15. Franco Malerba, *The Semiconductor Business, The Economics of Rapid Growth and Decline*, University of Wisconsin, Madison, WI, 1985, p. 100.

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THE FIRST HALF CENTURY OF CHEMISTRY AT CLARK UNIVERSITY

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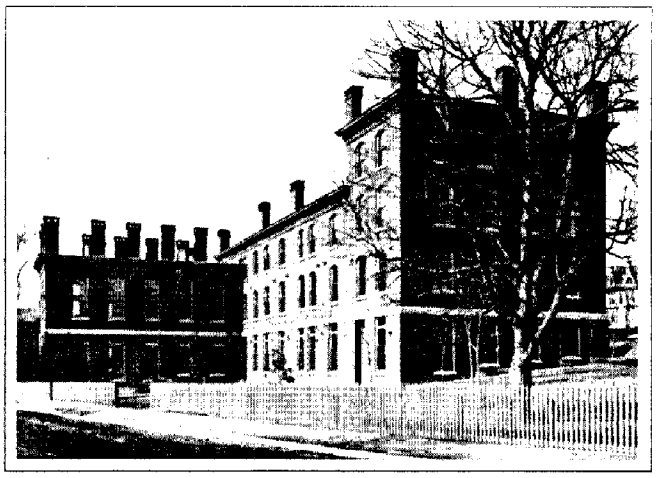
In 1987 Clark University observed the centennial of its founding, which was instigated by Jonas Clark (1815-1900), a successful businessman in Worcester, Massachusetts, where the institution was to be located. It was created strictly as a graduate school, with programs first set up in physics, chemistry, mathematics, biology, and psychology. G. Stanley Hall (1846-1924), holding a Ph.D. in psychology from Harvard, was appointed the first President (1).

Clark University sprang into being just as the 19th century was coming to an end. This coincided with the peak of activity in the traditional sciences, including chemistry, in Germany, whereas these fields were still in the early stages of development in the United States and Canada. Thus it is understandable that the graduate programs at Clark were tailored after the German model. President Hall himself had spent time in Germany before beginning his Ph.D. His first action, on being chosen to head up the new university, was to sail for Europe, where he spent six months establishing contacts with German professors and evaluating young Americans who were studying there. Both Hall's personal experiences in Germany and his hiring of German-trained faculty in all of the disciplines contributed to the molding of the character of the early Clark graduate program. It was similar to the program in chemistry established by Ira Remsen at Johns Hopkins, where Hall had held the position of Professor of Psychology and Pedagogy before his selection as the first president of Clark.



The chemical laboratory at Clark, circa 1890

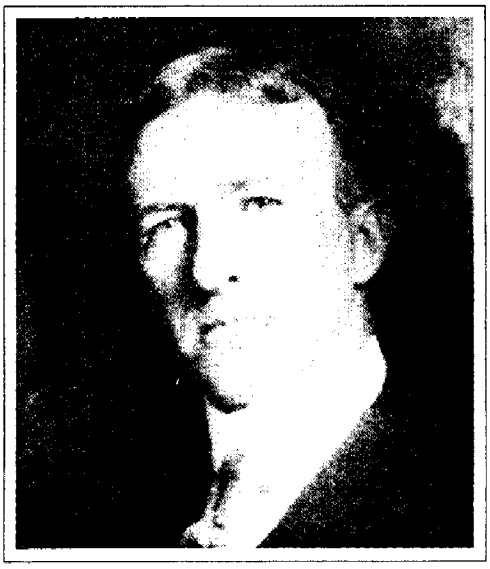
John Ulric Nef

Although the university had its beginning in 1887, the chemistry department came into existence slightly later. By 1890 the chemistry laboratory was completed and the first faculty member to head up chemistry, Arthur Michael (1853-1942), was appointed in 1889. He had spent time in several German university laboratories, though he never earned an advanced degree. However, his tenure at Clark was fleeting, lasting only a few months in the fall of 1889, not even long enough to make the listing in the university catalog. The reason for his abrupt departure was the refusal of Jonas Clark to allow laboratory privileges for Michael's wife, also a student of chemistry. This placed President Hall in an awkward position, for he had included this promise as one of the conditions of Michael's appointment. Michael simultaneously held a teach-

ing position at Tufts University, where he taught intermittently during the period 1880-1907, after which he became professor of organic chemistry at Harvard, though most of his work was done in his private laboratory in Newton, Massachusetts.

