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

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Structure of Atom

Dual Behaviour of Matter – de Broglie's equation

de Broglie proposed that like radiation, matter also exhibit dual behaviour i.e., both particle and wave like properties. This means that electrons should also have momentum as well as wavelength. He gave the following relation between wavelength (λ) and momentum (p) of a material particle.

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

Where m is the mass of the particle, v is the velocity and p is the momentum. The above equation is known as **de Broglie's equation**.

Just like electromagnetic radiations, an electron beam also undergoes diffraction. This is an evidence for the wave nature of electrons. An electron microscope works on the principle of wave nature of electron.

According to de Broglie, every moving object has a wave character. The wavelengths associated with ordinary objects are so short (because of their large masses) that their wave properties cannot be detected. The wavelengths associated with electrons and other subatomic particles (with very small mass) can be detected experimentally.

Heisenberg's Uncertainty Principle

Werner Heisenberg proposed the uncertainty principle which is the consequence of dual behaviour of matter and radiation.

It states that **"*it is impossible to determine simultaneously, the exact position and exact momentum (or velocity) of a moving microscopic particle like electron*"**.

Mathematically, it can be given as in equation: $\Delta x. \Delta p \geq \frac{h}{4\pi}$

Or, $$\Delta x. m\Delta v \geq \frac{h}{4\pi}$$

Or, $$\Delta x. \Delta v \geq \frac{h}{4\pi m}$$

Where Δx is the uncertainty in position,

Δv is the uncertainty in velocity

and Δp is the uncertainty in momentum of the particle.

If the position of the electron is known with high degree of accuracy (Δx is small), then the velocity of the electron will be uncertain [Δv is large] and vice versa.

Significance of Uncertainty Principle

Heisenberg Uncertainty Principle is significant only for motion of microscopic objects and is not applicable to macroscopic objects. According to this Principle, **we cannot determine the exact position and momentum of an electron.** Thus it rules out the existence of definite paths or orbits of electrons. We can only say the probability of finding an electron at a given point.

Reasons for the Failure of the Bohr Model

In Bohr model, electrons are moving in well defined circular orbits about the nucleus. The wave character of the electron is not considered in Bohr model. Further, an orbit is a clearly defined path and this path can completely be defined only if both the position and the velocity of the electron are known exactly at the same time. This is not possible according to the Heisenberg uncertainty principle. Therefore, Bohr model of the hydrogen atom not only ignores dual behaviour of matter but also contradicts Heisenberg uncertainty principle.

QUANTUM MECHANICAL MODEL OF ATOM

On the basis of dual nature of matter and the uncertainty principle, Erwin Schrodinger and Werner Heisenberg proposed a new model of atom called Quantum mechanics. The fundamental equation of quantum mechanics was developed by Schrödinger and is known as Schrödinger equation.

It is written as:

$$\hat{H}\psi = E\psi$$

where $\hat{H}$ is a mathematical operator called *Hamiltonian operator*, E is the total energy of the system (K.E + P.E) and ψ is called the wave function.

On solving the above equation, we get different values for E and ψ.

When Schrödinger equation is solved for hydrogen atom, the solution gives the possible energy levels the electron can occupy and the corresponding wave function (ψ). These quantized energy states and corresponding wave functions are characterized by a set of three quantum numbers.

Significance of ψ

The wave function (ψ) is a mathematical function and it has no physical meaning. Wave functions of hydrogen or hydrogen like species with one electron are called atomic orbitals. All the information about the electron in an atom is stored in its orbital wave function ψ. It may be positive or negative.

But ψ^2 has some physical significance. It gives the probability of finding an electron at a point within an atom. So ψ^2 is known as **probability density** and is always positive. From the value of ψ^2, it is possible to predict the probability of finding the electron around the nucleus.

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