Chapter 12

ATOMS

Explain Thomson's atom model

J.J. Thomson was the first scientist to propose a model of atom. According to this model -
The entire positive charge of the atom was uniformly distributed in a sphere and electrons were embedded in such a manner that their mutual repulsions were balanced by attractive force by +ve charges.
This atom model is known as plum pudding model (water melon model)
This model could not explain stability and emission spectra of atoms.

- What are the conclusions of Rutherford's α particle scattering experiment.

In α particle scattering experiment, α particles from a source made in to a beam and was allowed to fall on a thin gold foil. The scattered α particles were observed through a rotatable detector consisting of zinc sulphide screen and a microscope. α particles on striking the screen produced scintillations. Using this a arrangement number of scattered α particles were studied as function of angle of scattering. The main observations were

a. Most of the α particles came out of they gold foil without suffering any deviation from their straight line path. This shows that most region of the atom is hollow.

b. A few α particles collided with atoms of gold foil suffered large deflection. A very few α particles even turned back towards the source itself. This showed that the entire +ve charge and almost the whole mass of the atom is concentrated in a small region called nucleus at the centre of the atom.

Explain Rutherford's model of the atom

According to this model

a. The entire positive charge of the atom is concentrated in a small region called nucleus, at the centre of the atom.

b. The electrons revolves round the nucleus. The coulomb's force of attraction between nucleus and electrons provides the necessary centripetal force for the revolution of electrons.

Drawbacks

According to classical electromagnetic theory a revolving electron (accelerated charge) should radiate energy continuously and thus electron should spiral inward and finally fall in to the nucleus. Thus this model could not explain the stability of atom.
As the energy of revolving electron decreases continously the atom should give a continuous spectrum. Thus this model fails to explain the line spectra of atoms.

Explain the postulates of Bhor's atom model

Bhor modified Rutherford's atom model on the basis of Quantum theory of radiation. The postulates of Bhor atom model are.

a. An electron in an atom could revolve in certain stable orbits without the emission of radiant energy. According to this postulate each atom has certain definit stable states in which it can exist, and each possible state has definit energy. These are called stationary states of the atom.

b. Electron revolves round the nucleus only in those orbits for which anguler momentum is integral multiple of ie. $\frac{h}{z\pi}$ (where h is plank's constant)

n=1, 2, 3 .... are called principle Quantum Number

c. When an electron jumps from a higher stable orbit to lower stable orbit, the energy difference is rediated in the form of a photon of energy.

$$h\upsilon = E_1 - E_f$$

Where E_i - energy of higher stable orbit.

E_f - energy of lower stable orbit.

Radius of n^{th} orbit (hydrogen atom)

For a hydrogen atom (1 proton 1 electron)

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

m - mess of electron

v- speed of electron

r - redion of orbit

$$r = \frac{e^2}{4\pi\varepsilon_0 mv^2}$$

For n^{th} orbit $r_n = \frac{e^2}{4\pi\varepsilon_0 mv^2}$ ....(1)

According to Bhor's postulate for the n^{th} orbit, angular momentum.

Angular momentum $L_n = \frac{nh}{2\pi}$

ie. $mV_n r_n = \frac{nh}{2\pi}$ ....(2)

Using (2) Eqn (1) becomes

$$r_n = \frac{e^2}{4\pi\varepsilon_0 m\left(\frac{nh}{2\pi m r_n}\right)^2}$$

Rearanging or $r_n = \frac{n^2}{m}\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2}$

For n=1, $r_1 = \frac{h^2\varepsilon_0}{\pi m e^2} = 0.53\times10^{-10} m$

This is called Bhor radius (a_0)

ie. $a_0 = 0.53A^0$

Note : For hydrogen like atom (Having one electron and atomic number Z>1)

$$r_n = \frac{n^2h^2\Sigma_0}{\pi m Ze^2} = \frac{n^2 a_0}{z}$$

- Speed of electron in n[th] orbit (V_n) - Hydrogen atom.

For hydrogen atom $\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$

$$\therefore V = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

For n[th] orbit $V_n = \frac{e}{\sqrt{4\pi\varepsilon_0 mr_n}}$ ....(1)

But $mV_n r_n = \frac{nh}{2\pi}$ ....(2)

Eqn (1) becomes $V_n = \frac{e}{\sqrt{4\pi\varepsilon_0 m \frac{nh}{2\pi m V_n}}}$ ie, $V_n = \frac{1}{n}\frac{e^2}{4\pi\varepsilon_0}\frac{1}{\left(h/2\pi\right)}$

Rearranging $V_n = \frac{e^2}{2\varepsilon_0 nh}$

For first Bhor orbit (n=1) $V_1 = \frac{e^2}{2\varepsilon_0 h} = 2.19x10^6 m/s = \frac{c}{137}$

