Electromagnetic spectrum:-

V I B G Y O R

cosmic rays	γ rays	X rays	UV		IR	micro wave	radio wave
most dangerous			400 ($\approx$380 nm)		700 nm		

$E\uparrow \ \lambda\downarrow$ $\quad$ $E\downarrow \ \lambda\uparrow$

$\longrightarrow \lambda\uparrow$

$\longleftarrow$

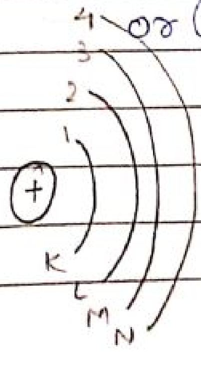
Bohr's atomic model:

- it is based on classical quantum physics and is applicable for uni-electron species. (like, hydrogen, He^+, Li^{+2}). Following are the main postulates of this model:

I) electrons are moving in circular path namingly ORBITS.

II) this orbits are called STATIONARY ORBIT, each orbit having fixed energy.

III) the energy levels are represented by an integer called QUANTAM NO. (where n = 1, 2, 3, 4 or K, L, M, N, respectively).



G x पर देखा I M Radio.

Gama ray, x-ray, ultra (UV), visible, infrared ray (IR)

IV) when electron revolve around nucleus then centripetal force ~~क्षतिपूर्ति~~ compensate the force of attraction.

centripetal force = attracted force.

$$\boxed{\frac{mv^2}{r} = \frac{Kze^2}{r^2}} \text{ — eq (1)}$$

K = coulomb constant (9×10^9)

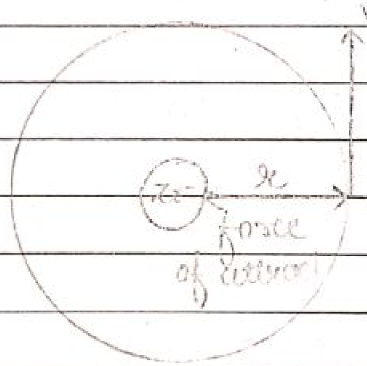
v = velocity of e^-

z = atomic no.

m = mass

r = distance b/w nucleus & shell (radius)

e = charge. (1.6×10^{-19}C)



V) electrons move in (only) those orbits having angular momentum (mvR) and integer value of $\frac{h}{2\pi}$.

here;

$$\boxed{mvr = \frac{nh}{2\pi}} \text{ — eq (2)}$$

here; n = 1, 2, 3 $\Longrightarrow \frac{h}{2\pi}; \frac{h}{\pi}; \frac{3h}{2\pi}$ $\left(\frac{x\,h}{2\pi}\right)$

vi) when electron jump from lower energy level (lower orbit) to higher energy level (higher orbit) it absorbs the energy while, if electron move from higher orbit to lower it emits the energy.

$$\boxed{\Delta E = \underbrace{E_f}_{\text{final energy}} - \underbrace{E_I}_{\text{initial energy}}}$$

$\Delta E = +ve = $ absorb

$\Delta E = -ve = $ emit

* nucleus से जितना दुर उतनी energy ज्यादा

↪ loss of energy or gain of energy by an electron in the form of EMR (quanta / quantum).

⇛ Application:

(a) velocity of an electron in orbit :-

⟹ from eq(1);

$$\frac{mv^2}{r} = \frac{Kze^2}{r^2}$$

$$\Longrightarrow \boxed{mv^2 r = Kze^2} \text{ — eq(3)}$$

comparing with eq(2);

$$\frac{\cancel{m}v^2\cancel{r}}{\cancel{mvr}} = \frac{Kze^2 \cdot 2\pi}{nh}$$

#imp ⟹ $$\boxed{V = \frac{Kze^2 \cdot 2\pi}{nh}} \text{ — eq(4)}$$

* $V = 2.186 \times 10^6 \left(\frac{Z}{n}\right)$ m/sec.

$\frac{V_1}{V_2} = \frac{Z_1}{Z_2} \times \frac{n_2}{n_1}$

Q:14 find velocity of an electron (hydrogen) moving in third orbit.

$\Rightarrow$ $V = 2.186 \times 10^6 \left(\frac{1}{3}\right)$

absorb
emit

$\longrightarrow 0.728 \times 10^6$

$\underline{7.28 \times 10^5}$

Q:15 what is the ratio of speeds of electrons in 1st orbit of H-atom and 4th orbit of He^+-ion.

