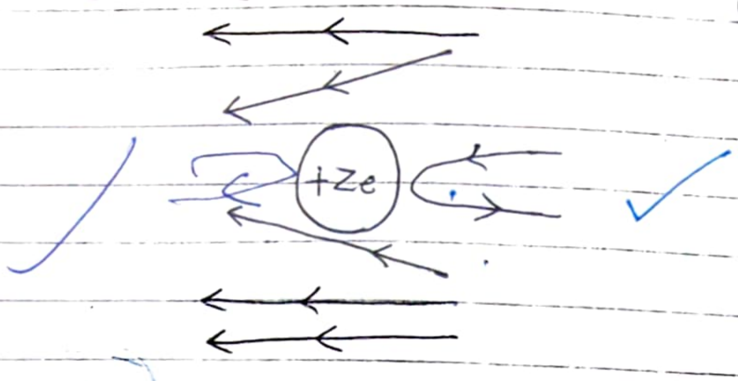
Devangi

Ch- Atoms

Rutherford / Geiger marsden / α- scattering experiment

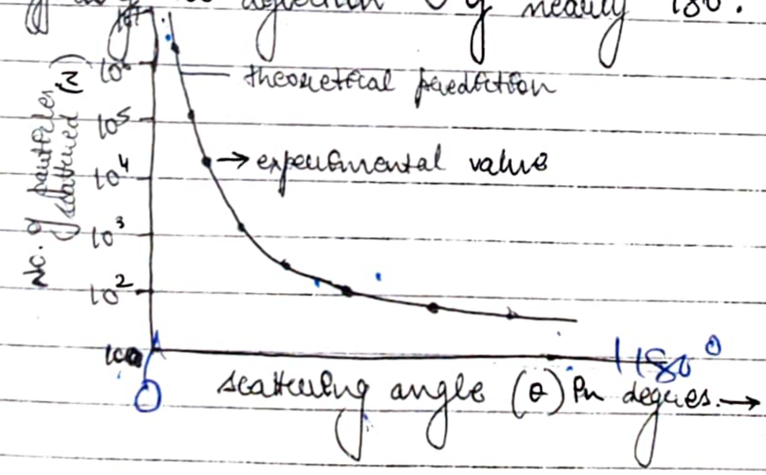


Observations

1. Most of the α- particles pass straight through the gold foil or suffer only small deflections. (1)

2. A few α- particles, about one in 8000 get deflected by 90° or more.

3. Occasionally, an α- particle gets rebounded from the gold foil suffering a deflection of nearly 180°.



(2)

Significance / Results

1. As most of the α- particles went straight through the foil, thus most of the space is empty inside the atom.

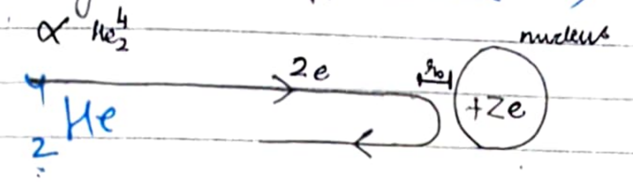
2. To explain large scattering of α- particles, Rutherford suggested

that all the positive charge and mass of atom is concentrated in a very small region called the nucleus of the atom.

3. The nucleus is surrounded by a cloud of e- whose total -ve charge is equal to total +ve charge on the nucleus so that the atom as a whole is electrically neutral.

Distance of closest approach (r_0)

$^{A}_{Z}X$



Ze

Law of conservation of energy

$$KE = PE$$

$$\frac{1}{2}mv^2 = W$$

$$\frac{1}{2}mv^2 = qV$$

$V = \frac{W}{q}$

$W = qV$

$$\frac{1}{2}mv^2 = 2e\left[\frac{Kq}{r}\right]$$

$V = \frac{Kq}{r}$

$$\frac{1}{2}mv^2 = 2e\left[\frac{1}{4\pi\varepsilon_0}\frac{Ze}{r_0}\right]$$

$\frac{1}{4\pi\varepsilon_0}\frac{2e}{r_0}$

$$\boxed{r_0 = \frac{1}{4\pi\varepsilon_0}\frac{4Ze^2}{mv^2}}$$

→ depends inversely on velocity.

