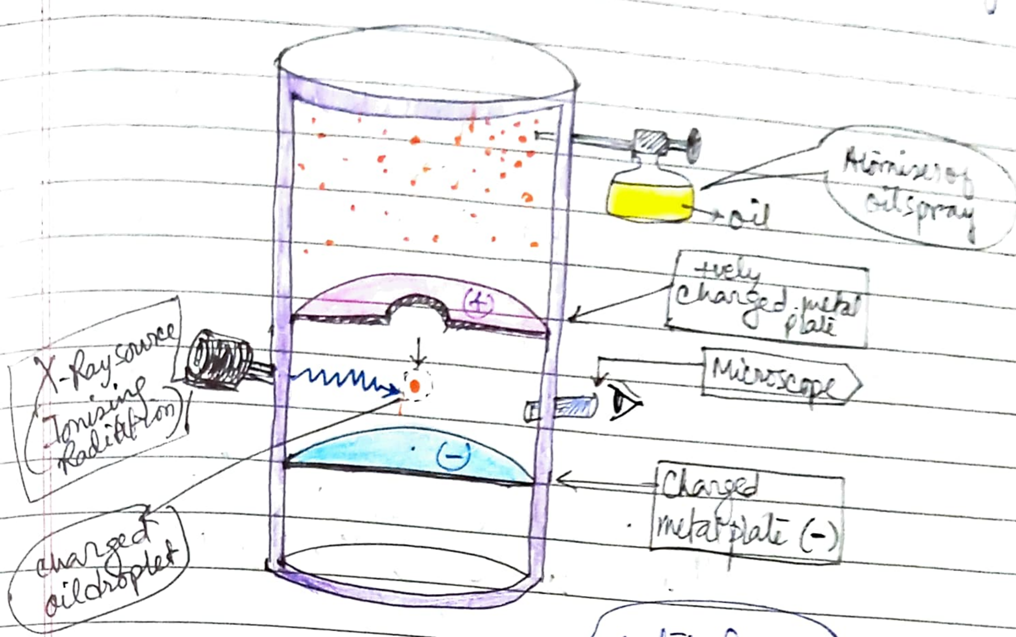
Mass of electron can be calculated

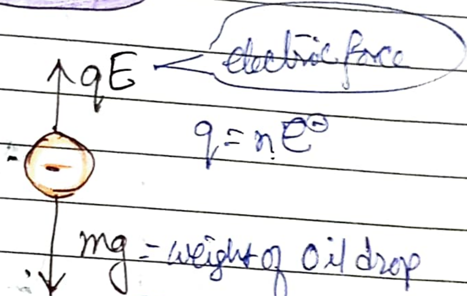
Mass of proton = 1.672×10^{-27} kg

mass of neutron = 1.675×10^{-27} kg

mass of electron = 9.109×10^{-31} kg

Millikan's Oil Drop Experiment — measurement of charge for each electron.

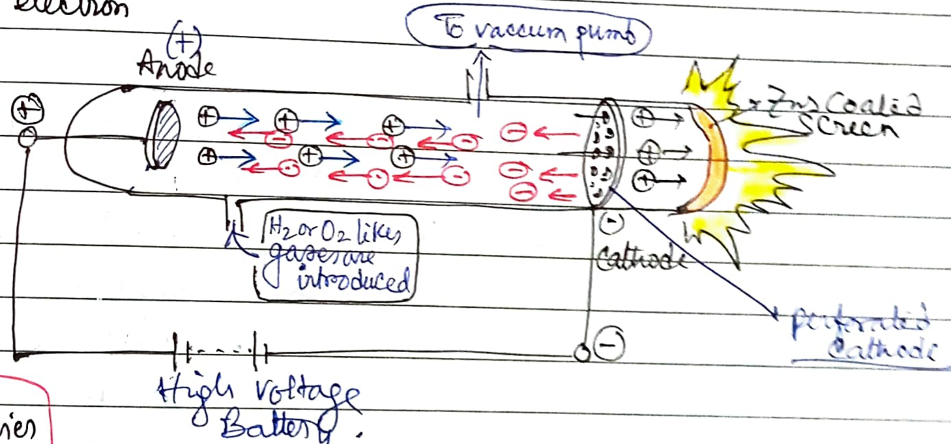




$q = ne^{-}$

$$mg = ne^{-}E$$

Charge of electron $\rightarrow e^{-} = 1.602 \times 10^{-19}$ Coulomb.



mass of a proton is 1837 times heavier than one electron

$$e^{-} \rightarrow H \xrightarrow{-e^{-}} H^{+} \xrightarrow{-e^{-}} H^{+} \xrightarrow{-e^{-}} H^{+} \qquad e/m_{H}$$

$$O_2 \xrightarrow{-e^{-}} O_2^{+} \xrightarrow{-e^{-}} O_2^{+} \xrightarrow{-e^{-}} O_2^{+} \qquad e/m_{O_2}$$

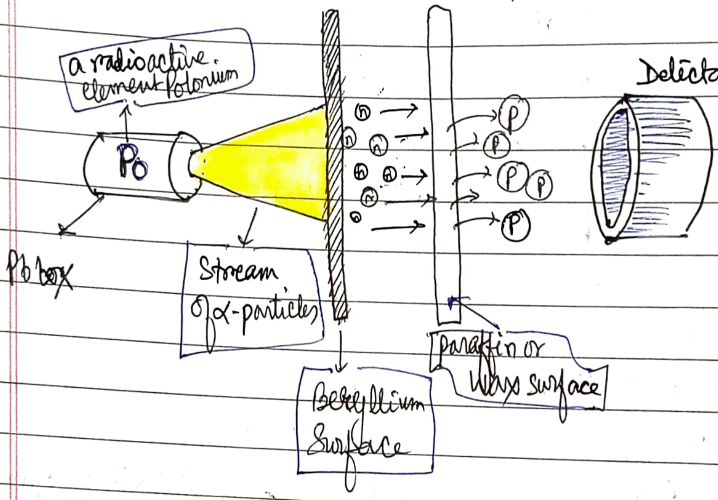
Charge/mass ratio for anode rays are different for individual gaseous substances.
Highest e/m ratio will be by hydrogen gas.

Characteristic of anode/canal rays:

- It depends on the nature of the gas taken in the discharge tube but with much slow speed as compared to cathode
- Canal rays are simply the raise of +ve charged gaseous ions.
- e/m ratio of anode rays is smaller than that of cathode rays. | e/m ratio of proton = 9.5...

Discovery of Neutron – James Chadwick (1932)

$$_{4}^{9}Be + \underset{\alpha\text{-particles}}{\left(_{2}^{4}He\right)^{++}} \longrightarrow {}_{6}^{12}C + {}_{0}^{1}n$$

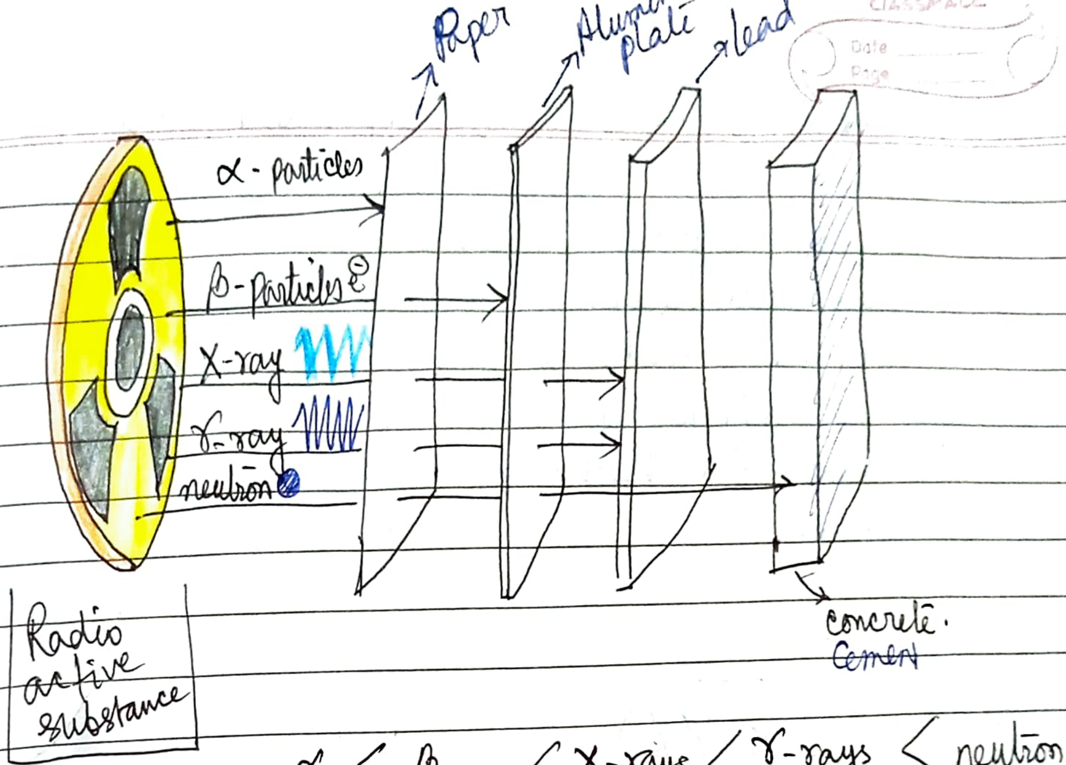


C_nH_{2n+2}, paraffin or wax is hydrogen rich substance
alkane

Q1. In Rutherford's α-scattering experiment he used "gold" foil because it's malleable & can be drawn into very thin sheets. Why did James Chadwick use Beryllium while discovering neutrons then? He could've used Gold as well.

Be has lowest value of neutron separation energy.

From this table, we can see that Be has the lowest neutron separation energy (S_n)



$C\,kg^{-1}$

$\underset{\text{particle}}{\alpha} < \underset{\text{particle}}{\beta} <$ X-rays $<$ γ-rays $<$ neutron

Order of penetration

After Rutherford's Discovery of Nucleus

Radius of an atom $\approx 10^{-10}$ m. & the same for nucleus $\approx 10^{-15}$ m.

$$\frac{\text{Volume of Nucleus}}{\text{Volume of atom}} = \frac{\frac{4}{3}\pi\left(10^{-15}\right)^3}{\frac{4}{3}\pi\left(10^{-10}\right)^3}$$

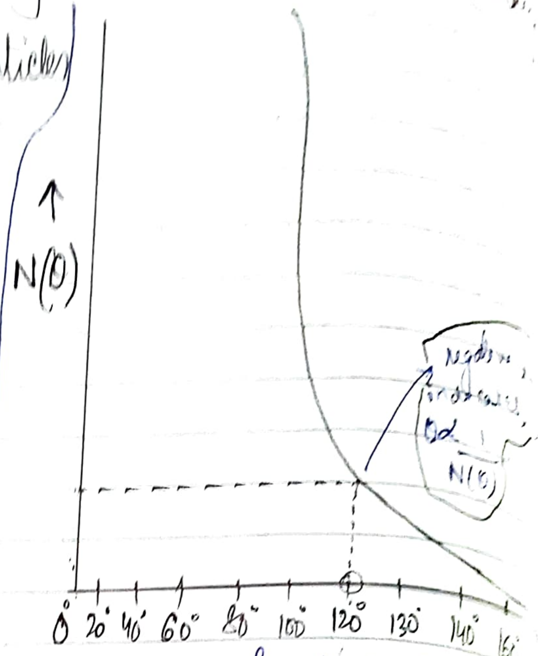
$$\frac{V_{nucleus}}{V_{atom}} = \frac{10^{-45}}{10^{-30}} = 10^{-15}$$

Volume of Nucleus → $\boxed{V_{Nucleus} = 10^{-15} \times \text{Volume of an atom}}$.

∴ Volume of Nucleus is 10^{15} times smaller than that of an atom.

Graph for α scattering experiment conducted by Ruth...