$\Rightarrow$ $\frac{V_1}{V_2} = \frac{Z_1}{Z_2} \times \frac{n_2}{n_1}$

$\frac{V_1}{V_2} = \frac{1}{\cancel{2}} \times \frac{\cancel{4}^{\,2}}{1}$ $\therefore$, $\underline{2:1}$.

Q:16 if velocity of electron in first orbit of atom-H is 2.18×10^6 m/s, what is its value in third orbit?

$\Rightarrow$ $\frac{V_1}{V_2} = \frac{Z_1}{Z_2} \times \frac{n_2}{n_1}$

$\frac{2.18 \times 10^6}{V} = \frac{1}{1} \times \frac{3}{1}$

$V = \frac{2.18 \times 10^6}{3} \longrightarrow \underline{7.27 \times 10^6 \text{ m/s}}$

(b) calculation of radius of Bohr's orbit :-

$\Longrightarrow$ from eq(1);

$$\Longrightarrow \boxed{v^2 = \frac{kze^2}{mr}} \text{ —— } eq(5)$$

put the value of eq (4) in here;

$$\frac{2\pi kze^2}{nh} = \frac{kze^2}{mr}$$

$$\Longrightarrow \boxed{\frac{4\pi^2 k^2 z^2 e^4}{n^2 h^2} = \frac{kze^2}{mr}}$$

$$\longrightarrow \frac{4\pi^2 kze^2}{n^2h^2} = \frac{1}{mr}$$

#imp

$$\Longrightarrow \boxed{r = \frac{n^2 h^2}{4\pi^2 kze^2 \cdot m}} \text{ —— } eq(6)$$

$$* \boxed{r = 0.0529 \times \frac{n^2}{Z} \text{ nm}}$$

nanometre

$$\text{also, } \boxed{r = 0.529 \frac{n^2}{Z} \; A^{o}}$$

angstrom

$$\boxed{\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \times \frac{Z_2}{Z_1}}$$

$V = \frac{2\pi r}{T}$ (time p).

$T = \frac{2\pi r}{v} \quad \left(\because r = \frac{n^2}{Z} \;\&\; v = \frac{Z}{n} \right)$

$$T = \frac{\frac{n^2}{Z}}{\frac{Z}{n}} = \frac{n^3}{Z^2}$$

$$\therefore \frac{T_1}{T_2} = \frac{n_1^3}{Z_1^2} \times \frac{Z_2^2}{n_2^3}$$

Q:17 the ratio of radii of second orbits of He^+, Li^{2+} and Be^{3+}:

$\Rightarrow$ $r = 0.0529 \frac{n^2}{Z}$ nm.

$\Rightarrow He^+ : Li^{2+} : Be^{3+}$.

$\frac{1}{2} : \frac{1}{3} : \frac{1}{4} \longrightarrow \underline{\underline{6 : 4 : 3}}$

LCM = 12

$\Rightarrow \frac{6 : 4 : 3}{12}$.

Q:18 if radius of 1^{st} orbit of hydrogen atom is 0.53 Å then radius of 1^{st} orbit of He^+ is?

$\Rightarrow \frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \times \frac{Z_2^2}{Z_1^2}$

$\frac{0.53}{x} = \frac{1}{1} \times \frac{2}{1}$ $\therefore He^+ = \underline{0.265 Å}$

Q:19 difference in angular momentum associated with electron in two successive orbits of hydrogen atom is:

$\Rightarrow mvr = \frac{nh}{2\pi}$

$= \frac{h}{\pi} - \frac{h}{2\pi} \longrightarrow \frac{h}{\pi}\left(1 - \frac{1}{2}\right)$

$\longrightarrow \frac{h}{\pi}\left(\frac{2-1}{2}\right) \longrightarrow \frac{h}{\pi}\left(\frac{1}{2}\right) \Rightarrow \boxed{\frac{h}{2\pi}}$

$v = \frac{Z}{n})$

(c) Calculation of energy of electron :-

$$E = KE + PE$$

$$= \frac{1}{2} mv^2 + \frac{Kze^2}{r}$$

$$= \frac{1}{2} mv^2 + \frac{Kze(-e)}{r}$$

b'coz 2 diff. charge e⁻.

