Arnold Sommerfeld: 1868–1951

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Arnold Sommerfeld, who, at the age of eighty-two, died on April 26, 1951, of injuries suffered in a traffic accident, was one of the great leaders in theoretical physics of the past generation. In the importance of his contributions to the development of the old quantum theory of the atom he takes second place only to Niels Bohr. As a teacher and leader in theoretical physics during the period 1910–35 he was preeminent.

Sommerfeld's greatest contribution to atomic physics, his development in 1916 of a relativistic theory of the fine structure of spectral lines, excited great interest among physicists; and, even though the theory was later modified in its details by the changes required by quantum mechanics and the electron spin, its striking success stimulated physicists all over the world to the further development of quantum theory as applied to problems of atomic and molecular structure.

Arnold Johannes Wilhelm Sommerfeld was born December 5, 1868, in Königsberg, East Prussia. He received the degree Dr. Phil. in Königsberg in 1891. From 1893 to 1897 he served as assistant in the Mineralogical Institute in Göttingen and as assistant to Felix Klein in the Mathematical Institute. His Habilitation was made in 1895 on the basis of his famous work on the mathematical theory of diffraction. From 1897 to 1900 he was professor of mathematics at the Mining Academy in Clausthal, and he then served as professor of mechanics at the Technische Hochschule in Aachen from 1900 to 1906. From 1906 until his retirement in 1935 (he continued lecturing until 1938) he was professor of theoretical physics in the University of Munich, as successor to Boltzmann. Throughout this period in Munich he presented lectures in theoretical physics that were outstanding for their clarity. Many able students were attracted to his Institute for Theoretical Physics, including a number of Americans, especially during the years following his trip to the United States in 1922, when he served as Karl Schurz professor at the University of Wisconsin and visited many other universities. He returned to the United States in 1928 as visiting professor at the California Institute of Technology. Among his students and associates in the Institute for Theoretical Physics were M. von Laue, W. Heisenberg, P. Debye, P. P. Ewald, W. Pauli. Jr., P. S. Epstein, G. Wentzel, K. F. Herzfeld, H. Ott, F. London, W. Heitler, E. Guillemin, V. Guillemin, K. Bechert, F. G. Slack, E. C. Kemble, L. Pauling, Carl Eckart, H. A. Bethe, O. Laporte, P. M. Morse, A. Landé, R. Peierls, A. Unsöld, W. V. Houston, and E. U. Condon. As Heisenberg said on Sommerfeld's eightieth birthday, not only did Sommerfeld have students—he developed practically a whole generation of theoretical physicists, who are now widely distributed over the world.

The breadth of his interests was extraordinary, ranging from the construction, with E. Wiechert, of a harmonic analyzer in 1892 through the study of methods of solution of differential equations, the treatment of the transmission of radio waves over the earth's surface, the search for empirical numerical relationships in the spectra of atoms, and many other subjects, to the investigation of the most complex problems of quantum theory. His first great work was the writing of four volumes on the theory of the spinning top, in collaboration with Felix Klein. He then served as editor of the volume on physics of the *Encyclopädie der mathematischen Wissenschaften,* and soon became interested in quantum theory and atomic structure.

The first great event in Sommerfeld's institute came in 1912. Sommerfeld had suggested to P. P. Ewald that as his doctoral research he investigate the behavior of electromagnetic waves with wavelengths in the optical region in a lattice of atoms, as in a crystal. Some theoretical considerations of Wien and Sommerfeld had suggested that x-rays might have wavelengths about 10^{-9} cm, and that they were to be considered as electromagnetic waves. Max von Laue, who was *Privatdocent* in Sommerfeld's institute, then had the idea, during a discussion with Ewald, that x-rays should produce a diffraction pattern on passage through a crystal. The experiment was carried out by Friedrich, Sommerfeld's assistant, and Knipping, a student; and on June 8, 1912, Sommerfeld communicated to the Munich Academy of Sciences a description of the work showing the wave nature of x-rays.

After his development in 1916 of the relativistic quantum theory of the fine structure of the hydrogen spectrum and of x-ray doublets, Sommerfeld prepared the first edition of his great book *Atombau und Spektrallinien,* which went through four more editions between 1921 and 1929. The English translation, *Atomic Structure and Spectral Lines,* from the third edition, appeared in 1923 and was widely adopted in the United States and elsewhere as a textbook for advanced courses. In 1929 there appeared his *Wellenmechanischer Ergänzungsband,* which was expanded and published in 1939 as Volume 2 of *Atombau und Spektrallinien.*

Sommerfeld wrote hundreds of papers, dealing with the theory of diffraction, the fine structure of atomic spectra, the electronic theory of metals, the theory of chemical valence, and many other subjects. During the last years of his life he collected his lecture notes into a series of six books, entitled *Lectures on Theoretical Physics*. The successive volumes cover mechanics, the mechanics of deformable media, electrodynamics, optics, thermodynamics and statistics, and partial differential equations of physics. All these volumes except the one on thermodynamics and statistics have appeared in English translation as well as in German; he had nearly completed the manuscript for this volume at the time of his death. Like his earlier books, these works are characterized by extraordinary clarity of expression and argument.

