Walter H. Stockmayer

1914–2004

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Jeffrey Kovac
and Marshall Fixman

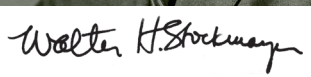
NATIONAL ACADEMY OF SCIENCES

WALTER HUGO **STOCKMAYER**

April 7, 1914–May 9, 2004

Elected to the NAS, 1956

Walter H. Stockmayer was a pioneer in applying the principles of physical chemistry to analyze the behavior of polymer systems. He combined theoretical insight, mathematical ability, and experimental skill to address important problems such as gelation, chain dimensions—including the excluded volume effect—both static and dynamic light scattering, and dielectric relaxation. Not only a first-rate scientist, he was a gifted teacher and thoughtful mentor to generations of scientists. In addition, Stockmayer was a fine pianist and an active mountaineer.



By Jeffrey Kovac and Marshall Fixman

Early life and education

Stockmayer, known to colleagues and friends as Stocky, was born in Rutherford, NJ, to parents of German ancestry. His father had earned a Ph.D. in organic chemistry at the Technical University of Stuttgart under the direction of Carl Magnus von Hell (known for the Hell-Volhard-Zelinsky halogenation reaction), went to work in the German dyestuff industry, and in 1909 came to the United States, where he worked as an industrial chemist, mainly on printing inks. Walter's mother, who attended Hunter College and taught school in New York City, met his father in a German choral society in New York called Liederkranz. Walter spoke only German until he entered kindergarten; he learned to read and write that language, including the Gothic script, so that he could correspond with his grandmother in Germany. Because there was much music in his home, he began to study piano at an early age and continued to play throughout his life.

Attracted to science, particularly chemistry, Stockmayer entered the Massachusetts Institute of Technology (MIT) in the fall of 1931 after graduating from Rutherford High School. Karl T. Compton had recently become the president of MIT, with a mandate to

improve the basic sciences. One of Compton's first hires was the young theorist, John C. Slater (NAS, 1932), who moved from Harvard University to become head of the Institute's physics department. The undergraduate curriculum at MIT was quite rigid at the time. Virtually all students, except architects, were required to take one year of chemistry, two years of physics, two years of calculus, and two years of English and history.

It was in freshman physics that Stockmayer encountered Nathaniel H. Frank, who he came to regard as the best teacher he ever had. Frank, a renowned theorist who also was committed to physics education, was an inspiration to his students in general and served as a role model for Stockmayer in his own teaching career. Frank authored several well-regarded textbooks, including (with J. C. Slater) *Introduction to Theoretical Physics*.

Another person at MIT who inspired Stockmayer was John G. (Jack) Kirkwood (NAS, 1942), who had earned his Ph.D. in 1929 after working with Frederick G. Keys (NAS, 1930). Kirkwood, who was a research associate at MIT collaborating with Slater while Stockmayer was an undergraduate, went on to become a leading figure in statistical mechanics until his death in 1959 at age 52.

As he related in his oral-history interview, Stockmayer initially felt overwhelmed at MIT—his high school had not been nearly so demanding—but he adapted quickly and became an excellent student, majoring in chemistry but also taking a lot of physics and mathematics courses. As a senior, Stockmayer was accorded the honor of becoming a teaching assistant in the qualitative analysis summer course required of all chemistry majors. Stockmayer made enough money that summer to buy his first car, a used Model A, and was able to take a course in advanced calculus as well. As a senior, he did a thesis with physicist Hans Mueller that involved measuring the Kerr effect—the change in refractive index in response to an applied electric field—in some liquids.

Throughout his undergraduate days at MIT, Stockmayer was involved in extracurricular activities—for example, he performed in musical groups and served as the sports editor of the school's daily newspaper. He was class president both as a junior and a senior, and as they neared graduation his classmates voted him most likely to succeed, most respected, and most popular.

Rhodes Scholarship

After graduating from MIT in 1935, Stockmayer spent two years at Oxford University as a Rhodes scholar. Enrolled in Oxford's Jesus College, where his research supervisor was David L. Chapman, Stockmayer did research on the poisoning of palladium catalysts by

carbon monoxide for his B.Sc. After Stockmayer obtained some good preliminary results, fellow student Max Burrows completed the project. Their joint findings were published in the November 27, 1940, issue of *Proceedings of the Royal Society* (176:474–483).