$$E. = \frac{1}{2} mv^2 - \frac{Kze^2}{r}$$

put the value of mv^2 from eq (1)

$$\longrightarrow E = \frac{Kze^2}{2r} - \frac{Kze^2}{r}$$

$$\boxed{E = -\frac{Kze^2}{2r}} \text{ — eq (7)}$$

put the value of 'r' from eq(6)

$$\longrightarrow E = -\frac{Kze^2}{2 \times \left[\frac{n^2h^2}{4\pi^2 Kze^2 \cdot m}\right]}$$

$$E = -\frac{Kze^2}{\cancel{2}} \times \frac{\overset{2}{\cancel{4}}\pi^2 Kze^2 \cdot m}{n^2h^2}$$

eq(8) — $\boxed{E = \frac{-2K^2z^2e^4\pi^2 \cdot m}{n^2h^2}}$ or $\frac{-2\pi^2K^2z^2e^4m}{n^2h^2}$

$$E = \frac{-2\pi^2 (Kze^2)^2 \cdot m}{n^2h^2}$$

$E = \frac{-Kze^2}{2r}$ $KE = \frac{Kze^2}{2r}$ $PE = \frac{-Kze^2}{r}$

* Relation between E (total energy) & KE (kinetic):

$$E = -KE \quad \text{or} \quad -E = KE.$$

* Relation between E (total energy) & PE (potential):

$$2E = PE \quad \text{or} \quad E = \frac{PE}{2}$$

* Relation between KE (kinetic) & PE (potential):

$$2KE = -PE. \quad \text{or} \quad -2KE = PE$$

$$KE = \frac{-PE}{2}$$

* Relation between E_f (final energy) & E_i (initial e):

$\boxed{\Delta E = E_f - E_i}$ → energy absorbed or emitted by an e^- can be calculated by it.

$$\Delta E = \frac{-13.6\, z^2}{n_f^2} - \left[\frac{-13.6\, z^2}{n_i^2}\right]$$

$$\boxed{\Delta E = 13.6\, z^2 \left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right] \text{ eV/atom}}$$

putting each constant's value in eq(8): $\boxed{E = -13.6 \frac{z^2}{n^2} \text{ eV/atom.}}$ — eq(9)

$\boxed{E = -2.18 \times 10^{-18} \frac{z^2}{n^2} \text{ J/atom.}}$ — eq(10)

* Ground state of an electron:

for H ⟶ $n = 1$

for He ⟶ $n = 2$

* Excited state of an electron:

→ 1st excited state means $n = 2$.

→ 2nd excited state means $n = 3$.

→ 3rd excited state means $n = 4$.

excited state ⇒ $n = +1$

* Ionisation potential / energy / enthalpy:

→ energy required to remove an electron from ground state to infinite state.

$$\Delta E = 13.6 Z^2 \left(\frac{1}{n_i^2} - \frac{1}{n_f^2} \right)$$

here,

in the case of hydrogen (H).

$n_i = 1 \quad n_f = \infty.$

$$\Delta E = 13.6 \times (1)^2 \left(\frac{1}{(1)^2} - \frac{1}{(\infty)^2} \right)$$

$$\boxed{\because \frac{1}{\infty} = 0}$$

$$\boxed{\Delta E = 13.6 \text{ eV/atom}}$$

Q:20 how much energy of an electron should be absorbed when it moves from second excited state to fifth orbit?

when z not said than take H.

$\Rightarrow$ $H \Rightarrow z = 1$ $n_i = 3$ $n_f = 5$.

$$\Delta E = 13.6 \times (1)^2 \left[\frac{1}{9} - \frac{1}{25} \right]$$

$$= 13.6 \left[\frac{25-9}{225} \right] \longrightarrow 13.6 \left(\frac{16}{225} \right) \text{ ev/atom}$$

$$\Longrightarrow \frac{136}{10} \left(\frac{16}{225} \right) \longrightarrow \frac{2176}{2250} \Longrightarrow \underline{0.9}$$

Q:21 ratio of energies of hydrogen atom for first and second excited state is:

$$\Longrightarrow E = \frac{\frac{-13.6 z^2}{n_1^2}}{\frac{-13.6 z^2}{n_2^2}}$$

$$= -13.6 \left[\frac{\cancel{z_1}^2}{n_1^2} \times \frac{n_1^2}{\cancel{z_2^2}} \right] \quad \boxed{\frac{=9}{4}}$$

Q:22 in hydrogen atom, energy of first excited state is -3.4 eV. Then, KE of same orbit of hydrogen is:

$\Longrightarrow$ $E = -KE$.