Sommerfeld received many honorary degrees and awards, and was honorary member of many scientific academies. Two years ago the American Association of Physics Teachers presented to him the Oersted Medal, in recognition of his outstanding contributions as a teacher of physics. Additional recognition of Sommerfeld's contributions as an investigator and a teacher was given by his students in four memorial volumes: the book *Probleme der modernen Physik,* celebrating his sixtieth birthday, the December 1938 issue of *Physical Review,* celebrating his seventieth birthday, the book *Cosmic Radiation,* fifteen lectures edited by Heisenberg and given in honor of Sommerfeld's seventy-fifth birthday, and the August–November 1948 issue of the *Zeitschrift für Naturforschung,* honoring his eightieth birthday. The hazard of a mechanized world has prevented his students from celebrating during his lifetime still further anniversaries of the birth of this great man, who retained his extraordinary mental vigor and acuity up to the end.

Technical Papers

A New Class of Hypnotics: Unsaturated Carbinols

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Recent pharmacological investigation (*1*) has shown that certain ethinyl tertiary carbinols (*2*) exhibit significant hypnotic activity in several species (mice, rats, guinea pigs, rabbits, cats, dogs, and monkeys). Hypnotic effects followed oral as well as parenteral administration of the compounds. Earlier investigators have described the induction of generalized central nervous system depression in experimental animals with tertiary carbinols (*3*). The only tertiary carbinol to attain clinical use as a hypnotic is amylene hydrate, a saturated compound (*4, 5*). In our studies, the simple unsaturated aliphatic carbinols were found to possess high activity, desirable duration of action, and low toxicity. Of the latter group, 3-methyl-pentyne-ol-3,[1] was considered worthy of extensive pharmacodynamic, biochemical, and clinical study. Its structural formula is

$$\begin{array}{c} \qquad\quad CH_3 \\ \qquad\quad | \\ HC\equiv C-C-CH_2-CH_3 \\ \qquad\quad | \\ \qquad\quad OH \end{array}$$

Barbiturate potentiation in the mouse (*6*) and direct hypnotic activity in dogs were used to evaluate quantitatively the oral hypnotic efficacy of the test compounds. The hypnotic effect was characterized by the appearance of a distinct and sequential reaction pattern—sedation, loss of righting reflex, and sleep. An interesting parallel in relative hypnotic activity for 3-methyl-pentyne-ol-3 and other hypnotics was found in experimental animals and in man (Table 1). (The value of 100 has been arbitrarily assigned to pentobarbital sodium.)

TABLE 1

ORAL ACTIVITY OF 3-METHYL-PENTYNE-OL-3 AND OTHER HYPNOTICS IN EXPERIMENTAL ANIMALS AND IN MAN

Drug	Human dose (mg/70 kg)	Relative activity		
		Man	Dog	Mouse
3-Methyl-pentyne-ol-3	250	40.0	20.0	71.9
Amylene hydrate	1500	6.7	10.0	20.0
Paraldehyde	5000	2.0	4.3	4.6
Phenobarbital	100	100.0	50.0	100.0
Pentobarbital sodium	100	100.0	100.0	100.0
Presidon	300	33.3	20.0	33.3

3-Methyl-pentyne-ol-3 is distinguished by a high selectivity of action. When measured in rats at the maximal tolerated dose, according to a modified Wolff-Hardy procedure (*7, 8*), it was not analgesic (*1*). The absence of analgesic effect was confirmed in mice and dogs. No anesthesia was observed when the compound was administered intravenously to dogs in sublethal amounts. This absence of anesthetic properties was observed in mice and rats also (*1*). When tested according to the *in vitro* Magnus-Dale technique, 3-methyl-pentyne-ol-3 was found not to possess antispasmodic action. Furthermore, in marked contrast to barbiturates and other hypnotics, 3-methyl-pentyne-ol-3, even in large doses, did not depress respiration. Caffeine given parenterally caused rapid recovery from the deep hypnotic state induced by overdoses.

[1] Dormison, trade-mark of Schering Corporation, Bloomfield, N. J.