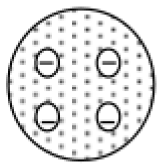
Atomic Structure (Physics)

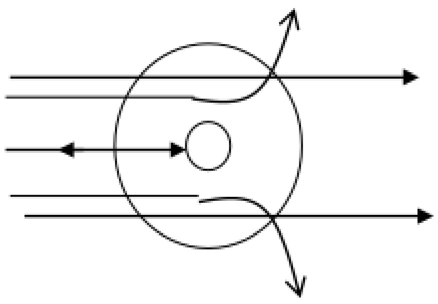
Thomson's Model



- Thomson's tried to explain about the arrangement of +ve & -ve charges in an atom.
- An atom is a +vely charged sphere of diameter about 10^{-10} m is which +ve charge are uniformly distributed where as -ve charges are slightly embedded like plum in a pudding.
- This model is also called plum-pudding model.
- He explained unequal concentration of electric change.
- Atom is electriclly neutral, the concentration of electric charge must be equal.
- This model could not explain about the atomic stability.
- This model could not explain abou α -particle scattering experiment.
  Hence, this model is fails to exist

Rutherford's Model

Rutherford's carried out of α particle scattering experiment and achieved the following observation.



Observation

i. Most of α -particles cross thin gold foil without any deflection.
ii. Some of α -particles are deflected with particular angle i.e. less than 90^0 i.e. acute angle.
iii. Few α -particles are totally back at an angle 180^0.

Postulates

i. The +vely charged and massive particles are concentrated to the inner core of an atom that inner core is called nucleus having diameter about 10^{-14} m to 10^{-15} m.
ii. The space around the nucleus is totally empty.
iii. The -vely charged particles are revolving round the circular path, known as electrons.

Failures

i. This model could not explain atomic stability.
ii. This model could not explain origin of line spectra.

Therefore, Rutherford's model fails to exist

Application of Rutharord model is to determine the closed distance of approach

When +vely charged particle approaches towards a stationary nucleus then due to replusion between them the kinetic energy of +vely charged particle gradually decreases & a stage come at which potential energy gain by charged particle due to stationary nucleus balanced its K.E.

We have,

$$\mathrm{P.E} = \mathrm{K.E}$$

$$\frac{q_1 q_2}{4\pi\epsilon_o r_o} = \mathrm{K.E}$$

$$\mathrm{K}\frac{\mathrm{Z_1 e Z_2 e}}{\mathrm{r}_o} = \mathrm{K.E}$$

Closest distance $(\mathrm{r_o}) = \dfrac{kZ_1eZ_2e^2}{K.E}$

$\therefore$ The closest distance of approach of any +vely charged particle to the stationary nucleus.

Bohr's Model

- Electron revolves round the stationary orbit. The necessary centripetal force provided by the electrostatic force of attraction between electron & nucleus.

  i.e $\dfrac{mv^2}{r} = \mathrm{k}\dfrac{\mathrm{ze}^2}{r^2} \cdots\cdots (\mathrm{i})$

- Those orits are called stationary orbits in which an angular momentum of an e^- is integral multiple of $h/2\pi$.

  i.e. $\mathrm{mvr} = \dfrac{nh}{2\pi} \cdots\cdots (\mathrm{ii})$

- Electrons absorbs energy to jump from lower orbit to higher orbit and when an electron jump from higher energy state to lower enery state, it will radiate energy.

  i.e $\Delta E = E_{n_2} - E_{n_1}$

  $hc/\lambda = E_{n_2} - E_{n_1}$

  Radiated wavelength is:

  $$(\lambda) = \frac{hc}{E_{n_2} - E_{n_1}} \cdots\cdots (\mathrm{iii})$$

- The no of possible photons due to transition of electron from energy level are:

  $$N = \frac{n(n-1)}{2} \cdots\cdots (\mathrm{iv})$$

  where, n is the no. of orbit.

- **Radius of n^{th} orbit**

  The radius of n^{rh} orbit of hydrogen like atom is:

  $$\begin{aligned} r_n &= \frac{n^2h^2}{4\pi^2\,\mathrm{kzm}\,e^2} \times \frac{n^2}{z} \\ &= 0.53 \times 10^{-10}\frac{n^2}{z} \end{aligned}$$

  $$\therefore\ r_n \propto \frac{n^2}{z}$$

  for $\mathrm{H-atom, z = 1}$ so, $\mathrm{r} = \dfrac{\varepsilon_0 \mathrm{h}^2}{\pi \mathrm{me}^2}\mathrm{n}^2$

  If $\mathrm{n} = 1,\ \mathrm{r_1} = 0.53 \times 10^{-10}\mathrm{m}$
  $= 0.53\mathring{A}$

  if $\mathrm{n} = 2,\ \mathrm{r_2} = 2.12\mathring{A}$ and so on.

