Cincinnati Chemists

III. Robert Bowne Warder (1848-1905)

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Robert Bowne Warder (figure 1) was born in Cincinnati, Ohio, on 28 March 1848, one of seven children of John Aston Warder and Elizabeth Bowne Haines (1). The elder Warder was a physician who eventually left medicine to become one of the founders of the American horticultural and forestry movement (2). He was the founder and editor of *The Western Horticultural Revie*w and the once-famous Warder strawberry was named in his honor. He also helped to landscape Spring Grove Cemetery, was involved in the founding of Arbor Day, and was instrumental in establishing a tree planting program for the streets and parks of Cincinnati.

At the time of Robert Warder's birth, the family was living in a Gothic cottage known as "Scarlet Oaks" (figure 2) in the Cincinnati suburb of Clifton. However, as his interest in horticulture increased, the elder Warder decided to move to a more rural location. So in 1855 he purchased 300 acres of land in North Bend, Ohio, just west of Cincinnati, from the widow of President William Henry Harrison, upon which he eventually built a stone English manor house of his own design known as "Aston." It was in this house that Robert Warder spent much of his childhood and all of his adolescence. Unlike the cottage in which he was born, which was replaced by a huge gothic mansion of the same name in 1867, Aston still exists and was placed on the National Register of Historical Places in 1978.

Figure 1. Robert Bowne Warder (1848-1905).

Figure 2. "Scarlet Oaks" the Gothic cottage in which Warder was born in 1848.

The Warders were Quakers and, as a consequence, when of age, the younger Warder was sent to Earlham College in Richmond, Indiana, which was run by the Society of Friends. After graduating in 1866, he held a variety of jobs. From 1866-1867 he taught high school in Mooresville, Indiana; from 1869-1871 he worked as an assistant in the chemical laboratory of A. P. S. Stuart at the Illinois Industrial University at Champaign; and from 1871-1872 he was involved with the geological surveys in Ohio and Indiana.

These experiences apparently convinced Warder that he needed to improve the level of his chemical training, so in 1873 he not only completed an M.A. at Earlham, but enrolled in the Lawrence Scientific School at Harvard, from which he received a B.S. de-

gree in chemistry the next year. This was followed by a year (1874-1875) of study and travel in Germany, where Warder spent time in the laboratories of Heinrich Will at Giessen and August Hofmann at Berlin, though he apparently never completed a formal graduate degree (3).

Professorship at Cincinnati

Returning to the family estate in North Bend, Warder accepted the position of Assistant Professor of Chemistry and Physics at the newly founded University of Cincinnati in the Fall of 1875. Here he joined the newly appointed 28-year old Professor of Chemistry and Physics, Frank Wigglesworth Clarke (1847 -1931), also a graduate of the Lawrence Scientific School. Though chartered by the State of Ohio in 1870, the University of Cincinnati did not begin active operation until 1874. That year Clarke and four other faculty members were appointed and classes were held in rooms above the store fronts in downtown Cincinnati, since the new University building (figure 3) was not completed until the next year (4). Clarke modeled his new department on that of his *alma mater*, so that from the beginning a full four-year program leading to a specialized B.S. degree in chemistry was offered, with options for graduate work at both the M.S, and Ph.D, levels – a program available at only 5% of American colleges and universities at the time (5).

Clarke and Warder seem to have fairly evenly divided up the course work in both physics and chemistry. With respect to the latter, Clarke taught the inorganic courses and Warder the organic, while both taught the courses in analytical chemistry (6). Clarke, however, gradually tired of teaching physics and, beginning with the 1878-1879 academic year, became Professor of Chemistry only, with Warder assuming the title of full Professor of Physics, though, interestingly, the University catalog fails to show any similar redistribution of their teaching responsibilities. But this arrangement was short-lived as the next year Warder was dismissed from his position, "not from any fault of his," as Clarke later recalled, "but for want of money to pay his salary" (7).

