Charles Edward Munroe
1849-1938

By Charles A. Browne[1]

The American Chemical Society has been fortunate in having had among its past-presidents a goodly number of vigorous octogenarians whose births occurred in the second quarter of the nineteenth century and whose active careers began before the establishment of a national organization of American chemists. These men exerted in their several ways important influences in shaping the early destinies of our Chemical Society and continued to show an interest in its affairs until the end of their lives. They belonged to that early school of chemists who, well grounded in the use of the blow-pipe and other discarded fundamentals, were not always sympathetic with modern educational trends. C. F. Chandler, H. W. Wiley, F. W. Clarke, and C. E. Munroe were four conspicuous examples of this type, and those who knew these men will recall certain traits which they had in common. They were all rugged individualists, yet combined with this quality were other characteristics of geniality, optimism, and sympathetic interest in the work of younger men. It is to C. E. Munroe, the last survivor of this distinguished group, that the present sketch is devoted. His death at the age of 89 on the afternoon of December 7, 1938, at his home in Forest Glen, Maryland, severed the last living link which connected the American Chemical Society with its charter members of 1876.

Charles Edward Munroe was born at East Cambridge, Massachusetts, on May 24, 1849, the third of six children of Enoch and Emeline (Russell) Munroe. He was descended from a long line of New England and Scotch progenitors, his ancestry dating back to George Munro, tenth Baron of Fowlis in Scotland, of the fifteenth century. The founder of his colonial line was William Munro of Inverness, Scotland, who was born in 1625, banished with other prisoners to America by Cromwell after the battle of Worcester, and settled at Cambridge Farms (now Lexington), Massachusetts, about 1652. From him came a prolific race of descendants who participated in the growth of the new country and performed their part in the Colonial wars that culminated in the American Revolution. More than twenty of Munroe's ancestral connections were in the company of Minutemen who fought in the opening engagement at Lexington on April 19, 1775.

From the Munroes of Lexington sprang many men and women who were prominent in the upbuilding of New England. Interest in industrial and educational affairs was a family trait, of which only a few examples need be cited. Edmund Munroe, a great uncle of the chemist, was a founder of the New England Glass Company and a man of wealth and influence. Enoch Munroe, the father, was an instrument maker and his son Charles no doubt inherited from him his keen interest in all kinds of scientific apparatus. A

(1) For assistance in preparing this sketch the writer wishes to express his indebtedness to Mr. Treadway B. Munroe for supplying him with much unpublished biographic material relating to his father and also for the photograph of Dr. Munroe which is herewith reproduced from an engraving made by Adolf Eckstein in Berlin from a photograph by Edmonston in Washington. This was always regarded by Dr. Munroe as his best portrait. Acknowledgments are also made, to Dr. Nevil Monroe Hopkins, closely associated professionally with Dr. Munroe for many years, for helpful information and suggestions, and to Mr. J. N. Taylor, for material contained in his valuable booklet "A Half Century in Chemical Education—A Chronological Record of the Scientific Contributions of Charles Edward Munroe," published by the *General Science Quarterly*, Salem, Mass., 1926.

cousin, James Phinney Munroe, was treasurer of the Munroe Felt and Paper Company, secretary of the Massachusetts Institute of Technology, and vice-chairman of the Federal Board for Vocational Education. An older sister Emma F. Munroe was prominent as a teacher and philanthropist, while a younger brother George H. Munroe was a paper manufacturer. The blending of these family interests in industry and education came to full fruition in the subject of the present sketch.

Munroe's love of chemistry began early and from first to last it was joyful and compelling. It had also a contagious quality that inspired everyone within his circle and was a great contributing factor to his success as a teacher and lecturer. As a boy he equipped a small chemical laboratory in an attic room, over the entrance of which, in the merry spirit that always stayed with him, he inscribed the words, "All hope abandon ye who enter here." Desirous of increasing his stock of chemicals, he went one day to the neighboring drug store of Dr. Abner Ham to buy an ounce of potassium cyanide. The venerable doctor peered down at the lad through his glasses and asked with surprise what he wished to do with so poisonous a substance. "To make experiments," was the reply. Dr. Ham then questioned him and, finding that he had picked up an amount of chemical knowledge unusual for one so young, decided that what he needed most was not potassium cyanide but direction. He offered him therefore a position as occasional helper and errand boy, together with the opportunity of making such chemical experiments as discretion and the resources of his store permitted. The proposal was eagerly accepted. There was never a doubt in the boy's mind as to the choice of a career. His grandmother once asked him what he was going to be. He answered at once "a chemist." "But Charles how are you going to make a living?" Again the prompt reply "Grandmother I don't know but I like chemistry and am going to follow it."