Rutherford model of an atom

1. An atom consists of small and massive central core in which the entire +ve charge and almost the whole mass of the atom are concentrated. This core is called nucleus.

2. The size of nucleus ($\approx 10^{-15}$ m) is very small as compared to the size of the atom ($\approx 10^{-10}$ m).

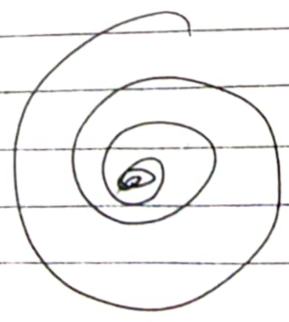
3. The nucleus is surrounded by a suitable number of electrons so that their total -ve charge is equal to the total +ve charge on the nucleus and the atom as a whole is electrically neutral.

4. The e^-s revolve around the nucleus in various orbits just as planets revolve around the sun. The centripetal force required for their revolution is provided by the electrostatic attraction b/w the e^-s and the nucleus.

Limitation

1. Acc. to electromagnetic theory, an accelerated charged particle must radiate electromagnetic energy. An e^- revolving around the nucleus is under continuous acceleration towards the centre. It should continuously lose energy and move in orbits of gradually decreasing radii. The e^- should follow a spiral path and finally it should collapse into the nucleus. Thus the Rutherford's model cannot explain the stability of an atom.

2. As the e^-s spiral inwards, they would emit a continuous spectrum instead of actually observed line spectrum.



Page No.
Date

Bohr's theory of H-atom

Bohr's postulate

1. Electrons are revolving around nucleus in a fixed orbit. These orbits are called stationary orbits. Energy of e⁻s in these orbits is always fixed.

2. Angular momentum of e⁻ in a particular orbit is integral multiple of $\frac{h}{2\pi}$.

$$L = \frac{nh}{2\pi}$$

$L = p \times r$
$L = mvr$

where L = angular momentum
n = integer ; principle quantum no.
$L = mvr$

$$\boxed{mvr = \frac{nh}{2\pi}} \quad ; n = 1, 2, 3 \ldots$$

3. Energy transaction will take place when e⁻ jumps either from lower to higher or higher to lower orbit which is expressed as —

$$\boxed{E_i - E_f = h\nu}$$

E_i → energy of initial orbit; E_f → energy of final orbit.

Prove that circumference of orbit in which e⁻ is revolving is integral multiple of de broglie's wavelength using Bohr's postulate.

$$2\pi r = \frac{2\pi nh}{2\pi mv}$$

$$= n\left(\frac{h}{mv}\right)$$

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

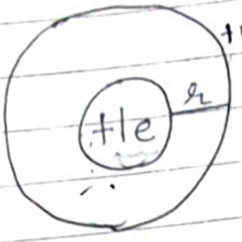
P.T.O

$\boxed{2\pi r = n\lambda}$ $\left(\because \lambda = \frac{h}{mv}\right)$

Bohr's theory of H-atom

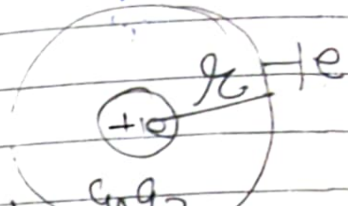
Consider an e^- of mass 'm', charge 'e' is moving around nucleus.