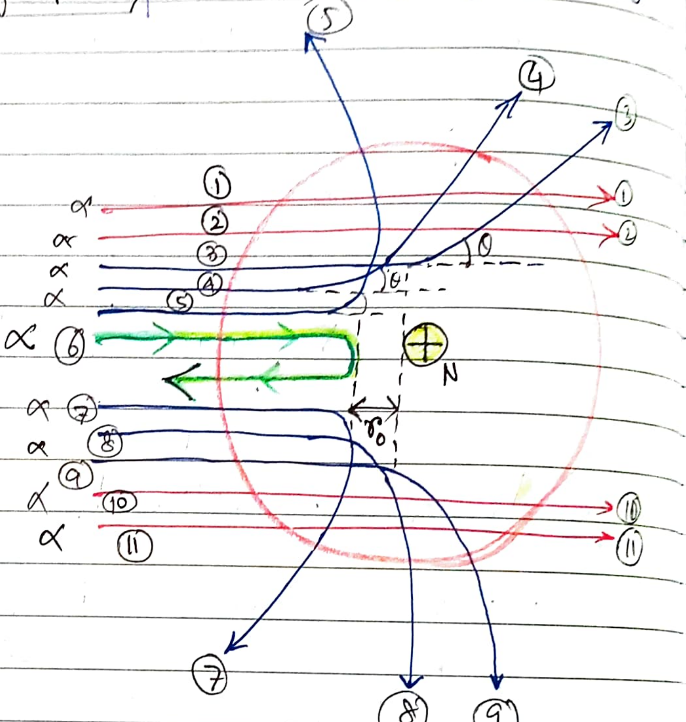
N(θ) is the number of α-particles a area that reach the screen at a scattering angle of θ, N(180°) is this number for backward scattering.



On the basis of Coulomb's law, this relation was established between the no. of particles (N) scattered at angle (θ)

$$\boxed{N \propto \frac{1}{\sin^4(\theta/2)}}$$

Estimation of Closest approach / distance of α-particles to the nucleus.

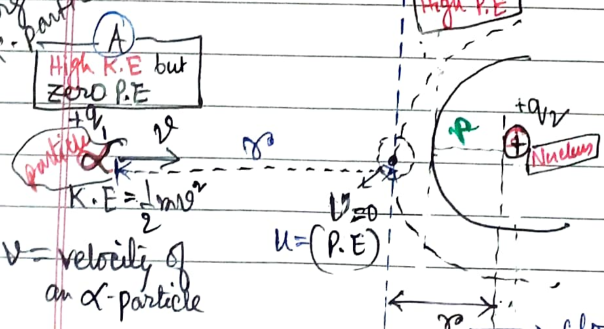


The scattering of α-particles

Nuclear charge = Ze

$q_1 = 2e$

Say the charge of an α-particle is $+q_1$



v = velocity of an α-particle

→ force of attraction between an α-particle (q_1) was thrown towards the Nucleus of charge (Ze) is

$$F = k \cdot \frac{q_1 \times q_2}{r^2} \qquad \because k = \frac{1}{4\pi\epsilon_0}$$

This force is given by $F = (-)\frac{dU}{dr}$

Where U = is the potential energy

$$\therefore \frac{k q_1 q_2}{r^2} = -\frac{dU}{dr}$$

$$k q_1 q_2 \int_r^{\infty} \frac{dr}{r^2} = -\int_U^0 dU$$

constant

$$k q_1 q_2 \left[\frac{-1}{r}\right]_r^{\infty} = (-)\left[U\right]_U^0$$

$$-k q_1 q_2 \left(\frac{1}{\infty} - \frac{1}{r}\right) = -(0 - U)$$

$$-k q_1 q_2 \left(-\frac{1}{r}\right) = U$$

The value of potential energy in terms of electrostatic force

$$\boxed{U = \frac{k q_1 q_2}{r}}$$

On the basis of conservation of energy law:

At the point A, Total energy $E_A = P.E + K.E = \frac{k.(2e)(Ze)}{r} + \frac{1}{2}mv^2$

At the point B, Total energy $E_B = P.E + K.E = \frac{k.(2e)(Ze)}{r_0} + 0 \times \frac{1}{2}m$

$$E_A = E_B \Rightarrow \frac{2kZe^2}{r} + \frac{1}{2}mv^2 = \frac{2kZe^2}{r_0} + 0$$

if $\lim_{r \to \infty}$ then $\frac{2kZe^2}{r} = 0$ therefore $\frac{1}{2}mv^2 = \frac{2kZe^2}{r_0}$

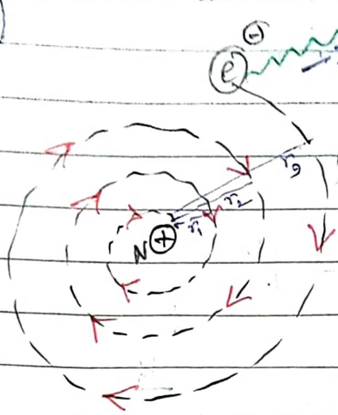
[where m = is the mass of α-particles]

$$r_0 = \frac{4kZe^2}{mv^2} \Rightarrow \boxed{r_0 \propto \frac{1}{v^2}}$$

E.M waves — Electromagnetic waves

Drawbacks of Rutherford's Atomic Model

- It couldn't explain Nuclear Collapse.
- It couldn't explain the line spectra for various elements.
- It couldn't explain the energies & distribution of electrons around nucleus.



Rutherford established his atomic model on the basis of Classical theory of E.M waves which predicts that — When a charged particle rotates around another particle in a spinning, Tangential velocity is the rectilinear or translation velocity, v

$v = r\omega$, r = radius of the circular path

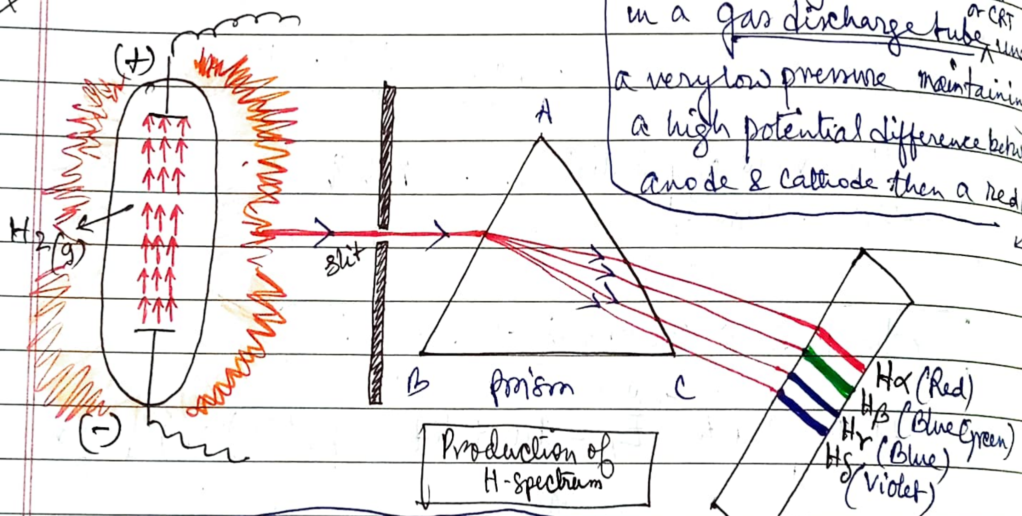
ω is the rotational velocity along a circular path.

for an electron spinning around the +vely charge Nucleus always losing its energy (K.E)

$$-\frac{1}{2}mv^2 = -\frac{1}{2}m(r\omega)^2$$

23/07/22

If pure H_2 gas is taken in in a gas discharge tube or CRT under a very low pressure maintaining a high potential difference between anode & cathode then a red

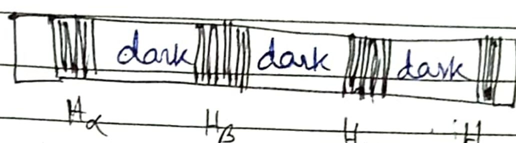


Production of H-spectrum

Coloured radiation is emitted from the CRT which is subjected to pass through a prism, then a fine line spectrum of Hydrogen gas is obtained.

According to Rutherford's atomic model, an electron in H_2 atom emits energy continuously during the rotation around the nucleus. As a result of which is a ~~to~~ spectrum is formed of that emitting energy, we should get a continuous spectrum as given above. But in reality (experimentally found) the nature of the line spectrum of hydrogen like single electron ~~of~~ system is found as

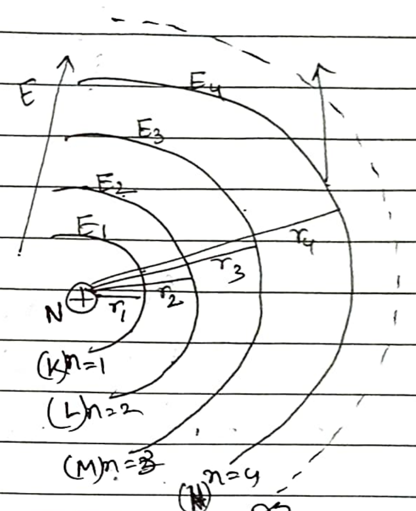
it always it energy



Discontinuous Spectrum

Bohr's Modification (1913)

This model is applicable only for - Hydrogen like single electron system such as - Li^{++}, Be^{3+}, He^{+} etc.



Postulates • The electron continue revolving in their respective orbits ~~of~~ fixed radius and energy, during rotation around the nucleus electron neither loses or gains energy, The energy remains constant known as stationary states or allowed energy states. These orbits are arranged concentrically around the nucleus.

$$\boxed{E_1 < E_2 < E_3 < E_4 < E_5 \ldots\ldots}$$

• Angular momentum (mvr) of an electron in a given orbit is quantised. $\boxed{mvr_n = n.\frac{h}{2\pi}}$ where n = a +ve whole number integer

when $n=1$, $mvr_1 = 1.\frac{h}{2\pi}$; when $n=3$, $mvr_3 = 3.\frac{h}{2\pi} = 1.5\frac{h}{\pi}$

" $n=2$, $mvr_2 = 2.\frac{h}{2\pi} = \frac{h}{\pi}$; when $n=4$, $mvr_4 = 4.\frac{h}{2\pi} = 2.\frac{h}{\pi}$

momentum, $p = m \times v$ (mass of the particle) (velocity) ; $K.E = \frac{1}{2} m v^2$

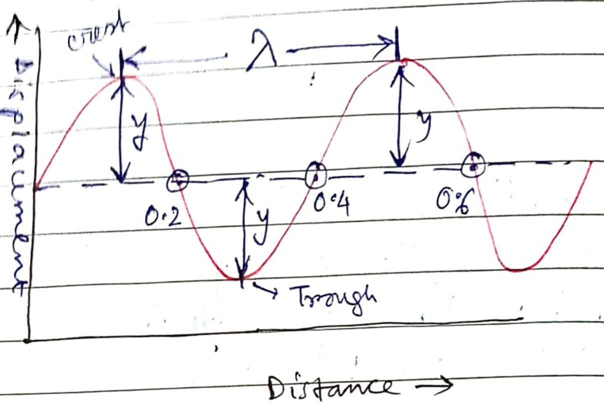
$$E = \frac{m^2 v^2}{2m}$$

$$m^2 v^2 = 2mE$$

$$p = (2mE)^{1/2}$$

$$\therefore \boxed{p \propto E^{1/2}}$$

- Characteristics of a wave



λ = wavelength (Distance between 2 neighbouring crests / troughs of a wave)

$a = y$ = amplitude

frequency = no. of waves ~~which pass through a particular point~~ in a particular point in one second.