The zeal for chemistry, thus early aroused, accompanied the boy into the Cambridge High School, which was one of the earliest in the United States to make chemistry a part of its curriculum. The principal of the school, W. J. Rolfe, the well-known Shakespearean scholar and editor of school texts, was interested in chemistry but instruction in this subject devolved chiefly upon his associate, J. A. Gillet, with whom Rolfe collaborated in the publication of a "Handbook of Chemistry for School and Home Use" (Boston, 1869). These teachers encouraged the precocious talent of young Munroe by making him an assistant whose duty it was to fill the reagent bottles and look after the chemical supplies.

The same enthusiasm followed the youth into the Lawrence Scientific School of Harvard, where he came under a group of distinguished teachers, chief of whom were Wolcott Gibbs, Josiah Cooke, and Louis Agassiz. It was the latter who inspired him to develop a hobby for collecting minerals. Munroe's Latin diploma states that as a reward of his studies at Harvard he was admitted, after an "examen rigidum in Chemia," on June 28, 1871, to the "Baccalaurealem Gradum in Scientia summa cum laude." It is doubtful if many chemical certificates carry the signatures of so many eminent scientists as this sheet of parchment. In addition to that of President Eliot, who was himself a chemist, it bears the autographs of Agassiz as zoölogist and geologist, Peirce as astronomer, Lovering as mathematician and physicist, Gray as botanist, Wyman as anatomist, Eustis as engineer, Gibbs as chemist, and Cooke as chemist and mineralogist.

Several lasting friendships were formed by Munroe in his undergraduate years at Harvard; among these should be mentioned his classmate Thomas M. Chatard, and Frank W. Clarke who graduated in 1867 but remained a year longer to take a postgraduate course under Gibbs. Charles L. Jackson of '67 and Henry B. Hill of '69 were also close college friends and associates in the Chemistry Department of Harvard.

As was the case with Clarke, Chatard and other chemistry students, Munroe's favorite teacher at Harvard was Wolcott Gibbs, who had succeeded E. N. Horsford as Rumford Professor in 1863, and it was under Gibbs that his first published researches in chemistry were conducted. The first of these was a note on "The Purity of Commerical Nitrate of Silver," published in his junior year in the *Philadelphia Photographer* for May, 1870. This was followed by two articles on "The Estimation of Phosphoric Acid" and "The Use of Porous Cones in Filtration," published during his senior year in the *American Journal of Science* for 1871. The clay filter cone was devised by Munroe for use in quantitative analysis to replace paper filters which cannot be dried above 100°

without loss from charring. In making these cones he incorporated with the wet clay a little ammonium chloride, the volatilization of which during baking secured the necessary porosity. The device sprang into immediate favor and won for the inventor the favorable notice of many prominent chemists. The filter cone was connected hermetically by a specially constructed rubber gasket with a Sprengel pump, a piece of apparatus that had been newly introduced for producing reduced pressures. The filtering cone with its adapter was the precursor of Caldwell's perforated porcelain crucible, Gooch's asbestos crucible, and Munroe's later perforated platinum crucible with a felt of metallic platinum.

The experiments of Munroe with baked clays led to his invention of a device for producing refrigeration by the evaporation of water from porous surfaces, analogous to the principle of the well-known water cooler or "monkey-jug." For this application he was granted his first U. S. Patent No. 116,344, on June 27, 1872, for "Improvement in Refrigerators."

Munroe's growing reputation as a chemist led to his appearance as an expert in 1871 in the patent suit of the United Nickel Company *vs.* Andrew J. Forbes, his testimony appearing in the records of the Circuit Court of the United States Massachusetts District for 1871. This was the first of the many legal cases in which Munroe gave expert chemical testimony during the course of his long career.

In his undergraduate work, Munroe enjoyed the privilege of studying the valuable mineral collections of Professor Cooke, who, being impressed by his student's aptitude, entrusted him with the task of cleaning, relabeling and classifying the specimens in his cabinets which had been recently enriched by new acquisitions. The work not only greatly widened Munroe's acquaintance with minerals but it enabled him to make the acquaintance of many eminent scientists who came to view Cooke's collections.

