Atoms

12

INTRODUCTION

Write from the beginning of civilisation, people were very curious to know that what from the substances are made up of but, first significant attempt in this direction was made by Daltion & from where Dalton's atomic model starts.

MODEL

A model is simply a set of hypothesis based on logical and scientific facts.

Theory : When any model satisfies majority of scientific queries by experiment verification then it is termed as theory otherwise, model is simply not accepted.

In Nutshull we can say that every theory is a model but every model is not a theory. So, after more & more clarity about the substances, various new models like Dalton, Thomson, Rutherford, Bohr etc came into the pictures.

1. Dalton's atomic model :

(i) Every element is made up of tiny indivisible particles called atoms.

(ii) Atoms of same element are identical both in physical & chemical properties while atoms of different elements are different in their properties.

(iii) All elements are made up of hydrogen atom. The mass of heaviest atom is about 250 times the mass of hydrogen atoms while radius of heaviest atom is about 10 times the radius of hydrogen atom.

(iv) Atom is stable & electrically neutral.

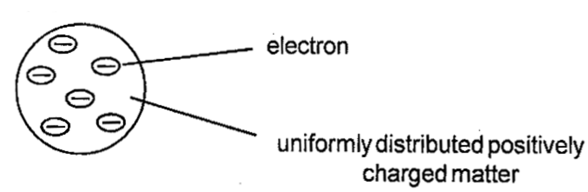
Reason of Failure of model :

After the discovery of electron by J.J. Thomson (1897), it was established that atom can be divided. Hence the model was not accepted.

2. Thomson's atomic model (or Plum-pudding model)

(i) Atom is positively charged solid sphere of radius of the order of 10^{-10}m in which electrons are embedded as seeds in a watermelon.

(ii) Total charge in a atom is zero & so, atom is electrically neutral



Achievement of model -

Explained successfully the phenomenon of thermionic emission, photoelectric emission & ionization

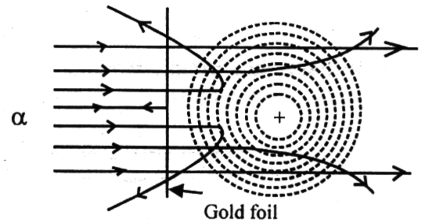
Falure of the model -

(i) It could not explain the line spectrum of H-atom

(ii) If could not explain the Rutheford's α-particle scattering experiment.

3. Rutherford's atomic model -

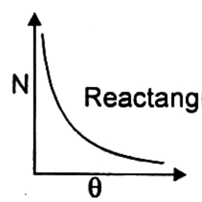
Result of the experiment :



(i) Majority of α-particles passes underviated through gold foil that is possible when most part of the atom remains hollow.

(ii) Few of α-particles (< 1 in 8000) deflects at an angle larger than 90º & even some at 180º which is possible only in that case when there exists a solid positive mass confining in a very narrow space.

(iii) $N \propto \dfrac{1}{\sin^4\left(\frac{\theta}{2}\right)}$ $\Rightarrow$ If $\theta\uparrow$ then $N\downarrow\downarrow$



Equation indicated that at larger deflection (scattering) angle, no. of particles deflected are very-very less

Graph for N & θ show that coulomb's law holds for atomic distances also.

(iv) $N \propto$ (Nuclear charge)^2

Solved Examples

Ex.1 The number of particles scattered at 60º is 1000 per minute in an α-particle scattering experiment, using gold foil, using gold foil. Calculate the number of particle per minute scattered at 90º angle

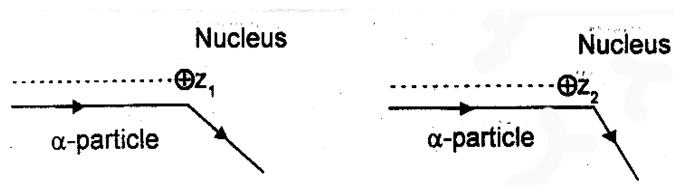
Sol. Let N = No. of α-particle scattered per minute at an angle 90º.

$$\therefore\ N \propto \frac{1}{\sin^4\left(\frac{90}{2}\right)}\ ;\ 1000 \propto \frac{1}{\sin^4\left(\frac{60}{2}\right)}$$

$$\therefore\ N = 1000 \times \frac{\sin^4\left(\frac{90}{2}\right)}{\sin^4\left(\frac{60}{2}\right)} = 250/\text{minute}$$

Ex.2 As shown below, α-particles are making head-on-collision towards stationary nucleus of charge z_1e & z_2e then which of the following is correct -

