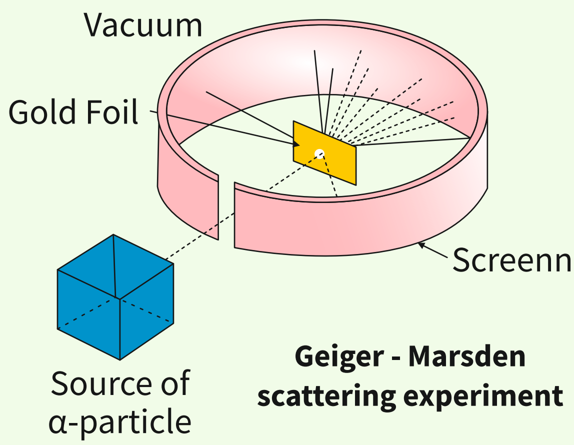
12. ATOMS

RUTHERFORD'S NUCLEAR MODEL OF AN ATOM



Geiger - Marsden scattering experiment

- α - particles were emitted by the radioactive element $_{83}B^{214}$ were bombarded on a thin gold foil.
- Scattered α - particles are collected on ZnS screen.

LIMITATIONS

- This model does not explain the presence of nucleus in the atom.
- This is not able to explain scattering of α - particles
- This is not able to explain the spectrum of atoms

OUTCOMES

- Most of the α - particles went straight without any deviation.
- Some of α - particles were deflected by some angles.
- Very few α - particles were deflected by an angle 180°

CONCLUSIONS

- Positive charges was concentrated in small region of an atom is called nucleus.
- Negative charges were revolving in circular orbit around the nucleus

LIMITATIONS

- This model does not explain the stability of nucleus.
- This model does not explain the line spectra of atom.

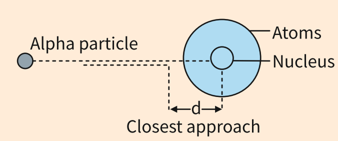
Distance of Closest Approach of Alpha Particle

At closest approach, system only have electric potential energy

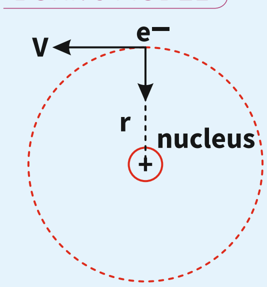
$$K = U = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{d}$$

$$d = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{K}$$

$$d = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{\left(\frac{1}{2}mv^2\right)}$$



BOHR'S MODEL



- Valid for only one – electron atom.
- Electron is revolving around the nucleus in a stable orbit.
- Attractive coulomb force between electron and nucleus is equal to the centripetal force on electron

$$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r} \quad (r = \text{radius of orbit})$$

POSTULATES

- Electron in an atom could revolve in certain stable orbits with emission of radiant energy.
- $L = \frac{nh}{2\pi}$; L = angular momentum, h = Planck's constant $= 6.6 \times 10^{-34}$ Js
- $h\upsilon = E_i - E_f$

  E_i & E_f are the energies of initial & final states, $E_i > E_f$

RADIUS OF n^{th} ORBIT

$$r_n = \frac{n^2h^2\varepsilon_0}{Z\pi me^2} = \frac{0.53n^2}{z}\text{Å}$$

$$r_n \propto \frac{n^2}{z},\ r_n \propto \frac{1}{m}$$

ORBITAL FREQUENCY IN n^{th} ORBIT

$$f_n = \frac{V}{2\pi r} = \frac{me^4Z^2}{4\varepsilon_0 n^3h^3}$$

$$f_n \propto \frac{Z^2}{n^3}$$

VELOCITY OF ELECTRON IN n^{th} ORBIT

$$v_n = \frac{ze^2}{2nh\varepsilon_0} = 2.19\times10^6\ \frac{Z}{n}\text{m/s}$$

$$\Rightarrow v_n \propto \frac{Z}{n}$$

POTENTIAL AND KINETIC ENERGY IN n^{th} ORBIT

$$U_n = \frac{-1}{4\pi\varepsilon_0}\frac{Ze^2}{r} = \frac{-me^4z^2}{4\varepsilon_0^2h^2n^2} \qquad K_n = \frac{1}{2}mv^2 = \frac{me^4z^2}{8\varepsilon_0^2h^2n^2}$$

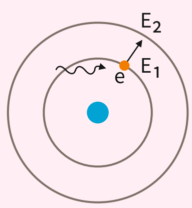
TOTAL ENERGY IN n^{th} ORBIT

$$E_n = K_n + U_n = \frac{-me^4Z^2}{8\varepsilon_0h^2n^2} \qquad E_n = -K_n = \frac{U_n}{2}$$

$$E_n \propto \frac{-13.6z^2}{n^2}\text{eV} \qquad E_n \propto \frac{Z^2}{n^3},\ E_n \propto m$$

EXCITATION ENERGY

- ✦ $E_{excitation} = E_2 - E_1$
- ✦ E_1 = energy of lower orbit
- ✦ E_2 = energy of higher orbit



EXCITATION POTENTIAL

$$V_{excitation} = \frac{E_{excitation}}{e} = \frac{E_2-E_1}{e}\ \text{(volts)}$$

IONIZATION ENERGY

✦ Minimum energy required to remove the electron.

$$E_{ionization} = \frac{13.6\,z^2}{n^2}\ \text{eV}$$

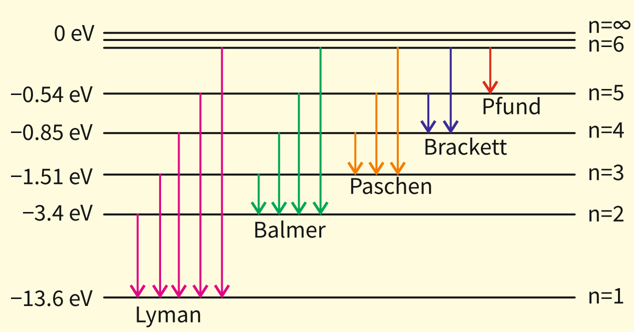
IONIZATION POTENTIAL

$$V_{excitation} = \frac{E_{excitation}}{e} = \frac{13.6\,z^2}{n^2}\ \text{volts}$$

BINDING ENERGY

- ✦ Minimum energy required to bound the electron from nucleus
- ✦ B.E. = - Eionization = $\frac{13.6\,z^2}{n^2}$ eV

Line Spectra of the Hydrogen Atom



✦ The wave number or wavelength of the emitted photon when electron jumps from higher orbital state 'n_2' to lower orbital state 'n_1' is

$$\bar{\nu} = \frac{1}{\lambda} = \frac{E_{n_2}-E_{n_1}}{hc} = \left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

R = Rydberg constant = $1.097\times10^7\ m^{-1}$

✦ Number of spectral lines when electron jump From n^{th} orbit = $\frac{n(n-1)}{2}$

De Broglie's Explanation of Bohr's Second Postulate of Quantisation

$$2\pi r_n = n\lambda$$

$$2\pi r_n = \frac{nh}{mv_n}$$

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