Biography of Wilhelm Ostwald

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Ostwald, Wilhelm

in full Friedrich Wilhelm Ostwald
(b. Sept. 2, 1853, Riga, Latvia, Russia—d. April 4, 1932 Leipzig, Germany), Russian-German chemist and philosopher who almost single-handedly established physical chemistry as an acknowledged branch of chemistry. He was awarded the Nobel Prize for Chemistry in 1909 for his work on catalysis, chemical equilibria, and reaction velocities.

Early Life and Education

Wilhelm was the second son of Gottfried Ostwald, a master cooper, and Elisabeth Leuckel, both descendants from German immigrants. After his early education in Riga, he enrolled at the University of Dorpat (now Tartu, Estonia) in 1872 where he studied chemistry under Carl Schmidt and received the candidate's degree (1875), master's degree (1876), and doctorate (1878). Preforming his later career, he subsequently became assistant at the Institutes of Physics and Chemistry and lectured on physical chemistry, already the subject of both his master and doctor thesis. In 1880, he married Helene von Reiher. They had two daughters and three sons, of whom Wolfgang became a famous colloid chemist. After their move to Leipzig, the Ostwalds adopted the German nationality in 1888.

Scientific Career

In 1881, Ostwald was appointed full professor of chemistry at the Riga Polytechnic Institute before he became chair in physical chemistry at the University Leipzig (1887-1906). By the time he started his scientific career, chemistry, particularly in Germany, was dominated by synthetic organic chemistry, investigating which product can be produced from what compounds. Ostwald recognized the lack of a more profound and quantitative understanding of general issues of chemistry, such as the selective forces (chemical affinities or activities) in chemical reactions, which he sought to achieve by applying physical measurements and mathematical reasoning. To that end, already in 1875, he began studying the point of equilibrium in reactions systems where two acids in aqueous solution compete with each other for reaction with one base and vice versa. Since chemical analysis would have changed the equilibria, he skillfully adapted the measurement of physical properties to that problem, such as volume, refractive index, and electrical conductivity. The idea was not completely new, as Julius Thomson in Denmark had already studied the heat of such reactions. In addition, for the analysis of his experimental results, Ostwald could draw on the important law of mass action proposed shortly before by Cato

Guldberg and Peter Waage in Norway. However, Ostwald made the general approach, adapting physical measurements to issues of chemical dynamics, a program not only of his own chemical work but also of a new school.

In 1884, Ostwald received the doctor thesis of a young Swedish Chemist, Svante Arrhenius, on the electrical conductivity of solutions with the bold claim that salts, acids, and bases dissociate into electrically charged ions when dissolved in water. That dissociation theory should become a backbone of the new school of physical chemistry (also called the "Ionists") with which Arrhenius soon associated himself. Ostwald immediately recognized that if all acids contain the same active ion, the different chemical activities of acids was simply the number of active ions dependent on the different degree of dissociation. In addition, if the law of mass action was applied to the dissociation reaction a simple mathematical relation could be derived between the degree of dissociation (α), the concentration of the acid (c), and an equilibrium constant specific for each acid (K):

$$\alpha^2/(1-\alpha)c = K$$

This is Ostwald's famous dissolution law (1885) which he proved to be valid by measuring electric conductivities of over 200 organic acids and thereby substantiated the dissociation theory.

At the same time, the Dutch chemist Jacobus Henricus van't Hoff, who should become the third of the "triumvirate" of the new physical chemistry school, suggested his theory of osmosis, according to which the osmotic pressure of solutions depends on the number of dissociated ions, in analogy to the pressure of ideal gases. Putting his theory on general thermodynamic grounds, he derived also Raoult's laws of vapor pressure lowering and freezing point depression of solutions. Thereby, the new physical chemistry grew to a comprehensive theory of solutions, based on both thermodynamics and dissociation theory.

Ostwald was particularly successful in systematizing the matter, applying it to other fields, and organizing a school. That was the more important as most chemists rejected the dissociation theory on partly justified grounds, such that convincing them required both concessions about its restricted validity and proofs of its broad usefulness. In many textbooks on general, inorganic, and analytical chemistry, Ostwald presented the new ideas not only in a comprehensive form as a new branch of chemistry, but also as an extremely fruitful approach to classical issues. He particularly revolutionized analytical chemistry through solution theory and his theory of indicators. His *Zeitschrift für physikalische Chemie* (*Journal for Physical Chemistry*), founded in 1887, rapidly established as the standard journal in the field. Furthermore, the Leipzig Institute of Physical Chemistry attracted students and post-docs from all over the world. Educated in both the new ideas and experimental skills, at least 60 students of Ostwald later became professors of physical chemistry in numerous countries.

