

# Bohr's theory of hydrogen atom

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## 1 The theory

Niels Bohr introduced the atomic Hydrogen model in 1913. He described it as a positively charged nucleus, comprised of protons and neutrons, surrounded by a negatively charged electron cloud. In the model, electrons orbit the nucleus in atomic shells. The atom is held together by electrostatic forces between the positive nucleus and negative surroundings.

Niels Bohr suggested that the problem about hydrogen spectrum can be solved if we can make some assumptions. According to classical theory, the frequency of the electromagnetic waves emitted by a revolving electron is equal to the frequency of revolution. As the electrons radiate energy, their angular velocities would change continuously and they would emit a continuous spectrum against line spectrum actually observed. So, Bohr concluded that even if electromagnetic theory successfully explained the macroscopic phenomenon, it could not be applied to explain microscopic phenomenon, that in atomic scale. So he made bold suggestions called as Bohr's postulates.

## 2 Hydrogen Energy Levels

The Bohr model is used to describe the structure of hydrogen energy levels. The image below represents shell structure, where each shell is associated with principle quantum number  $n$ . The energy levels presented correspond with each shell. The amount of energy in each level is reported in eV, and the maximum energy is the ionization energy of 13.598eV.

## 3 Hydrogen Spectrum

The movement of electrons between these energy levels produces a spectrum. The Balmer equation is used to describe the four different wavelengths of Hydrogen which are present in the visible light spectrum. These wavelengths are at 656, 486, 434, and 410nm. These correspond to the emission of photons as an electron in an excited state transitions down to energy level  $n=2$ . The Rydberg formula, below, generalizes the Balmer series for all energy level transitions. To get the Balmer lines, the Rydberg formula is used with an  $n_f$  of 2.

## 4 Rydberg Formula

The Rydberg formula explains the different energies of transition that occur between energy levels. When an electron moves from a higher energy level to a lower one, a photon is emitted. The Hydrogen atom can emit different wavelengths of light depending on the initial and final energy levels of the transition. It emits a photon with energy equal to the difference of square of the final (n<sub>f</sub>) and initial (n<sub>i</sub>) energy levels.

$$Energy = R(1/n^2_f - 1/n^2_i)$$

The energy of a photon is equal to Planck's constant,  $h=6.626 \times 10^{-34} \text{m}^2\text{kg/s}$ , times the speed of light in a vacuum, divided by the wavelength of emission.

$$E = hc$$

Combining these two equations produces the Rydberg Formula.

$$1 = R(1/n^2_f - 1/n^2_i)$$

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## 5 Limitations of the Bohr Model

The Bohr Model was an important step in the development of atomic theory. However, it has several limitations:

- \*It is in violation of the Heisenberg Uncertainty Principle.
- \*The Bohr Model considers electrons to have both a known radius and orbit, which is impossible according to Heisenberg.
- \*The Bohr Model is very limited in terms of size. Poor spectral predictions are obtained when larger atoms are in question.
- \*It cannot predict the relative intensities of spectral lines.
- \*It does not explain the Zeeman Effect, when the spectral line is split into several components in the presence of a magnetic field.
- \*The Bohr Model does not account for the fact that accelerating electrons do not emit electromagnetic radiation.

## 6 Sources

<http://www.tutorvista.com/content/physics/physics-iv/atoms-and-nuclei/bohns-hydrogen-atom.php>