In S.I unit, unit of frequency = Hz or cps (cycles per second)

$$1 \text{ cps} = 1 \text{ Hz}$$

$$1 \text{ KHz} = 10^3 \text{ Hz}$$

$$1 \text{ MHz} = 10^6 \text{ Hz}$$

$$\text{Velocity} = \frac{\text{distance}}{\text{Time}} \qquad \text{frequency } (\nu) = \frac{1}{T}$$

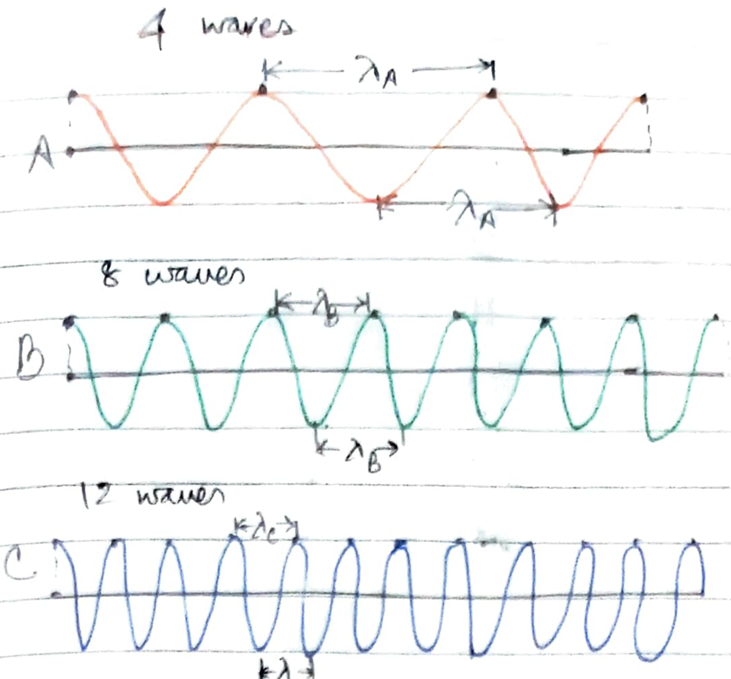
$$\therefore v = \frac{\lambda}{T} \qquad \therefore \lambda = v \times T$$

~~velocity~~

$$\lambda = v \cdot \frac{1}{\nu}$$

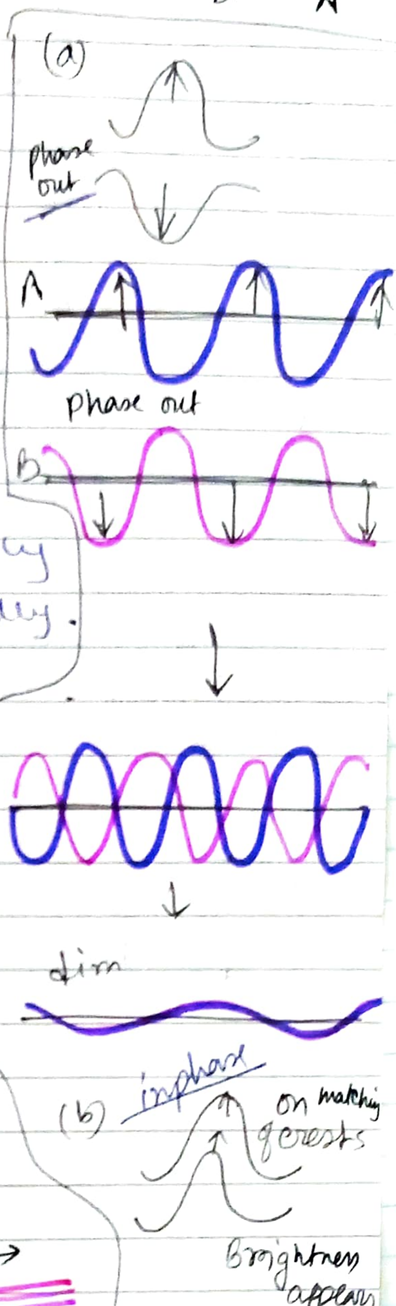
$$v = \nu \times \lambda$$

velocity frequency wavelength



$\lambda_A > \lambda_B > \lambda_C$

$\nu_C > \nu_B > \nu_A$

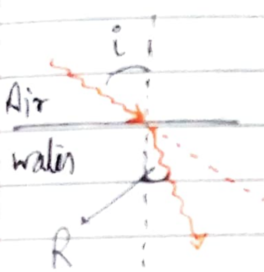


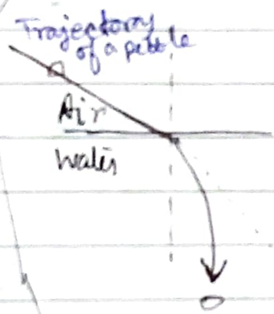
Wave

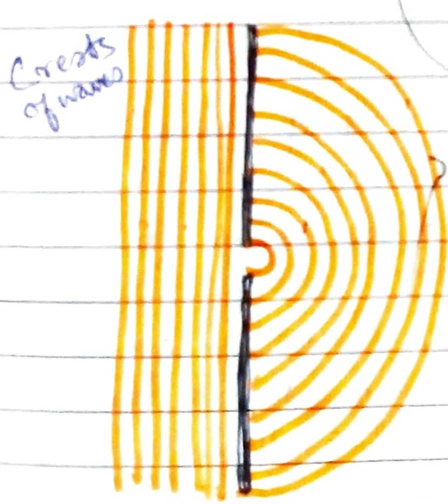
The speed of a light wave, passing b/w media changes immediately, bends its path due to refraction.

Particles

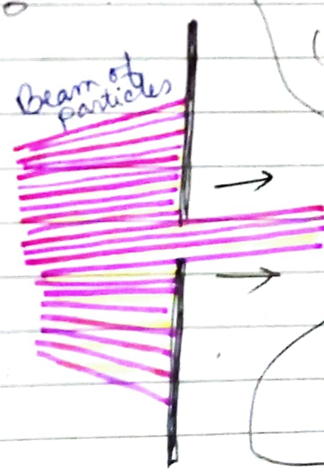
The speed of a particle continuously changing gradually.



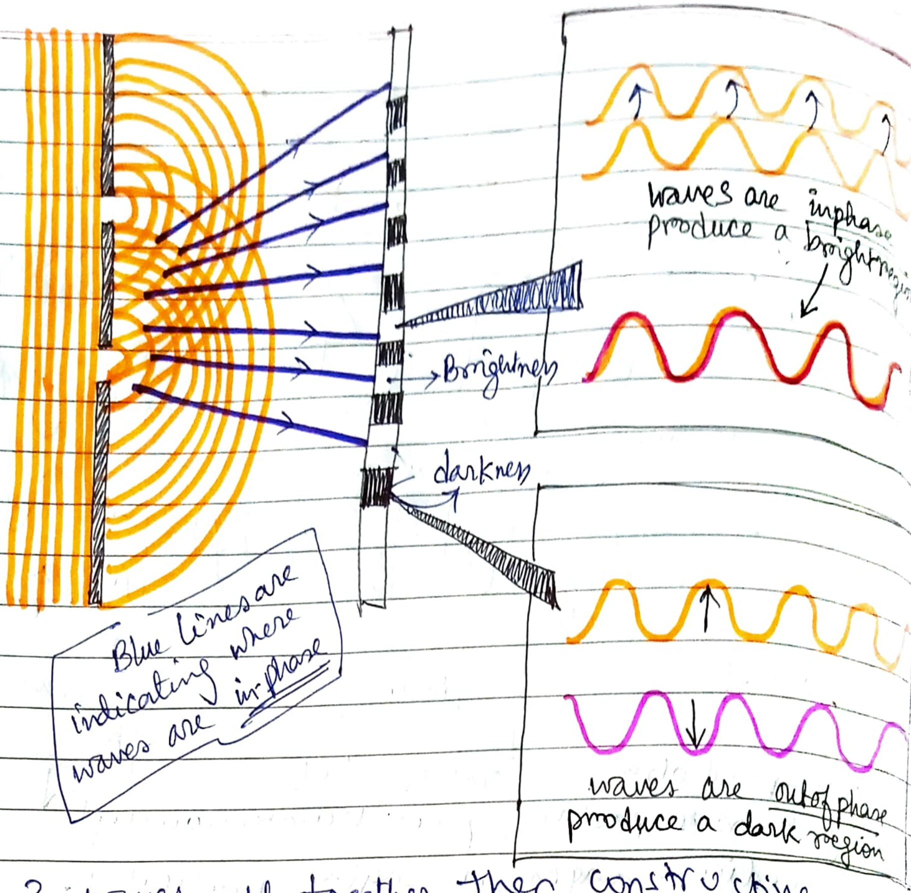




A wave bends around both edges of a small opening, forming a semicircular wave (diffraction)



Particles either enter a small opening or don't, it goes straight forward → Particle never shows diffraction if Two adjacent slits are present



- When 2 waves add together then constructive interference → brightness appears
- when 2 waves subtract from each other then destructive interference → darkness will come

Justification of Bohr's Angular momentum using De Broglie's hypothesis.

According to Planck's equation

$E \propto \nu$ (frequency)

① → or $E = h\nu$, where h = proportionality constant known as Planck's constant whose value $= 6.626 \times 10^{-34}$ JS (Universally Constant)

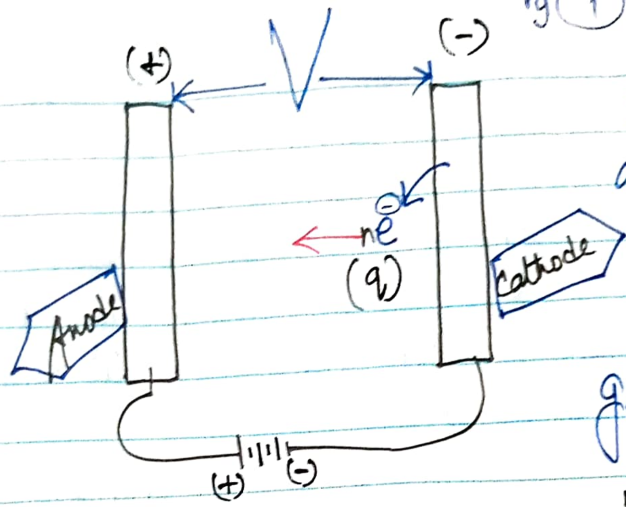
According to mass-energy law of equivalence given by Einstein we came to know that —

② → $E = mc^2$

where m = mass of the particle
c = velocity of light $= 3 \times 10^8$ m/s
& if 'v' = velocity of particle which is comparable with the velocity of light.

Compairing equations ① & ②

we get $mc^2 = h\nu$ | ν = frequency of the wave



If a charge q is accelerated through a potential difference "V" volt then

Gain in K.E = Electrical work done

$$\frac{1}{2}mv^2 = q \times V$$

$$\frac{m^2v^2}{2m} = q \times V$$

$\because$ $\boxed{mv = p}$

$$p^2 = q \times V \times 2m$$

$$\boxed{p = \sqrt{2mqV}}$$

As per De Broglie

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

for an electron the above equation after putting the values of "m", mass of electron & charge "q" is fixed & potential difference b/w Cathod & anode is "V" fixed then

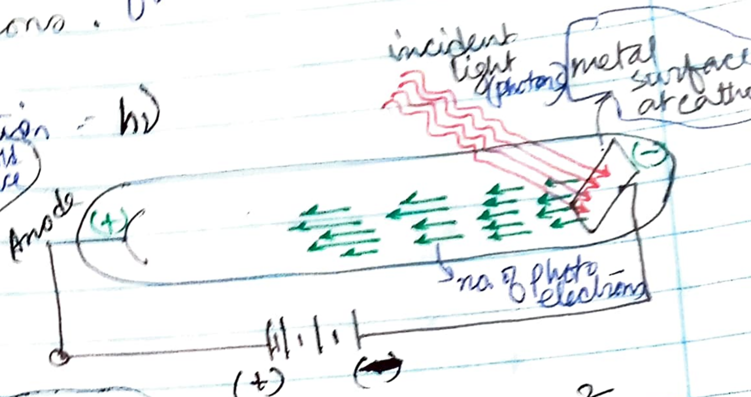
$$\boxed{\lambda = \frac{123}{\sqrt{V}} \text{ Å}}$$

13/08/22

Pg. (2)

Photo Electric Effect, BBR — all are evidences supporting that electron has some particle nature —

When metal surface is exposed to a certain radiation of higher frequency, the e^{-}s are given out. This phenomenon is known as photoelectric effect & emitted photons are known as photoelectrons.



Say, the incident radiation - $h\nu$

energy required to remove the e^{-} from the metal surface ← Threshold Energy

Where ν_0 represents the threshold frequency

$$h\nu = h\nu_0 + \frac{1}{2}mv^2$$

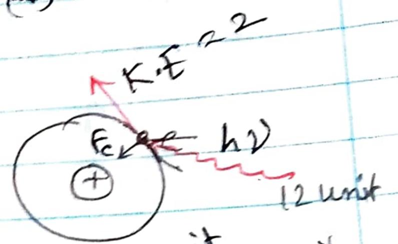
Energy of incident radiation with high frequency ν

Work function (ϕ)

K.E of the photoelectrons

$$h(\nu - \nu_0) = K.E$$

$$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{2}mv^2$$



F_c = 10 unit

12 − 10 = 2 unit

From de Broglie

$$\lambda = \frac{h}{mv} \qquad p =$$

$$\frac{1}{\lambda} = \frac{p}{h}$$

① K.E of photoelectrons $\propto \nu$ of the incident light & is independent on the intensity of radiation.

② The magnitude of photoelectrons (no. of photo e^{-}s) or photocurrent $\propto$ intensity of radiation.