Figure 3. The University of Cincinnati as it appeared during Warder's association with the school. Located on the steep slope of the Vine Street Hill, roughly at the point where Clifton avenue takes a sharp turn to the east, the chemistry laboratory was originally located in the basement of the brick building on the left. The University moved from this site to its present location near Burnet Woods in 1895.

Warder spent the 1879-1880 academic year teaching at Haverford College in Pennsylvania, but by the Fall of 1880 had returned to his father's estate at North Bend and was again associated with Clarke at the University, this time as a "Licensed Instructor in Chemistry and Physics," a position which the University catalog euphemistically described as being similar to that of a *Privatdozent* at a German University. In other words, Warder received no salary from the University and had to collect fees directly from the students who chose to attend his lectures, a position which he retained until his departure from the University two years later.

Later Career

Clarke was a friend and associate of Harvey Washington Wiley (1844-1930), who had become Professor of Chemistry at Purdue University the same year as Clarke had been appointed to the faculty at Cincinnati. In 1883 both of them, apparently fed up with the mediocre salaries and students which seemed endemic to the fledgling universities of the Midwest, resigned their professorships and accepted positions with the U.S. government in Washington DC – Clarke with the U.S. Geological Survey and Wiley with the Division of Chemistry of the Bureau of Agriculture. Between them, they apparently arranged for Warder to succeed Wiley as Professor of Chemistry at Purdue (figure 4) and as State Chemist for Indiana, a position which he held until 1887. That year Warder joined Clarke and Wiley in Washington DC as Professor of Chemistry at Howard University, again probably at their instigation, as both were by this time quite powerful members of the Washington chemical community and Clarke had taught at Howard prior to coming to Cincinnati. Here Warder remained until his death in 1905.

Research Activities

Warder's interest in chemical research was sparked during his stay in Hofmann's laboratory at Berlin by a fellow American student, Charles Loring Jackson (later

Professor at Harvard), and resulted in a short note on the preparation of "Phenylenharnstoff," which appeared in the *Berichte* in 1875 (8). However, after assuming the position at Cincinnati, he appears to have ceased to do laboratory research, probably more because of the time consuming daily commute between the University and North Bend, where he continued to live, then because of the teaching schedule, since Clarke, who had a comparable teaching assignment, if we are to believe the catalogs, managed to remain highly productive, producing nearly 70 papers and five books during his nine-year stay at Cincinnati. This situation radically changed after Warder's return to the University in 1880 as an unpaid Licensed Instructor, and involved not only a surge of laboratory activity but a complete shift in his field of interest from organic to physical chemistry.

Chemical tradition has it that the discipline of physical chemistry began in 1887 with the founding of the *Zeitschrift für physikalische Chemie* and the publication of the second volume of Wilhelm Ostwald's famous *Lehrbuch*. This is, of course, an exaggeration, since a tradition of physical chemistry was begun in France by Berthollet and Gay Lussac in the late 18th and early 19th centuries, which, in alliance with the crystallographic tradition of Haüy, continued through the 1860s and 1870s in the work of Pasteur, Berthelot, Le Bel and others. Likewise, there was a similar tradition in Germany, the most notable example being the school of Bunsen, Kopp and Horstmann at Heidelberg. What was missing, however, was an explicit sense of mission and group identity, both of which were provided by the writings of Ostwald and his identification of this new discipline with the recent work of van't Hoff and Arrhenius on ionic dissociation and the colligative properties of solutions.

In this light it is interesting to see what was going on in the Cincinnati chemical community in the late 1870s and early 1880s. In 1878 Clarke served as Chairman of the Chemical Subsection of the American Association for the Advancement of Science, which he had been instrumental in founding. In his address to the subsection, which was meeting in St. Louis, he noted that, "among chemists today, there seem to be two schools: at least practically, if not in point of abstract theory" (9). The first of these, he continued:

... seems to take an interest only in the statical side of the science; its chief aim is to discover immense numbers of new compounds, and to theorize upon their constitution. Strangely enough, these chemists have devoted nine-tenths of their energy to the compounds of a single element, carbon; scarcely regarding other substances save in so far as they unite with this or with bodies containing it.