Swiss-born John Ulric Nef (1862-1915), a doctoral student of Adolf Baeyer in Munich, was Michael's successor. He and Michael were to have disagreements on experimental results a few years later. Nef remained at Clark for only three years, spending the remainder of his career at the University of Chicago. He had two Ph.D. students at Clark: Thomas H. Clark (1892 - no relation to Jonas) and John L. Bridge (1894). Both carried out research on benzoquinones. Curiously, Bridge's thesis, which was completed at Chicago, was written in German and carried the title "Ueber die Aether des Chinonoxims." One of Nef's first Ph.D. students at Chicago, Adolf Bernhard, had been a graduate fellow at Clark in 1892 and followed Nef to Chicago.

Morris Loeb (1863-1912), with a doctoral degree from Berlin under August W. Hofmann, served as lecturer at Clark from 1889-1891 and so overlapped with Nef. He then became Professor of Chemistry at New York University, a position which he held until his early death at the age of 49 (2). With the abrupt departure of Nef, Samuel Mulliken (1864-1934), already holding the position of graduate fellow (1890-1892), presided over the chemistry program briefly between 1892 and 1894 under the rubric of "Instructor and Acting Head". A doctoral student of Johannes Wislicenus at Leipzig, Mulliken left for MIT in 1895, where he remained until his death. His son, Robert Mulliken (1896-1986), received the Nobel Prize in Chemistry in 1966. While at Clark, Mulliken directed the Ph.D. thesis of Julius B. Weems (1894) on a project involving Kolbe electrolysis.



Benjamin S. Merigold

Martin André Rosanoff

Percy N. Evans (1869-1925), another recent doctoral student from Leipzig, holding the position of honorary fellow for 1894, might well have succeeded to the head of chemistry, had the program continued. But a crisis brought on by a severe shortage of funds and by what some viewed as serious mismanagement by President Hall led to a discontinuation of instruction in chemistry. Instead Evans spent the rest of his career at Purdue.

The early period of chemistry at Clark had lasted only five years. In that time five faculty or staff had been engaged, and three Ph.D. students had emerged. The break in the chemistry program lasted for ten years. No chemistry faculty were listed in university catalogs from 1895-1902. The first chemistry faculty designated as "undergraduate" appeared in the 1902 catalog, but graduate faculty emerged again only in 1904. Charles W. Easley (1876-1929), who held A.B. and A.M. degrees from Dickinson College, was appointed instructor of undergraduate chemistry in 1902 and remained at Clark until 1908, when he had completed his own Ph.D. He was joined in 1903 by Benjamin Shores Merigold (1873-1962). Merigold held A.B., A.M. and Ph.D. degrees from Harvard, where he had been a student of Theodore W. Richards. First listed as graduate instructor and then as undergraduate assistant professor, he had been an instructor from 1900-1903 at Worcester

Polytechnic Institute. He spent the rest of his career at Clark, retiring in 1946.

Though Merigold was already on the scene when the "graduate revival" began in 1907; and though he had both seniority and a Ph.D., he was not chosen to head chemistry. Instead the appointment was given to Martin André Rosanoff (1874-1951), a native of Russia, who had earned an undergraduate Ph.B. at New York University, very likely under the tutelage of Morris Loeb. He had spent some time abroad in Berlin and Paris (under Charles Friedel) and then became assistant to James M. Crafts at MIT. He earned no advanced degree but was awarded an honorary D.Sc. by New York University in 1908. He headed the Clark Chemistry Department for seven years (1907-1914).