③ One photon can eject only one photo-electrons, so if the intensity of incident radiation is more, then no. photo electrons ejected will be more

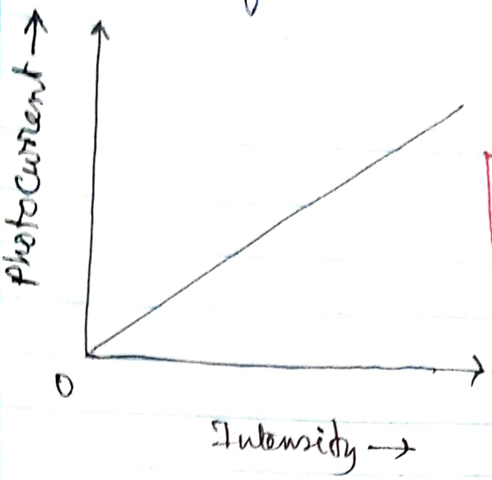
$mc^2 = h\nu$

Pg-③

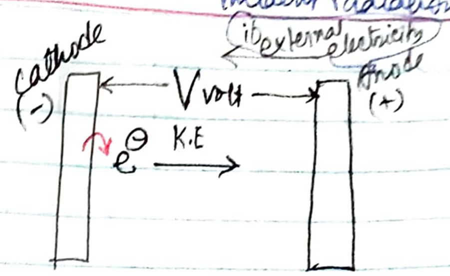
Stopping Potential

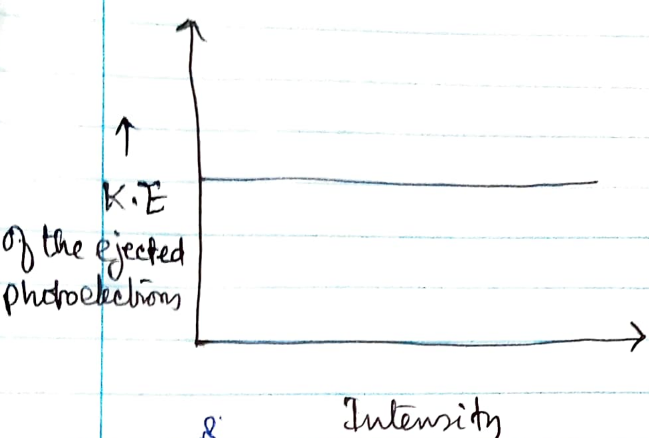
Stopping Potential - The energy (or minimum -ve potential) required to stop the photo-electron is known as Stopping potential, which is also independent of the intensity of the incident radiation.

$\boxed{\text{Stopping potential} \propto K.E \propto \text{frequency of the incident radiation}}$



$\boxed{\because \text{ No. of photocurrent} \propto \text{Intensity of the incident radiation}}$





$$\left(\tfrac{1}{2}mv^2\right) \text{K.E of ejected electrons} = q \times V$$

$$V_s = \frac{K.E_{max}}{q}$$

Stopping potential

$$\boxed{V_s \propto \text{frequency of the incident radiation}}$$

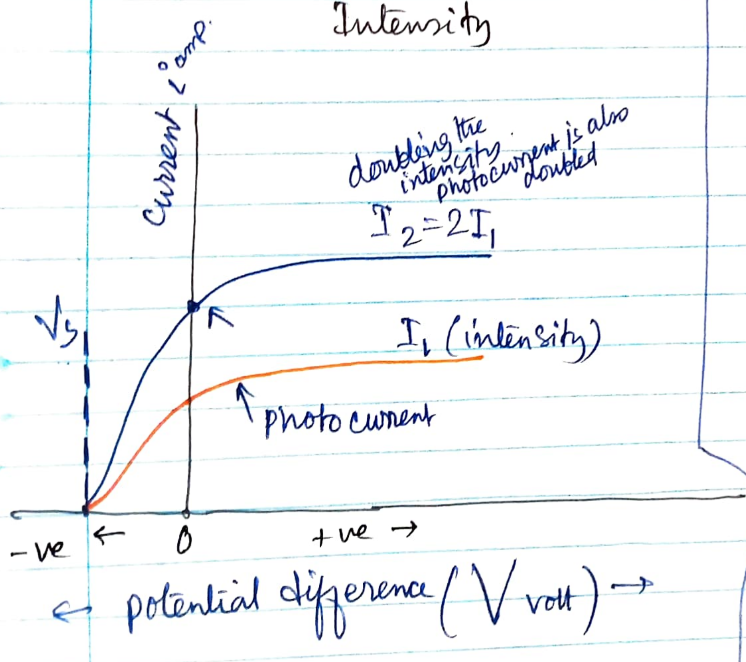
$$m^2v^2 = 2mqV$$

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

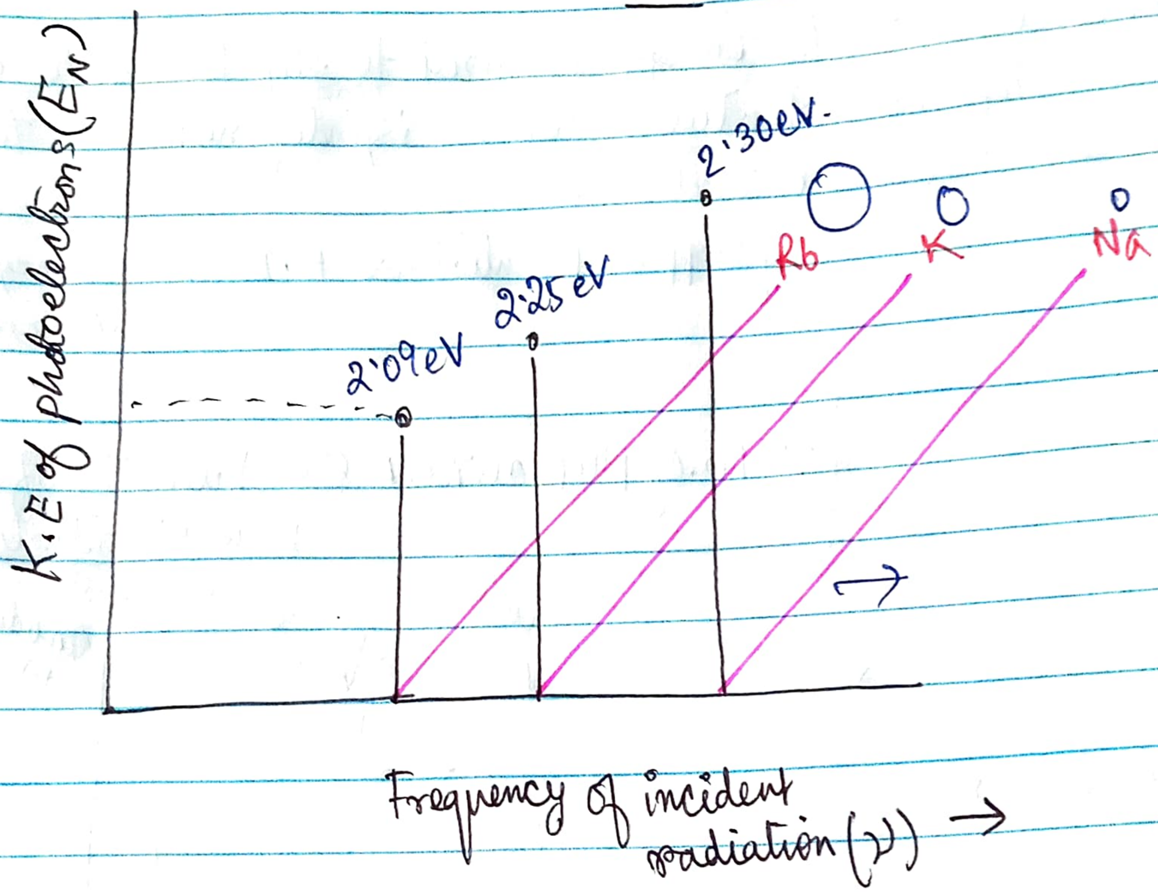
$$\lambda = \frac{h}{\sqrt{2mqV}}$$

Putting all the known values of h, m_e, q (charge of $e^{\ominus}$) we'll get

$$\boxed{\lambda = \left(\frac{150}{V}\right)^{1/2} \text{Å}}$$



P-4



K.E of photoelectrons (E_k)
2.09eV
2.25 eV
2.30eV.
Rb
K
Na
Frequency of incident radiation (ν)

we get $$mc^2 = h\nu$$

or, $$mc^2 = h.\frac{c}{\lambda}$$

ν = frequency of the wave
λ = wavelength of that wave

$$mc = \frac{h}{\lambda}$$ if c be replaced by v then we'll get

$$mv = \frac{h}{\lambda}$$

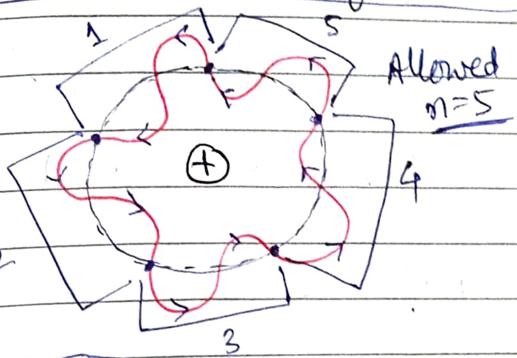
represents the wave nature of the matter

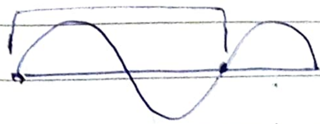
$$\boxed{\lambda = \frac{h}{mv}}$$

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

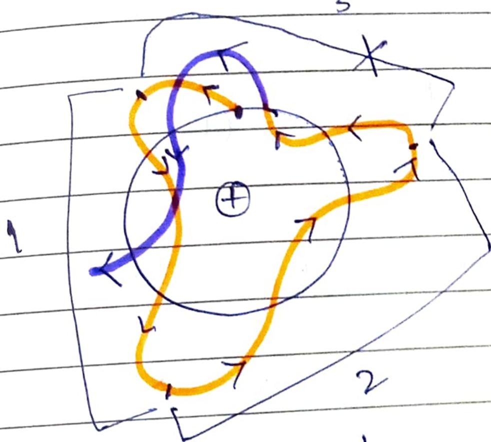
momentum represents the particle nature of the matter

This is DeBroglie's equation for Dual character of matter.

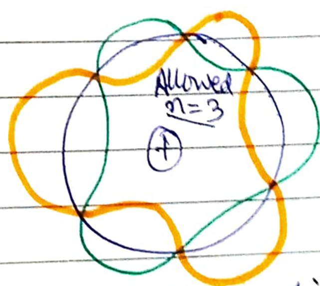




Same path has to be followed either destructive interference will appear.



Forbidden, $n = 3\frac{1}{3}$



Circumference of the orbit

$$2\pi r = n\lambda$$

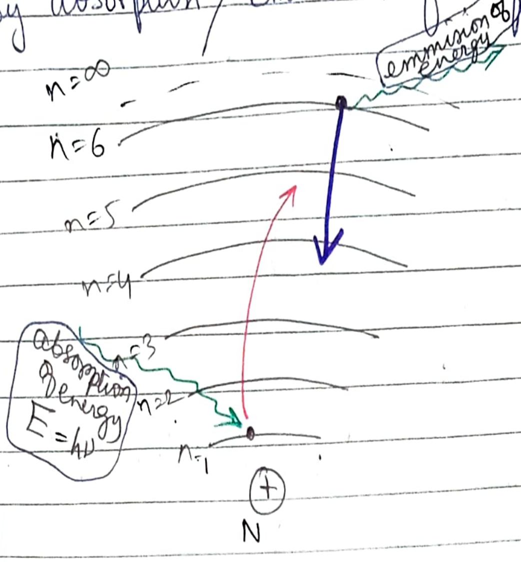
$$2\pi r = n.\frac{h}{mv}$$

$$\boxed{mvr = n.\frac{h}{2\pi}}$$ proved

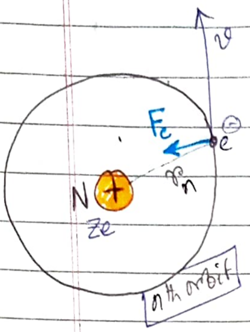
Angular momentum of an electron is quantised

(Quntum Theory)

- An electron can move from one energy level to another either by absorption / emmision of required amount of energy.



