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## This Month in Chemical History: Part 1 of 2

By Harold Goldwhite

April, like most months, is rich in anniversaries of scientists who made major contributions to chemical sciences. Among them are James Watson, Robert Woodward, Carl Lindemann, and Glen Seaborg. But I choose to discuss the career of a great physicist whose work made such an impact on our science that it changed the thinking and work of every chemist who followed him. I refer to Max Karl Ernst Ludwig Planck, born in Kiel, Germany, on April 23 (a birthday he shares with Shakespeare), 1858.

The Planck family had, in common with the family of J. Clerk Maxwell, a long history of public service as lawyers, scholars, and clergymen. Planck's father was a professor of law. The family moved from Kiel to the independent state of Bavaria when Max was 9 years old. He attended the Maximilian Gymnasium in Munich, where he chose an emphasis on physics over music (he remained an excellent pianist all his life), perhaps through the influence of his physics teacher H. Muller. His experience for his first 3 years at the University of Munich was less inspiring, and he transferred to Berlin, where he encountered two distinguished physicists as teachers. Kirchhoff, the collaborator of Bunsen in spectral analysis, apparently delivered his polished lectures in such a manner as to put many in his audience to sleep. Helmholtz, the great expert on electrical and optical phenomena, was often unprepared and difficult to follow.

Planck read widely in physics and decided to specialize in thermodynamics, after reading some of Clausius's work. His doctoral thesis, which included a critique of Clausius's views on irreversibility, was successfully submitted to the University of Munich in May 1879. It is worth noting that some of Planck's results had already been published by J. Willard Gibbs in a very long article published in the somewhat obscure *Transactions of the Connecticut Academy of Sciences*, an article that was not brought to the attention of the European thermodynamicists for decades. On the strength of his thesis, Planck was appointed Privat-Dozent at Munich and then in 1885 was called to Kiel as Extraordinary Professor of Theoretical Physics.

In 1889, on the death of Kirchhoff, the prestigious University of Berlin asked Boltzmann to succeed him. Initially, he accepted, but then changed his mind. In his place, the somewhat unlikely choice was the young 34-year-old Planck, who was appointed Professor in 1892, becoming a colleague of the great Helmholtz. Planck remained at Berlin for the rest of his professional career, retiring in 1928. His successor was Schroedinger.

Planck's work before he ascended to the Berlin Chair was collected in his important thermodynamics text, published in 1897, and included discussion of chemical potentials and their applicability to equilibrium constants; dissociation of real gases; and the thermodynamics of colligative properties, including freezing-point depression and osmotic pressure. These treatments of really fundamental chemical and physical problems led him to the forefront of classical thermodynamics.

At Berlin, he began to turn his attention to emissivity phenomena, the so-called black-body radiation. His predecessor, Kirchhoff, had provided theoretical backing for the observations that the distribution of radiant energy with wavelength (or frequency!) emitted from a heated enclosure did not depend on the material of the enclosure. It was therefore a quite general or universal result. In 1893, Wien had used experimental data to derive his displacement law, which connected the enclosure temperature with the frequency of maximum energy output. The efforts of some of the best physicists of the day, including Rayleigh and Jeans, were able to explain parts of the Wien law at low frequencies and high temperatures, but failed at other extremes. The field was open for Planck's efforts.

## This Month in Chemical History: Part 2 of 2

By Harold Goldwhite

In the first of this two-part series on Max Planck, I sketched his career to the point where, in 1897, he began to work on explaining the phenomena of black-body radiation, a problem that had challenged some of the best physicists of the day and that they had failed to solve. At first, he tried combining electrostatics and thermodynamics, but Boltzmann correctly criticized Planck's formulation. Planck then successfully combined Wien's work with that of Rayleigh and Jeans, but a satisfactory physical explanation was still lacking.

When Planck tried to apply Boltzmann's statistical formula for entropy to the problem, he found he had to assume that the enclosure walls were composed of electrodynamic oscillators, which could only emit energy that was not infinitesimally variable but was connected to the oscillator frequency by the now-famous formula  $E = h\nu$ , where  $h$  is what Planck called a quantum of action. Later generations dubbed it Planck's constant. Planck obtained a value for  $h$  from experimental data that is close to the currently accepted value. He introduced these new ideas in two presentations to the German Physical Society in Berlin on October 19 and December 14, 1900. Their impact was to be felt throughout 20th-century science.

At first, however, Planck's novel view of radiation, while it was agreed to be interesting, was viewed as a kind of formalism: a way of accounting for the data without necessarily providing a fundamental physical explanation of the phenomena underlying it. Boltzmann was impressed, and Planck himself is supposed to have told one of his sons that he had made a discovery that was in the class of one of Newton's. But he was still trying classical approaches to the problem until finally, toward the end of his career, he wrote: "My vain attempts to somehow reconcile the elementary quantum with classical theory continued for many years and cost me great effort.... Now I know for certain that the quantum of action has a much more fundamental significance than I originally suspected."

That significance was first postulated by the obscure patent clerk in Switzerland, Albert Einstein, in his wonder year of 1905. He broadened the quantum approach to radiation by applying it to all radiation, inventing the photon as a particle of radiation—a collection of which sometimes behaves as a wave! Planck trumps Maxwell. With this revolutionary idea, Einstein was able to explain another familiar physical phenomenon, originally described by Hertz, which like black-body radiation had eluded the net of classical physics, namely, the photoelectric effect. Quantum theory was on its way to being accepted as one of the great foundational ideas of science, and Planck was awarded the Nobel Prize for Physics in 1918 and received many honorary degrees and fellowships.

Planck's personal life was not easy. His first wife, with whom he had four children, died in 1909, and three of those children died during World War I, a son at the Front and two daughters in childbirth. He remarried and had another son. When Hitler came to power in 1933, Planck was 75. He accepted the Presidency of the Kaiser Wilhelm Society (now known as the Max Planck Society), hoping to modify the views of the new Fuhrer toward some scientists, but in vain. Planck's surviving son from his first marriage, Eric, was executed by the Nazis for his part in the July 1944 plot against Hitler. The Planck family house was destroyed during the bombardment of Berlin, but Planck was escorted by American forces to Goettingen in West Germany, where he lived until his death on October 4, 1947, just a few months short of his 90th birthday.

This article has been greatly aided by the following sources: *A Biographical Dictionary of Scientists*, Trevor I. Williams, Ed., Wiley, 1982; *From X-rays to Quarks*, Emilio Segre, Freeman, 1980; and *The Strange Story of the Quantum*, Banesh Hoffmann, Dover, 1959.