BOHR ATOM

Hydrogen atom theory- new era in atomic structure and spectroscopy.

It provides explanation of different series of hydrogen atom and ionied helium.

Rydberg constant

BOHR'S CIRCULAR ORBIT

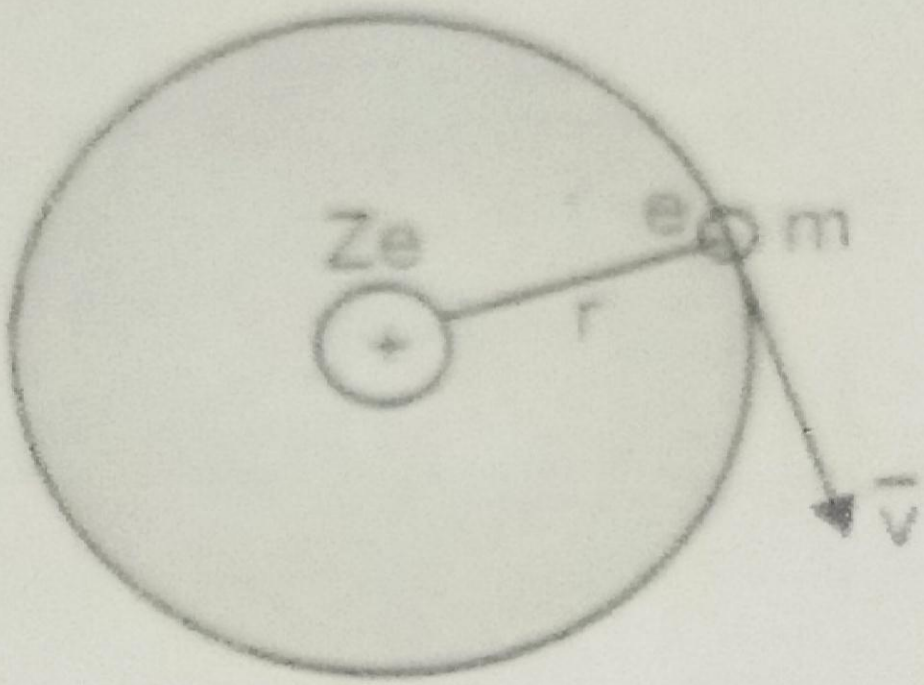
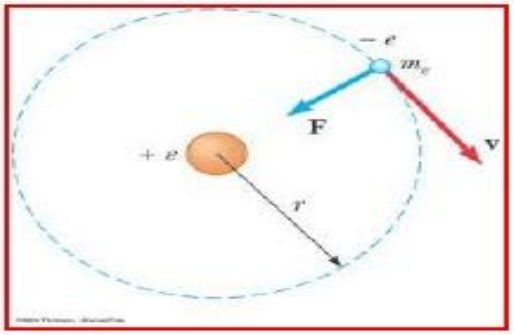


Fig. 1.6 : Bohr's circular orbit

Bohr's Postulates

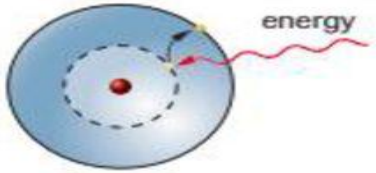
- Bohr started from the assumption that the electron moves in circular orbits around the proton under the influence of the attractive electric field.



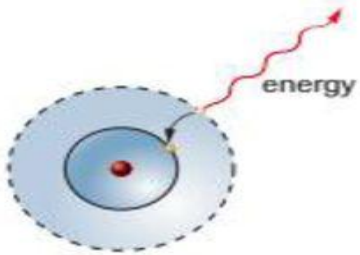
- **Postulate 1:** Only certain orbits are stable. These are ***stationary*** or more precisely ***quasi-stationary states***. An electron ***does not*** emit EM radiation when in one of these states (orbits)

Bohr's Second Postulate

- Electrons can change their energy only by undergoing a transition from one stationary state to another.
- **High-to-low-energy-state = emitting energy (bright line spectrum)**
- **Low-to-high-energy-state = absorbing energy (dark-line spectrum)**



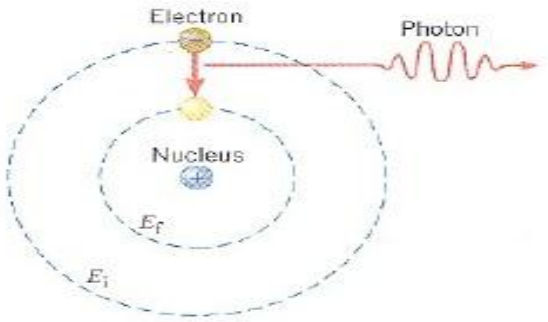
(a) An electron gains a quantum of energy.