Calculation of the radius of Bohr's orbit



Electrostatic force = Centripetal force (in

$$\frac{K\cdot Ze^2}{r_n^2} = \frac{mv^2}{r_n}$$

$$\boxed{v^2 = \frac{KZe^2}{mr_n}} \quad \text{— (i)}$$

Nuclear charge = Z×e

Electrostatic force of attraction $F_e = \frac{K(Ze)(e)}{r_n^2}$ (q_1, q_2)

From Bohr's postulate we know that

$$mvr_n = n\cdot\frac{h}{2\pi} \Rightarrow$$

$$v = \frac{n\cdot h}{2\pi m r_n}$$

$$v^2 = \frac{n^2h^2}{4\pi^2 m^2 r_n^2} \quad \text{— (ii)}$$

Comparing equations (i) & (ii) we get

$$\frac{KZe^2}{mr_n} = \frac{n^2h^2}{4\pi^2 m^2 r_n^2}$$

$$\boxed{r_n = \frac{n^2h^2}{4\pi^2 mKZe^2}} \quad \text{— (iii)}$$

[Putting the values of $\pi = 3.14$, $m_e = 9.109 \times 10^{-31}$ kg, $K = 9 \times 10^9$ Nm^2/C^2, Charge of electron $= 1.602 \times 10^{-19}$ C & $h = 6.626 \times 10^{-34}$ Js]

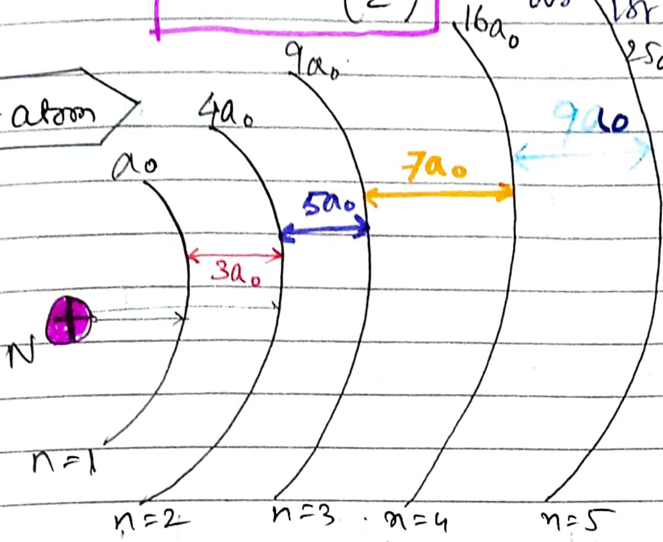
$$\boxed{r_n = 0.529\left(\frac{n^2}{Z}\right)}\ \text{Å} \longrightarrow (iv)$$

or, $r_n = 0.53\left(\frac{n^2}{Z}\right)$ Å

or $\boxed{r_n = a_0\left(\frac{n^2}{Z}\right)}$ where $a_0 = 0.53$ Å is known as 1st Bohr's orbit.

For H-atom

$Z = 1$



$r_1 = a_0$

$r_2 = 4a_0$

$r_3 = 9a_0$

$r_4 = 16a_0$

$r_5 = 25a_0$

For $He^{\oplus}$ ion $\boxed{Z = 2}$

$n=1,\ r_1 = \frac{a_0}{2}$

$n=2,\ r_2 = 2a_0$

$n=3,\ r_3 = 4.5a_0$

$n=4,\ r_4 = 8a_0$

For Li^{2+} ion $\boxed{Z = 3}$

$n=1,\ r_1 = \frac{a_0}{3}$

$n=2,\ r_2 = \frac{4}{3}a_0$

$n=3,\ r_3 = 3a_0$

$n=4,\ r_4 = \frac{16}{3}a_0$

(1) If the radius of 2nd orbit of Li^{2+} ion is 'x'. Then find radius of 1st orbit of $He^{\oplus}$ in terms of 'x'.

for Li^{2+}, $n=2$, $r_2 = \frac{4}{3}a_0 = x$ (Given)

or $a_0 = \frac{3x}{4}$

for He^{+}, $n=1$, $r_1 = \frac{a_0}{2} = \frac{1}{2}\cdot\frac{3x}{4}$

$r_1 = \frac{3x}{8}$ Ans

Velocity $v = \frac{nh}{2\pi m r_n} = \frac{nh}{2\pi m \cdot \left(\frac{n^2h^2}{4\pi^2 mkZe^2}\right)}$

$$\boxed{v = \frac{2\pi Z e^2 k}{nh}} \text{ — (v)}$$

Putting the values of π, e, k & h we'll get

velocity of electron in the n^{th} orbit. ← $\boxed{v = 2.18 \times 10^6 \left(\frac{Z}{n}\right) \frac{m}{second}}$ — (vi)

Time period of revolution of an $e^{\ominus}$ in its orbit.

velocity $= \frac{\text{distance}}{\text{Time}}$

Time $= \frac{\text{distance}}{\text{velocity}}$

$T = \frac{2\pi r_n}{v}$ ∵ $v \propto \frac{Z}{n}$

or $T \propto \frac{r_n}{v}$ & $r_n \propto \frac{n^2}{Z}$

or $T \propto \frac{\frac{n^2}{Z}}{\frac{Z}{n}} \Rightarrow \boxed{T \propto \frac{n^3}{Z^2}}$ — (vii)

Q) Find out the ratio of time period of revolution of electron in second orbit of Li^{2+} to 3^{rd} orbit of He^{+}.

Time period of revolution

for the 2nd orbit of Li^{2+} ion,

$$T_{Li^{2+}} \propto \frac{(2)^3}{(3)^2}$$ and the same for He^{+} ion

$$T_{He^{+}} \propto \frac{(3)^3}{(2)^2}$$

$\therefore$ The ratio of time period of revolution

$$\frac{T_{Li^{2+}}}{T_{He^{+}}} \propto \frac{8/9}{27/4}$$

$$T_{Li^{2+}} : T_{He^{+}} = 32 : 243$$

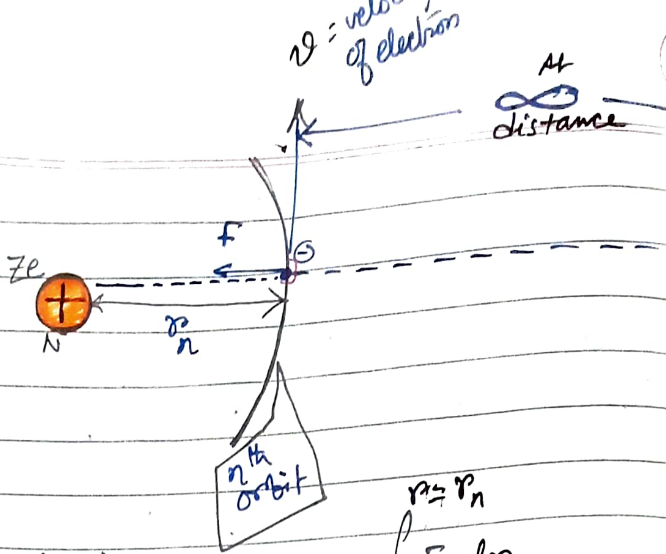
$$\text{Frequency}(\nu) = \frac{1}{\text{Time period }(T)}$$

$$\boxed{\nu \propto \frac{Z^2}{n^3}} \quad \text{— (viii)}$$

Calculating the energy of an electron: The energy of electron at ∞ is arbitrarily assumed to be zero. This state is called, "Zero Energy" State. When the e^- moves and comes under the influency of nucleus, it does some work and spends its energy in the process. Thus the energy of the electron decreases (↓) & becomes negative (–ve).

[The –ve sign also indicates that the electron is bound to the nucleus.]

P.E of the electron at a distance "r_0" from the nucleus is equal to the work done in moving the electron from ∞ to the point, at a distance "r_0" from the nucleus.



$$P.E\,(U) = \text{work done} = \int_{r=\infty}^{r=r_n} F.dr$$

[F = Coulomb force]

$$\text{or, } U = \int_{r=\infty}^{r=r_n} \frac{k.Ze.e}{r^2}\,dr$$

[K = Dielectric constant of the medium $= \frac{1}{4\pi\epsilon_0}$]

$$\text{or, } U = kZe^2 \int_{r=\infty}^{r=r_n} \frac{dr}{r^2}$$

$$\text{or, } U = kZe^2 \left[-\frac{1}{r}\right]_{r=\infty}^{r=r_n}$$

P.E of atomic system i.e. $e^{\ominus}$ + nucleus → $\boxed{U = (-)\frac{kZe^2}{r_n}}$

Total energy = K.E + P.E

$$\boxed{E_{Total} = \frac{1}{2}mv^2 - \frac{kZe^2}{r_n}} \quad \text{— ⓐ}$$

Since Coulombic force = Centripetal force

$$\frac{kZe^2}{r_n^2} = \frac{mv^2}{r_n}$$

$$\boxed{mv^2 = \frac{kZe^2}{r_n}}$$

Putting the value of mv^2 in equation ⓐ we get

$$E_{Total} = \frac{1}{2}.\frac{kZe^2}{r_n} - \frac{kZe^2}{r_n}$$

$$\boxed{E_{Total} = -\frac{kZe^2}{2r_n}}$$

$$\boxed{K.E = -\frac{P.E}{2}} \quad \text{— (i)} \qquad \boxed{\text{Total energy } E_T = (+)\frac{P.E}{2}} \quad \text{— (ii)}$$

$$\boxed{K.E = -\text{ Total Energy}} \quad \text{— (iii)}$$

$$T.E = -\frac{kZe^2}{2r_n} = -\frac{kZe^2}{2 \cdot \frac{n^2h^2}{4\pi^2 mkZe^2}}$$

$$\text{or, } T.E = -\frac{kZe^2}{2n^2h^2} \cdot 4\pi^2 mkZe^2 = -\frac{k^2\pi^2 me^4}{h^2}\left(\frac{Z}{n}\right)^2$$

Putting the values of $k = 9 \times 10^9\ Nm^2/C^2$

$\pi = 3.14$,

mass of $e^{\ominus}$, $m_e = 9.109 \times 10^{-31}$ kg

charge of $e^{\ominus} = 1.602 \times 10^{-19}$ C

$h = 6.626 \times 10^{-34}$ J s

$$\boxed{T.E = (-)\ 13.6\left(\frac{Z}{n}\right)^2 \text{ eV/atom.}}$$

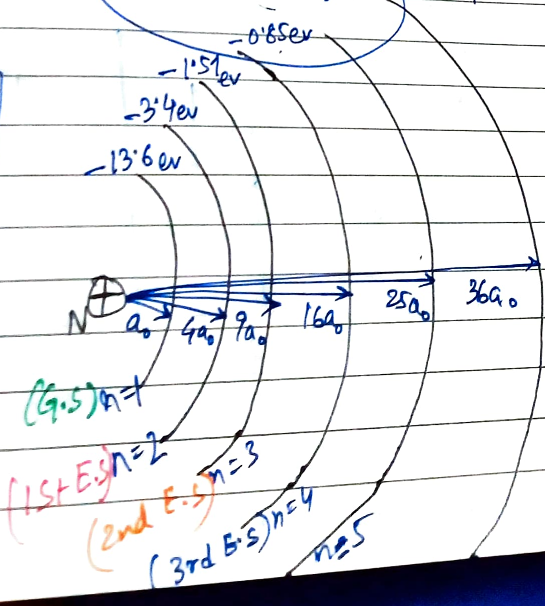
$1\text{ eV} = 1.602 \times 10^{-19}$ J

or $$\boxed{T.E = (-)\ 2.18 \times 10^{-18}\left(\frac{Z}{n}\right)^2 \text{ J/atom.}}$$

$\therefore$ $T.E \propto (-)\frac{1}{n^2} \rightarrow E_1 < E_2 < E_3 < E_4 \ldots$

For H-atom

$Z = 1$,



$$\boxed{E_{Total} = -\frac{kZe^2}{2r_n}}$$

$$\boxed{K.E = -\frac{P.E}{2}} \; -(i) \qquad \boxed{\text{Total energy } E_T = (+)\frac{P.E}{2}} \; -(ii)$$

$$\boxed{K.E = -\text{Total Energy}} \; -(iii)$$

$$T.E = -\frac{kZe^2}{2r_n} = -\frac{kZe^2}{2\cdot\frac{n^2h^2}{4\pi^2 mkZe^2}}$$

or $$T.E = -\frac{kZe^2}{2n^2h^2}\cdot 4\pi^2 mkZe^2 = -\frac{k^2\pi^2 m e^4}{h^2}\left(\frac{Z}{n}\right)^2$$