^1_1H



^1_1H

$q_1 = e$
$q_2 = e$



Since e^- is moving in circle,

$$F = \frac{mv^2}{r} \quad -(1)$$

$f = k\frac{q_1q_2}{r^2}$

$f = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

Electrostatic force b/w e^-s and proton

$$F = \frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r^2} \quad -(2)$$

Centripetal force
The force required to move a body in circle

comparing (1) and (2),

$$\frac{mv^2}{\cancel{r}} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^{\cancel{2}}} \quad -(3)$$

Using Bohr's postulate

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

$$v = \frac{nh}{2\pi} \times \frac{1}{mr} \quad -(4)$$

Put (4) in (3),

$$\cancel{m}\left[\frac{n^2h^2}{4\pi^2m^{\cancel{2}}r^{\cancel{2}}}\right] = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{\cancel{r}}$$

$$\frac{n^2h^2 4\pi\varepsilon_0}{4\pi^2 me^2} = r$$

Page No.
Date

$$r = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2} \longrightarrow A$$

$$\boxed{r \propto n^2}$$

$$\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2}$$

$$r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}$$

for I^{st} orbit $n = 1$,

$$r_1 = \frac{h^2 \varepsilon_0}{\pi m e^2}$$

$$\boxed{r_1 = 5.29 \times 10^{-11}\ m}$$

Ques. What is ratio of radii of ground and I^{st} excited state?

Sol^n grounded $n = 1$

I^{st} excited $n = 2$

$r_1 \propto 1^2$

$r_2 \propto 2^2$

$$\frac{r_1}{r_2} = \frac{1}{4}$$

$$\boxed{\begin{aligned} r_2 &= 4r_1 \\ r_3 &= 9r_1 \\ r_4 &= 16r_1 \end{aligned}}$$

$r \propto n^2$

$r_1 \propto 1^2$

$r_1 \propto 1^2$

$r_2 \propto 2^2 r_1$

$r_3 \propto 3^2 r_1$

$r_4 \propto 4^2 r_1$

Page No.
Date

Energy of electron in an orbit

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

$$K.E = \frac{1}{2} m v^2 \longrightarrow (5)$$

Put (3) in (5)

$$K.E = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{e^2}{r} \longrightarrow (6)$$

$$\left\{ \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} \right.$$

$$P.E. = W = qV$$

$$P.E. = -e\left[\frac{1}{4\pi\varepsilon_0}\frac{e}{r}\right]$$

$$P.E = -\frac{1}{4\pi\varepsilon_0}\left(\frac{e^2}{r}\right) \rightarrow (7)$$

$$T.E = K.E + P.E.$$

$$T.E = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{e^2}{r} - \frac{e^2}{4\pi\varepsilon_0 r}$$

$$T.E. = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}\left[\frac{1}{2} - 1\right]$$

Page No.
Date

$$T \cdot E = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{e^2}{r} \rightarrow (8)$$

$$K \cdot E = -T \cdot E.$$

$$P \cdot E = 2T \cdot E.$$

$$\boxed{K \cdot E + P \cdot E = T \cdot E}$$

Q. Energy of an ~~orbit~~ $\bar{e}$ in a particular orbit is $-13.6eV$. find K.E + P.E.

Ans
$$K \cdot E = -T \cdot E = \boxed{+13.6eV}$$

$$\boxed{P \cdot E = -27.2eV}$$

for total energy put (A) in (8)

$$T \cdot E = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{e^2 \pi m e^2}{n^2 h^2 \varepsilon_0}$$

$$T \cdot E = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\pi m e^4}{h^2 \varepsilon_0} \frac{1}{n^2} \rightarrow (9)$$

$$E \propto \frac{1}{n^2}$$

Page No.
Date

$$\boxed{E_n = -\frac{13.6}{n^2}\ eV}$$

Q1 What is energy of ground state $n = 1$?

Ans $E_1 = -13.6\ eV$

Q2 Energy of I excited $(n = 2)$

Ans $E_2 = -\frac{13.6}{4}\ eV$

Q3 How much is energy ratio when $\bar{e}$ jumps from ground to II excited.

Ans Ground $n = 1$
II excited $n = 3$

$$\boxed{\frac{E_1}{E_3} = \frac{9}{1}}$$

Page No.	
Date	

I permitted level $n=1$

II " " $n=2$

III " " $n=3$

Bohr's Hydrogen spectrum.