[1] $z_1 > z_2$ [2] $z_1 < z_2$
[3] $z_1 = z_2$ [4] can not be said



Rutherford's atomic model -

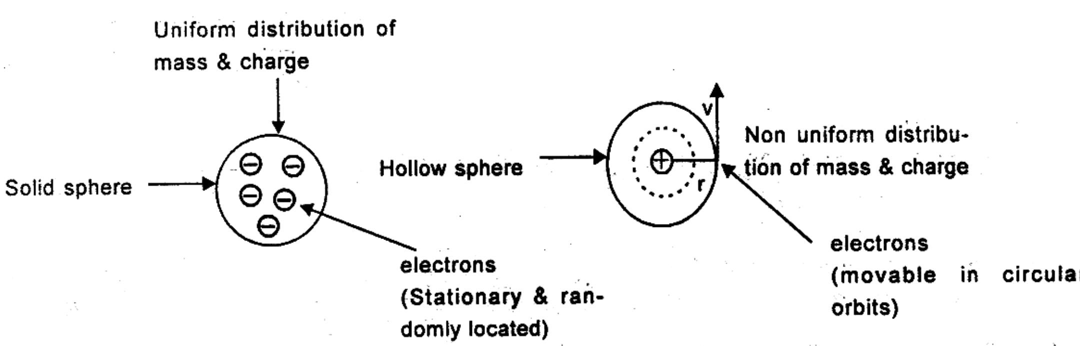
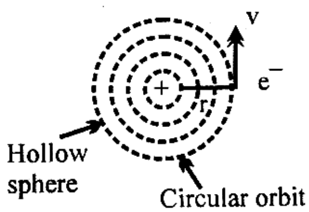


Fig : Thomson's model Fig : Rutherford's model

(i) The whole positive charge & almost whole moss of an atom (leaving aside the mass of revolving e^- in various circular orbits) remains concentrated in a nucleus of radius of the order of 10^{-15} m.



(ii) $\sum q$ (+)ve on proton in a nucleus = $\sum q$ (–)ve on e^- in various circular orbits & hence, the atom is electrically neutral.

(iii) The necessary centripetal force for revolving round the nucleus in circular orbit is provided by coulomb's electrostatic force of attraction $\frac{mv^2}{r} = \frac{k(ze)(e)}{r^2}$

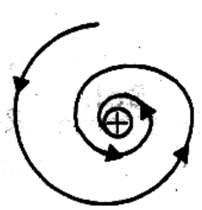
Reason of failure of model -

(i) It could not explain the line spectrum of H-atom

Justification : According to Maxwells electromagnetic theory every accelerated moving charged particle radiates energy in the form of electromagnetic waves & therefore during revolution of e^- in circular orbit its frequency will continuously vary (i.e of decrease) which will result in the continuously emission of lines & therefore spectrum of atoms must be continuous but in reality, one obtains line spectrum for atoms.

(ii) It could not explain the stability of atoms.

Justification : Since revolving election will continuously radiates energy & therefore radii of circular path will continuously decreases & in a time of about 10^{-8} sec revolving electron must fall down in a nucleus by adopting a spiral path



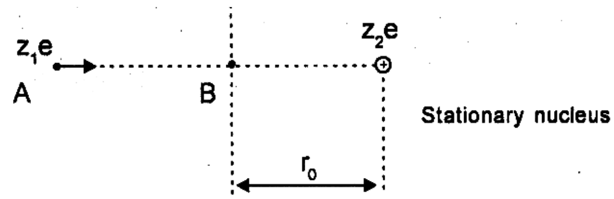
Path of electron spiral

3.1 Application of rutherford's model

Determination of distance of closest approach: When a positively charged particle approaches towards stationary nucleus then due to repulsion between the two, the kinetic energy of positively charged particle gradually decreases and a state comes when its kinetic energy becomes zero & from where it again starts its original path.

Definition : The distance of closest approach is the minimum distance of a stationary nucleus with a positively charged particle making head on collision from a point where its kinetic energy becomes zero.

Suppose a positively charged particle A of charge q ($=z_1e$) approaches from infinity towards a stationary nucleus of charge z_2e then,



Let at point B, kinetic energy of particle A become zero then by the law of conservation of energy at point A & B,

$TE_A = TE_B$

$KE_A + PE_A = KE_B + PE_B$

$E + 0 = 0 + \frac{k(z_1e)(z_2e)}{r_0}$ (in joule)

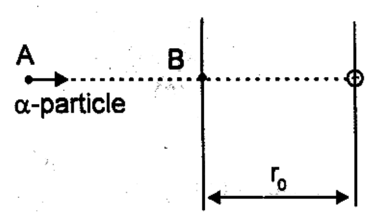
$\therefore\ r_0 = \frac{k(z_1e)(z_2e)}{E} m$

Solved Examples

Ex.3 An α-particle with kinetic energy 10 MeV is heading towards a stationary point-nucleus of atomic number 50. Calculate the distance of closest approach.

