Conference on the history of quantum physics
Max-Planck-Institut für Wissenschaftsgeschichte
Berlin, 2–6 July 2007
Abstract

Title: Walther Nernst, Albert Einstein, Otto Stern, Adriaan Fokker, and the rotational specific heat of hydrogen

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In 1911, the German physical chemist Walther Nernst argued that the new quantum theory promised to clear up long-standing puzzles in kinetic theory, particularly in understanding the discrepancies between the predictions of the equipartition theorem and the measured specific heats of gases. Nernst noted that hydrogen gas would be a good test case. The first measurements were published by his assistant Arnold Euken in 1912, and showed a sharp drop in the specific heat at low temperatures, corresponding to rotational degrees of freedom "freezing out." In his 1911 paper, Nernst also developed a theory for a quantum rotator (a tiny rotating dumbbell representing a diatomic gas). Remarkably, he did *not* quantize rotational energies. Instead, the specific heat fell off because the gas reached equilibrium by exchanging harmonic oscillator quanta with quantized Planck resonators. Nernst's theory was flawed. But Einstein adopted a corrected version at the 1911 Solvay Conference, and in 1913, he and Otto Stern published a detailed treatment. Following Nernst, Einstein and Stern did not quantize the rotators. But they did explore the new zero-point energy that Max Planck had introduced in his "second quantum theory" in 1911. Einstein and Stern calculated the specific heat of hydrogen for two cases, one that assumed a zero-point energy for a rotator and one that did not. Only the former, with a zero-point energy, led to reasonable agreement with Eucken's data.

But Einstein's and Stern's physical picture was sharply different from Nernst's. There was no question of rotators exchanging quanta with resonators. Instead, in a second and almost unrelated section of their paper, they followed a line of argument that Einstein had begun in 1909 with his papers on "wave particle duality," and had extended in a paper written in 1910 with Ludwig Hopf. Using this fluctuation-based approach, Einstein and Stern showed that Planck's zero-point energy might reduce or even eliminate the need to quantize physical systems. In particular, they derived Planck's radiation law by considering resonators—with a *different* zero-point energy—in equilibrium with a Maxwellian electromagnetic field; and in the process, they implicitly justified their approach to the specific heat. No assumption of discontinuity was required! Einstein and Stern were tentative in making this suggestion, and in any event, Einstein abandoned it later that year at the second Solvay Conference, citing unnamed inconsistencies. Later in 1913, in a new approach to the specific heat of hydrogen, Paul Ehrenfest did quantize the rotators, following a suggestion by H. A. Lorentz at the first Solvay Conference. So did Niels Bjerrum, a Danish chemist who was working on molecular spectra in Nernst's laboratory. Einstein could easily have followed Lorentz's approach himself. That he did not do so shows just how fluid and uncertain quantum theory remained, even for Einstein, over a decade after Planck had first introduced his strange new law of black-body radiation into physics.