While at Oxford, Stockmayer attended lectures, including some by Erwin Schrödinger, and engaged in independent study. He carried out the latter mainly by reading and working the problems in the classic textbook *Thermodynamics and the Free Energy of Chemical Substances* by Gilbert Newton Lewis and Merle Randall and by reading the recently published *Introduction to Quantum Mechanics with Applications to Chemistry* by Linus Pauling and E. Bright Wilson. Another interest vying for his time at Oxford, however, was rowing. Recruited within a few days of his arrival by the captain of the college's boat club, Stockmayer soon became quite a good rower and competed in the races at Henley in both college and university boats.

Graduate study at MIT

After Oxford, Stockmayer returned to MIT for his Ph.D. His first choice for a research advisor was Isadore Amdur, who was doing some of the initial work on molecular beams, but in those days graduate students were given less choice. Stockmayer and another student, Henry G. Ingersoll, were told by George Scatchard (NAS, 1946) that they would work with James A. Beattie who needed students to help him study the compressibility of hydrocarbon gas mixtures. Stockmayer and Ingersoll measured the p, V, T behavior of mixtures of methane and normal butane, and they then fit the data to a modification of the Beattie-Bridgman equation of state to determine the best "mixing rules"—formulas that use the coefficients for pure fluids to calculate the empirical coefficients in the equation of state for multicomponent systems.

While obtaining the experimental data, Stockmayer was trying to learn statistical mechanics by reading the classic 1929 textbook of the same name.[1] Making good use of what he learned, Stockmayer wrote a single-author paper on the calculation of the second virial coefficient of polar gases. In that paper he introduced what is now known as the "Stockmayer potential" (essentially a Lennard-Jones potential supplemented by a point dipole), which remained in wide use for many years.

As Stockmayer recalled in his oral history, Beattie was occasionally angry with him because he was reading Fowler's book while performing experiments. The thermostat bath was hand-controlled, and Stockmayer would get so engrossed in the book that the

1 Fowler, R. H. 1980. *Statistical Mechanics: The theory of the properties of matter in equilibrium*, 2nd edition. New York: Cambridge University Press.

temperature would get as much as 25° too high. He would turn off the heat, go back to reading, and the temperature would drop to 20° or so below the value he wanted. So the results came more slowly than Beattie preferred. Eventually, enough data were collected, and Stockmayer received his Ph.D. in 1940. He stayed on at MIT for a year as an instructor and published additional papers, with Beattie, on the properties of gases and gas mixtures.

One of the other graduate students at MIT during this time was Bernard Vonnegut, who became Stockmayer's lifelong friend. Vonnegut grew into a renowned atmospheric scientist—he invented the technique of cloud seeding, for example—and spent much of his career at the State University of New York at Albany. Bernard was the elder brother of the novelist Kurt Vonnegut, which is certainly how Stockmayer found his way into the novel *Breakfast of Champions*. In Chapter 20 there is a diagram of a polyester molecule that plays a minor role in the plot. Kurt writes:

> *The man who told me how to diagram a segment of a molecule of plastic was Professor Walter H. Stockmayer of Dartmouth College. He is a distinguished physical chemist and an amusing and useful friend of mine. I did not make him up. I would like to be Professor Walter H. Stockmayer. He is a brilliant pianist. He skis like a dream.*[2]

Columbia University

In 1941 Stockmayer moved to Columbia University, which had advertised for an instructor to teach evening classes for extension students. He was interested in Columbia because Joseph E. Mayer (NAS, 1946)—perhaps the preeminent figure in statistical mechanics in the United States at that time—was a member of the chemistry department. Mayer and his wife Maria Goeppert Mayer (NAS, 1956) had just published their textbook, *Statistical Mechanics,* on the subject. Other prominent members of the department were Harold C. Urey (NAS, 1935), Louis P. Hammett (NAS, 1943), Victor K. LaMer (NAS, 1945), and George Kimball (NAS, 1954). Stockmayer learned from Mayer in part by attending the weekly Mayer/Kimball research meetings, where Mayer tried out his ideas on the multicomponent grand-ensemble and molecular-distribution functions. Among Mayer's graduate students at the time were Paul M. Doty (NAS, 1957), Bruno H. Zimm (NAS, 1958), and William G. McMillan.