Putting the values of $k = 9\times10^9\, Nm^2/C^2$

$\pi = 3.14$,

mass of $e^{\ominus}$, $m_e = 9.109\times10^{-31}\,kg$

charge of $e^{\ominus} = 1.602\times10^{-19}\,C$

$h = 6.626\times10^{-34}\,Js$

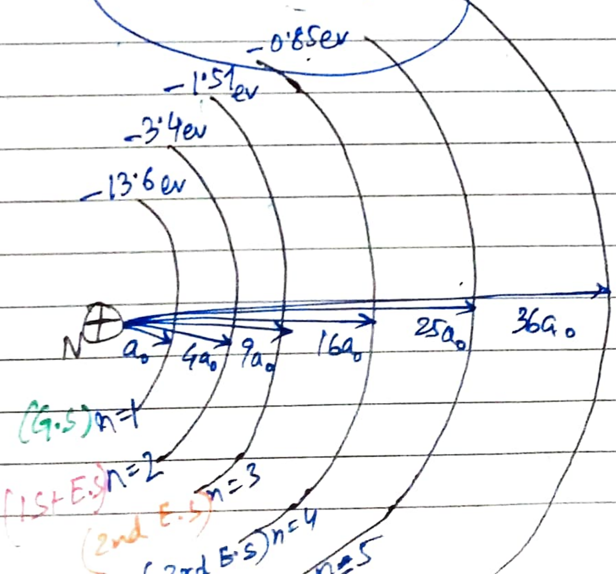
$$\boxed{T.E = (-)\,13.6\left(\frac{Z}{n}\right)^2 eV/atom.}$$

$1\,eV = 1.602\times10^{-19}\,J$

or $$\boxed{T.E = (-)\,2.18\times10^{-18}\left(\frac{Z}{n}\right)^2 J/atom.}$$

$\therefore\; T.E \propto (-)\frac{1}{n^2} \rightarrow E_1 < E_2 < E_3 < E_4 \ldots$

For H-atom
$Z=1$,



$E_n = -13.6\left(\frac{\;}{n^2}\right)$

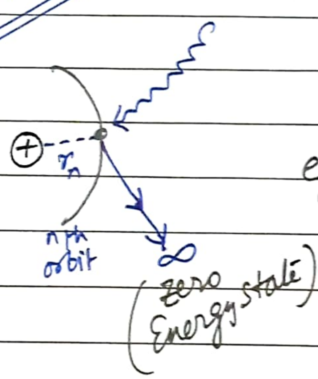
- **Ground State** (G.S)
  This is the lowest energy state of any atom / ion. $(n=1)$

- **Excited State**
  States of atom other than ground state are called excited state (E.S). ∴ E.S ⇒ $n=2$, $n=3$, $n=4$, $n=\ldots$

  eg:- G.S of H-atom $= -13.6$ eV
  G.S of He^+ ion $= -54.4$ eV.

- **Ionization Energy** (I.E) This is the minimum energy required to move an electron from neutral state to infinity i.e. $n=\infty$.

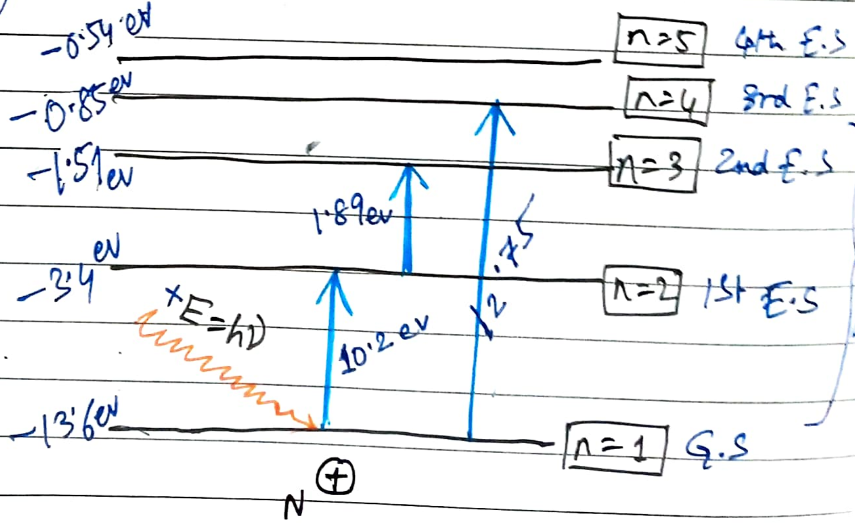
endothermic



eg:- $(I.E)_1$ for H-atom $= 0-(-13.6)$
$= +13.6$ eV

$(I.E)_1$ for He^+ atom $= 0-(-54.4)$
$= +54.4$ eV

- **Excitation Energy** The energy required to move an electron from G.S to an excited state.

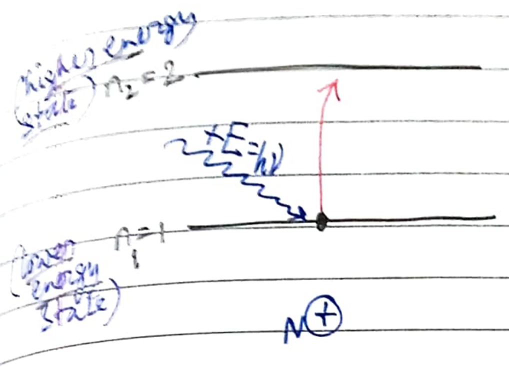


$\Delta E_{n_2 \to n_3} = -1.51-(-3.4)$

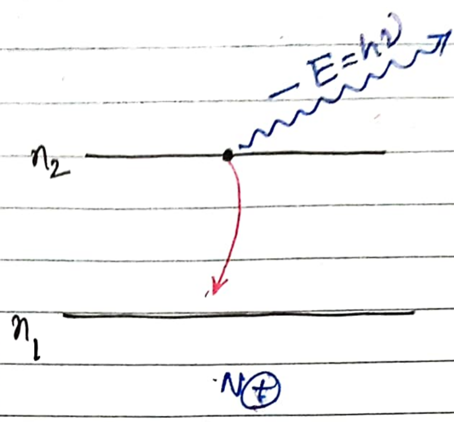
$\Delta E_{n_1 \to n_2} = -3.4-(-13.6)$
$= 10.2$ eV

Spectrum

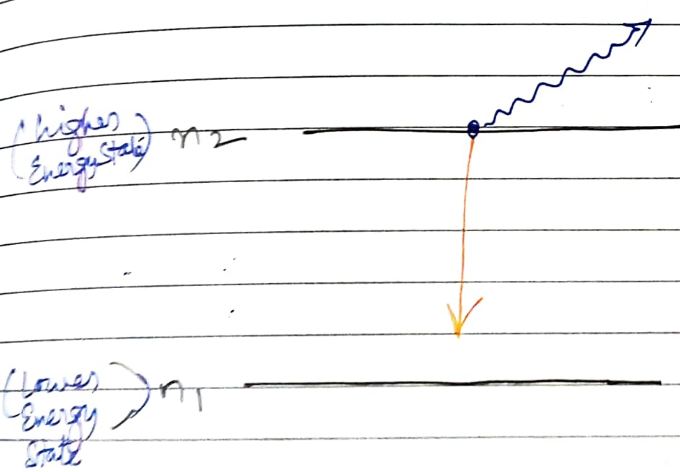
- Based on nature
  - Continuous — Eg: White light
  - Discrete — Eg: Hydrogen lined spectrum
- Based on origin
  - Emmission
  - Absorption



It's a case of Absorption Spectra



It's a case of Emmission Spectra



$$E_{n_2} = -13.6\left(\frac{Z}{n_2}\right)^2$$

$$E_{n_1} = -13.6\left(\frac{Z}{n_1}\right)^2$$

$$\Delta E_{n_2 \to n_1} = (-)13.6\,(Z)^2\left\{\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$$

or, $$\frac{hc}{\lambda} = 13.6(Z)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(Wave number) $$\bar{\nu} = \frac{1}{\lambda} = \frac{13.6}{hc}(Z)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\bar{\nu} = R_H(Z)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

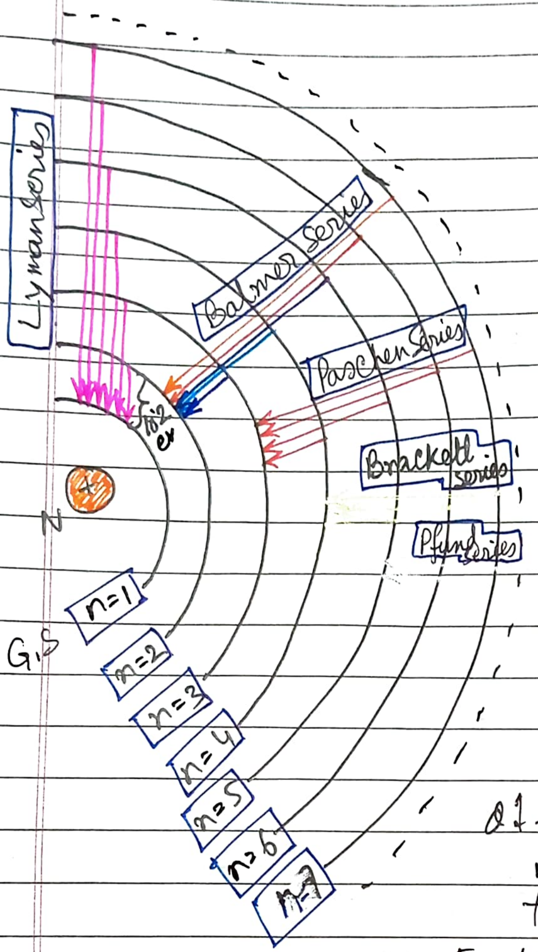
where R_H = Rydberg's constant

$R_H = \frac{13.6}{hc}$ eV

or $R_H = 1.09678 \times 10^7\ m$

With the help of Bohr's formula

$$\boxed{\frac{1}{\lambda} = R_H Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$$



Series	n_1	n_2	Spectral Region
Lyman	1	2,3,4....	U.V
Balmer	2	3,4,5....	Visible
Paschen	3	4,5,6....	near I.R
Brackett	4	5,6,7....	I.R
Pfund	5	6,7,8....	I.R

Q. Find the longest and smallest wavelength in the LYMAN SERIES for H-atom.

$\because E = h\nu$

$E = h \cdot \frac{c}{\lambda}$

$\therefore E \propto \frac{1}{\lambda}$

In case of LYMAN SERIES, the smallest energy gap is in between $n_2 \rightarrow n_1$

$n_2 = 2, \quad n_1 = 1$

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

$$\frac{1}{\lambda} = \frac{3}{4} R_H$$

minimum frequency ← $\boxed{\lambda_{max} = 4/3 R_H}$

Similarly, for smallest wavelength the energy gap will be largest that's in between $n_2 = \infty \longrightarrow n_1 = 1$

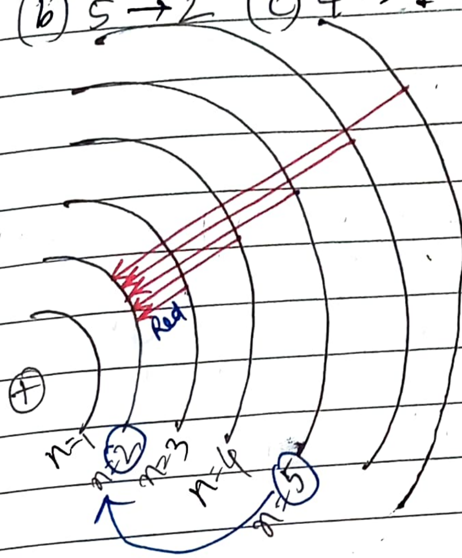
$$\frac{1}{\lambda} = R_H (1)^2\left(1 - \frac{1}{\infty}\right)$$

$$\frac{1}{\lambda} = R_H$$

$\boxed{\lambda_{min} = \frac{1}{R_H}}$ → maximum frequency

Q2 In Bohr's series of lines for H-spectrum, the 3rd line from the red end corresponding to which one of the following inter-orbit jumps of the e^- for Bohr orbits in an atom of hydrogen? (AIEEE 2003)

(a) $3 \rightarrow 2$ (b) $5 \rightarrow 2$ (c) $4 \rightarrow 1$ (d) $2 \rightarrow 5$



For Balmer series, $n_1 = 2$

VIBGYOR

↓ min. energy

1st line of Balmer $3 \rightarrow 2 \rightarrow$ (Red line)

Q3 Of the following transition in H-atom the one which gives an absorption line of lowest frequency is: (a) $n=1$ to $n=2$ (c) $n=2$ to $n=1$ (b) $n=3$ to $n=8$ (d) none of these

Q4 If the series limit of the wavelength of the Lyman series for the H-atom is 912 Å, then the series limit of wavelength for the Balmer series of the H-atom is

(a) 912 Å (b) 912×2 Å (c) 912×4 Å (d) $\frac{912}{2}$ Å

Q5 No. of visible lines when an e^- returns from 5th orbit to ground state in hydrogen spectrum is:

(a) 5 (b) 4 (c) 3 (d) 10

No. of photons emitted by a sample of H-atom :