III postulate

$$E_i - E_f = h\nu.$$

$$E_i - E_f = \frac{hc}{\lambda}$$

$$-\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\pi m e^4}{h^2 \varepsilon_0 n_i^2} + \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\pi m e^4}{h^2 \varepsilon_0 n_f^2} = \frac{hc}{\lambda}$$

$$\frac{1}{\lambda} = -\frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\pi m e^4}{h^3 \varepsilon_0 c}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right].$$

$$\frac{1}{\lambda} = \frac{1}{2}\left(\frac{1}{4\pi\varepsilon_0}\right)\frac{\pi m e^4}{h^3 \varepsilon_0 c}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right).$$

$$\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$$

Where R → Rydberg const

$R = 1.09 \times 10^{7} m^{-1}$.

I) Lyman Series   Lyman lies in UV region

This is formed when $\bar{e}$ jumps from any of the higher to I orbit.

$n_f = 1$, $n_i = 2, 3, 4, 5$ — —

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

I member of Lyman

When $\bar{e}$ jumps from II orbit to I orbit

$n_f = 1$ $n_i = 2$

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right].$$

II member of Lyman.

When $\bar{e}$ jumps from III orbit

to I orbit

$n_f = 1 \qquad n_i = 3$

$$\frac{1}{\lambda} = R\left(\frac{1}{(1)^2} - \frac{1}{3^2}\right).$$

(shortest)

Short series of Lyman

When $\bar{e}$ jumps from infinity to I

$n_f = 1 \qquad n_i = \infty$

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

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

$$\boxed{\lambda_{\text{Lyman short}} = \frac{1}{R}}$$

Lyman series lie in UV region

II. Balmer series

This is formed when $\bar{e}$ jumps from any of the higher orbit to II orbit.

$n_f = 2$ $\quad n_i = 3, 4, 5, 6 ---$

~~I member~~

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_i^2}\right].$$

I member of Balmer

when $\bar{e}$ jumps from III orbit to II orbit

$n_f = 2, \quad n_i = 3$

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right).$$

II member of Balmer.

$n_f = 2, \quad n_i = 4$

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

Page No.
Date

Shortest series of Balmer

$n_f = 2 \qquad n_i = \infty$

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

$$\frac{1}{\lambda_{\text{Balmer short}}} = \frac{R}{4}$$

$$\lambda_{\text{Balmer short}} = \frac{4}{R}$$

$$\boxed{\lambda_{\text{Balmer short}} = 4\,\lambda_{\text{Lyman short}}}$$

Balmer Series lies in visible Region.

III:- Paschen Series

when e^- jumps from any of the higher to III orbit.

$n_f = 3 \qquad n_i = 4, 5, 6, 7 \ldots$

$$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_i^2}\right]$$

I member

$n_f = 3 \quad n_i = 4.$

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right).$$

II member

$n_f = 3 \quad n_i = 5$

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{5^2}\right).$$

Short series of Paschen

$n_f = 3 \quad n_i = \infty$

$$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{\infty^2}\right).$$

$$\frac{1}{\lambda} = \frac{R}{9}$$

$$\lambda_{\text{Paschen short}} = \frac{9}{R}$$

$$\boxed{\lambda_{\text{Paschen short}} = 9\,\lambda_{\text{Lyman}}}$$

Page No.
Date

Paschen lies in Infra Red Region

IV Brackett series.

When $\bar{e}$ jumps from any of the higher to IV orbit.

$n_f = 4 \qquad n_i = 5, 6, 7, 8 - -$

$$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_i^2}\right]$$

I member of Brackett.

$n_f = 4 \qquad n_i = 5$

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{5^2}\right)$$

II member of Brackett $n_f = 4$

$n_i = 6$

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{6^2}\right)$$

Short series of Brackett.

$n_f = 4 \qquad n_i = \infty$

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

$$\frac{1}{\lambda_{Bra}} = \frac{R}{16}$$

$\lambda_{Brack} = 16\,\lambda_{Ly}$ short

This lies in infrared region.