Paul J. Flory's (NAS, 1953) famous papers on gelation of step-growth polymers appeared in the *Journal of the American Chemical Society* in November 1941, and Stockmayer was

2 Vonnegut, K. 2000. *Breakfast of champions*, London: Vintage. 228.

intrigued. Flory had treated the problem as one of molecular statistics and predicted a kind of phase transition, but Stockmayer thought that gelation could be approached using more conventional statistical mechanics, which is what he set out to do.

As he developed the theory, he had help from Maria Mayer in understanding the complicated combinatorics. He also wrote to Flory, who invited him to visit at the Esso Laboratory in Linden, NJ. They had a productive conversation, and Flory encouraged Stockmayer to write up his results, which he did in two articles published in the *Journal of Chemical Physics* in 1943 and 1944.[3] All this research was done on the side, because the first priority after teaching was war work. For Stockmayer, this involved studying the deuterium exchange reaction together with Harold C. Urey and Kimball; at that time heavy water was still considered important for the Manhattan Project. Nevertheless, Stockmayer and Flory became lifelong friends, despite some later scientific disagreements. Stockmayer also had contact with Herman Mark (NAS, 1961) and the polymer group at Brooklyn Polytechnic Institute, initially at a symposium organized by the New York Academy of Sciences in 1942 and in occasional visits to Brooklyn. After finishing their degrees, both Zimm and Doty moved to Brooklyn Polytechnic to do postdoctoral research in polymers.

A bit of good fortune helped move Stockmayer farther down the polymer path. When Lester Weil, a Columbia graduate student in organic chemistry, lost his research advisor to a war job, he needed a new advisor and a new project. The liberal policies of the department allowed Stockmayer, just an instructor at the time, to become Weil's advisor, and Stockmayer sent him off to work on an experimental study of the effects of dilution on the gel point. Although those experiments were never conclusive, Weil did earn his Ph.D. in 1945 and worked for many years in the American space program. A second graduate student, Homer Jacobson, was assigned to Stockmayer around the same time, and he began work on theoretical and experimental studies of ring-chain equilibrium in linear condensation polymerization. Jacobson stayed at Columbia and finished his doctoral work with Beckmann when Stockmayer returned to MIT in 1943.

Back to MIT

In fall 1943, Stockmayer returned to MIT as an assistant professor of chemistry. It being wartime, most of his work involved teaching young members of the Navy and

3 Stockmayer, W. H. 1943. Theory of molecular size distribution and gel formation in branched-chain polymers *J. Chem. Phys*. 11:45–55.

Stockmayer, W. H. 1944. Theory of molecular size distribution and gel formation in branched polymers. II. General cross-linking. *J. Chem. Phys.* 12:125–131.

doing war-related research. He remained at MIT until 1961, during which time he was promoted to associate professor (in 1946) and professor (1952). As Stockmayer's accomplishments began to gain recognition, he was elected fellow of the American Academy of Arts and Sciences (in 1946) and member of the National Academy of Sciences (1956).

At MIT Stockmayer was primarily, but not entirely, engaged in research on the physical chemistry of polymers. He also became interested in light scattering, both theoretical and experimental. One of his significant contributions to the field was a four-page analysis that developed and applied a special "semi-grand" ensemble—part canonical and part grand canonical—to light scattering from polymer solutions. One of his first MIT graduate students, Harry E. Stanley, built a light-scattering instrument that was used by the Stockmayer group for many years—for example, in investigating the interactions between unlike polymers.

Stockmayer also studied polymer-chain dimensions. His contributions included an article with Zimm on branched and ring polymers and one with Zimm and Marshall Fixman (NAS, 1973) on excluded volume. When Fixman had come to MIT as a graduate student from Washington University in 1950, he joined the Stockmayer research group, thereby beginning a lifelong scientific collaboration and friendship with his mentor. Stockmayer himself regarded Fixman as his best graduate student ever, a judgment borne out by Fixman's subsequent career.