At the time of his graduation, Munroe expected to continue his studies at Harvard as Gibbs' assistant, but events were shaping themselves otherwise. One day he was notified by Gibbs that there was to be an inspection of the laboratory and that he should prepare to demonstrate his new filter cone. The delegation consisted of President Eliot, Professor Cooke, and former Rumford Professor of Chemistry, Dr. E. N. Horsford. They were greatly interested in the demonstration of the new filtering device, but Munroe learned afterward that the principal object of the visit was not to see the new cone but to look him over as a possible candidate for the position of chemist on a geological expedition to San Domingo. He did not receive this appointment and was preparing to continue in his old position when he was notified one day by Gibbs to pack up his apparatus and report to President Eliot; he then kindly added: "Please do not refuse to do what the President desires." The result of this visit to Eliot was the transfer of Munroe from Gibbs' laboratory to that of Cooke, where his duties were to consist in teaching upper classmen quantitative analysis.

This change came about as a result of the reorganization of the Harvard curriculum which Eliot put into effect shortly after his inauguration as president. He considered it advisable in 1871 for reasons of economy to consolidate the chemical instruction of the Lawrence Scientific School with that of Harvard College, a change that involved the concentration of all the chemical work under Cooke and the transfer of Gibbs from his chosen field of chemistry to the Department of Physics. The consolidation, apparently justifiable on grounds of economy, was vigorously opposed by Gibbs' friends, some of whom declared that the real motive in deposing Gibbs was not economy but the satisfaction of injured pride, for in 1863 Gibbs had been preferred, as a candidate for the Rumford professorship, to Eliot, who, as assistant professor, had every reason to expect the appointment himself.

Without discussing the issues involved in this historic controversy, it cannot be denied that a grave injustice was done to Gibbs. Forty years later, on November 11, 1911, when the bust to Gibbs was unveiled in Rumford Hall of the Chemists Club in New York, Munroe was most fittingly chosen to pay a tribute to his old master. He gave then the following account of the episode, which changed so completely the course of his own career:

"Strange as it may seem Dr. Gibbs became, on coming to Harvard, a storm center. President Hill called him because he had a vacant chair in chemistry to fill and he found in Gibbs the most eminent chemist in America. Gibbs accepted the position at Harvard because it seemed to offer the largest opportunity for usefulness in the field for which he was especially equipped. But his appointment thwarted the realization of the ambitions of others;

it became a cause of dissension and the arraying of groups of men against each other. The situation had become acute as I entered upon the scene. In the regular performance of my duties I was unwittingly forced to know of it though then I knew not the reason for it or the extent of it. I was especially embarrassed to come upon Professors Gibbs and Cooke, when they were engaged in a gentlemanly, but very personal, altercation.

"Unknowingly to me, out of this came my opportunity. While holding the position of private assistant to Dr. Gibbs I was appointed Assistant in Chemistry in the College under Professor Cooke. With the courtesy that prevails among gentlemen all these arrangements were ostensibly in the hands of Dr. Gibbs and it was from him that I received my instructions to make that visit to President Eliot at which I received notification of my appointment to the college. Naturally and most properly I reported to Dr. Gibbs that I had obeyed his instructions, and the results of so doing, and I can never forget his admonition. Knowing my loyalty to him, knowing that inadvertently I had become somewhat acquainted with the distressing situation he said: 'Mr. Munroe I have been deposed and you are appointed to take my place. You know that my relations with Professor Cooke have not been entirely amicable, yet let me say that you can serve me best by serving him with entire devotion.' "

Munroe always spoke with admiring affection of both Gibbs and Cooke. Although there was a professional coolness between the two men, Munroe maintained cordial relations with both. In fact a cardinal trait of his character was a conciliatory spirit which made it impossible for him to become a partisan in the quarrels of his friends.

His services to Cooke were invaluable. He collected the exhibits for his lectures and assisted in his experiments. On the memorable occasion of one of Cooke's Lowell Institute Lectures, that came just after the great Boston Fire of November 9–10, 1872, Munroe had to carry much of the apparatus from Cambridge to the Washington Street lecture hall, there being no street-car or cab service because of an outbreak of epizoötic among the horses of the city. At these lectures Munroe was called upon by Cooke to perform the experiments and the experience thus gained gave him confidence to begin giving lectures of his own before students of the Boston Dental College and other small audiences.

One of his lectures on a lump of coal necessitated a large diagram of a coal bed. This was made by the scene painter of a theater, and in going to get it Munroe had to cross the stage. Just at this moment the curtain went up and revealed him rushing in great embarrassment behind a group of chorus girls. He was recognized by many students in the audience who greeted him reproachfully with the cry "Oh Professor!" In relating this incident, Munroe ended with the remark "It was then that may hair turned white."