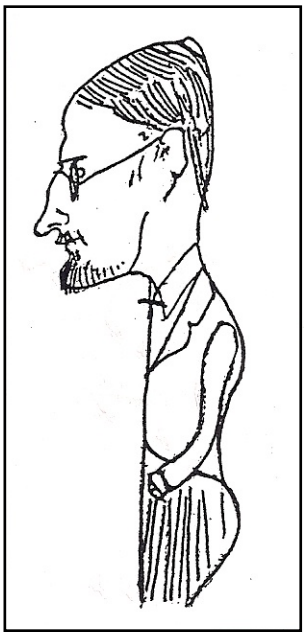


Figure 4. A student caricature of Warder found inside a copy of the 1884 edition of F. W. Clarke's *The Elements of Chemistry* – the textbook used by Warder during his professorship at Purdue.

The second group, which was rapidly growing in England:

... may be described as essentially dynamical in its ideas. It sees in every chemical reaction three objects of study: first, the substances which enter into the reaction; secondly, the phenomena which occur during the reaction; thirdly, the substances produced by the reaction. The second term, the term which involves all the transformations of energy, is to them of at least equal importance with the others.

In terms of chemists who were active in this second school, Clarke noted the work of Mitscherlich (isomorphism), Kopp (molecular volumes), Thomsen and Berthelot (thermochemistry), Gladstone (chemical constitution and refractive index), and Harcourt, Esson, Boguski, and Kajander (chemical kinetics). Conspicuously absent are, of course, the names of van't Hoff, Arrhenius and Ostwald for the simple reason that in 1878 van't Hoff was just two years into his first academic appointment and was still concentrating on organic chemistry, while Arrhenius and Ostwald were still students.

Clarke also outlined his own vision of a research program for the new dynamical school of chemistry (9):

First, what laws govern the transformations of energy that occur during chemical change? Second, how do the properties of compounds stand related to those of the elements contained in them? Third, what is the nature of chemical union?

Clarke was largely interested in the second question, and while still at Howard had contracted with the Smithsonian Institution to produce a series of volumes on the physical and chemical *Constants of Nature*. Beginning with a volume on specific gravities, boiling and melting points, and chemical formulas in 1873, Clarke published, during his stay at Cincinnati, volumes on the specific heats of solids and liquids (1876), a supplement to the first volume on specific gravities, etc. (1876), tables of thermal expansion for solids and liquids (1876), and a volume of revised atomic weight values (1882). He was also asked by Ira Remsen to edit the physical section of *The American Chemical Journal* (10).

After his return to Cincinnati, Warder became actively involved in Clarke's program of dynamical chemistry and began to study chemical kinetics. This resulted in the publication in 1881 in *The American Chemical Journal* of Warder's famous study of the kinetics of the saponification of ethyl acetate with sodium hydroxide (11):

$$CH_3COOC_2H_5 + NaOH \rightarrow C_2H_5OH + CH_3COONa \quad [1]$$

and in the publication of a shorter version of the same paper in 1882 in the *Berichte* (12). Warder found that the reaction was first order with respect to both the ester and the base or second order overall. This definitive work was quoted in the textbooks of Ostwald (13), van't Hoff (14), Nernst (15) and Mellor (16) well into the first decade of this century.

Warder studied not only the rate constant at 21°C but also its temperature dependency, which he modeled by means of a power series, concluding that it was best represented by the expression (10, 17):

$$k = 1.436 + 0.0082T^2 \quad [2]$$

Recent work on the temperature dependency of diffusion in liquids had shown that it varied with the first, rather than second, power of the temperature, thus implying that temperature increased the rate of reaction not only by increasing the rate of collision but by internally activating the molecules in some fashion, and Warder speculated that this most likely involved an increase in the vibrational stretching of the chemical bonds (10, 18). The Arrhenius equation was not published until 1889 and, as Laidler has pointed out in his historical study of attempts to model the temperature dependency of rate constants, a simple empirical evaluation of the level of the agreement between the data and the proposed equation is insufficient to pick out the exponential form proposed by Arrhenius as the unique solution. As a result, earlier workers in the field used a variety of equations, all of which were of acceptable accuracy (19). The present universal adoption of the Arrhenius equation is rather the result of the fact that it has a theoretical underpinning and gives results at equilibrium which are consistent with thermodynamics.