Where C - Velocity of light

$$\therefore V = \frac{1}{n}\frac{C}{137}$$

For hydrogen like atom(z>1), $V_n = \frac{Ze^2}{2\varepsilon_0 nh} = \frac{z}{n}\frac{C}{137}$

- Energy of electron is n[th] state (Hydrogen atom)

PE of electron = $= \frac{-1}{4\pi\varepsilon_0}\frac{e^2}{r_n}$

KE of electron $= \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r_n} = \frac{e^2}{8\pi\varepsilon_0 r_n}$

$\therefore$ Total energy $E_n = \frac{-e^2}{4\pi\varepsilon_0 r_n} + \frac{e^2}{8\pi\varepsilon_0 r_n}$

ie $E_n = \frac{-e2}{8\pi\varepsilon_0 r_n}$

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

$$\therefore E_n = \frac{-e^2}{8\pi\varepsilon_0 \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}}$$

ie $E_n = \frac{-me^4}{8n^2 \varepsilon_0{}^2 h^2}$ or $E_n =^{-} \left(\frac{e^2}{8\pi\varepsilon_0}\right)\left(\frac{e^2}{4\pi\varepsilon_0}\right)\left(\frac{m}{n}\right)\left(\frac{2\pi}{h}\right)^2$

Substituting the values

$$E_n = \frac{-2.18x10^{-18}}{n^2} J$$

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

$(1.6x10^{-19} J = lev)$

The -ve sign of the total energy of an e^- moving in an orbit means that the electron is bound with the nucleus. Energy will be required to remove the election from the hydrogen atom to distance infinitely for away from its nucleur

Note:-For Hydrogen like atom

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

Explain the formation of line spectra of Hydrogen atom

According to the third postulate of Bhor's model when on atom makes a transition from higher energy state quantum nucleur n_i to the lower energy state with quantum number n_f $(n_f<n_1)$ the difference of energy is carried away by a photon of frequency υ if such that,

$h\upsilon_{if} = E_{ni} - E_{nf}$ ....(1)

But $E_{ni} = \frac{-me^4}{8\varepsilon_0{}^2 h^2 n_i{}^2}$

$$E_{nf} = \frac{-me^4}{8\varepsilon_0{}^2 h^2 n_f{}^2}$$

$\therefore$ Eqn 1 $\Rightarrow$

$$h\upsilon_{if} = \frac{me^4}{8\varepsilon_0{}^2 h^2}\left(\frac{1}{n^2{}_f} - \frac{1}{n_i{}^2}\right) \text{.............................(1)}$$

or $\upsilon_{if} = \frac{me^4}{8\varepsilon_0{}^2 h^3}\left(\frac{1}{n^2{}_f} - \frac{1}{n_i{}^2}\right)$ ....(2)

This equation is called Rydbers formula for the spectrum of hydrogen atom.
Eqn can be written as

$$\frac{c}{\lambda} = \frac{me^4}{8\Sigma_0{}^2h^3}\left(\frac{1}{n_f{}^2} - \frac{1}{n_i{}^2}\right)$$

(since $\upsilon = \frac{c}{\lambda}$)

$$\therefore \frac{1}{\lambda if} = \frac{me^4}{8\varepsilon_0{}^2h^3c}\left(\frac{1}{n_f{}^2} - \frac{1}{n_i{}^2}\right)$$

$Here \frac{me^4}{8\varepsilon_0{}^2h^3c} = R = 1.097x10^7 m^{-1}$ is called Rydberg const.

$$\therefore \frac{1}{\lambda if} = R\left(\frac{1}{n_f{}^2} - \frac{1}{n_i{}^2}\right) \text{.......................... } 3$$

Spectral lines of Hydrogen atom

a. Lymen Series

For this series $n_f = 1$, $n_i = 2, 3, 4.$ .... α

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

This series is in uv region
The series limits of lymen series given by

$\frac{1}{\lambda} = R\left(\frac{1}{1} - \frac{1}{\alpha}\right)$ μ , $\lambda = \frac{1}{R}$ (Lowest wave length or highest frequency)

The first member of this series is given by

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

$\lambda = \frac{4}{3R}$ (lowest frequency)

b. Balmer Series

For this series $n_f = 2$, $n_i = 3, 4, 5.$ .... α

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

This is in visible part
Series limit is given by

$\frac{1}{\lambda} = R\left(\frac{1}{4} - \frac{1}{\alpha}\right)$ $\quad \therefore \lambda = \frac{4}{R}$

First member $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$ $\mu , \lambda = \frac{36}{5R}$