Among Munroe's chemistry pupils at Harvard was Harvey W. Wiley, of the class of '73, and between these two arose a deep and lasting friendship. Wiley, who was Munroe's senior by five years, was then pursuing a year of postgraduate study and being a B.A. of Hanover College had no intention of taking another degree. Munroe, however, persuaded him to try for a B.S. at Harvard, but the regulations required that he must first pass the examinations for each of the four college years. Wiley, after being duly coached by Munroe, had no difficulty in fulfilling this requirement, and he thereby attained the unique distinction of being promoted from freshman to senior year in the brief space of seventeen days. Munroe always referred to Wiley as his most distinguished student and helping him to run this gauntlet of tests was jokingly mentioned as his greatest pedagogical achievement. He was fond of quoting Wiley's classic Chemico Metrical Madrigal, which was composed in his own laboratory at Harvard in the interval of a slow filtration:

> "And when she speaks from parlor or stump,
> The words which gracefully gambol and jump
> Sound sweet like the water in Sprengel's pump
> In magnesic phosphate ablution."

In August, 1873, Munroe, Wiley, and Clarke attended the meeting of the American Association for the Advancement of Science at Portland, Maine. Other eminent chemists were also present, including such men as George F. Barker, T. Sterry Hunt, Samuel W. Johnson, and William McMurtrie. It was a memorable meeting which grew in historic importance, for all seven of the chemists named became future presidents of the American Chemical Society. A committee of these and other chemists, of which Munroe was secretary, petitioned the governing body of the Association to form a subsection of chemistry. The petition was granted and the meeting of this subsection became a recognized feature of the Association until 1881, when it was made a full section. Munroe was the last survivor of the original group of founders of Section C.

The teaching of industrial chemistry in American colleges was looked upon as a degradation of science seventy years ago. Dr. E. N. Horsford, former Rumford Professor at Harvard, lost caste

among some of his chemistry colleagues when he took up the manufacture of phosphate baking powder. Ten years later, in 1872–73, Munroe, in defiance of tradition and against the advice of some of his friends, established a course in Chemical Technology at Harvard. Another innovation was his establishment in the summer of 1873 and 1874 of a Summer School in Chemistry, the first school of the kind in the United States. This new departure in the teaching of chemistry was a great success but it had the disadvantage of preventing Munroe's attendance at the historic Priestley Centennial at Northumberland on July 31–August 1, 1874—a deprivation which he always regretted.

The broad foundations of Munroe's chemical career as teacher, lecturer, investigator, inventor, writer, and consulting expert were well established during the seven years of his connection with Harvard as student and instructor. He was now 25 years of age and his course henceforth was simply a development of the experiences gained during his period of preparation in Cambridge.

Munroe left Harvard in the autumn of 1874 to accept the professorship of chemistry at the United States Naval Academy, Annapolis, Md., where he remained until 1886. He inherited from the Academy students the nickname of "Munzie," and even today many retired admirals of the Navy, who learned their chemistry in his lecture room and laboratory, speak with affection of "Munzie Munroe." In addition to instructing students in chemistry, his work at Annapolis was of a varied character. He compiled a complete catalog of the extensive mineral collections at the Academy, which was published in several installments by the Government Printing Office, and made an investigation of the service water of Annapolis. The most noteworthy feature, however, of his work at Annapolis was the commencement of his researches on nitroglycerine, gunpowder, guncotton, and other explosives, the results of which were published in the *Proceedings of the U. S. Naval Institute.* He began also his practice of making extensive abstracts of articles and books on explosives, which were published between 1882 and 1897, under the title "Notes on the Literature of Explosives" in a series of 29 articles in the *Proceedings of the Naval Institute.* Munroe was a past-master in the writing of abstracts, his labors in this field extending over a period of nearly sixty years. His collected abstracts and reviews on explosives, if assembled together, would make a small library, and they are a testimony not only of his industry but of his immense grasp of the subject. He was by habit an early riser, and much of this work of culling the literature was performed before breakfast. The same work was carried on later through the thirty published volumes of *Chemical Abstracts.* Munroe regarded such labor not as hack-writing but as a discipline essential to the success of every specialist and he continued the practice as long as he was able to hold a pen.

An event of great importance that occurred during Munroe's residence in Annapolis was his marriage on June 20, 1883, to Mary Louise Barker, daughter of Professor George F. Barker. It was a chemical marriage in every respect. The groom and the bride's father were both chemists and the stone of the engagement ring was a white tourmaline which Munroe had cut from a beautiful crystal that he saw uncovered by a blast in a mineral deposit of Maine. The union was a most happy one and the bride having had experience from childhood with the ways of a chemist knew how to manage her own household accordingly.