Another product of Warder's kinetic study was a short paper on the use of phenolphthalein as an acid-base indicator (20). This compound was first prepared by von Baeyer and its use as an acid-base indicator had been suggested by Luck. Warder had investigated the method as a means of rapidly determining the amount of unreacted NaOH at each stage of his study of the kinetics of the saponification process but had discovered that there were problems with fading of the color at the end point due to the absorption of carbon dioxide from the air. He made a detailed study of the problem and developed a technique for eliminating this source of error which was still being mentioned in analytical textbooks 60 years later (21).

Chemical Societies and Journals

A second significant event which occurred around the time of Warder's return to Cincinnati was the founding of a local chemical society in November of 1880 with Clarke as the Chairman (22). This was incorporated as the Section of Chemistry and Physics of the Department of Science and Arts of the Ohio Mechanics' Institute (figure 5) in March of 1881. This department was under the progressive leadership of Lewis Hosea, who was trying to upgrade the quality of the Institute's educational programs. In January of 1882 the department began the publication of a quarterly journal known as the *Scientific Proceedings of the Ohio Mechanics' Institute* (figure 6), with Warder as the active editor (23). This carried the minutes of the meetings of both the Section of Chemistry and Physics and the Section of Mechanics and Engineering, as well as printing key papers delivered at the meetings, many of which were later reprinted in other journals.

In the spirit of the program for dynamical chemistry, Clarke gave papers before the section on his redetermination of atomic weights and their bearing on Prout's hypothesis, a review of Ostwald's work on chemical dynamics, and a paper on a new chemical theory of odors. Warder was even more prolific, talking on his phenolphthalein work, on Brodie's ideal chemistry (which attempted to replace the atomic theory with a chemical form of Boolean algebra), on a new form of

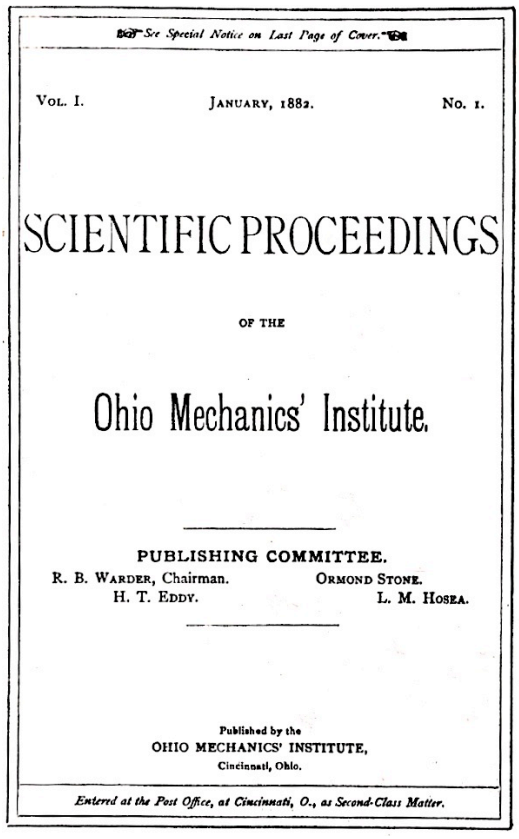
Figure 5. The Ohio Mechanics' Institute. Located on the corner of 6th and Vine Street, this building served as the home of the Institute from 1848-1911.

the periodic table, on a criterion for the measurement of the speed of chemical action, on the speed of saponification using barium hydroxide, on Urech's investigations of the speed of the inversion of sugar cane, on the influence of pressure on chemical reactions, and on the speed of slow combustion of phosphorus. In April of 1883 he proposed that a flyer be sent to the chemists of America in order to organize a cooperative program for the determination of rate constants and to establish a criterion for reducing both published and future work to a common set of units. Alfred Springer, a local industrial chemist, also spoke to the section on Franz Wald's theory of energy-producing chemical reactions (22-23).