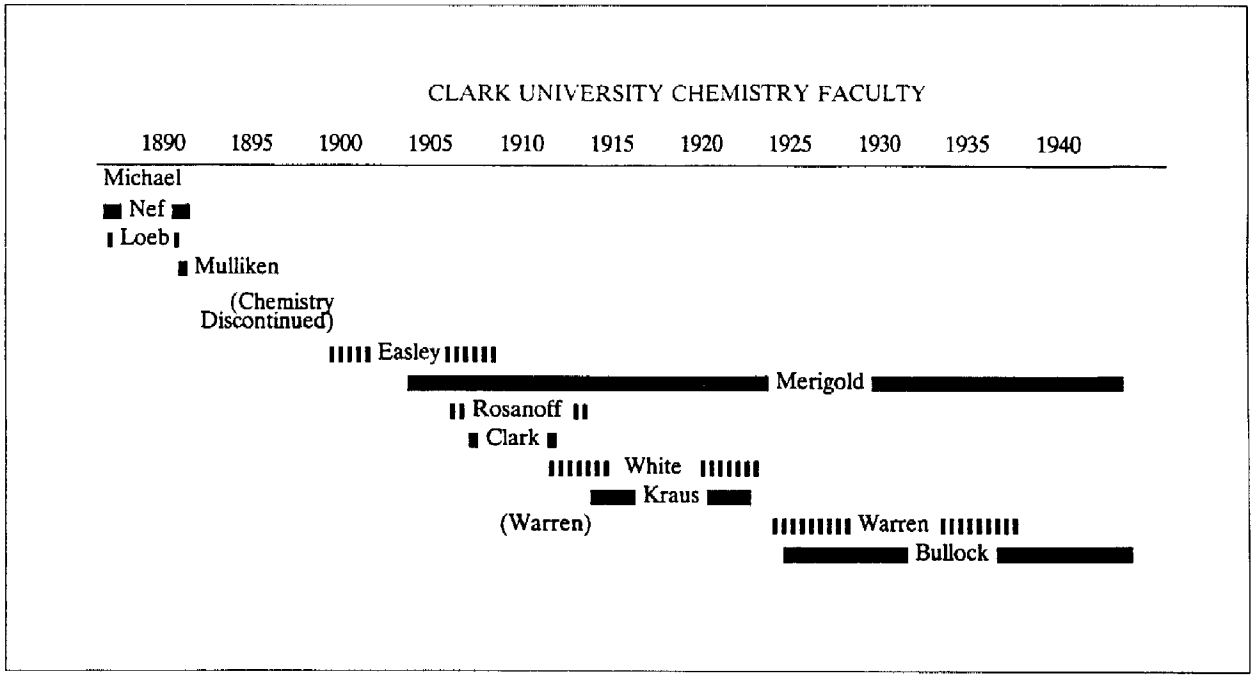
The result was a renaissance in chemistry for Clark. Rosanoff directed the dissertations of all eight of the students who earned Ph.D. degrees during his tenure. Though several of the dissertations concerned classical topics in physical chemistry, such as the determination of vapor pressures and dielectric constants, others dealt with what might be called physical organic chemistry - notably, the role of catalysis in esterification and in the inversion of sugars. In his annual report to the president for 1910-1911, Rosanoff described his work with C. W. Bacon, on "a complete solution of the eighteen-centuries-old problem of fractional distillation", as "the most important result of the year and probably of many future years." In the same year he was awarded the Nichols Medal by the New York Section of the American Chemical Society. His professional accomplishments notwithstanding, Rosanoff was fired in 1914 because of difficulty in getting along with other faculty and administrators. The rest of his career was spent at the Mellon Institute, at Duquesne University, and as a private consultant (3).

Other faculty were gradually added to the Department during Rosanoff's tenure. Robert Harvey Clark (1880-?), a Canadian with a Ph.D. from Leipzig under Arthur Hantzsch, held the positions of docent, acting assistant professor, and finally assistant professor during the 1910-1911 term. He was followed the next year by William Homer Warren (1866-1954), who, like Merigold, had received all of his chemical training (through the Ph.D.) at Harvard, where his mentor was Charles L. Jackson. After a varied industrial and academic career, Warren returned to Clark in 1925 as professor of organic chemistry and remained until his retirement in 1937.

The period of Warren's absence from Clark was filled by George Frederic White (1885-1929), who rose through the ranks to become professor of organic chemistry, retiring in 1925. White, a Johns Hopkins Ph.D. under Harry C. Jones, co-authored a laboratory manual in inorganic chemistry in 1911 (4) and authored a book on qualitative chemical analysis in 1916 (5). He also published about a dozen papers, either from Woods Hole or Clark, some coauthored by Clark students, and one in collaboration with Charles Kraus (see below).

Additional teaching during the Rosanoff era was done by MIT faculty members Arthur A. Noyes (1866-1936) and James F. Norris (1871-1940), who were listed in Clark catalogs in the 1912-1914 period as nonresident lecturers.

Rosanoff was followed as head by Charles A. Kraus (1875-1957), a Ph.D. student of A. A. Noyes at MIT. During his tenure at Clark (1915-1924), he supervised the thesis work of 17 Ph.D. students, mostly on the behavior of metals and organometallics in liquid ammonia. Master's degrees were



awarded to many students, several of them remaining at Clark to complete the Ph.D. When Kraus left Clark to head the department at Brown University, several students went with him to complete their degrees in Providence. Kraus was eventually the recipient of the Nichols, Gibbs, and Priestley medals and served as President of the ACS in 1939.

