Symposium on the Centenninal of Planck's discovery of the Quantum Hypothesis

Sponsored by the Lorentz Institute and Studium Generale, Leiden, Dec. 11, 2000

Birth of Quantum Mechanics

Summary

The introductory remarks at the Planck symposium were given by Prof. Nico van Kampen from the University of Utrecht, who spoke about Planck's life and the impact of his quantum hypothesis which culminated, a quarter of a century later, in the birth of the modern quantum theory. This presentation was followed by a talk by Michael Nauenberg which emphasized the often neglected but important role of advances in high precision measurements of long wave infrared radiation which were made at the Physicalisch Techniche Reichanstalt (PRT), then newly built in Berlin, near the turn of the century. These experiments were crucial to Planck's eventual explanation of the black body radiation spectrum in terms of his quantum hypothesis: that the energy of harmonic oscillators with frequency \( f \) is parceled out in multiples of a finite elements of magnitude \( e=hf \), where \( h \) is the famous constant introduced by Planck. His approach to the black body radiation problem was anchored in the laws of thermodynamics which turned out to be a fortunate circumstance, because these were the only physical laws which survived unaltered the transition from the classical to the quantum world. Therefore, these laws provided the only secure bridge to the early development of the new physics. Another essential ingredient which led to Planck's success was his adaptation of Ludwig Boltzmann's fundamental statistical relation between entropy and disorder. Fortunately, in his 1877 paper Boltzmann had worked out, as an example of his method, the case of a fictitious gas of molecules having finite energy elements rather than continuous energy as required by classical mechanics. This calculation then provided Planck with the essential mathematics which he needed to deduce his famous radiation formula, and he was able to accomplish this result in a matter of a few weeks after having worked on the solution of the radiation problem for over five years. The familiar quote that this was an "act of desperation", as Planck remarked some 30 years later, is usually interpreted as his reluctant introduction of quantum discontinuities into physics, but it may instead have referred to his having to turn at the eleventh hour to his previous nemesis, Ludwig Boltzmann, for a solution to this most vexing problem in physics. Indeed, Planck confessed that at the time he did not give much thought to these discontinuities.

After a coffee break Prof. Anne Kox from the Univ. of Amsterdam spoke on the important role of H.A. Lorentz in clarifying the meaning of Planck's quantum hypothesis. Lorentz, who was then at the Univ. of Leiden, was one of the main leaders of theoretical physics at the beginning of the twentieth century, and his views, made in published papers as well as in correspondence with colleagues such as Max Planck, Albert Einstein and Wilhelm Wien, were therefore especially influential. By an impressive tour de force which provoked even Einstein's admiration, Lorentz deduced the Rayleigh long wave limit of Planck's radiation formula from the classical electron theory of metals developed by Drude. Lorentz found this agreement most remarkable given the fundamentally different assumptions made in the two theories, but he made no progress in understanding the underlying mechanism behind Planck's hypothesis, although he was persuaded by Wien of the essential need of this hypothesis to explain the radiation experiments. Kox also pointed out that Thomas Kuhn's well known iconoclastic interpretation in which he claimed that Planck, in fact, had not constrained his oscillators to multiples of finite energy elements, contradicts directly Lorentz reading of Planck's work. It also contradicts Ehrenfest's understanding of Planck's hypothesis. (The
renowned physicists Res Joos has referred to Kuhn's interpretation as "Unsinn", but it nevertheless continues to have support in postmodernist circles) Kox's talk was followed by a presentation by Dr. Frans von Lunteren from the Univ. of Utrech of the contributions of Paul Ehrenfest, who succeed Lorentz as professor of physics at the Univ. of Leiden in 1912. One of Ehrenfest early contributions was his valuable critical evaluation of the application of Boltzmann's statistical mechanics to black body radiation, and later he contributed to the development of the quantum theory the fundamental connection of adiabatic invariants to Planck's quantum of action.

The symposium ended with an incisive commentary by Martin Klein whose seminal work on Planck in the early 60's has been the foundation for most of the subsequent historical studies of Planck's achievements. Klein pointed out that Planck gained confidence in the importance of his result not only because his radiation formula gave an excellent fit to the PRT experiments, but also because it gave a good determination of Boltzmann's previously undetermined constant "k", and consequently also Avogadro's constant "N", and the electronic charge "e" which were poorly known at the time. His results for these constant were subsequently confirmed by independent experiments. Klein also mentioned that Planck emphasized that his new constant "h" together with Newton's constant "G" and the velocity of light "c" allowed, for the first time, the introduction of universal units, now known as Planck scales, for the fundamental variables of physics: length, time and mass. As is well known, such units are absent in classical physics. It took another 16 more years before an independent high precision verification of Planck's constant "h" was made by Millikan's careful measurement of the photo electric effect. Somewhat earlier Planck's quantum hypothesis became the cornerstone for the successful Bohr atom.