Among the instructors whom Munroe met at the Naval Academy was A. A. Michelson, who taught the classes in physics. One of the chapters of Munroe's unfinished autobiography "The Life of a Professor" is devoted to a most interesting account of his life-long friendship with Michelson. One day at lunch Michelson suddenly asked "Munroe, why didn't Foucault move his mirrors farther apart?" This query marked the turning of Michelson's attention to his famous experiments upon the velocity of light, which begun at the Naval Academy were afterward amplified with such brilliant success by means of continually improved apparatus.

Another friend at the Naval Academy was Commander (afterward Admiral) W. T. Sampson. When Sampson went to Newport in 1886 to help organize the work of the Naval Torpedo Station and War College he persuaded Munroe to accompany him. An added inducement for making this change was the opportunity which it afforded Munroe of renewing associations with his former teacher Wolcott Gibbs who, since his retirement, had made Newport his home.

The six years spent by Munroe at the Newport Torpedo Station in chemical research on ex-

plosives were very productive. The development of a smokeless cannon powder was the chief object of his quest and the story is told in his Presidential Address "On the Development of Smokeless Powder" before the Washington Section of the American Chemical Society in February, 1896. He pointed out that the startling reports of the performance of a new smokeless powder in France was the incentive which caused the United States and other countries to undertake similar developments.

Munroe, who was ably assisted in his Newport experiments by George W. Patterson, reasoned that the most efficient powder would be the one of highest nitrogen content and greatest uniformity of composition. To attain this end he extracted the military guncotton, that was manufactured at the station for torpedoes, with methyl alcohol for the removal of lower nitration compounds, and then thoroughly mixed the extracted material, which had been dried, with mononitrobenzol. The plasticized mass was then forced through a die so as to form a perforated rod which was cut into pieces of suitable size; the solvent was then removed by boiling the product with water in closed vessels. The final powder when dried was exceedingly hard, and for this reason was given by Munroe the name of "Indurite" (U. S. Patent No. 489,684). His invention was a great step in developing smokeless powder manufacture in the United States and, although "indurite" was not adopted for service, the basic principle of Munroe's process was sound. The powder when properly made was remarkably stable and effective. President Harrison in his farewell message to Congress made the statement, "I consider one of the great achievements of my administration the invention of smokeless powder by Charles E. Munroe." The chief obstacle that prevented the general employment of "indurite" was inconstancy of composition due to the use of improperly nitrated guncotton and to difficulties in removing the residual solvent.

The investigations on smokeless powder led to the discovery of the remarkable Munroe effect. Munroe observed that if a block of guncotton with countersunk letters was detonated with its lettered surface against a steel plate, the letters would be indented into the surface of the metal. On the other hand, if the letters were raised above the surface of the block of explosive a detonation would reproduce the letters as before but this time in relief on the metal plate. In the same way the outlines of delicate leaves, laces, and even photographs were reproduced upon plates of the hardest steel. Striking examples of this effect can be seen in a very unique fire-screen which was presented by Munroe to the Cosmos Club of Washington. President Harrison was greatly impressed by a demonstration of this effect and referred to it in one of his state papers. The explanation of the Munroe phenomenon by which waves of hot compressed gases gather increased force through a hollow charge of explosive has led to much discussion. It is very well covered in an article by Marshall on "The Detonation of Hollow Charges."[2]

An event of great importance that occurred during this period was the first general meeting of the American Chemical Society at Newport on August 6-7, 1890. The story of this historic convention has been entertainingly told by Munroe in the Golden Jubilee number of the Journal of the American Chemical Society but modesty forbade him from stressing the underlying significance of his part in the movement which led to this meeting and to the reorganization of the then decadent American Chemical Society. Although not present at the organization meeting of the American Chemical Society in New York on April 6, 1876, Munroe, with 52 other non-residents of New York, had previously signified his desire to join the proposed organization and his name was thus enrolled as a charter member. He was one of a large group of chemists who, living beyond the confines of New York, hoped for the establishment of a Chemical Society that would be truly national. In this, however, they were disappointed.

The meetings, headquarters, elections and other activities of the Society as first organized were centralized in New York, with the result that the body was purely a local organization. The inevitable result was that almost as soon as formed the Society began to disintegrate. On January 4, 1877, F. W. Clarke submitted his resignation within two months after his election. Clarke's resignation was followed by those of George F. Barker, William McMurtrie, W. F. Hillebrand, Edgar F. Smith, H. W. Wiley and Ira Remsen. In other words, within five years after the Society's organization, seven of its

(2) Marshall, *J. Soc. Chem. Ind.*, **29**, 35-T (1920).

future presidents terminated their memberships. Edward Hart, S. P. Sadtler, W. D. Mason, E. W. Hilgard, R. C. Kedzie and many other prominent chemists also resigned. Conditions in the Society's affairs were later aggravated by the action of the secessionists in 1889 under the leadership of Clarke and Wiley in sending out an appeal for the organization of a rival National Chemical Society.