→ If an electron is any higher state (n) and makes a transition to the ground state, then the total no. of different photons emitted is equal to

$$\boxed{\frac{n(n-1)}{2}}$$

→ If an electron is any higher state $n = n_2$ and makes a transition to another excited state $n = n_1$, then total no. of different photons emitted equal to

$$\boxed{\frac{\Delta n(\Delta n + 1)}{2}}$$

where $\Delta n = (n_2 - n_1)$

Number of Spectral lines — Total no. or max. number of spectral lines :—

$n = 6$

↓

$n = 1$

No. of spectral lines $= \dfrac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$

$= \dfrac{(6-1)(6-1+1)}{2}$

$= \dfrac{5 \times \cancel{6}^{3}}{\cancel{2}} = 15$

Pf Br P B

6 → 5, 4, 3, 2, 1 L

5 → 4 Br, 3 P, 2 B, 1 L

4 → 3 P, 2 B, 1 L

3 → 2 B, 1 L

2 → 1 L

Total no. of spectral lines

Lyman Series = 5

Balmer " = 4

Paschen " = 3

Brackett " = 2

Pfund " = 1

Total = 15

Heisenberg's Uncertainty Principle

It is impossible to determine simultaneously the exact position & exact momentum (or velocity) of an e^-. ~~Ma~~

Mathematically, $\Delta x \times \Delta p \geq \frac{h}{4\pi}$

or, $\boxed{\Delta x \times m\Delta V \geq \frac{h}{4\pi}}$

where $\Delta x \Rightarrow$ uncertainity in position
$\Delta p =$ uncertainity or error in momentum
$m =$ mass of the particle
$\Delta V =$ Uncertainity in velocity
$h =$ Planck's Constant

When $\Delta x \to 0, \Delta p \to \infty$
But when we'll try to fix the uncertainity in velocity as well as the momentum of the particle then

$$\Delta p \to 0, \Delta x \to \infty$$

When λ is very small then Energy becomes very high, Since error must be occured $\rightarrow$

$$\boxed{\Delta E \times \Delta t \geq \frac{h}{4\pi}}$$

- It rules out the existence of definite paths or trajectories of e^- & other microscopic particles.
- The effect of uncertainity principle is significant only for the motion of microscopic particles & is negligible for macroscopic particles.

Orbitals

To accurately describe an electron in an atom four quantum numbers are required which arise from the solutions to the elaborate mathematical equations of Quantum Mechanics, which describe the exceedingly complex wave behaviour of electrons. These four quantum no.s arise from solutions to the complex equations which describe the wave & quantised behaviour of e^- surrounding the nucleus.

$+\frac{1}{2}$ $-\frac{1}{2}$

↑↓

These four quantum numbers are :-

- $n \rightarrow$ Principle Quantum number
- $l \rightarrow$ Azimuthal / Subsidiary / angular Quantum number
- $m_l \rightarrow$ Magnetic Quantum number
- $m_s \rightarrow$ Spin Quantum number.

Address of the subshell nl

$l = 0, 1, 2, 3 \ldots (n-1)$

$m_l = (2l+1)$
$m_l = \pm l, \pm(l-1), \pm(l-2), \cdots 0$

	n	l	m_l	m_s	Maximum no. of $e^{\ominus}$ in an orbital	Total no. of $e^{\ominus}$s in an orbit
K-shell	1	$0 \rightarrow 1s$	[↑↓] $2\times0+1=1$	$\pm\frac{1}{2}\times1=$	2	2
L-shell	2	$0 \rightarrow 2s$	[↑↓]	$(\pm\frac{1}{2}\times1)=$	2	8
		$1 \rightarrow 2p$	-1, 0, $+1$: [↑↓][↑↓][↑↓] x y z; $2\times1+1=3$	$(\pm\frac{1}{2}\times3)=$	6	
M-shell	3	$0 \rightarrow 3s$	[↑↓]	$(\pm\frac{1}{2}\times1)=$	2	18
		$1 \rightarrow 3p$	[↑↓][↑↓][↑↓]	$(\pm\frac{1}{2}\times3)=$	6	
		$2 \rightarrow 3d$	[↑↓][↑↓][↑↓][↑↓][↑↓] -2 -1 0 $+1$ $+2$; $2\times2+1=5$	$(\pm\frac{1}{2}\times5)=$	10	

$l = 0 \rightarrow s$ orbital
$l = 1 \rightarrow p$ ''
$l = 2 \rightarrow d$ ''
$l = 3 \rightarrow f$ ''

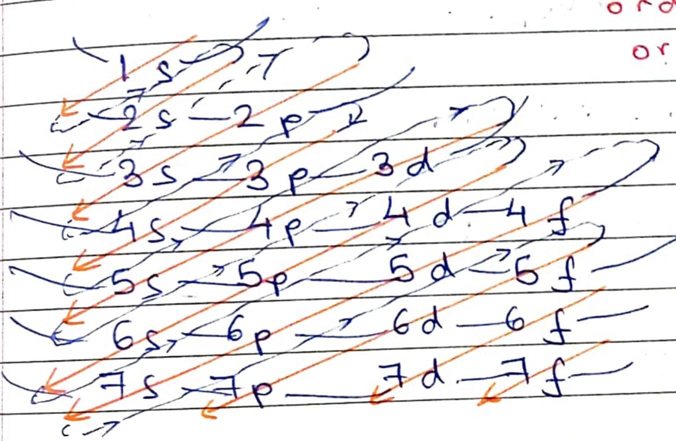
	n	l	m_l	m_s	
N-Shell	4	$0 \rightarrow 4s$	$\boxed{\uparrow\downarrow}$	$\left(\pm\frac{1}{2}\times 1\right) = 2$	32
		$1 \rightarrow 4p$	$\boxed{\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow}$	$\left(\pm\frac{1}{2}\times 3\right) = 6$	
		$2 \rightarrow 4d$	$\boxed{\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow}$	$\left(\pm\frac{1}{2}\times 5\right) = 10$	
		$3 \rightarrow 4f$	$-3\ -2\ -1\ 0\ +1\ +2\ +3$ $\boxed{\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow}$	$\left(\pm\frac{1}{2}\times 7\right) = 14$	

$m_l = (2\times 3+1) = 7$

$n \rightarrow$ Both size & shape of an orbit
$l \rightarrow$ shape of the orbital
$m_l \rightarrow$ orientation of orbital

Rain drops Model:

N+



Sequential energy order of different orbitals:

$1s < 2s\,2p < 3s\,3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p$ ......

energy ↑

(*) $_9X \rightarrow 1s^2 2s^2 2p^5$

$\boxed{\uparrow\downarrow}$ 1s ($n=1$) $\boxed{\uparrow\downarrow}$ 2s $\boxed{\uparrow\downarrow\,\uparrow\downarrow\,\uparrow\downarrow}$ $2p_x\ 2p_y\ 2p_z$ ($n=2$)

No. of valence $e^- = 2+5 = 7$

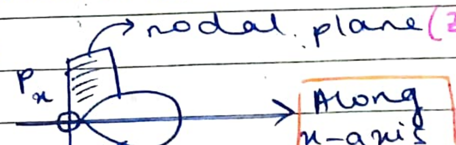
valency = 1

Nature of the element: Non-metallic

SHAPE OF P ORBITAL:

$l = 1$ — elliptical sub orbital

elliptical $l = 1$



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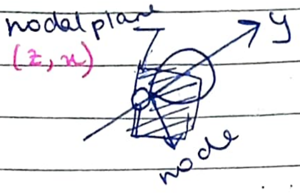
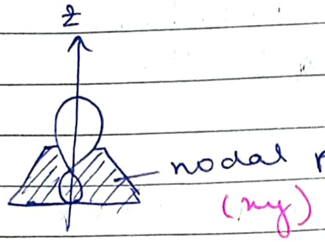
Along y-axis



* According to Hund's Rule incompletely filled d-orbital (d^9 for Cu) is less stable than that of fully filled or half-filled d-orbital (d^{10}, Cu) since only 2 variable valency of Cu may be possible, 1 & 2 Cu (I) & Cu (II)

Along z-axis



* Position of element - check electronic configuration for the given atomic no.
  - Period = principal quantum no = 2
  - group no. = 17
  - block = p-block (check last orbital in which e^- enters.

For p-block elements, Total no. of e^- in $ns^2 np^{1-6} + 10$

∴ Group no: $2 + 5 + 10 = 17$

Eg 2

$_{11}Na$ — $1s^2, 2s^2, 2p^6, 3s^1$

Block - s - orbital Group = 1

Period - 3

valency - 1+

valence e^- — 1+

∴ Metallic in nature

For s-block elements, group no. is the valence electron no.

(G.S) $_{29}Cu \rightarrow [Ar]_{18} 4s^1 3d^{10}$ → Fully filled d-orbital (diamagnetic) & colourless

Cu in (+I) state $Cu^{(+)} \rightarrow [Ar]_{18} 4s^0 3d^{10}$ → " " " " " lower energy

" +II state $Cu^{++} \rightarrow [Ar]_{18} 4s^0 3d^9$

1l	1l	1l	1l	1
d_{xy}	d_{yz}	d_{zx}	$d_{x^2-y^2}$	d_{z^2}

→ due to presence of one unpaired e^- it's paramagnetic & produce Deep blue colour inner core electronic configuration

eg 3

$_{21}Y$ — $[1s^2\ 2s^2\ 2p^6]_{10}Ne\ 3s^2\ 3p^6]_{Ar_{18}}, 4s^2, 3d^1$

Period: 4

Group: 1+2 = 3, Sub group: $\overline{III}$ B → for transition elements

group no

block: d-block

$\therefore\ _{21}Y \rightarrow [Ar]_{18}\ 4s^2\ 3d^1$

For d-block elements, group no = Total no. of e^- in $ns^2 + (n-1)d^{1-10}$

Range of valency = 1 to 3

eg 4 $Ti_{22} = [Ar]_{18}\ 4s^2\ 3d^2$

period: 4

Group: 4, subgroup: $\overline{IV}$ B

Valency: 2 to 4

eg 5 $V_{23} = [Ar]_{18}\ 4s^2\ 3d^3$

period: 4.

Group: 5, subgroup $\overline{V}$ - B

Valency: 3 to 5

valence e^-: 3, 5

eg 6 $Cr_{24} \rightarrow [Ar_{18}]\ 4s^2\ 3d^4$ ✗

1↓		1	1	1	1	
4s		3d				

[This violates [Hund's Rule' for maximum multiplicity.]**

energy of 3d > energy of 4s

incompletely filled 'd' orbital becomes less stable than half-filled d-orbital

Correct one:

$Cr_{24} \rightarrow [Ar_{18}]\ 4s^1\ 3d^5$

→ no. of unpaired e^- = 5

colourful.

1		1	1	1	1	1
4s		$3d^5$				

→ halffilled d orbital becomes more stable than incompletely filled d orbital

** According to Hund's rule of Maximum Multiplicity, half filled / fully filled orbital is more stable than incompletely filled orbitals.

* This can be explained with the help of Exchange Energy concept. [E ex] → This is the minimum amount of energy required to promote one electron from lower lying energy orbital to next higher energy orbital.

$$\boxed{E_{ex} \propto \frac{n(n-1)}{2}}$$

$n \rightarrow$ no. of unpaired e^-.

For Cr_{24} :

for d^4 system,

$$E_{ex} = k \cdot \frac{4(4-1)}{2} = 6k \text{ unit energy}$$

k → proportionality constant.

for d^5 system,

$$E_{ex} = k\frac{(5-1)5}{2} = 10k \text{ unit energy}$$

This is comparitively more stable.

** eg 7 $_{29}Cu$ — $[Ar]_{18}\ 4s^2\ 3d^9$ ✗ → no unpaired e^- present since it's diamagnetic.

Correct configuration — $[Ar]_{18}\ 4s^1\ 3d^{10}$

we take 1 e^- from 4s as its energy is less than 3d

colourless

(cuprous) Cu^+ — $[Ar]_{18}\ 4s^0\ 3d^{10}$

(cupric) Cu^{++} — $[Ar]_{18}\ 4s^0\ 3d^9$

deep blue colour

↑↓ | ↑↓ | ↑↓ | ↑↓ | ↑ → unpaired e^- (paramagnetic)

In case of fully filled orbital, there is no scope for any electronic transition.