$\cancel{-}3.4 = \cancel{-}KE$

$\underline{\underline{KE = 3.4 \text{ eV}}}$

Q:23 Match the following:

(I) energy of ground state He^+ — (a) 6.04 eV
(II) PE of 1st orbit of H-atom — (b) −27.2 eV
(III) KE of 2nd excited state of He^+ — (c) 54.4 eV
(IV) IP of He^+ — (d) −54.4 eV.

$\Longrightarrow$ (I) −54.4 eV $\left[\frac{-13.6 \times (4)}{1}\right]$

(IV) +54.4 eV.

(III) $-13.6 \times \frac{4}{9}$ $\Rightarrow \frac{54.4}{9}$

$\boxed{= 6.04 \text{ eV}}$

(II) PE = 2E

PE = 2(13.6)

PE = 27.2

Q: IP for H and He^+.

$E = 13.6 \times Z^2 \left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

$\Longrightarrow$ $H \rightarrow E = 13.6 \times (1)^2 \left(\frac{1}{(1)^2} - \frac{1}{(\infty)^2}\right)$

$\boxed{= 13.6 \text{ eV/atom}}$

$He^+ \rightarrow E = 13.6 \times (2)^2 \left[\frac{1}{(1)^2} - \frac{1}{(\infty)^2}\right]$

$\boxed{= 54.4 \text{ eV/atom}}$

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Q:24 find out the Kinetic energy and potential energy when electrons are available in 3rd exc. state.

$\Rightarrow$ $n = 4$.

$E = -13.6 \times \frac{1}{16}$ $\therefore KE = -E$

$= -(-8.5)$

$= \cancel{-8.5}\ -0.85$ $\therefore KE = 0.85$.

$\therefore 2KE = PE$.

$PE = 2(0.85)$ $\therefore P = \cancel{17.0}\ 1.7$

Q:25 write down the energy of an electron for ground state of hydrogen atom & Helium$^+$ ion.

$\Rightarrow$ $E_1 = -13.6 \times \frac{(1)^2}{(1)^2}$ $E_2 = -13.6 \times \frac{(2)^2}{(1)^2}$

$= -13.6$ ev/atom $= -54.4$ ev/atom

* Separation energy:

$\rightarrow$ electrons are removed from any atom ~~with~~ at any excited state.

here; $n > 1$

Q:26 find: Sep. energy of an electron available in 2nd excited state.

$\Rightarrow$ $E = 13.6 \times (1)^2 \left[\frac{1}{(3)^2} - \frac{1}{(\infty)^2}\right]$

$= \frac{13.6}{9} \longrightarrow 1.51$ ev

⟹ Limitations / Drawbracks of Bohr:

- He could not explain line spectra of atoms containing more than one electron.

- He also could not explain presence of multiple spectral lines.

- He was unable to explain splitting of spectral lines in magnetic field (zeeman effect) and in electric field (stark effect).

- No conclusion was given for principle of quantisation of angular momentum.

- He was unable to explain 'De-Broglie's' concept of dual nature of matter.

- He could not explain Heisenberg's uncertainity principle.

Hydrogen spectrum: (hydrogen line spectrum)

(hydrogen line spectrum)

- when an electric charge is applied on hydrogen gas at low pressure, blueish light is emitted due to excitation of hydrogen atoms electron.

- there are 3 possiblities during applied electric charge.