At this crisis, Munroe, who had remained loyal to the American Chemical Society, wrote a stirring letter (read at the meeting in New York on November 1, 1889), in which he pointed out the necessity, if the Society was to exist, of holding general meetings outside of New York and of establishing local sections. The effect of this letter was reflected in a very optimistic editorial in the first issue of the Journal for 1890 upon the reorganization of the Society. The Constitution was revised and provisions were made for including the suggestions proposed by Munroe. In view of the fact that he was the proponent of these reforms the duty of demonstrating their success was put squarely up to him. The Directors of the Society voted to hold the first general meeting of the Society in Munroe's home city of Newport on August 6 and 7, 1890, and appointed him the chairman of the local committee of arrangements. The general meeting which he arranged was a brilliant success, and thus was initiated the policy of the Society that has continued to the present day.

Only second to this service of organizing the first general meeting of the Society was Munroe's leadership in organizing its first local section which was established at Providence, R. I., on June 4, 1891. Munroe was thus accomplishing from within the Society the reforms that Clarke and Wiley were attempting to inaugurate from without. There is reason to believe that the three friends were working together with complete understanding and adroit strategy from opposite directions in their efforts to accomplish a common purpose. It was the whip of opposition wielded by Clarke and Wiley that forced the Directors of the Society to accept the reforms that Munroe had proposed. With the adoption of these reforms, the factional war came quickly to an end. The seceders rejoined the Society, and bringing with them a host of new members gave impetus to the phenomenal growth that has continued without interruption until the present time.

In 1892, Munroe terminated his connections at Newport to accept the Professorship of Chemistry at Columbian College (later George Washington University) in Washington, D. C. This was a pleasant change in many ways. Munroe was first and foremost a teacher and educational opportunities were greater in the Capital City than at Newport. There were also the additional advantages of contact with Government Departments and of frequent intercourse with his old friends, Clarke, Wiley and Chatard.

The new connection was not only most advantageous to Munroe but it was highly beneficial to the college. According to his former pupil and later associate on the George Washington Faculty, Dr. Nevil Monroe Hopkins, "the advent of Professor Munroe marked a new era for old Columbian College. It was greatly due to his reputation, hard work and energy that the conservative college became a flourishing and progressive university."

It is impossible to describe within the limits of this sketch the manifold activities of the forty-six years which Munroe spent in Washington. In addition to the general courses which he gave in chemistry at George Washington University, he was Dean of the Corcoran Scientific School of this institution from 1892 to 1898, and Dean of the School of Graduate Studies, which he established, from 1893 to 1917. As an introductory book in his classroom work, he employed, with perhaps a bit of pardonable favoritism, the revised edition of Barker's "Text-book of Elementary Chemistry, Theoretical and Inorganic," which was later superseded by Smith's Translations of Richter's Inorganic and Organic Chemistry. For instructions in analytical chemistry, he employed the works of Fresenius, and for organic preparations the book of Gattermann. Munroe was a magnetic lecturer, his delivery being spontaneous and enlivened with frequent anecdotes of personal experience. His manner toward students was firm, yet friendly and cordial. He taught his pupils to confirm their analyses and then to adhere with unwavering confidence to the truth of their results. To inculcate this principle he sometimes feigned surprise and doubt and, unless forewarned by the twinkle in his eye, the student must then be on his guard not to falter in his answers. He was a central figure at students' reunions, and on one memorable occasion exhibited a large map of the

United States on which he had marked the locations of the country's chemical resources. After explaining the various regions, he closed impressively with the words—"This, gentlemen, is your field. I present you with these opportunities."

Munroe had at the University his own private laboratory into which no one was permitted to enter. This policy was the result of his extensive work as an expert in trials and litigations. After one early experience in which his analytical operations were tampered with, he made it a rigid rule that reagents and samples were only to be handled by himself.

Another trait of Munroe was his intense patriotism. Immediately following the blowing up of the "Maine" in February, 1898, he telegraphed the offer of his services to the Government, and again in February, 1917, directly after diplomatic relations were broken off with Germany, he was equally prompt to place his expert knowledge and experience at the disposal of the President.