In 1915, during the interim period following Rosanoff's abrupt departure and before Kraus arrived, a Ph.D. was completed by Elmer A. Harrington, a former assistant in chemistry, who acknowledged a Professor Webster in Physics as having suggested the project, which dealt with the dielectric constants of aqueous solutions.

B. S. Merigold, who had served on the chemistry faculty longer than any of the remaining colleagues, finally succeeded Kraus as Director of Laboratories in 1926, a position he retained until his retirement in 1946. There is no indication in either the Clark Archives or *Chemical Abstracts* that Merigold directed research students or authored chemical publications.

Following the departure of President Hall in 1920, there was a change in the character of the chemistry department. Though no Ph.Ds were awarded between 1926, (i.e., shortly after Kraus's departure) and 1934, the number of A.M. degrees in chemistry continued to average four per year throughout this period. In the next seven-year period (1934-1940), only eight Ph.Ds were awarded (and only in four of those years), but 20 students earned A.M. degrees. Research was revived somewhat in the period when Warren and Jesse L. Bullock (1889-?) were members of the chemistry faculty. Between them they directed the dissertations for all eight Ph.Ds granted in the 1930s. After earning his A.B. at Harvard, Bullock had spent ten years in industry before joining the Clark faculty in 1926, where he remained until his retirement in 1959. He did not complete his doctoral degree at Harvard until 1932.

Where did Clark graduate students originate? Because it was founded as a graduate institution, the early students necessarily came from elsewhere. The three earliest Ph.Ds had earned baccalaureate degrees at Worcester Polytechnic Institute, Wesleyan University, and the University of Maryland. Rosanoff's doctoral students came from City College of New York, New York University (his own alma mater), Dickinson College, Barnard College, and Kentucky State University, as well as Clark. After the chemistry A.B. was introduced in 1908, Clark undergraduates often continued as graduate students. Indeed this became the common pattern during the Kraus era, with many A.B. chemistry majors continuing at Clark to complete the Ph.D., though about half terminated at the A.M. Interestingly, a pipeline from Kalamazoo College also apparently developed, since one Clark Ph.D. in each of the years 1920, 1921, 1922, 1924, and 1926 was a Kalamazoo undergraduate. Almost without exception, the A.M. preceded the Ph.D., the usual time lapse between the two degrees being between two and three years (6).

Only two women earned graduate degrees from Clark prior to 1940. Lillian Rosanoff Lieber, sister of Martin Rosanoff, completed her Ph.D. under her brother's direction in 1914 with a dissertation entitled "Theory of the Catalysis of Sugar Inversion by Acids." She became a research fellow at Bryn Mawr (1915-1917) under J. Barnes, and an instructor of physics for one year each at Wells College (1917-1918) and at Connecticut College (1918-1919). She was promoted to Assistant Professor after one year at Connecticut College but resigned in August of 1920. Lillian eventually became Professor of Mathematics at Long Island University, Director of the Galois Institute of Mathematics and Art, and author of a large number of popular books on mathematics and relativity theory, all of them written in free verse and illustrated with abstract cartoons by her husband, Hugh Gray Lieber. In 1955, she published a volume of her brother's collected papers on chemistry containing a rather uninformative introduction, also written in free verse (3).

Charles A. Kraus

A second woman, Marion Jeanette Sears, earned an A.M. in 1936. Arthur Michael's wife, Helen Abbott, whom he married in 1889, the same year he was appointed at Clark, might have been the first woman graduate, had she been allowed laboratory space.

An evaluation of the later careers of all the Clark graduates prior to 1940, though a worthy goal, is well beyond the scope of this paper; and a few examples will have to suffice instead. The first Ph.D., Thomas H. Clark, was briefly an instructor at Tufts and Clinton Liberal Institute. In 1899 he was appointed Instructor in Chemistry and Physics at Plymouth State College, New Hampshire, a position he held for four years. John L. Bridge (Ph.D., 1894) earned an M.D. at Harvard and became a physician in Connecticut. Julius B. Weems (Ph.D., 1894) served as Professor of Agricultural Chemistry at Iowa State from 1895-1904. In 1915 he became Chief Chemist for the Department of Agriculture in Richmond, Virginia, where he remained until his death in 1930.

