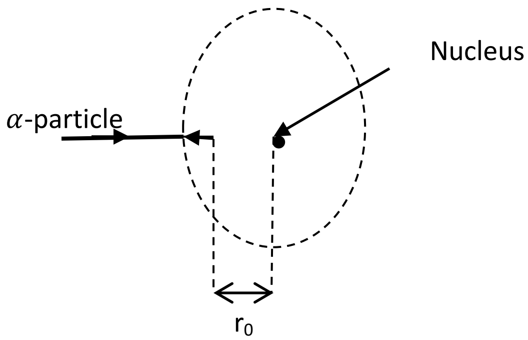
Ch-12:Atoms

1. Distance of closest approach-Estimation of nuclear size



The minimum distance from the nucleus up to which, α particle approaches and retraces its path, is called the distance of closest approach.

The charge on the α-particle is $q_1 = +Ze$ and charge on nucleus, $q_2 = +Ze$ where Z is the atomic number of foil atoms. So electrostatic potential energy of α-particle and nucleus at distance r_0 is

$$U = \frac{1}{4\pi\epsilon_0}\left(\frac{q_1 q_2}{r}\right) = \frac{1}{4\pi\epsilon_0}\left(\frac{2Ze^2}{r_0}\right)$$

This potential energy is equal to initial kinetic energy, so, initial K. E. of α-particle is

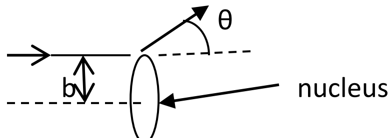
$$K = \frac{1}{2}mv^2 = \frac{1}{4\pi\epsilon_0}\left(\frac{2Ze^2}{r_0}\right) \Rightarrow r_0 = \frac{Ze^2}{m\pi\epsilon_0 v^2}$$

2. **Impact parameter**:

The scattering of α particle from a nucleus depends upon the closest approach to the nucleus.

''It is defined as the perpendicular distance of velocity vector of the α-particle from the central line of the nucleus when it is far away from the atom''.

The shape of the trajectory of scattered α-particle depends on the (i) impact parameter b and (ii) the nature of the potential field.



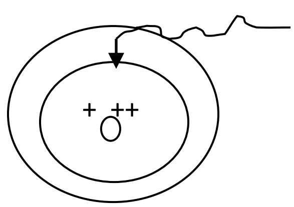
Rutherford deduced the following relationship between the impact parameter b and the scattering angle θ as

$$b = \frac{1}{4\pi\epsilon_0}\left(\frac{Ze^2 \cot\frac{\theta}{2}}{K}\right), where\ K = \frac{1}{2}mv^2$$

For a head-on collision, the impact parameter b= 0, scattering angle θ = 180^0. That ie, α-particle is reversed back along its original path.

$$Impact\ parameter, b \propto \cot\left(\frac{\theta}{2}\right)$$

3. **Bohr's atomic model: Postulates of Bohr's theory of hydrogen atom:** Bohr's model based on the following **three postulates**.
Quantum condition: The electrons can revolve only in those orbits in which the angular momentum is the integral multiple of h/2 π. That is,
$L_n = mvr = \frac{nh}{2\pi}, where\ n = 1, 2, 3,$ are principal quantum number.
Stationary orbit: An electron in atom can move around nucleus in certain circular stable orbits without emitting radiations, is called stationary orbit.
Frequency condition: When the atom receives the energy from outside, then one (or more) of its outer electrons leaves its orbit and goes to some higher orbit. This state of atom is called **excited state**. The electron in the higher orbit stays only for 10^{-8} s and returns back to lower orbit. While returning back, the electron radiates energy in the form of electromagnetic waves



If the energy of the electron in the higher orbit be E_2 (here is E_i) and that in the lower orbit be E_1 (here is E_f) So, frequency of the emitted radiation is given by

$$f = \frac{E_2 - E_1}{h}, where, h = Planck's\ constant$$

This equation is called Bohr's frequency condition.