V) P-fund series

when $\bar{e}$ jumps from any of the higher to V orbit

$n_f = 5$, $n_i = 6, 7, 8$ ——

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n_i^2}\right)$$

I member

① $n_f = 5$ $n_i = 6$

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{6^2}\right).$$

II member

$n_f = 5$ $n_i = 7$

$$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{7^2}\right)$$

short series

$n_f = 5$ $n_i = \infty$

$E_n = -\frac{13.6}{n^2}$ eV

Page No.	
Date	

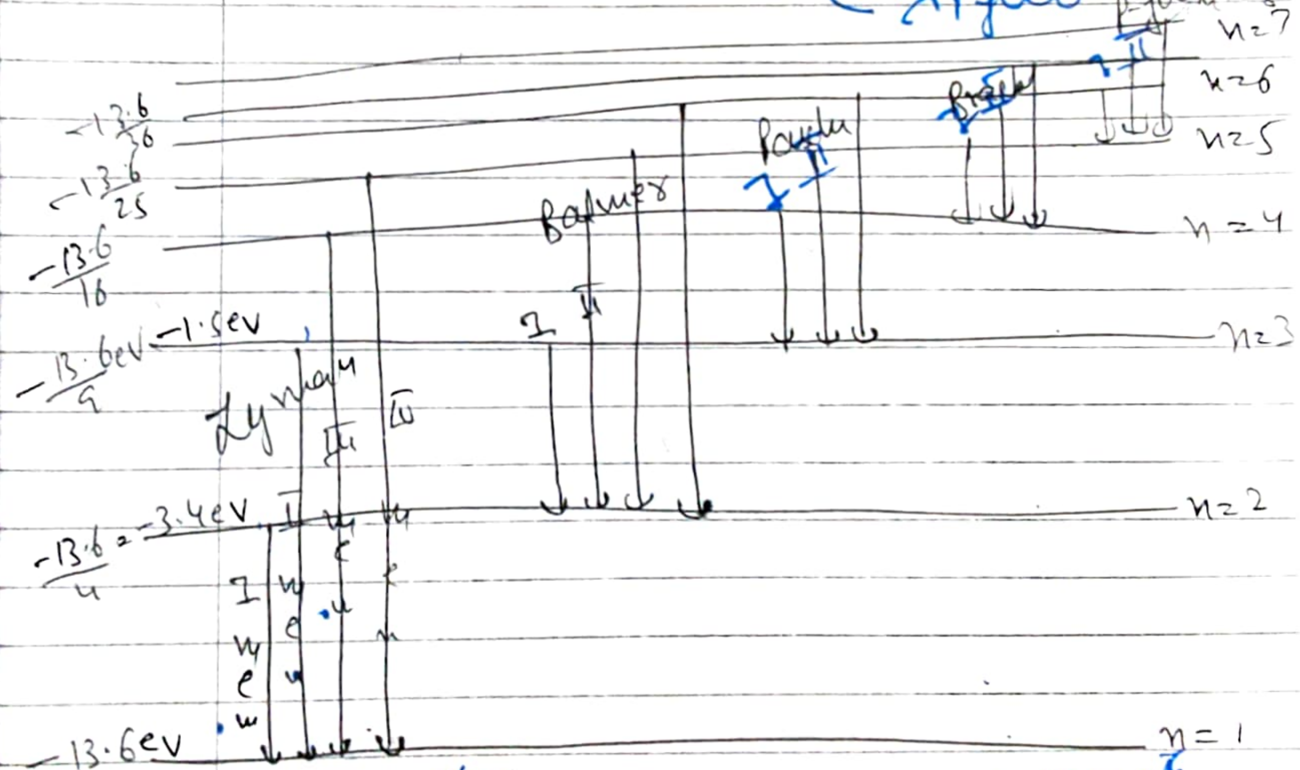
$$\frac{1}{\lambda} = R\left(\frac{1}{25} - \frac{1}{\infty}\right)$$

$$\lambda_{p\text{-fund}} = \frac{25}{R}$$

$$\boxed{\lambda_{p\text{-fund}} = 25\,\lambda_{lyman}}$$

It lies in far IR region

$\lambda_{lyman} < \lambda_{Balmer} < \lambda_{Paschen} < \lambda_{Brack} < \lambda_{Pfund}$