Warder's commitment to physical chemistry naturally extended to his activities at the University as well. The 1879-1880 catalog noted that "Instructor Warder will form a class in organic chemistry; or in physical chemistry, if there be sufficient demand," and a similar announcement appeared in the 1883-1884 catalog (24). Since both dates correspond to periods when Warder was no longer at the University (the catalogs were prepared a year ahead of time) one might doubt whether he ever really gave the proposed courses. However, *The Cincinnati Gazette* of 27 April 1881 indicated that Warder was giving a series of lectures at the University on the subject of thermochemistry (25). Note that the proposed course in physical chemistry for the 1879-1880 academic year was being offered seven years before Ostwald supposedly founded physical chemistry as a separate subdiscipline.

The Section of Chemistry and Physics also addressed a number of practical problems presented by local industry and Warder was personally involved in studies of surface drainage in Cincinnati, the investigation of a so-called new form of ozone being sold as an antiseptic (which turned out to be SO_2), a new device for preventing the sticking of telegraph keys, the contamination of maple syrup via its concentration in galvanized iron pans, the adulteration of candy, the contamination of water by brine, and the presence of reflection ghosts in refracting telescopes.

While the mission of the Section of Chemistry and Physics was strictly that of a scientific society and did not involve classroom instruction, the members also agreed to present a series of popular public lectures on science at the Mechanics' Institute as part of the Institute's larger educational mission. The local newspapers carried detailed accounts of these lectures and indicate that Clarke was especially active in this regard. Only two accounts of Warder's performance seem to exist, both involving a series of three lectures on mechanics which he gave on the 9th, 16th and 23rd of February 1883. The first lecture on "Forces in Equilibrium" and the second on "Forces Producing Motion" seem to have proceeded satisfactorily. Indeed, *The Cincinnati Commercial Gazette* of 10 February noted at the con-



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VOL. I. JANUARY, 1882. No. 1.

SCIENTIFIC PROCEEDINGS

OF THE

Ohio Mechanics' Institute.

PUBLISHING COMMITTEE.

R. B. WARDER, Chairman. ORMOND STONE.
H. T. EDDY. L. M. HOSEA.

Published by the
OHIO MECHANICS' INSTITUTE,
Cincinnati, Ohio.

Entered at the Post Office, at Cincinnati, O., as Second-Class Matter.

Figure 6. Title page of the first issue of the *Scientific Proceedings of the Ohio Mechanics' Institute*.

clusion of the first lecture that "the Professor was greeted with a round of applause, for which he smiled his thanks, as the audience took its leave." By the end of the third lecture on "Perpetual Motion," however, the reporter had changed his tune, and complained that the "lecture was abstract in character [and] interesting only to those who possessed a knowledge of physics" (25).

After the departure of Clarke in the summer of 1883, the Mechanics' Institute underwent a radical reorganization and both the chemical society and the journal ceased to exist. Warder's new position at Purdue seems to have left little time for research, as he published only three papers and a brief note during his five year stay. This was partly because the position of State Chemist consumed much of his time in routine analyses of "a commercial character rather foreign to his natural tastes." Nevertheless, he managed to combine the two by attempting to apply his knowledge of physical chemistry to an analysis of the chemistry behind the analytical procedures he was using. The result was a paper on the "Influence of Time in Fertilizer Analysis" (26) and one "On the Speed of Dissociation of Brass" (27), both of which were published in the British weekly, *The Chemical News*.

After his move to Howard University, Warder, apparently stimulated by the large chemical community in Washington DC, began to actively pursue chemical kinetics once again, often attempting to mathematically analyze data published by others. Among the papers of this period are "The Chemical Kinetics of Oxidation" (28), "The Speed of Esterfication as Compared with Theory" (29), and the "Dynamical Theory of Albuminoid Ammonia" (30). The latter, like the work at Purdue, was an attempt to elucidate the physical chemistry behind a procedure for the determination of organic nitrogen in water proposed by the British chemist, James A. Wanklyn, and widely used at the time by chemists connected with public health boards (34).