Sol. $\because\ TE_A = TE_B$

$\therefore\ 10 \times 10^6 e = \frac{K \times (2e)(50e)}{r_0}$



$r_0 = 1.44 \times 10^{-14}$ m $\qquad r_0 = 1.44 \times 10^{-4}$ A°

Ex.4 A beam of α-particle of velocity 2.1×10^7 m/s is scattered by a gold (z = 79) foil. Find out the distance of closest approach of the α–particle to the gold nucleus. The value of charge/mass for α-particle is 4.8×10^7C/kg.

Sol. $\frac{1}{2}m_\alpha v_\alpha^2 = \frac{K(2e)(ze)}{r_0}$

$$r_0 = \frac{2K\left(\frac{2e}{m_\alpha}\right)(79e)}{v_\alpha^2} = \frac{2\times(9\times10^9)(4.8\times10^7)(79\times1.6\times10^{-19})}{(2.1\times10^7)^2};$$

$r_0 = 2.5\times10^{-14}$m

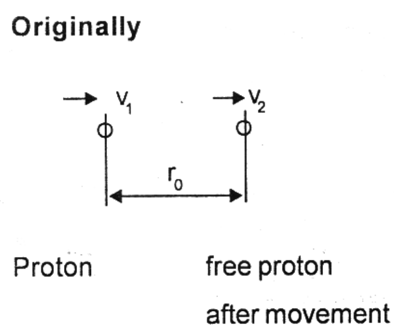
Ex.5 A proton moves with a speed of 7.45×10^5 m/s directing towards a free proton originally at rest. Find the distance of closest approach for the two protons.

[special case → when nucleus also moves]

Sol. v = 7.45×10^5 m/s u = 0

O o

Proton Free proton



At the time of distance of closest approach

By the law of cons. of energy

$$\frac{1}{2}mv^2 + 0 = \frac{ke^2}{r_0} + \frac{1}{2}mv_1^2 + \frac{1}{2}mv_1^2 \text{ .... (1)}$$

By the cons. of momentum $mv + 0 = mv_1 + mv_1$

$\therefore \quad v_1 = \frac{v}{2}$

From equation (1) $\frac{1}{2}mv^2 = \frac{ke^2}{r_0} + m\left(\frac{v}{2}\right)^2$

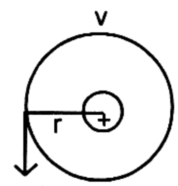
$$r_0 = \frac{4}{mv^2}\times ke^2 = \frac{4\times(9\times10^9)(1.6\times10^{-19})^2}{(1.66\times10^{-27})(7.45\times10^5)^2};$$

$r_0 = 1.0 \times 10^{-12}$m

4. Bohr's atomic model

Bohr proposed his model for H or H-like atoms by mixing the concepts of classical physics with quantum mechanics. This model is based on law of conservation of angular momentum.

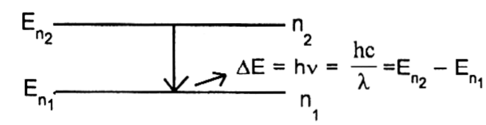
(1) (a) Concept of stable, stationary, quantized, fixed allowed radii orbit, or maxwell's licensed orbits

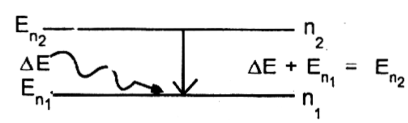


According to Bohr, if an electron revolve in these orbits then electron neither radiate nor absorb any energy.

(b) Emission of energy

Where n = principle quantum no.





E_n = energy of e^- in nth orbit

(c) Absorption of energy

(2) Electron revolve only in those orbits in which its angular momentum is integer multiple of $\frac{h}{2\pi}$

$mvr = I\omega = n\frac{h}{2\pi}$

(3) $\frac{mv^2}{r} = \frac{KZe^2}{r^2}$

4.1 Determination of radius, velocity & energy of e⁻ in Bohr's orbit

(A) Determination of radius of circular path (orbit)

$\because mvr = \frac{nh}{2\pi}$ ....(1)

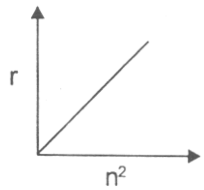
$\therefore v = \frac{nh}{2\pi mr}$ ....(2) & $\frac{mv^2}{r} = \frac{kze^2}{r^2}$

$\therefore m\left(\frac{nh}{2\pi mr}\right)^2 = \frac{kze^2}{r}$; $\quad r_n = v\left(\frac{n^2h^2}{4\pi^2 mkze^2}\right)$

$r_n = \frac{n^2}{z}\times\frac{h^2}{4\pi^2 mke^2}$; $\quad r_n = \frac{n^2}{z}\times 0.529\text{Å}$ ....(3)

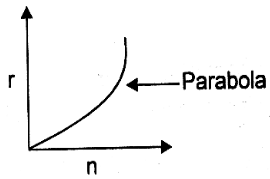
Results :