Q 600, 1000, 2000, 4000 Å

Which one is lyman

-13.6, 3.4, $\frac{-13.6}{9}$, $\frac{-13.6}{4}$ shortest

Drawbacks of Bohr

1. This theory is applicable only to hydrogen like single electron atoms, and fails in the case of atoms $\bar{c}$ two or more e^-s.

2. In the spectrum of hydrogen, certain spectral lines are not single lines but a group of closed lines, which slightly different frequencies.

contd— Bohr's theory could not explain these fine features of the H – spectrum.

3. It does not explain why only circular orbit should be chosen when elliptical orbits are also possible.

4. As e^-s exhibit wave properties also, so, orbit of e^-s cannot be exactly defined in Bohr's theory.

5. Bohr's theory does not tell anything about the relative intensities of the various spectral lines. Bohr's theory predicts only the frequencies of these lines.

6. It does not explain the further splitting of spectral lines in a magnetic field (Zeeman effect) or in an electric field (Stark effect).

PAGE NO.

Excitation Energy : The excitation energy of an atom is defined as energy required by its electron to jump from ground state to any of the excited states.

I^{st} excitation energy of hydrogen $= E_2 - E_1 = -3.4 - (-13.6) = \underline{10.2 \text{ eV}}$

II^{nd} excitation energy of Hydrogen $= E_3 - E_1 = -1.51 - (-13.6)$
$= \underline{12.09 \text{ eV}}$

Ionisation Energy : It is defined as energy required to knock an electron completely out of atom i.e. energy required to take an electron, from it's ground state to outermost orbit i.e. $\underline{n = \infty}$.

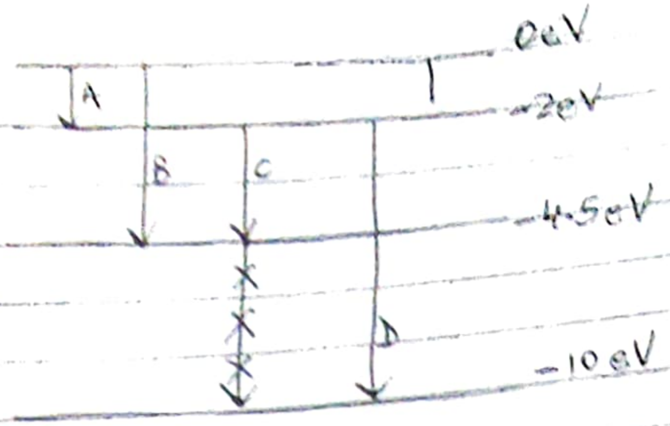
Ionisation energy of hydrogen $= E_\infty - E_1 = 0 - (-13.6)$
$= \underline{13.6 \text{ eV}}$

Excitation Potential : It is that accelerating potential which gives to a bombarding electron, sufficient energy to excite the target atom, by raising one of its electrons from an inner to an outer orbit.

Ionisation Potential : It is that accelerating potential which gives to a bombarding e^-, sufficient energy to ionise the target atom, by knocking one of its electrons completely out of the atom.

Ionisation potential of Hydrogen $= 0 - (-13.6)$
$= \underline{13.6 \text{ V}}$

2020
V.V. Imp
Ques.



(i) If 275 nm light is incident, which of the transition will take place and;

(ii) which transition corresponds to —

(a) max. wavelength

(b) min. wavelength.

Solⁿ (i) $\frac{hc}{\lambda} = E$

$$E = \frac{\overset{4}{\cancel{6.6}} \times 10^{-34} \times 3 \times 10^{8}}{275 \times 10^{-9} \times \cancel{1.6} \times 10^{-19}}$$

$$E = \frac{12 \times 10^{2}}{275}$$

$$E = \frac{1200}{275}$$

$$E = 4.5 \text{ eV}$$

Hence, -4.5 eV transition will take place.