- **Velocity of e^- in n^{th} orbit**

Velocity of e^- in n^{th} orbit of atom is:

We have,

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

$$\begin{aligned}
\mathrm{V_n} &= \frac{nh}{2\pi mr_n} = \frac{\mathrm{e^2}}{2\varepsilon_0\mathrm{h}}\frac{\mathrm{z}}{\mathrm{n}} \\
&= \frac{n \times 6.64 \times 10^{-34}}{2 \times 3.14 \times 9.1 \times 10^{-31} \times 0.53 \times 10^{-10}\mathrm{n/z}} \\
\mathrm{V_n} &= \frac{\mathrm{C}}{137}\frac{\mathrm{z}}{\mathrm{n}} \\
\mathrm{V_n} &= 2.18 \times 10^6\frac{\mathrm{z}}{\mathrm{n}}
\end{aligned}$$

$$\therefore \mathrm{V_n} \propto \frac{\mathrm{z}}{n}$$

For hydrogen atom $Z = 1$. So, $v = \frac{C}{137}\frac{1}{n}$

If $n = 1, v_1 = \frac{C}{137}$

If $n = 2, v_2 = \frac{C}{137}\frac{1}{2}$

& so on.

- **Energy in n^{th} orbit**

  Total energy in n^{th} orbit is:

$$E_n = K.E. + P.E.$$

Again,

$$\mathrm{P.E.} = \frac{-\mathrm{Ze^2}}{4\pi\varepsilon_0\mathrm{r}}$$

$$\mathrm{K.E.} = \frac{\mathrm{Ze^2}}{8\pi\varepsilon_0\mathrm{r}}$$

$$\therefore\ \mathrm{E_n} = -\frac{\mathrm{Ze^2}}{8\pi\varepsilon_0\mathrm{r}} = -\frac{\mathrm{Z^2me^4}}{8\varepsilon_0^2\mathrm{n^2h^2}}$$

$$= -13.6\frac{\mathrm{z^2}}{n^2}\ \mathrm{ev}$$

$$\therefore\ \mathrm{E_n} \propto \frac{\mathrm{z^2}}{n^2}$$

For hydrogen $Z = 1$, So, $E_n = -13.6\frac{1}{n^2}\ ev$

- **Time period for an e^- in the n^{th} orbit**

$$\mathrm{T_n} = \frac{2\pi r_n}{V_n} = \frac{2\pi \times 0.53 \times 10^{-10}n^2/\mathrm{z}}{2.18 \times 10^6\mathrm{z/n}}$$

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

For hydrogen $\mathrm{z} = 1$ so, $\mathrm{T_n} \propto \mathrm{n}^2$

- ### Frequency of an e^- in the n^{th} orbit

$$\mathrm{f_n} = \frac{V_n}{2\pi r_n}$$

$$\mathrm{f_n} \propto \frac{z^2}{n^3}$$

For hydrogen $\mathrm{z} = 1$ So, $\mathrm{f_n} \propto \frac{1}{n^3}$

Eq^n for wavelength is, $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Where,

$$R = \frac{me^4}{8\varepsilon_0^2 ch^3} = \text{Rydberg's constant}$$
$$= 1.097 \times 10^7\, m^{-1}$$

$n_1 =$ lower energy state
$n_2 =$ higher energy state

  - #### Current :

$$\mathrm{I_n} = \frac{q}{t} = \mathrm{qf}$$

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

  - #### Magnetic field at the center is :

$$\mathrm{B_n} = \frac{\mu_o I}{2r}$$

$$\therefore\ \mathrm{B_n} \propto \frac{\mathrm{z}^2/\mathrm{n}^3}{\mathrm{n}^2/\mathrm{z}} \propto \frac{\mathrm{z}^3}{n^5}$$

Emission Spectra

- ### Lyman Series:

If $n_1 = 1$ & $n_2 = 2, 3, 4, \ldots$

Then $1/\lambda = \mathrm{R}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For 1^{st} line $\mathrm{n_1} = 1\,\&\,\mathrm{n_2} = 2$

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

for series limit $\mathrm{n_1} = 1, \mathrm{n_2} = \infty$

so, $\frac{1}{\lambda} = \mathrm{R}$

$\rightarrow$ It lies in u-v region

- **Balmer series:**

  If $n_1 = 2\ \&\ n_2 = 3, 4, 5, \ldots$

  So, $1/\lambda = \mathrm{R}\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$