Charles Easley, Rosanoff's first Ph.D. student at Clark,

served on the chemistry faculty at University of Maine, from 1909-1919, and then became Professor of Chemistry at Syracuse University. One of Kraus's doctoral students, Charles B. Hurd, after one-year appointments at Colby College and Trinity College, began a career at Union College, where over the next 30 years he directed an outstanding undergraduate research program in colloid chemistry (7).

This historical account of the evolution of the chemistry department at Clark University has focused on the first 50 years, for which archival information was examined. Despite a turbulent beginning a century ago, when the stability and continuity of the department were severely threatened, the department went on to enjoy periods of professional activity for which it has earned justified recognition.

References and Notes

Acknowledgments: Information on the faculty and students in chemistry at Clark has come from two sources: the excellent recent history of Clark University by William A. Koelsch (1); and the Clark University Archives. I am grateful to University Archivist Stuart W. Campbell and his assistant, Betty A. Bacinskas, for their willingness to provide a roster of chemistry faculty and staff from university catalogs during Clark's first 30 years. Information on students was acquired by searching a student file compiled by Professor Koelsch, from commencement programs, and alumni class lists.

1. W. A. Koelsch, *Clark University, 1887-1987*, Clark University Press, Worcester, MA, 1987.

2. T. W. Richards, ed., *The Scientific Work of Morris Loeb*, Harvard, Cambridge, MA, 1913.

3. L. Lieber, ed., *Collected Works of Martin André Rosanoff*, Galois Institute, New York, 1955. If this collection is accurate, it shows that Rosanoff ceased to publish after 1916. The volume also contains an unpublished paper by Lillian and her brother based on her Ph.D. work at Clark.

4. G. F. White and E. C. Bingham, *A Laboratory Manual of Inorganic Chemistry*, Wiley, New York, NY, 1911.

5. G. F. White, *A Laboratory and Class-Room Guide to Qualitative Chemical Analysis*, Van Nostrand, New York, NY, 1916. A second edition appeared in 1920.

6. A complete listing of all graduate and undergraduate degrees in chemistry given by Clark for the period 1892-1940 is available from the author upon request.

7. W. J. Hagan Jr., "Charles Hurd and Colloid Chemistry at Union College, 1923-1959", *J. Chem. Educ.*, **1988**, *65*, 191-193.

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CHEMICAL INDUSTRY IN COLONIAL VIRGINIA

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In the latter part of the 16th century many Englishmen advocated the founding of a colony in North America, and a number of reasons were put forward. These ranged all the way from extending Christianity to strengthening the defenses of England against Spain. Probably foremost in the minds of the members of the London Company was the discovery of gold and of a direct route to the South Seas, but it was also hoped that the new country would supply England with tar, pitch, rosin, glass, soap-ashes (potash), copper, iron, steel, and wine.

English settlers first landed at Jamestown in May, 1607. Early in 1608 the "first supply" of about 100 additional settlers, including a perfumer, was landed. In the fall of 1608 the "second supply" - including eight Dutchmen and Poles - was landed. The Dutch and Poles were sent over to establish the glass and naval stores industries. Evidently they got right to work, because a few weeks later samples of pitch, tar, glass, frankincense and soap-ashes (potash) were shipped to England. These industries did not survive long, principally because the colonists were too busy fighting off starvation and the Indians. Captain John Smith (1580-1631) did not approve of attempting to establish industries before sufficient food and shelter had been provided for the colonists. He asked for carpenters, masons, farmers, fishermen, blacksmiths and common laborers.

About the time the Pilgrims were landing in New England, the colonists in Virginia were attempting to revive the glass works. In 1621 six Italian glass workers came over, primarily to make beads for use in the Indian trade, but also to produce bottles, table glass, and other glassware for sale in England. Great precautions were taken to keep the process secret, because the beads were the money used in trading with the Indians and the Company was anxious to keep their value up. It was emphasized especially that the Virginians must not know the process. The glass works, located at Jamestown, escaped the general destruction accompanying the massacre of 1622 and continued in operation until 1624. At that time the Italian workmen, who were anxious to return to Europe and who had been sabotaging production by means of slow-down tactics, wrecked the plant and broke the furnace by striking it with an iron bar. That ended the manufacture of glass in that plant. The original site of this glassworks at Jamestown was located in 1931.

From the beginning, many people had been interested in locating iron ore and setting up plants for its reduction. One of the strongest motives for colonization was the expectation that Virginia would furnish England with plenty of cheap raw iron. Early on, Smith recognized the adaptability of the colony to iron manufacture, and in 1609 a quantity of ore was shipped to