Chemistry Study Materials for Class 11 (NCERT Based Notes of Chapter- 02)

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Structure of Atom

BOHR'S MODEL FOR HYDROGEN ATOM

The general features of the structure of hydrogen atom and its spectrum was first explained by Niels Bohr. The important postulates of his theory are:

1. The electron in the hydrogen atom can move around the nucleus in circular paths of fixed radius and energy. These paths are called orbits or stationary states or allowed energy states. These energy levels are numbered as 1,2,3 etc or as K, L, M, N, etc. These numbers are known as **Principal quantum numbers**.

2. The energy of an electron in an orbit does not change with time. However, when an electron absorbs energy, it will move away from the nucleus (i.e. to a higher energy level) and when it loses energy, it will move towards the nucleus (i.e. to a lower energy level).

3. The radius of orbits can be given by the equation: $r_n = a_0 n^2$

where a_0 = 52.9 pm.

Thus the radius of the first stationary state is 52.9 pm (called the Bohr radius). As n increases, the value of r will increase.

4. The energy of electron in an orbit is given by the expression: $E_n = -R_H (1/n^2)$, where n = 1,2,3…… and R_H is a constant called Rydberg constant.

Its value is 2.18×10^{-18} J.

The energy of the lowest state (the ground state) is given by $E_1 = -2.18 \times 10^{-18}$ **J**. As the value of n increases, the energy of the electron also increases.

5. The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by:

$$v = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

Where E_1 and E_2 are the energies of lower and higher energy levels respectively. This expression is commonly known as *Bohr's frequency rule*.

6. The angular momentum of an electron is an integral multiple of h/2π.

i.e. $m_e vr = \frac{nh}{2\pi}$ Where m_e is the mass of electron, v is the velocity of electron and r is the radius of Bohr orbit. n = 1, 2, 3, …..

Thus an electron can move only in those orbits whose angular momentum is an integral multiple of h/2π. So only certain fixed orbits are allowed.

Significance of negative energy of electron

When the electron is free from the influence of nucleus, its energy is taken as zero. In this situation, the electron is at the orbit with n = ∞. When the electron is attracted by the nucleus and is present in orbit n, the energy is emitted and its energy is lowered. That is the reason for the presence of negative sign in equation.

Explanation of Line Spectrum of Hydrogen

According to Bohr atom model, radiation is absorbed if the electron moves from lower energy to higher energy level and radiation is emitted if the electron moves from higher orbit to lower orbit. The energy gap between the two orbits is given by equation: $\Delta E = E_2 - E_1$

But $E_1 = \frac{-R_H}{n_1^2}$ and $E_2 = \frac{-R_H}{n_2^2}$

Therefore, $\Delta E = R_H [1/n_1^2 - 1/n_2^2]$

$$= 2.18 \times 10^{-18} [1/n_1^2 - 1/n_2^2]$$

The frequency associated with the absorption and emission of the photon can be given as $\mathbf{v} = \frac{\Delta E}{h} = \frac{R_H}{h}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$= \frac{2.18 \times 10^{-18}}{6.626 \times 10^{-34}}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= 3.29 \times 10^{15} [1/n_1^2 - 1/n_2^2]$$

The wave number $(\bar{\nu}) = 1/\lambda = \frac{\nu}{c} = \frac{R_H}{hc}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$

$$= \frac{3.29 \times 10^{15}}{3 \times 10^8}\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$$

$$= 1.09677 \times 10^7\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\} m^{-1} = 109677\left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\} cm^{-1}$$

In case of absorption spectrum, $n_2 > n_1$ and the term in the bracket is positive and energy is absorbed.

On the other hand,

in case of emission spectrum $n_1 > n_2$, ΔE is negative and energy is released.

Limitations of Bohr Atom Model:

Bohr atom model could explain the stability and line spectra of hydrogen atom and hydrogen like ions (e.g. He^+, Li^{2+}, Be^{3+} etc). But it has the following limitations:

1. It could not explain the fine spectrum of hydrogen atom.
2. It could not explain the spectrum of atoms other than hydrogen.
3. It was unable to explain the splitting of spectral lines in the presence of electric field (**Stark effect**) and in magnetic field (**Zeeman Effect**).
4. It could not explain the ability of atoms to form molecules by chemical bonds.
5. It did not consider the wave character of matter and Heisenberg's uncertainty principle.

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