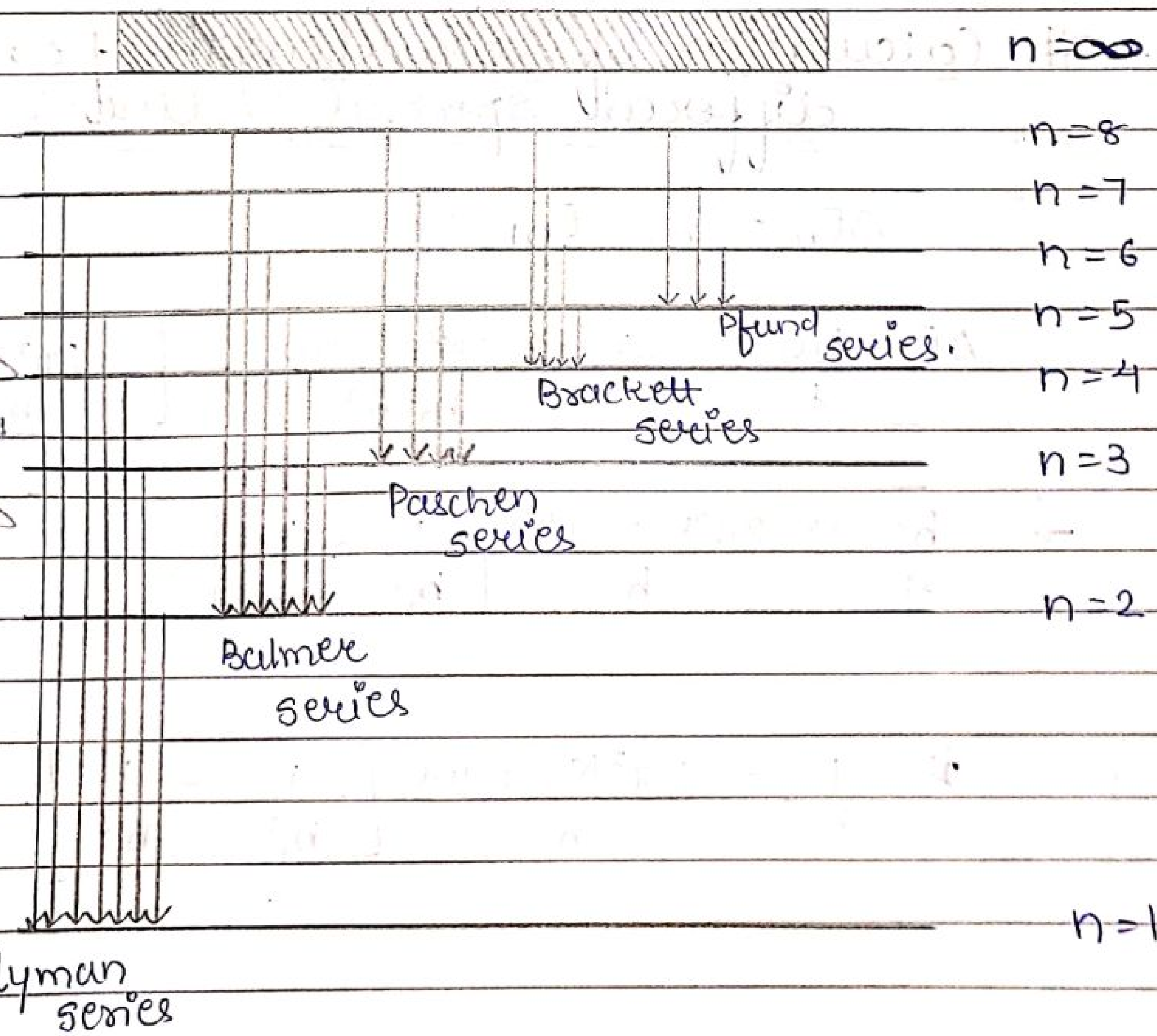
- H_2 gas $\longrightarrow$ $\underbrace{H_2}_{\text{molecule}} + \underbrace{H^+}_{e^-} + \underbrace{H + H}_{\text{atoms}}$.

- when this light is passed through a prism, a spectrum of different / several isolated sharp line is obtained.

- the wavelength of various lines show that spectrum line lie in $\underbrace{\text{UV}}_{\text{ultraviolet}}$; visible and $\underbrace{\text{IR}}_{\text{infrared rays}}$ region.
This lines are grouped into different series

- This different series can be shown by following:

Line Spectrum of Hydrogen



Spectral lines series	Region	n_1	n_2
Lyman series	UV	1	2, 3, 4, ... ∞
Balmer series	visible	2	3, 4, 5, ... ∞
Paschen series	IR	3	4, 5, 6, ... ∞
Brackett series	IR	4	5, 6, 7, ... ∞
Pfund	IR	5	6, 7, 8 .... ∞
Humphery	IR	6	7, 8, 9 .... ∞

Calculation of wavelength for different spectral lines:

Rydberg constant

$$\boxed{\Delta E_n = E_{n_2} - E_{n_1}}$$

$$\Delta E = \frac{hc}{\lambda} \Longrightarrow -\frac{2\pi^2 K^2 z^2 e^4 m}{n_2^2 h^2} - \left[-\frac{2\pi^2 K^2 z^2 e^4 m}{n_1^2 h^2}\right]$$

$$\rightarrow \frac{hc}{\lambda} = \frac{2\pi^2 K^2 z^2 e^4 m}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\bar{\nu} = \frac{1}{\lambda} = \frac{2\pi^2 K^2 z^2 e^4 m}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

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$$\Longrightarrow \bar{\nu} = \frac{1}{\lambda} = \boxed{Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)cm^{-1}}$$

Here;

$R =$ Rydberg constant $\longrightarrow \frac{2\pi^2 K^2 e^4 m}{eh^3} = \boxed{109677\ cm^{-1}}$

$$\frac{1}{R} = \frac{1}{109677} \Longrightarrow \boxed{913\ A^\circ}$$

Q:27 find wavelength for 1^{st} and last line of lyman series.

$\frac{1}{\infty} = 0.$

$\Longrightarrow n_1 = \cancel{1} \quad n_2 = \infty. \quad z = 1$

for ~~first~~ last line of lyman series:

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

$$= (109677)(1)^2\left[\frac{1}{(1)^2} - \frac{1}{(\infty)^2}\right]$$

$$\frac{1}{\lambda} = 109677\left[\frac{1}{1}\right]$$

$\therefore$ wavelength $= 1/R$ or 109677

for first line;

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

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

$$= R\left(\frac{1}{1} - \frac{1}{4}\right)$$

$$= R\left(\frac{4-1}{4}\right)$$

$\therefore \frac{1}{\lambda} = \frac{3R}{4}$ or $\lambda = \frac{4}{3R} \rightarrow \frac{4}{3} \times 913\ \text{Å}$

λ_{max} and λ_{min} for diff. spectral series:

$\Rightarrow$ for Lyman series

$\lambda_{max} \Rightarrow n_2 = 2$

for Lyman series

$\lambda_{min} \Rightarrow n_2 = \infty$

$\Rightarrow$ for Balmer series

$\lambda_{max} \Rightarrow n_2 = 3$

for Balmer series

$\lambda_{min} \Rightarrow n_2 = \infty$

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Q:28 find λ_{max} and λ_{min} for Balmer series?

$\Rightarrow$ $$\frac{1}{\lambda_{max}} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$ $\underline{\underline{z=1}}$

$$\frac{1}{\lambda_{max}} = Rz^2\left(\frac{1}{(2)^2} - \frac{1}{(3)^2}\right)$$

$$= R\left(\frac{9-4}{36}\right)$$ $\therefore \lambda_{max} = \frac{36}{5R}.$

$$\frac{1}{\lambda_{min}} = Rz^2\left(\frac{1}{(2)^2} - \frac{1}{(\infty)^2}\right)$$

$$\frac{1}{\lambda_{min}} = R\left(\frac{1}{4} - 0\right)$$ $\therefore \lambda_{min} = \frac{4}{R}.$

Q:29 maximum wave length ratio for Lyman and Paschen series.

$\Rightarrow$ $$\frac{1}{\lambda_{max}} = Rz^2\left(\frac{1}{(1)^2} - \frac{1}{(2)^2}\right)$$

$$= R\left(\frac{1}{1} - \frac{1}{4}\right)$$

$\therefore \lambda_{max} = \frac{4}{3R}$ (lymann)

$$\frac{1}{\lambda_{max}} = RZ^2\left(\frac{1}{(3)^2} - \frac{1}{(4)^2}\right)$$

$$= R\left(\frac{1}{9} - \frac{1}{16}\right)$$

$$\therefore \lambda_{max} = \frac{144}{7R} \quad \text{(Paschen).}$$

$$\therefore \frac{\text{Lyman}}{\text{Paschen}} \Longrightarrow \frac{\frac{4}{3R}}{\frac{144}{7R}} \Longrightarrow \frac{\cancel{4}}{3\cancel{R}} \times \frac{7\cancel{R}}{\cancel{144}_{36}} \Longrightarrow \boxed{\frac{7}{108}}$$