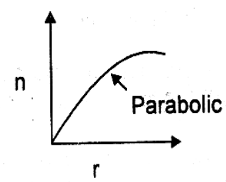
(i) $\because r_1 = \frac{(1)^2}{z} \times 0.529 Å$

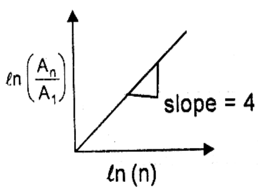


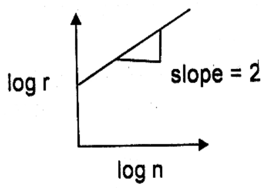
$\therefore r_n = n^2 r_1$

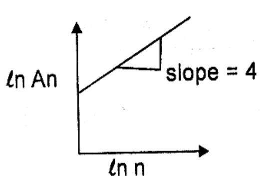
(ii) $\therefore r \propto n^2$

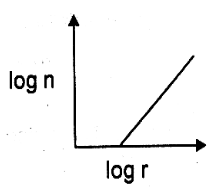












where A_n = Area of n^{th} circular orbit

Solved Examples

Ex.6 The radius of the shortest orbit of a single electron system is 18 pm. This system may be

[1] H [2] D

[3] He^+ [4] Li^{++}

Sol. For shortest orbit n = 1

$r_n = n^2 r_1$

$\frac{(1)^2}{z} \times 0.529 Å = 18 \times 10^{-2}$ Å

z = 3

Ex.7 Determine the ratio of area of circular orbits in doubly ionized lithium atom in 2nd & 3rd Bohr orbit

Sol. $\because A_n = \pi r_n^2$ & $r \propto n^2$

$\therefore A_n \propto n^4 \quad \therefore \frac{A_2}{A_3} = \frac{(2)^4}{(3)^4} = \frac{16}{81}$

Ex.8 Determine the ratio of perimeters in 2^{nd} & 3^{rd} Bohr orbit in He^+ atom.

Sol. Perimeter = $2\pi r$

$\therefore \frac{2\pi r_2}{2\pi r_3} = \frac{r_2}{r_3} = \frac{(2)^2}{(3)^2} = \frac{4}{9}$

(B) Determination of velocity of electron in circular orbit

$\therefore mvr = \frac{nh}{2\pi}$ ....(1)

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

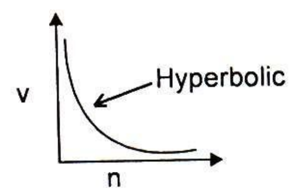
$\frac{mv^2}{r} = \frac{kze^2}{r^2} \Rightarrow v = \frac{2\pi kze^2}{nh}$

$\Rightarrow v = \frac{z}{n} \times \frac{2\pi ke^2}{h} \quad \Rightarrow \quad v = 18 \times 10^6 \frac{z}{n} m/s$

$v = \frac{c}{137} \frac{z}{n} m/sec$

where c = velocity of light in vacuum = 3×10^8 m/s

Results :



(i) $v \propto \frac{1}{n}$ (z = constant)

Solved Examples

Ex.9 Determine the ratio of speed of electrons in hydrogen atom in its 3rd & 4th orbit

Sol. $\because v \propto \frac{z}{n} \quad \therefore \frac{v_3}{v_4} = \frac{4}{3}$

Ex.10 Determine the ratio of speed of electron in 3rd orbit of He^+ to 4th orbit of Li^{++} atom

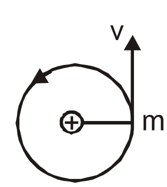
Sol. $\frac{v_3}{v_4} = \frac{\frac{2}{3}}{\frac{3}{4}} = \frac{8}{9}$

4.2 Determination of energy of electron in Bohr's circular orbit -

(1) Kinetic energy of electron

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

$KE = \frac{kze^2}{2r}$



Results

(i) KE of an e^- = positive quantity

(ii) r↑, KE↓

(iii) of $r = \infty$, KE = 0

(2) Potential energy of an electron

$$PE = \frac{k(+ze)(-e)}{r}$$

$$PE = \frac{-kze^2}{r}$$

Result :

(i) PE of an e^- = negative quantity

(ii) r↑ , PE↑

(iii) If r = ∞ , PE = 0

(3) Total energy of an electron :

Total energy of an electron in any orbit is sum of its kinetic & potential energy in that orbit.

$$TE = KE + PE = \frac{Kze^2}{2r} - \frac{Kze^2}{r} \; ; \; TE = -\frac{Kze^2}{2r}$$

Results :