Ostwald's later work on catalysis originated from early attempts at taking reaction velocities as a measure of chemical activity. As that turned out to be wrong on thermodynamic grounds, he broadly investigated temporal aspects

of chemical reactions and provided a systematic conception of the field. He first recognized catalysis as the change of reaction velocity by a foreign compound, which allowed him to measure catalytic activities. He distinguished catalysis from triggering and from autocatalysis that he considered essential to biological systems. His most famous contribution to applied chemistry was on catalytic oxidation of ammonia to nitric acid, a patented process that became exploited in the industrial production of fertilizers.

Other Notable Activities

By the late 1880s, Ostwald's interests began to include cultural and philosophical aspects of science. In 1889, he started republishing famous historical papers of science in his book series *Klassiker der exakten Wissenschaften*, with over 40 books only during the first four years. History of chemistry, already part of his textbooks for educational reasons, became a subject of its own in many further books, one of which derived from a series of lectures he had given as the first German-American exchange professor at Harvard in 1905/6. He was particularly interested in general laws of scientific progress, psychological characteristics of great scientists, and conditions of scientific creativity, all of which should serve the advancement of future science.

The more Ostwald considered thermodynamics as the fundamental theory of science, for which he saw evidence in the pioneering works of the American physicist Josiah W. Gibbs and others, the more did he engage in natural philosophy. Two aspects may roughly characterize his philosophy. (1) The primacy of energy over matter (being only a manifestation of energy), a position that went back to 18th- and 19th-century dynamism as opposed to materialism and which was now reformulated as "Energetics" by including the principles of thermodynamics. (2) Positivism in the sense of rejecting theoretical concepts that are not strictly founded on empirical grounds, a position for which Ostwald found many contemporary proponents, such as Ernst Mach and Pierre Duhem. Because of both aspects, he rejected atomism for about 15 years and was heavily involved in philosophical debates with his atomist colleagues such as Ludwig Boltzmann, before he acknowledged the growing experimental evidence for the atomic hypothesis in 1909.

Ostwald was quick to enlarge his energetics, incorporating sociology, psychology, and ethics. Beyond academic interest, he made it an "energetic imperative" of his own life: "Do not squander energy—utilize it!" Since Ostwald had strong utilitarian ideas of science, he considered every obstacle to the progress of science as squandering of "social energy". Thus, after his early retirement from the chair in physical chemistry at the University of Leipzig (1906), he became an enthusiastic reformer in educational and organizational matters of science both on the national and international level. Ostwald was active in numerous academies, learned societies, and international movements, such as for the standardization of scientific documentation and the establishing of an artificial language (he contributed to Ido, a derivative of Esperanto).

Moreover, since he considered both war and traditional religion as squandering of energy, he committed himself to the international peace movement and was president of the Deutscher Monistenbund, a scientistic quasi-religion founded by Erich Haeckel.

Later years

A freelance at his private estate near Leipzig since 1906 with both a large library and laboratory, Ostwald started another scientific career in color theory in his 60s, supplementing his lifelong passion for painting. Once more he applied the multi-level approach characteristic of his earlier work. He developed instruments for the measuring of colors, elaborated a sophisticated classification of colors in order to derive mathematical laws of harmony, produced specimens in his chemical laboratory, founded a factory for paintboxes, wrote several textbooks on color theory and its history, and was active in reforms of artistic education.

After a short period suffering from bladder and prostate troubles, Ostwald died at the age of 78 in a Leipzig hospital and was buried at his private estate.

Ostwald was a man of science in the broadest sense, and an extremely prolific writer. He left 45 books and many booklets, about 500 scientific papers, 5,000 reviews, the edition of 6 journals, and over 10,000 letters.

Bibliography

Ostwald's autobiography *Lebenslinien*, 3 vols. (1926-1927) and the biography of his daughter Grete Ostwald, *Wilhelm Ostwald. Mein Vater* (1953) provide personal insights. Despite some shortcomings, the Russian biography by N. I. Rodnyj and Ju. I. Solowjew, *Vilgelm Ostvald* (1969; trans into German, 1977) is still a standard reference. The best English text is E. N. Hiebert & H.-G. Körber's entry in *Dictionary of Scientific Biography* (vol. XV, supp. I, 1978). For a comprehensive bibliography see *Poggendorff* (VIIa, supp. 1971). Since 1996, the Wilhelm-Ostwald Gesellschaft publishes its *Mitteilungen* including specific bibliographies.