4. **Radius of electron: n^{th} radius of electron;**

$$r_n = \frac{\epsilon_0 n^2 h^2}{\pi m Z e^2} \quad Or, r_n \propto \frac{n^2}{Z}$$

Where, n = no.of orbit, Z = atomic number, m=mass of one electron,e = charge of one electron,h = Plancks constant, ϵ_0 = Permittivity of free space
For, H-atom, Z = 1; For Hydrozen like atom: For He^+,Z = 2, for Li^{++},Z = 2, For Be^{+++},Z = 4, Now, for Hydrogen atom, n^{th} radius is,

$$r_n = r_1 n^2 \ or\ r_n \propto n^2$$

$$It\ means, ratio\ are: r_1 : r_2 : r_3 - -- = 1 : 4 : 9 - - -$$

Where r_1 = = 0.53 Ă (1 Ă= 10^{-10} m)= $\frac{\epsilon_0 h^2}{\pi m e^2}$

5. **Speed of nth orbit in Bohr's model of hydrogen atom**

$$v_n = \frac{e^2}{2\epsilon_0 nh}\ and\ v_n = \frac{v_1}{n}\ or\ v_1 \propto \frac{1}{n};\ v_1 = \frac{c}{137} = 2.19 \times \frac{10^6 m}{s}; c = speed\ of\ light\ in\ vacuum$$

6. **Speed of nth orbit in Bohr's model of hydrogen like atom**

$$v_n = \frac{Ze^2}{2\epsilon_0 nh}$$

7. **Fine structure constant** $\alpha = \frac{e^2}{2\epsilon_0 ch}, so\ v = \alpha \frac{c}{n}$
8. **Energy of the electron of H atom**:

The total energy in the n^th^ orbit is the sum of kinetic energy and potential

$$E_n = -\frac{me^4}{8{\epsilon_0}^2 n^2 h^2}$$

$$E_n = \frac{E_1}{n^2} = \frac{-13.6}{n^2} = \frac{-Rhc}{n^2}\ \ (in\ eV)$$

9. Some common terms used:

(i) **Absorption of energy**: When the electron in the atom can jump from lower orbit to higher orbit, it absorbs energy.

(ii) **Emission of energy**: When an electron jumps from higher to lower orbit, it emits energy.

(iii) Energy of photon is equal to the difference of two orbits. $[E_i - E_f = hf]$

(iv) **Ground state and ground state energy**: The lowest state of an atom (n =1) is called ground state and energy associated with ground state is called ground state energy.

(v) **Ionization energy**: Energy required to ionise an atom is called ionisation energy. It is the energy required to make the electron jump from present orbit to the infinite orbit.

$$E_{ionisation} = E_\infty - E_n = 0 - (E_n) = 13.6\ eV$$

10. **Energy needed to remove the electron from any energy level means Ionisation Energy**.
(Minimum energy required to free the electron from ground state of the hydrogen atom is 13.6 eV, it is called ionization energy.)
11. **Ionization Potential** : The potential difference through which an electron should be accelerated to get ionization energy is called ionisation potential.
12. **Excitation energy**: The energy required to take an electron from lower state to higher state is known as excitation energy. If lower state energy is E_{n_1} and higher state energy is E_{n_2}, then excitation energy is $\Delta E_{n_1 n_2} = E_{n_2} - E_{n_2}$
13. **Wavelength of photon emitted in De-excitation**:
According to Bohr, when an atom makes a transition from one energy level to a lower level, it emits a photon with energy equals to the energy difference between the initial and final level. If E_i is the initial energy of the atom before such a transition, E_f is its final energy after the transition. And the photon energy is $hf = \frac{hc}{\lambda}$, then conservation of energy gives

$$E = hf = \frac{hc}{\lambda} = E_i - E_f energy\ of\ emitted\ photon$$

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

14. **Rydberg formula:** $\frac{1}{\lambda} = Z^2 R\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right]$

Energy of the emitted radiation(H atom), $E = Rhc\left[\frac{1}{{n_1}^2} - \frac{1}{{n_2}^2}\right]$, here Rhc = -13.6 eV