(b) An electron loses a quantum of energy.

Bohr Postulate 3

Radiation is emitted or absorbed if an electron moves between energy levels.



Radiation is released in the form of a photon. The frequency of the photon emitted is related to the difference in the energy levels according to the Planck-Einstein formula:

$$E_i - E_f = hf$$

First Postulate : **(April 12)**

- Bohr's first assumption was that an *electron revolves in certain allowed circular orbits about the nucleus under the action of Coulomb's force.* The force of attraction between the electron of charge e and the nucleus of charge Ze is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} \qquad \ldots (1.6)$$

where a is the electron-nuclear distance, Z is the atomic number (Z = 1 for hydrogen) and ε_0 is the permittivity of free space. The force given by equation (1.6) is equal to the centripetal force mv^2/a, where v is the velocity and m is the mass of the electron. For equilibrium condition,

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} \qquad \ldots (1.7)$$

which gives

$$\boxed{v^2 = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{mr}} \qquad \ldots (1.8)$$

Second Postulate :

- Bohr's second assumption for the hydrogen atom may be stated as *"only those circular orbits for electrons are permitted for which the angular momentum ($\bar{L}$) is equal to the integral multiple of* $\frac{h}{2\pi}$.

Thus, $$\bar{L} = n\left(\frac{h}{2\pi}\right) \quad \ldots (1.9$$

where, n = 1, 2, 3, ...

- Orbital angular momentum of an electron is given by

$$\bar{L} = mvr \quad \ldots (1.10$$

where v is the linear velocity of electron in an orbit.

Equations (1.9) and (1.10) give

$$\boxed{mvr = n\left(\frac{h}{2\pi}\right)} \quad \ldots (1.1$$

- Orbits permitted by the condition shown by equation (1.7) are called allowed orbits f electrons. These orbits are called non-radiating orbits

Third Postulate :

- *A quantum of energy is radiated only when an electron jumps from higher energy orbit to the lower energy orbit and the frequency of emitted radiation is proportional to the difference between two energy states.*

Thus, $h\upsilon = E_1 - E_2$ ... (1.12)

where υ is the frequency, E_1 and E_2 are the energies of initial and final states.

From equation (1.7), we get

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

$$m^2v^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2m}{r} \quad \text{... (1.13)}$$

Equation (1.11) gives

$$mv = \frac{n}{r}\frac{h}{2\pi}$$

$$m^2v^2 = \frac{n^2}{r^2}\frac{h^2}{4\pi^2} \quad \text{... (1.14)}$$

From equations (1.13) and (1.14), we get

$$r = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2 Z} \quad \text{... (1.15)}$$

For hydrogen atom, Z = 1. So the radius of n^{th} orbit is given by

$$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2} \quad \ldots (1.16)$$

where n is called principal quantum number.

Equation (1.16) indicates that

$$r_n \propto n^2, \quad n = 1, 2, 3, \ldots\ldots$$

Thus radii of Bohr's orbit are proportional to the square of natural numbers.

Radius of first orbit, n = 1 is

$$r_1 = 0.53 \times 10^{-10}\ m = 0.53\ A^\circ$$

From equations (1.11) and (1.16), the velocity of an electron in n^{th} orbit is given by

$$v_n = \frac{e^2}{2\varepsilon_0 nh} \quad \ldots (1.17)$$

LIMITATION OF BOHR'S MODEL :

1. In Bohr's model the quantum idea of stationary orbits is mixed up with the classical idea of coulomb force.
2. The assumption of only circular orbit is utterly unjustified.
3. It can only explain the line of the hydrogen and hydrogen like atoms.
4. It can not explain the fine structure of hydrogen atom.
5. It can not make any calculation about the transition or the selection rules which apply to them.