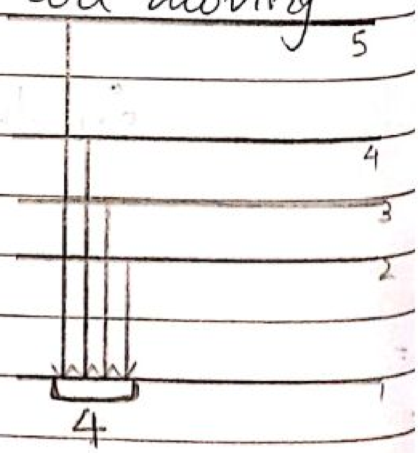
Calculation of Spectral Line:

(1.) No. of spectral line from n^{th} orbit → for single Hydrogen atom:

→ it can be calculated by $\boxed{(n-1)}$

eg: how much no. of sp. lines should be produced by an e⁻ (single atom) which are moving upto ~~fifth~~ orbit.

$\Longrightarrow (n-1) \longrightarrow (5-1) = \underline{\underline{4}}$.

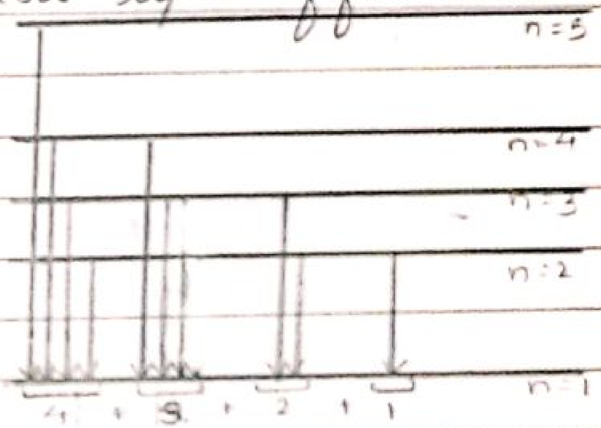


(II.) No. of spectral line from 'nth' energy level → to ground level:

(multi-atoms)

→ it can be calculated by $\boxed{\frac{n(n-1)}{2}}$

Q: find no. of total spectral lines may be generated if hydrogen atoms available upto fifth orbit. (multi-H-atom).



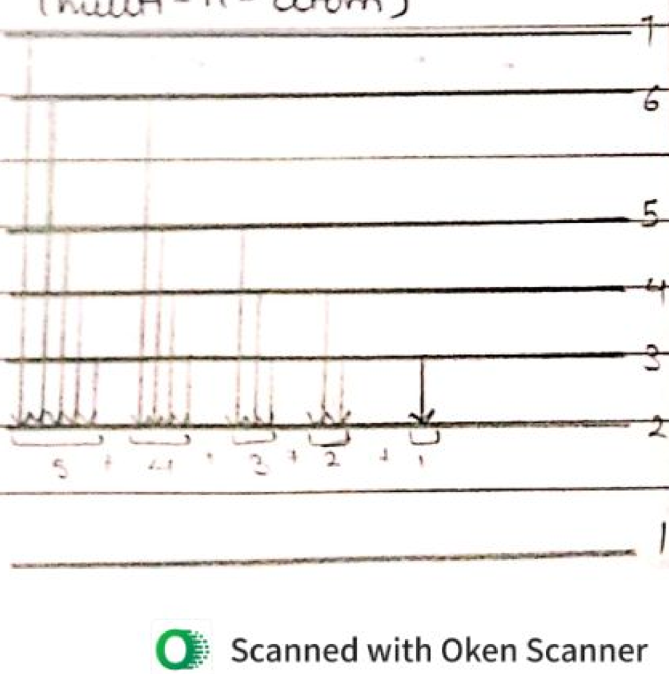
$\Rightarrow \frac{n(n-1)}{2}$

$\rightarrow \frac{5(\cancel{4}^{2})}{\cancel{2}}$ ∴, no. of s.line $= \underline{10}$

(III.) No. of spectral line from n_2 level to n_1 level:

→ $\boxed{\frac{(n_2-n_1)(n_2-n_1+1)}{2}}$: (multi hydrogen atom)

Q: no. of spectral line generated if electron move 7th orbit to second (2nd) orbit. (multi-H-atom)



$\Rightarrow \frac{(7-2)(7-2+1)}{2}$

$\frac{(5)(\cancel{6}^{3})}{\cancel{2}} \Rightarrow \underline{\underline{15}}$

∴, no. of s.line $= \underline{\underline{(15)}}$