During the Spanish American War Munroe assisted the Chief of Ordnance in conducting firing trials at Sandy Hook. He was also consulting expert of the engineering board for the defense of Washington and, under the sponsorship of Brigadier General Allen, organized a volunteer torpedo corps for mining the Potomac River. He instructed properly qualified young men on Analostan Island in handling military explosives and in loading and firing mines and torpedoes. This instruction was supplemented with boat drills and exercises in signalling and tactics.

A development in which Munroe participated at the Naval Proving Ground shortly prior to 1898 was the perfection of an armor-piercing high explosive shell that would detonate within a battleship through the agency of a delayed action fuse. He was instrumental in proving for the first time that a loaded shell could be made to stand such a shock of impact and penetration and then to explode on the inner side of a 14.5-inch plate of Harveyized steel. This discovery might have been used to advantage in the Spanish War had the Government been more prompt in hastening its adoption, but recognition was delayed and it remained for the Japanese to demonstrate in actual engagements the feasibility of the armor-piercing high explosive shell.

One of the greatest of Munroe's accomplishments in Washington was the exhaustive report which he and Chatard prepared on the chemical industries of the United States for the 12th Census. This survey of Chemicals and Allied Products was published as a 162-page bulletin (No. 210) by the Census Office in 1902. The report is invaluable for its wealth of historical and statistical information. For many years Munroe presented copies of this work to his students as a reference work in their courses of industrial chemistry. He made extensive abstracts of thousands of chemical patents and in Bulletin 92 of the Census for 1905 pointed out the close relationship of patents to industrial growth. He made a similar survey of chemical industries for the Census of 1910. In connection with these statistical studies Munroe, long before the outbreak of the World War, foresaw the necessity of developing the fixation of atmospheric nitrogen as a basic chemical industry of the United States. The inevitable exhaustion of the Chilean nitrate deposits caused him to emphasize the importance of the nitrogen question from the military standpoint in a forceful article in the *Journal of the U. S. Naval Institute* for 1909.

Munroe retired in 1918 as Professor Emeritus from George Washington University which, in recognition of his services, had conferred upon him the honorary degrees of Ph.D. in 1894 and LL.D. in 1912. He continued, however, to maintain a close contact with the affairs of the University in the upbuilding of which he had played so conspicuous a part. His thoughts were constantly with it and to it he bequeathed his extensive library of chemical books and publications.

Some years previous to the World War Munroe formed a chemical consulting and engineering partnership with Clarence Hall and Nevil Monroe Hopkins under the name of Munroe, Hall and Hopkins. The firm rendered important services to the explosives, ammunition, railway, mining, traction, gas light and numerous other industries, both private and municipal, over a period of several years. Of Munroe's numerous consulting cases his investigations for the city of Baltimore on the cost of illuminating gas were among the most important. His two published reports "Natural Gas for Baltimore" (1909) and "Cost of Gas for Baltimore" (1911) are models of technical exposition. The investigation resulted

in a marked lowering of the cost of gas to consumers.

Munroe's abilities as a chemical expert were displayed most effectively in the court room. The testimony of his colleague, Dr. Nevil Monroe Hopkins, is worth quoting in this connection.

"I had the honor of being associated with Professor Munroe in many cases in which he served as expert in courts of law. He always commanded universal respect—from Judge and Jury as well as from opposing counsel—by virtue of his dignity, integrity and great wealth of knowledge. He could say as quick as a shot, with a penetrating voice, *'I beg your pardon'* and with withering effect to an improper question put to him by an incautious and indiscreet member of the bar. His clarity of exposition of technical points at issue in complex disputes was a consequence of his many years of teaching."

As a consultant and adviser on the manufacture, handling and use of explosives, Munroe's services were in constant demand both before and after his retirement from teaching. During the construction of the Panama Canal he made a trip to the Isthmus to investigate the explosives used in the blasting operations. In the investigation of appalling explosions, such as the Black Tom disaster, the Wall Street tragedy, the bombing of Attorney General Palmer's home, and other similar catastrophes, he was invariably the first expert sought. He was Chief Explosives Chemist of the Bureau of Mines from 1919 to 1933; chairman of the Advisory Committee of the American Railway Association which drafted regulations for the safe transportation of explosives; chairman of the Committee on Explosives of the American Society of Testing Materials; chairman of the Committee on Explosives' Investigations of the National Research Council from 1918 to 1928; and Consulting Specialist on Explosives for the U. S. Forest Service since 1934. He prepared numerous reports and articles on explosives and explosions, wrote the Introduction to the "History of the Explosives Industry in America" by van Gelder and Schlatter, and from the first issue of *Chemical Abstracts* in 1907 until his death served continuously as Associate Editor on Explosives. His name is writ large in the history of the American Explosives Industry. Although absolutely fearless in the handling and investigation of explosives for a period of sixty years, it is interesting to note that as a result of his extreme care he never suffered a serious accident.