(i) TE of an electron in an atom = (–) ve quantity

(–) ve sign indicates that electron is in bound state

(ii) If r↑, TE↑

(iii) If r = ∞ , TE = 0

(iv) $TE = -KE = \frac{PE}{2}$ in any H-like atom

Total energy in terms of n $TE = -\dfrac{kze^2}{2\times\left(\dfrac{n^2h^2}{4\pi^2mkze^2}\right)}$

$$\Rightarrow TE = -\frac{2\pi^2mk^2z^2e^4}{n^2h^2} \quad \Rightarrow TE = -Rch\frac{z^2}{n^2} \text{ joule}$$

$$\Rightarrow TE = -13.6\frac{z^2}{n^2}\text{eV}$$

where R = Rydberg constant

$$= \frac{2\pi^2mk^2e^4}{ch^3} = \frac{me^4}{8\epsilon_0^2 ch^3} = 1.097\times10^7 m^{-1}$$

Remember that Rydberg constant is not a universal constant. In Bohr calculation it is determined by assuming nucleus to be stationary

For Bohr Rydberg constant $R_\infty = 1.097 \times 10^7 m^{-1}$

If nucleus is not assumed stationary then

$$R = \frac{R_\infty}{1+\left(\frac{m_e}{m_N}\right)} \qquad m_N = \text{mass of nucleus}$$

4.3 Results based on total energy equation

(i) With the increase in principal quantum number, both total energy & potential energy of an electron increases. While kinetic energy decreases

(ii) With the increase in principal quantum number, the difference between any two consecutive energy level decreases.

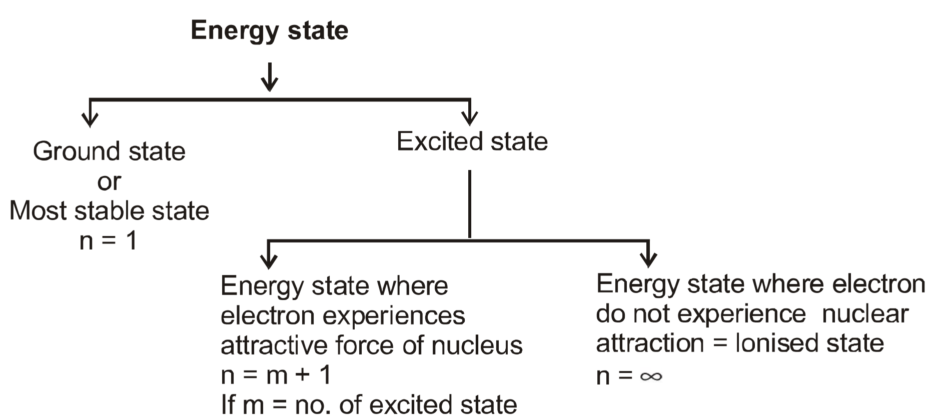
(iii) Total energy of an electron in any orbit in H-like atom = (Total energy of an electron in that orbit in H-atom xz^2)

(iv) PE of an electron in any orbit in H-like atom = (PE of an electron in that orbit in H-atom) xz^2

(v) KE of an electron in any orbit in H-like atom = (KE of an electron in that orbit in H-atom) z^2

(vi) $\Delta E_{n_1n_2}$ in any H-like atom = ($\Delta E_{n_1n_2}$ in H-atom) xz^2

SOME IMPORTANT DEFINITIONS & THEIR MEANING

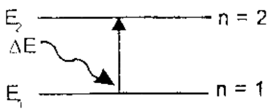


(i) Ionization energy & ionization potential - The minimum energy required to remove an electron from hydrogen or hydrogen like atom is called its ionization energy & corresponding potential through which an electron is accelerated for this is called ionization potential

$I.E = E_\infty - E_1 = -E_1$

$= \text{Binding energy of } e^-$

(2) Excitation energy & excitation potential : The minimum energy required to excite an atom is called excitation energy of the particular excited state & corresponding potential is called excitation potential.

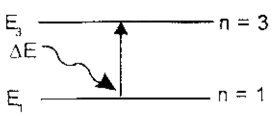


$\Delta E + E_1 = E_2$

$\Delta E = E_2 - E_1$

↑

Excitation Energy

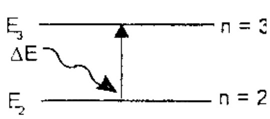


$\Delta E + E_1 = E_3$

$\Delta E = E_3 - E_1$

↑

2nd Excitation energy

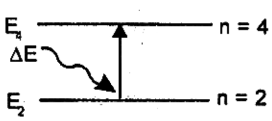


$\Delta E + E_2 = E_3$

$\Delta E = E_3 - E_2$

↑

Excitation energy of e^- for 1st excited state.

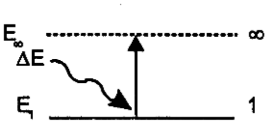


$\Delta E + E_2 = E_4$

$\Delta E = E_4 - E_2$

↑

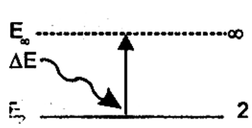
2nd Excitation energy for e^- in 2nd excited state.



