Bohr's quantum theory revised

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Niels Bohr and Paul Ehrenfest (with his son) at Leiden train station (Holland) in 1926. Credit: Courtesy of the Niels Bohr Archive, Copenhagen

Niels Bohr's atomic model was utterly revolutionary when it was presented in 1913. Although it is still taught in schools, it became obsolete decades ago. However, its creator also developed a much wider-ranging and less known quantum theory, the principles of which changed over time. Researchers at the University of Barcelona have now analysed the development in the Danish physicist's thought – a real example of how scientific theories are shaped.

Most schools still teach the atomic model, in which electrons orbit around the nucleus like the planets do around the sun. The model was based on Rutherford's first model, the principles of classical mechanics and emerging ideas about 'quantisation' (equations to apply initial quantum hypotheses to classical physical systems) advanced by Max Planck and Albert Einstein.

As Blai Pié i Valls, a physicist at the University of Barcelona, explains to SINC: "Bohr published his model in 1913 and, although it was revolutionary, it was a proposal that did little to explain highly varied experimental results, so between 1918 and 1923 he established a much more wide-ranging, well-informed theory that incorporated his previous model."

Bohr's theory, called quantum theory, proposed that electrons circle the nucleus following the classical laws but subject to limitations, such as the orbits they can occupy and the energy they lose as radiation when they jump from one orbit to another. But it also attempted to explain in a unified way all the quantum phenomena that had been observed to date.

"This theory rested on two fundamental pillars: the adiabatic principle, a method to find possible quantum states within the atom; and the correspondence principle, which links classic electrodynamics with the new quantum theory forged at that time," explains Pié i Valls who, together with Professor Enric Pérez, has published these historical analyses on the topic in the journal 'Annalen der Physik'.

The authors studied the use Bohr gave to the adiabatic hypothesis from when Austrian physicist Paul Ehrenfest set it out in 1911 until his Danish colleague raised it to a 'principle' and developed it to get the most out of it. They also detected the mutual influence between Bohr and German physicist Arnold Sommerfeld, who advanced his own formulation of 'quantification' and had a significant influence on developing the old quantum theory, the backdrop against which all the studies prior to the birth of quantum mechanics in 1925 were set.

"One of the most significant changes we have found is the reversal of the importance of the two fundamental principles," notes Pié i Valls. "In 1918, the central role played by the adiabatic principle almost entirely eclipsed the correspondence principle in Bohr's theory, and we mustn't forget that, but over the years, it faded into the background, while the correspondence theory gained importance and incorporated new, useful applications from calculus. With the establishment of quantum mechanics, the correspondence principle retained its central role, which it has to this day."

The authors bemoan the fact that Bohr's quantum theory is much less widely known than his atomic model, "obsolete since 1925, but which is still explained in schools today due to its considerable educational value and out of pure pragmatism—it is impossible to teach a theory as complex as quantum mechanics at certain levels."

This situation, however, has led to the public wrongly having the idea that the Bohr model is still valid, when the modern vision of the atom is, in fact, governed by the probabilistic laws of quantum mechanics, which force us to imagine the electron as a delocalised "probability cloud" around the nucleus of the atom.

More information: Blai Pié i Valls et al. The historical role of the Adiabatic Principle in Bohr's quantum theory, *Annalen der Physik* (2016). DOI: 10.1002/andp.201600178

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