∴ $\boxed{\text{shows no colour.}}$

DIAMAGNETIC : colourless (no unpaired e^-)
PARAMAGNETIC : colourful (unpaired e^-)

$Mn \rightarrow [Ar_{18}] 4s^2\ 3d^5$

25 block : d - block
period : 4
Group : 7

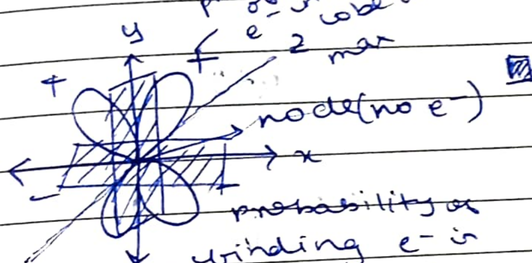
$\boxed{\uparrow\downarrow}_{4s^2}$ $\boxed{\uparrow|\uparrow|\uparrow|\uparrow|\uparrow}_{3d^5}$

PARAMAGNETIC due to unpaired e^-.

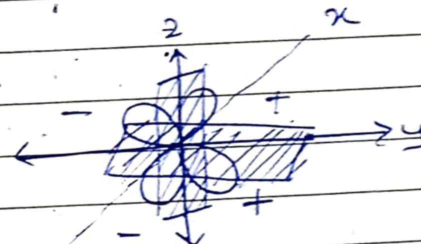
SHAPE OF D-ORBITAL :

d_{xy}	d_{yz}	d_{zx}	$d_{x^2-y^2}$	d_{z^2}
t_{2g}			e_g	

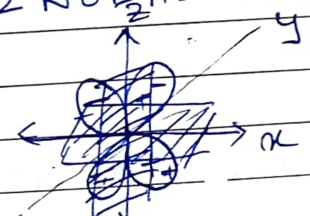
g → gyrad (energy level)
spherically symmetrical ← s → sharp
elliptical ← p → principle
double dumble ← d → diffuse
complex ← f – fundamental



d_{xy}
(2 NODAL PLANE)

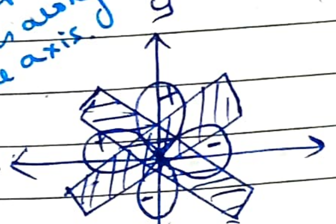


d_{yz}
(2 NODAL PLANE)

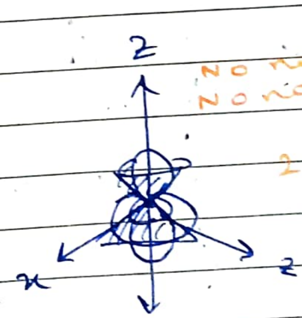


d_{xy}, d_{yz}, d_{zx} → Triplet set doubly filled gyrad. (t_{2g})

Exception: d_{zx}
lobes along the axis.



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



~~No node~~
No nodal plane
2 nodal cones

$3d_{z^2}$

equatorial gyrad (e_g)

$_6C$ $1s^2 2s^2 2p^2$ $_7N \rightarrow 1s^2 2s^2 2p^3$

$_{19}K - [Ar]_{18}\ 4s^1$

$\boxed{1\!\downarrow}\ \boxed{1\!\downarrow}\ \boxed{1\ |\ 1\ |\ \ }$
$2p_x\ 2p_y\ 2p_z$

① ~~Why does~~ the energy of 3d level is greater than 4s

This can be explained by Bohr-Bury's rule or $(n+l)$ rule

According to this

ans $E_{3d} > E_{4s}$

$(n+l) = 3+2 = 5$ ✓ $(n+l) = 4+0 = 4$

Then ~~why does~~ the energy of 4p greater than that of 3d?

$E_{4p} > E_{3d}$

$(n+l) = 4+1 = 5$ ✓ $3+2 = 5$

for 4p, Value of n > than that of 3d

AufBau Principle:

Maximum no. of electrons present in a Subshell

$= \boxed{2(2l+1)}$

Such as – for s-orbital, Maxi. no. of electrons $= 2(2\times0+1) = 2$

p " " " $= 2(2\times1+1) = 6$

d " " " $= 2(2\times2+1) = 10$

f " " " $= 2(2\times3+1) = 14$

Pauli's Exclusion Principle
No two e⁻'s can've same quantum no..

Find the value of all quantum no.s of 37th electron in Rubidium?

$_{37}Rb \rightarrow [Kr]_{36}\, 5s^1$

$n = 5$
$l = 0$
$m_l = 1 \rightarrow (2l+1) = 1$
$m_s = +\frac{1}{2}$

Extra stability of Completely Filled and Half-filled Orbitals

Electronic configuration of such elements are given below

- $Cr_{24} - [Ar]_{18}\, 4s^1 3d^5$

d block
- $Nb_{41} - [Kr]_{36}\, 4d^4 5s^1$

d block
- $Ru_{44} - [Kr]_{36}\, 4d^7 5s^1$

d block
- $Pd_{46} - [Kr]_{36}\, 4d^{10} 5s^0$

d block
- $La_{57} - [Xe]_{54}\, 4f^0 5d^1 6s^2$

d block element
- $Au_{79} - [Xe]_{54}\, 4f^{14} 5d^{10} 6s^1$

"
- $Cu_{29} - [Ar]_{18}\, 3d^{10} 4s^1$

"
- $Mo_{42} - [Kr]_{36}\, 4d^5 5s^1$

"
- $Rh\text{-}45 \rightarrow [Kr]_{36}\, 4d^8 5s^1$
- $Ag\text{-}47 \rightarrow [Kr]_{36}\, 4d^{10} 5s^1$
- $Pt\text{-}78 \rightarrow [Xe]_{54}\, 4f^{14} 5d^9 6s^1$

a node : It is a region of space where the probability of finding electron is zero ($\psi^2 = 0$)

Types of Nodes

- Radial nodes
- Angular nodes

Radial node - These are the point at some distance from the nucleus where the probability of finding e^- is 0.

$\boxed{\text{No. of radial nodes} : (n-l-1)}$

Angular node - These are associated to p - & d- orbitals (direction property). s orbitals are spherically symmetrical & hence it is non-directional & it cannot have angular node.

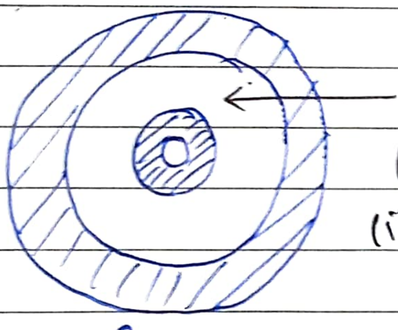
$\boxed{\text{no. of angular nodes} = l}$

Total no. of nodes = Radial nodes + Angular nodes

$= n - \cancel{l} - 1 + \cancel{l}$

$= n - 1.$

1)



2s

(i) Angular node = $l = 0$

(ii) Radial node = $n - l - 1$

$= 2 - 0 - 1$

$= 1$

(iii) Total nodes = $n - 1 = 1$

2)

1s

(i) Angular node = $l = 0$

(ii) Radial node = $n - l - 1$

$= 1 - 0 - 1 = 0$

(iii) Total nodes = $n - 1 = 0$

μ

spin Magnetic Moment (μ) - of 2 opposite spin electrons cancel each other making net magnetic moment = 0 for paired e^- (d^{10})

$$\boxed{M(\mu) = \sqrt{n(n+2)}\ BM}$$

→ units of magnetic moment in Bohr ~~Ez~~ Magneton

8) An ionic species has $M(\mu) = \sqrt{35}$ B.M, find the no. of unpaired e^- present in it.

$$\sqrt{n(n+2)} = \sqrt{35}$$

$$n^2+2n-35=0 \qquad n^2+7n-5n-35=0$$

$$\cancel{n(n+7)-7(n+5)=0} \qquad n(n+7)-5(n+7)=0$$

$$(n-5)(n+7)=0$$

$$n=+5,\quad n=-7$$

neglecting -ve sign the no. of unpaired $\bar{e}$ is 5

$_{25}Mn \rightarrow [Ar]_{18}\, 4s^2\, 3d^5$

$Mn^{2+} \rightarrow [Ar]_{18}\, 4s^0\, 3d^5$

↑	↑	↑	↑	↑
$3d_{xy}$	$3d_{yz}$	$3d_{zx}$	$3d_{x^2-y^2}$	$3d_{z^2}$

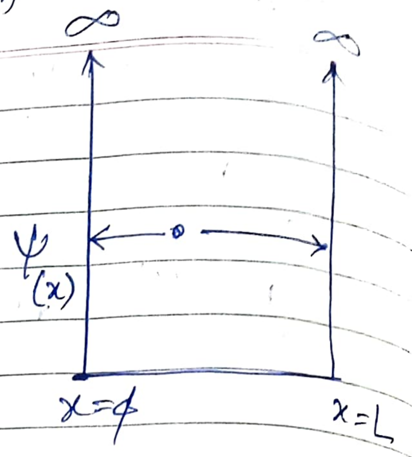
General wave function

$i = \sqrt{-1}$

$i^2 = (-1)^{1/2 \times 2}$

$$\boxed{\psi_{(x)} = A \sin \frac{2\pi x}{\lambda}}$$

If we'll consider a particle in 1 Dimensional box



On differentiating we'll get

$$\frac{\partial^2 \psi}{\partial x^2} = -\frac{4\pi^2}{\lambda^2}\psi$$

$$\frac{1}{\lambda^2} = -\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{1}{4\pi^2 \psi} \qquad \left[\because \lambda = \frac{h}{mv}\right]$$

or

$$\frac{m^2 v^2}{h^2} = -\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{1}{4\pi^2 \psi}$$

$$m^2 v^2 = -\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{h^2}{4\pi^2 \psi}$$

$$2m\,K.E = -\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{h^2}{4\pi^2 \psi}$$

$$\boxed{K.E = -\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{h^2}{8\pi^2 m \psi}}$$

Total Energy = K.E + PE

$$E_T = \frac{-\partial^2 \psi}{\partial x^2} \cdot \frac{h^2}{8\pi^2 m \psi} + U(PE)$$

$$-\frac{\partial^2 \psi}{\partial x^2} \cdot \frac{h^2}{8\pi^2 m \psi} = E_T - U$$

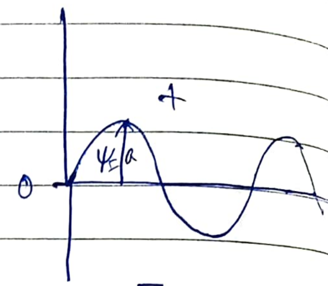
$$-\frac{\partial^2 \psi}{\partial x^2} = \frac{8\pi^2 m \psi}{h^2}(E_T - U)$$

1D $\rightarrow$ $$\frac{\partial^2 \psi}{\partial x^2} + \frac{8\pi^2 m \psi}{h^2}(E_T - U) = 0$$

Probability density of $e^{\ominus}$

$$|\psi_{(x)}|^2 = \psi^*_{(x)} \psi_{(x)}$$

never be imaginary



if $\psi_{(x)} = a + ib$

where $i = \sqrt{-1}$ (imaginary quantity)

& a, b are two real function

if its complex conjugate be $\psi_{(x)} = a - ib$

then probability density will be $|\psi_{(x)}|^2 = (a+ib)(a-ib)$

$= a^2 - aib + aib - i^2b^2$

$|\psi_{(x)}|^2 = a^2 + i^2 b^2$

$i^2 = (\sqrt{-1})^2 = -1$

$= a^2 - b^2$

$\frac{1}{2}mv^2 = K.E$
$m^2v^2 = 2m\,K.E$

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Schrödinger wave equation is based on wave model or quantum model. This model describes e^- or 3 dimentional wave model in the e^- field of +vely charged nucleus.

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2} + \frac{8\pi^2 m_e}{h^2}(E - V)\psi = 0$$

ψ = wave function representation of an orbital as well as an electron in 3d. → (Probability approach)

Q. The frequency of radiation emitted when the electron falls from $n = 4$ to $n = 1$ in a hydrogen atom will be (Given ionization energy of $H = 2.18 \times 10^{-18}$ J atom^{-1}) and $h = 6.625 \times 10^{-34}$ Js)

(1) $1.54 \times 10^{15}\ s^{-1}$ (2) $1.03 \times 10^{15}\ s^{-1}$ (3) $3.08 \times 10^{15}\ s^{-1}$
(4) $2.00 \times 10^{15}\ s^{-1}$.

Given
$n_1 = 1$
$n_2 = 4$

for H atom
$(Z = 1)$

$$E_{4\to 1} = +2.18 \times 10^{-18} J \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= +2.18 \times 10^{-18} J \left(1 - \frac{1}{16}\right)$$

$$h.\nu = +2.18 \times 10^{-18} \frac{J}{s} \times \frac{15}{16}$$

$$\nu = +\frac{2.18 \times 10^{-18} \times 15}{6.625 \times 10^{-34} \times 16}\ s^{-1}$$

$$= 3.08 \times 10^{15}\ s^{-1}$$

Ans: Option (3)