$\Delta E + E_1 = E_\infty = 0$

$\Delta E = -E_1$

(I.E.)



$\Delta E + E_2 = E_\infty = 0$

$\Delta E = E_\infty - E_2 = -E_2$

I.E. of e^- in 1st exc. state

If excitation energy & ionisation energy are represented in ev then corresponding value in volt is termed as excitation potential & ionisation potential respectively.

For example - Excitation energy & ionisation energy for H-atom are 10.2eV & 13.6eV respectively & there fore 10.2V & 13.6V are exciation & ionisation potential respectively.

DETERMINATION OF EXCITATION LEVEL AFTER THE COLLISION OF BOUND ELECTRON IN A ATOM BY PHOTON OR EXTERNAL ELECTRON

(A) Collision of bound electron by a photon : Whenever a photon collides with a bound electron of an atom then it either makes perfect elastic or perfect inelastic collision.

DETERMINATION OF NO. OF SPECTRAL LINES (THEORETICAL) IN EMISSION & IN ABSORPTION TRANSITIONS

1. No. of emission spectral lines - If the electron is excited to state with principal quantum number n then from n^{th} state, the electron may go to $(n-1)^{th}$ state, ...2^{nd} state or 1st state. So there are (n – 1) possible transitions starting from the nth state. The electron reaching (n – 1)th state may make (n – 2) different transitions. Similarly for other lower states. The total no. of possible transitions is

$$(n-1) + (n-2) + (n-3) + ...2 + 1 = \frac{n(n-1)}{2}$$

2. No. of absorption spectral lines - Since at ordinary temperatures, almost all the atoms remain in their lowest energy level (n = 1) & so absorption transition can start only from n = 1 level (not form n = 2, 3, 4 ....levels). Hence, only Lyman series is found in the absorption spectrum of hydrogen atom (which as in the emission spectrum, all the series are found No. of absorption spectral lines = (n – 1)

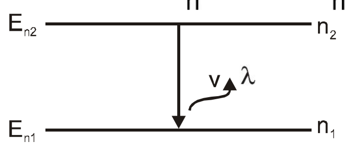
Remember : The absorption spectrum of sum has Balmer series also besides the Lyman series. Many H-atoms remain in n = 2 also due to very high temperature.

EXPLANATION OF H-SPECTRUM & SPECTRAL LINE FORMULA

In a hydrogen like atom, when an electron makes transition from any higher energy state n_2 to any lower energy state n_1 then a photon of frequency ν or wavelength λ is emitted.

Then $\Delta E = h\nu = \frac{hc}{\lambda} = E_{n_2} - E_{n_1}$

$\because\ E = -Rch\frac{z^2}{n^2}J = -13.6\frac{z^2}{n^2}eV$



$$\therefore\ \Delta E = -\frac{Rchz^2}{n_2^2} - \left(-\frac{Rchz^2}{n_1^2}\right)$$

$$\Delta E = Rchz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\therefore\ h\nu = \frac{hc}{\lambda} = Rchz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad ;$$

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

$\bar{\nu}$ = wave number

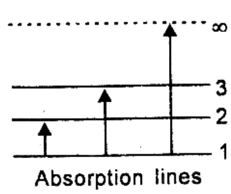
= no. of wave in unit length

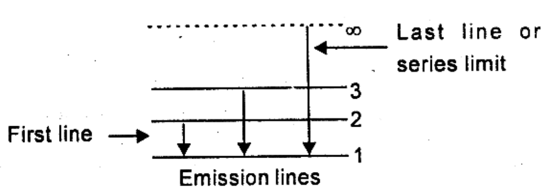
$\nu = c\bar{\nu}$

For H-atom, Z = 1 & therefore, $\boxed{\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}$

1. Lyman series -

$n_1 = 1,\ n_2 = 2, 3, 4\ ....\infty$





For 1^{st} line or series beginning

$n_1 = 1\ ,\quad n_2 = 2$

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

$$\lambda_{max} = \frac{4}{3R} = 1216Å$$

For series limit or last line $n_1 = 1,\ n_2 = \infty$

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

$$\lambda_{min} = \frac{1}{R} = 912.68Å$$

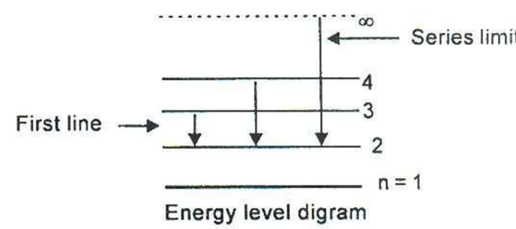
Note : Lyman series is found in UV region of electromagnetic spectrum