  For 1^{st} line $\mathrm{n}_2 = 3$

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

  for series limit $\mathrm{n}_2 = \infty$

  so, $\frac{1}{\lambda} = \frac{\mathrm{R}}{4}$

  $\rightarrow$ It lies in visible region

- **Paschen series:**

  If $n_1 = 3\ \&\ n_2 = 4, 5, 6, \ldots$

  So, $1/\lambda = \mathrm{R}\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$

  For 1^{st} line $\mathrm{n}_2 = 4$

  so, $\frac{1}{\lambda} = \mathrm{R}\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$

  for series limit $\mathrm{n}_2 = \infty$

  so, $\frac{1}{\lambda} = \frac{\mathrm{R}}{9}$

  $\rightarrow$ It lies in IR region

- **Brackett series:**

  If $n_1 = 4\ \&\ n_2 = 5, 6, 7, \ldots$

  So, $1/\lambda = \mathrm{R}\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$

  For 1^{st} line $\mathrm{n}_2 = 5$

  so, $\frac{1}{\lambda} = \mathrm{R}\left[\frac{1}{4^2} - \frac{1}{5^2}\right]$

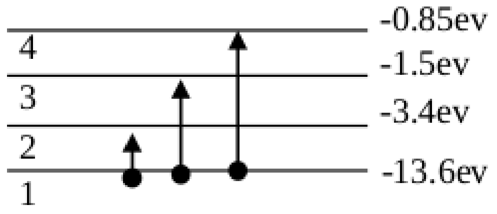
  for series limit $\mathrm{n}_2 = \infty$

  so, $\frac{1}{\lambda} = \frac{\mathrm{R}}{16}$

  $\rightarrow$ It lies in IR region

Excitation Energy/ Potential

Amount of energy required to jump the electrons from ground state to higher energy state is known as excitation energy. Required potential to do so is called excitation potential.



$n = 1$ to $n = 2$

Example:

1^{st} excitation energy is

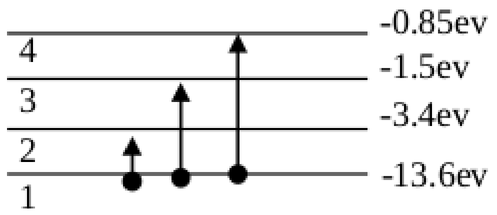
$$E = E_2 - E_1 = -3.4 + 13.6$$
$$= 10.2\, ev$$

Excitation potential

$$V_e = 10.2 \text{ volt}$$

Ionization Energy/Potential

Amount of energy required to jump the electrons from any energy state to infinite energy state is known as inonization energy. Required potential to knock out the electrous from an atom is known as ionization potential.



When an e^- ionized from $n = 1$

Requried ionization energy is:

$$(E_i) = E_\infty - E_1$$
$$= 0 - (-13.6)$$
$$= 13.6\, ev$$

$\therefore$ ionization potential $(V_i) = 13.6\,\text{volt}$

And so on.

Heisenberg's uncentainty principle

Heisenberg's uncentainty principle states that the product of uncertainity of two conjugate variables is always greater than or equal to $h/2\pi$.

i.e. $\Delta\text{x} \times \Delta\text{p} \geq \text{h}/2\pi$

$\text{x} =$ position
$\Delta\text{x} =$ uncertainity is position
$\text{P} =$ Momentum
$\Delta\text{P} =$ uncentainity is momentum

Similary for energy & time
ie. $\Delta\text{E} \times \Delta\text{t} \geq \text{h}/2\pi$

De-Broglie wave Equation

- He explained dual nature of matter (wave nature of matter)
- If matter posses wave nature, it will be associated particular wavelength ie $\lambda = h/p$

  h = planck's constant
  p = momentum

  Let,
  m = mass of matter
  V = velocity of matter

  Therefore, de Broglie wavelength for matter is:
  $\lambda = h/mv$

- When an e^- is accelerated through p.d. of V then de-Broglie's wavelength for an electron is:

  P.E. gain by $e^- = eV$

Accelerated $K.E. = \frac{1}{2}mv^2$

We have P.E = K.E

$$\mathrm{eV} = 1/2\mathrm{mv}^2$$
$$\Rightarrow \mathrm{v} = \sqrt{\frac{2eV}{m}}$$

We have, de-Broglie wave length for an electron is:

$$\lambda_{ele} = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{2eV}{m}}}$$

$$= \frac{h}{\sqrt{2meV}} = \frac{h}{\sqrt{2mE_k}}$$

$$= \frac{12.27}{\sqrt{v}}\mathring{A}$$