Coincident with his main activities, Munroe in the course of his long industrious life performed various miscellaneous public services which are too numerous to mention in detail. He was a member of the U. S. Assay Commission for 1885, 1890 and 1893; superintendent of the denatured alcohol exhibits at the Jamestown Exposition of 1907 and a member of its jury on chemicals; and a consulting expert of the U. S. Geological Survey and also of the Civil Service Commission. His services were also sought in international affairs. He was a secretary on applied chemistry for the Second Pan American Congress, and was appointed by the Swedish Academy of Sciences in 1900 to nominate candidates for Nobel prizes in chemistry. He received several decorations from foreign governments, among which may be mentioned those of the Turkish Order of Medjidieh and the Order of Leopold from Belgium.

No less extensive were Munroe's activities in the numerous scientific societies of which he was a member. In 1888 he was chairman of Section C of the American Association for the Advancement of Science with the rank of Vice-President. He took an active part in the meetings of the Chemical Society of Washington, of which he was president in 1895. He was honored with the presidency of the American Chemical Society in 1898, in which capacity he delivered an address on "Explosions Caused by Commonly Occurring Substances." Munroe's services to the American Chemical Society, of which he was a life member, were of the highest order, and in more ways than those which have been described. When collaborators failed to do their part in writing the chapter on "Industrial Chemistry" for the Fiftieth Anniversary Number of the *Journal* in 1926, it was Munroe again who saved the day by voluntarily assuming this extra burden. Munroe was also a member of the American Academy of Arts and Sciences, the American Philosophical Society, and the Washington Academy of Sciences, and an Honorary Fellow of the American Institute of Chemists. Of the foreign societies to which he belonged may be mentioned the Society of Chemical Industry, the Chemical Society of London (of which he was a Fellow), the Deutsche Chemische Gesellschaft of Berlin and numerous International Congresses of Pure and Applied Chemistry.

Munroe was a copious writer and all of his compositions are distinguished for their clarity

and breadth of information. He was the author of nearly three hundred articles, reports, reviews, addresses, and other contributions, many of which are listed in the attached Bibliography by Munroe's former pupil and assistant J. N. Taylor. As a speaker he possessed unusual gifts of expression. He had a striking presence, with clean cut features and snow-white hair and mustache. His attractive bearing and well modulated sympathetic voice won the immediate attention and good will of his audiences. He was in great demand as a lecturer, his course at the Lowell Institute of Boston in the season of 1891–92 being among his numerous speaking engagements.

In his social relations, Munroe was immensely popular. Nothing delighted him so much as to be among his scientific friends at the Cosmos Club, of which he was president in 1913 and 1914. Like his old friends Clarke and Wiley, he had a jovial temperament, and those who were so fortunate as to join this famous trio in one of their festive meetings will always remember the spontaneous flow of wit and merriment. His dinner parties, such as the one given to the Turkish Minister at the Cosmos Club, were the talk of the day. Munroe was also a member of the Chevy Chase Club of Washington, the Boston City Club and the National Arts Club of New York.

In 1916, Munroe sold his residence in Washington and established a new home at Forest Glen, Maryland, where upon a small estate he could enjoy all the privileges of a country gentleman and at the same time commute easily to the Capital City for attending to his numerous professional engagements. Here he delighted to show friends his gardens and orchard and to present them with gifts of fruit which he picked from his trees. He was a charming host and visitors were always welcome. It was here on June 20, 1933, that Professor and Mrs. Munroe celebrated their golden wedding anniversary. It was a joyful occasion, when the handsome well preserved couple, surrounded by two fine sons, three lovely daughters and eleven grandchildren, received the congratulations of a host of friends.

Munroe had a rare gift for friendships and a friend once made he "grappled to his soul with hoops of steel." The passing of Wiley, Clarke, Chatard, Washington, and other old comrades made him feel at times somewhat lonesome and dejected. He loved to speak about these men and his reminiscences of their friendship were memorable talks. It is a pity that the infirmities of age prevented him from writing more tributes like the splendid ones which he paid to Clarke in the December *Journal* for 1935, and to Norton in the *News Edition* for the same year.

The life of Charles Edward Munroe was singularly happy and productive. He was the last brilliant example of the old school chemist who cultivated his science upon all its sides, who saw it steadily and saw it whole. To him may well be applied those words of Ariosto

"Nature made him and then broke the mould."

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