2. Balmer series -

$n_1 = 2,\ n_2 = 3, 4, 5, 6, ...\infty$

wavelength of first line

i.e. maximum wavelength $\frac{1}{\lambda_{max}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$



$\therefore\ \lambda_{max} = 6563Å$

wavelength of last line or series limit i.e. minimum wavelength

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] \qquad \therefore\ \lambda_{min} = \frac{4}{R} = 3646Å$$

Note :

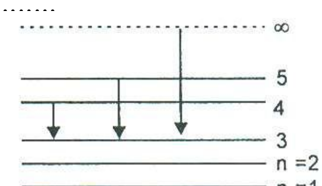
(a) Balmer series is found only in emission spectrum

(b) Balmer series lies in the visible region of electromagnetic spectrum

3. Paschen series -

$n_1 = 3,\ n_2 = 4, 5, 6........$

For first line $n_1 = 3$,



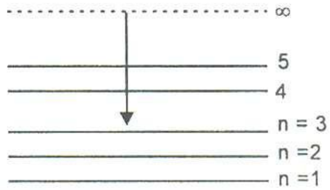
$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$\lambda_{max} = 18751Å$

For last line or series limit

$n_1 = 3,\ n_2 = \infty$

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right]$$



$$\lambda_{min} = \frac{9}{R} = 8107\text{Å}$$

Note:

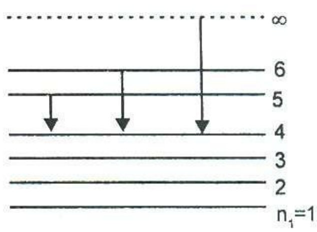
(a) Paschen series is also found only in emission spectrum

(b) Paschen series is obtained in infrared region of electromagnetic spectrum

4. Brakett series -

$n_1 = 4,\ n_2 = 5, 6, 7, ...\infty$

For first line $\frac{1}{\lambda_{min}} = R\left[\frac{1}{4^2} - \frac{1}{5^2}\right]$



$\lambda_{max} = 40477\text{Å}$

For last line or series limit $\frac{1}{\lambda_{min}} = R\left[\frac{1}{4^2} - \frac{1}{\infty^2}\right]$

$\lambda_{min} = \frac{16}{R} = 14572\text{Å}$

Note:

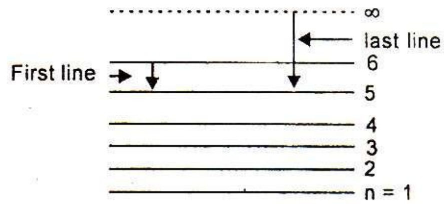
(a) Brakett series is also found only in emission spectrum

(b) Brakett series is also obtained in infrared region of electromagnetic spectrum

5. Pfund series -

$n_1 = 5,\ n_2 = 6, 7, 8, ...\infty$

For first line $\frac{1}{\lambda_{max}} = R\left[\frac{1}{5^2} - \frac{1}{6^2}\right]$



$\lambda_{max} = 74515\text{Å}$

For last line or series limit

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{5} - \frac{1}{\infty^2}\right]$$

$$\frac{1}{\lambda_{min}} = \frac{25}{R} = 22768\text{Å}$$

Note:

(a) Pfund series is also obtained only in emission spectrum

(b) Pfund series is situated in the infrared region of electromagnetic spectrum

GENERAL POINTS FOR SPECTRAL LINES IN EVERY SPECTRAL SERIES

(1) Wavelength of first line is maximum & last line is minimum.

(2) As the order of spectral series increases, wavelength also usually increases

$\lambda_{PE} > \lambda_{BR} > \lambda_P > \lambda_B > \lambda_L$

(3) Frequency of energy emission in lyman transitions are highest among all other series.

CONCEPT OF REDUCED MASS & ITS APPLICATION IN BOHR THEORY

(i) When mass of nucleus is assumed to be very-very large in comparison to mass of revolving particle then reduced mass is not to be applied otherwise it is to be applied

(ii) Bohr has assumed nucleus to be stationary is its all calculations.

(iii) Reduced mass of system of particles of mass m_1 & m_2 is written by

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

(iv) According to Bohr

$$\mu = \frac{m_e\, m_N}{m_e + m_N} = \frac{m_e\, m_N}{m_N}$$

$\therefore$ $m_N >> m_e = m_e$

where m_N = mass of nucleus

(v) For Muon - Proton system

mass of muonic atom = 207 × mass of electron (m_μ–)

$$\therefore \quad \mu = \frac{m_p \times m_{\mu-}}{m_p + m_{\mu-}} = \frac{1836 m_e \times 207 m_e}{(1836+207)m_e}$$