In 1890 Warder served as Chair of the Chemical Subsection of the American Association for the Advancement of Science at its annual meeting in Indianapolis and for his address before the section gave a superb review of the the current state of the theory of geometrical isomerism, complete with a detailed bibliography (31). It is also not with out significance that in 1887 he was asked by *The American Chemical Journal* to review the first volume of Ostwald's new publication, the *Zeitschrift für phyikalische Chemie* (32).

Personality and Religious Activities

Described as having a strong sense of ethics and a personality "formed under the influence of the Society of Friends," Warder appears to have been quiet and unassuming. The close connection between his career and those of Clarke and Wiley strongly suggests that he was content to let them fight the political battles while he quietly moved within their sphere of influence.

In 1884 Warder married Gulielma M. Dorland, the widow of Sebum Dorland, a friend from his college days, and also adopted her young daughter. The influence of his new wife, who was a devout Quaker, coupled with the unsatisfying nature of the routine analytical work he was forced to undertake as part of his position at Purdue, seems to have precipitated a crisis in Warder's life. Though in his youth he had experienced those "phases of skepticism that so often present themselves to students of science, and especially, perhaps, in the Continental Universities," he appears to have undergone an intense religious conversion about this time and to have made a conscious decision to lay aside "in large part his scientific ambitions," and to instead join his wife in dedicating the rest of their lives to "evangelical work."

There is no doubt that this conversion was the primary motivation behind Warder's decision to leave Purdue and to devote the rest of his life to teaching chemistry at Howard, as he almost certainly viewed his job there as a form of Christian missionary work – a not untypical attitude toward minority groups in the late 19th century (35):

With splendid equipment of scientific insight and training and with the large field of chemical research open to him in which undoubted laurels as student and pioneer were to be won – indeed it is hardly too much to say, were almost within his grasp – Robert B. Warder, knowingly and deliberately turned from a path leading not only towards mere scientific fame, but towards scientific achievement of undoubted usefulness to mankind, and chose to labor in a field of obscurity.

In contrast, Clarke, many years before, had recorded in his diary his humiliation at having to visit wealthy patrons in order to solicit funds for Howard (33).

While at Howard, Warder also taught Bible classes, served as Dean of the Faculty, became interested in the YMCA movement, the Moody Bible Institute, and the writing of religious poetry. At least one unintentionally amusing anecdote has been preserved concerning the impact of his religious views on his teaching (36):

An examination was being held. There was one who yielded to temptation. He opened his book. Professor Warder saw him. No abusive words were uttered. The unfortunate student was not sent abruptly from the

room to lose hope and in despair fall into other errors. Quietly Professor Warder approached, removed the book from his hands, and calmly and meaningly said: "Will the class give attention?" He was standing over the young man. When the class looked up, these unusual words were heard: "Let us pray." No student afterwards was ever known to cheat under him, and that young man emerged from the room that day a changed being.

It is, of course, debatable whether this incident was really an example of extreme religious piety or simply an example of shrewd insight into human psychology, as I doubt that there are many students, whether of the 19th century or the 20th century, who would not prefer to risk "the despair of falling into error" to the humiliation of being prayed over in front of their fellow students!

As mentioned earlier, Warder remained at Howard, though it provided little opportunity for research or professional development, until his untimely death on 23 July 1905 at the age of 57, apparently content, as his obituary in *The American Chemical Journal* phrased it, with "teaching chemistry and physics, but above all with setting an example and teaching the principles of a Christian life with an unselfish devotion" (1).

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24. *1879-1880 Catalog*, p. 35; *1883-1884 Catalog*, p. 41.

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35. *Robert Bowne Warder*, Washington: DC, 1905, pp. 24, 31. This is a collection of memorials, tributes, and newspapers obituaries collected and published by Warder's wife after his death.

36. *Ibid.*, pp. 34-35.

Publication History

Reprinted from the booklet W. B. Jensen, C*incinnati Chemists*, Oesper Collections: Cincinnati, OH, 2012. Available on line.