(ii) $E = \frac{hc}{\lambda} \rightarrow \boxed{E \propto \frac{1}{\lambda}}$

Max $\lambda \rightarrow A \rightarrow$ min. energy gap.

Min $\lambda \rightarrow D \rightarrow$ max. energy gap.

Energy

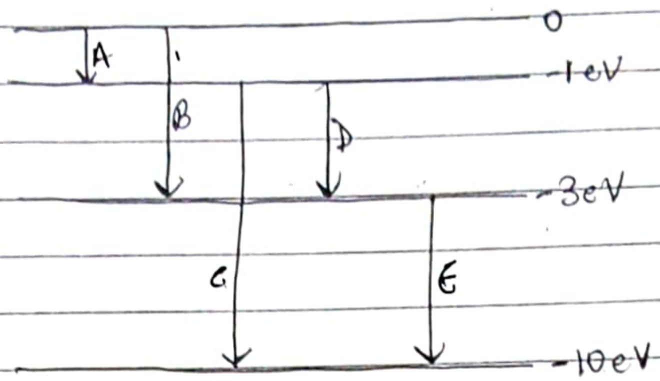
$A \rightarrow 0 - (-2) = 2eV$

$B \rightarrow 0 - (-4.5) = 4.5\ eV$

$C \rightarrow 2.5\ eV$

$D \rightarrow 8eV$

Quest.



If 620 nm light is incident, which transition is possible?

Sol^n

$E = \frac{hc}{\lambda}$

$E = \frac{\cancel{6.6}^{4} \times 10^{-34} \times 3 \times 10^{8}}{620 \times 10^{-9} \times \cancel{1.6} \times 10^{-19}}$

$E = \frac{12 \times 10^{2}}{620}$

$E = \frac{1200}{620}$

$E = 1.9$

$\boxed{E \simeq 2eV}$

$A \Rightarrow 1eV$

$B \Rightarrow 3eV$

$C \Rightarrow 9eV$

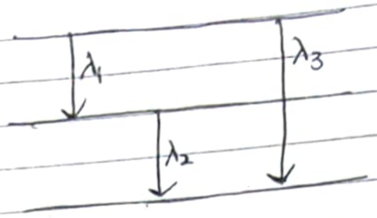
$\boxed{D \Rightarrow 2eV}$

Hence D transition will take place.

PAGE NO

100% 2020

Ques. Find relationship b/w three wavelengths λ_1, λ_2 and λ_3 from the given diagram.



Sol^n $E_1 = \frac{hc}{\lambda_1}$; $E_2 = \frac{hc}{\lambda_2}$; $E_3 = \frac{hc}{\lambda_3}$

$$E_1 + E_2 = E_3$$

$$\frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} = \frac{hc}{\lambda_3}$$

$$\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$$

$$\boxed{\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}}$$

Or

$$E_C - E_B = \frac{hc}{\lambda_1} \quad -(1)$$

$$E_B - E_A = \frac{hc}{\lambda_2} \quad -(2)$$

Adding (1) and (2)

$$E_C - E_A = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \rightarrow (3)$$

$$E_C - E_A = \frac{hc}{\lambda_3} \quad -(4)$$

comparing (3) and (4) ;

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\boxed{\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}}$$

2022 Ques. Using Bohr postulate, derive the expression for orbital time period of electron moving in n^{th} orbit of hydrogen atom.

Sol^n

$$T = \frac{2\pi r}{v}$$

$$T = \frac{2\pi r \times 2\pi m r}{nh}$$

$$T = \frac{4\pi^2 m r^2}{nh} \quad (1)$$

$$r_n = \quad (2)$$

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

$$v = \frac{nh}{2\pi} \times \frac{1}{mr}$$

comparing (1) and (2),

$$\boxed{T = \frac{n^3 h^3}{4\pi^2 m k^2 e^4}}$$