$$\mu \approx 207m$$

$$\mu \approx 186$$

(vi) For electron - position system

$$\mu = \frac{m_{e-} \times m_{e+}}{m_{e-} + m_{e+}}$$

$$\mu = \frac{m_e}{2}$$

m_e = mass of electron

(vi) radius in n^{th} orbit

$$r_n = \frac{n^2}{z} \times 0.529 \times \left(\frac{m_e}{\mu}\right) Å$$

(viii) Energy in n^{th} orbit

$$E_n = -\frac{z^2}{n^2} \times 13.6 \times \frac{\mu}{m_e} eV$$

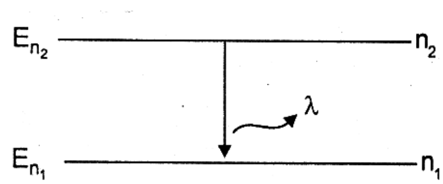
CONCEPT OF RECOILING OF AN ATOM & DETERMINATION OF MOMENTUM & ENERGY FOR RECOIL ATOMS

When ever any electron makes transition from any higher energy state to any lower energy state then photon is emitted & due to which in the back side atom is recoiled. The atom is recoiled by sharing some energy from the energy from the energy evolved during electronic transition.

If m = mass of recoil atom

v = velocity of recoil atom

Then $\frac{1}{2}mv^2 + \frac{hc}{\lambda} = E_{n_2} - E_{n_1} = \Delta E$



Recoil momentum of atom = $\frac{h}{\lambda}$ = momentum of photon

Recoil energy of atom = $\frac{p^2}{2m}$

SHORTCOMING'S OF BOHR'S ATOMIC MODEL

(i) It is valid only for one electron atoms. e.g. H, He^+, Li^{+2}, Na^{+10} etc.

(ii) Orbits were taken as circular but according to sommerfield these are elliptical.

(iii) Intensity of spectral lines could not be explained.

(iv) Nucleus was taken as stationary but it also rotates on its own axis.

(v) It could not be explained the minute structure in spectrum line

(vi) This does not explain the zeeman effect (splitting up of spectral lines in magnetic field) & stark effect (splitting up in electric field)

(vii) This does not explain the doublets in the spectrum of some of the atoms like sodium (5890Å & 5896Å)

IMPORTANT FORMULAE

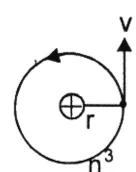
(1) Time period (T)

distance = time × speed

$2\pi r = T \times v$

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

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



$T_n \propto \frac{n^3}{z^2}$

(2) Frequency of revolution

$$f_n = \frac{v_n}{2\pi r_n} = \frac{4\pi k^2 z^2 m e^4}{n^3 h^3}; \quad f_n \propto \frac{z^2}{n^3}$$

(3) Momentum of electron

$$P_n = \frac{2\pi m k z e^2}{nh}, \qquad P_n \propto \frac{1}{n}$$

(4) Current (I)

$$I = \frac{e}{T} = e\nu = \frac{ev}{2\pi r}\ ; \ I \propto \frac{z^2}{n^3}$$

(5) Angular velocity of electron

$$\omega_n = \frac{8\pi^3 k^2 z^2 m e^4}{n^3 h^3}$$

$$\therefore \ \omega_n \propto \frac{z^2}{n^3}$$

(6) Magnetic moment of electron (M)

M = iA

$$M = \frac{ev}{2\pi r} \times \pi r^2, \quad M = \frac{evr}{2}$$

$$M = \frac{e(mvr)}{2m} = \frac{eJ}{2m}; \ \frac{M}{J} = \frac{e}{2m},$$

$$M = \frac{e}{2m}\left(\frac{nh}{2\pi}\right) = n\left(\frac{eh}{4\pi m}\right)$$

$M = n\mu_B$ μ_B = Bohr magneton = 9.3×10^{-24} Amp. m^2

$M \propto n$

(7) Magnetic field or Magnetic induction at the centre

$$B = \frac{\mu_0 i}{2r} = \frac{\mu_0 ev}{4\pi r^2}$$

(8) 4 __________ –0.85 eV

3 __________ –1.51 eV

2 __________ –3.4 eV

n = 1 __________ –13.6 eV

Energy levels values for H-atom

(9) Difference of energy levels in H-atom

$\Delta E_{12} = 10.2\text{eV}$ $\Delta E_{24} = 2.55\text{eV}$

$\Delta E_{13} = 12.09\text{eV}$ $\Delta E_{23} = 1.89\text{eV}$

$\Delta E_{14} = 12.75\text{eV}$

(10) $\Delta E = \frac{hc}{\lambda^2}\Delta\lambda$, where λ = mean wavelength,

$\Delta\lambda$ = differnce in wavelength &

ΔE = difference in energy levels

(11) Total no. of electron in a shell = $2n^2$

(12) Total no. of electron in a subshell = $2\,(2l + 1)$