Fixman tells the story of his first meeting with Stockmayer in late 1950 or early 1951. Fixman was making the rounds of the research groups in the physical chemistry division in order to choose one to join. He was standing outside one of Stockmayer's labs talking with one of his graduate students. The long halls of Building 6 at MIT were crowded with students between classes. Far in the distance a group was moving as one, surrounding a taller figure who seemed to be their leader. "Who is that," Fixman asked with some contempt, "the student body president?" In fact, it was Stockmayer. It was only after Stockmayer's death that Fixman learned that he had actually been his class president. It would have been an easy mistake to make. Stockmayer was one of those people who looked much younger than his age.

Fixman and Stockmayer at Stockmayer's home in Norwich, VT.

Stockmayer was known as an innovative and inspiring teacher, a status that was recognized time and time again. For example, in 1960 he received the College Chemistry Teacher Award from the Manufacturing Chemists' Association. A good example of his pedagogical creativity dates from his early days at MIT, when, the first time he taught statistical mechanics, only two students took the course. One of them, Harold S. Mickley, came to class one day and said that he had been talking with a faculty member about the heat capacity of SO_3, which apparently had not been measured. And because Stockmayer had discussed in class the calculation of thermodynamic properties from spectra, Mickley wondered if they could actually make the calculation for SO_3. Stockmayer then turned the course into a research project. He and the two students spent the rest of the term working on the problem together, and they obtained reasonable results, which were then published in the *Journal of Chemical Physics* in 1944.[4]

During the 1954–55 academic year, Stockmayer was a Guggenheim Fellow at the newly-established Institut Charles Sadron in Strasbourg, France. That region of the country, Alsace, appealed to Stockmayer both for scientific and cultural reasons. He was able to connect with his German roots, visit some of his relatives, and, because he spoke German and French, communicate easily in that bilingual region. He even published an article in French with Henri Benoit, a Strasbourg-based statistical mechanic interested in light scattering, whom he had met when Benoit spent a year at Harvard with Doty. Because international travel for American scientists was uncommon in those days, the year in Strasbourg gave Stockmayer a rare chance to meet many other European scientists as well—including Hermann Staudinger, one of the creators of the macromolecular hypothesis.

For a glimpse of Stockmayer's delightful sense of humor, consider an article that he coauthored with John S. Waugh (NAS, 1974) on self-diffusion and impurity-controlled proton relaxation in liquid ethane. To account for the dependence of the self-diffusion coefficient on the density of the liquid, the two researchers used the Doolittle equation, which involves the free volume, which in turn can be related to the difference between the hypothetical density of the liquid at 0K (ρ_o) and the density at the temperature of the measurement. In their paper, Stockmayer and Waugh noted that the fit of the data gave a value for ρ_o that was "at deep shortstop in comparison with independent estimates made in various other ways."[5] To document the phrase "at deep shortstop," which referred to

4 Stockmayer, W. H., G. M. Kavanagh, and H. S. Mickley. 1944. The thermodynamic properties of gaseous sulfur trioxide. *J. Chem. Phys.* 12:408–412.

5 Gaven, J. V., W. H. Stockmayer, and J. S. Waugh. 1963. Self-diffusion and impurity-controlled proton relaxation in liquid ethane. *J. Chem. Phys*. 38:227–235.

the overestimate of the value, 0.85, as compared to other estimates between 0.72 and 0.75, they cited a paper by one H. Wagner in the *Journal of Chemical Education*. This was to suggest the Hall of Fame shortstop Honus Wagner, the "flying Dutchman" who played for the Pittsburgh Pirates decades earlier and who many baseball historians considered the greatest shortstop ever. Stockmayer later explained that because he wanted to be current, he spent a long time trying to find an article with an author named P. Rizzuto—so as to be able to suggest Phil Rizzuto, the star shortstop at that time with the New York Yankees—but, alas, the search was unsuccessful.

Near the end of Stockmayer's time at MIT, a bit of good fortune brought Peter Verdier into his group as a post-doc. Verdier had just finished his Ph.D. at Harvard (he had worked with E. Bright Wilson on microwave spectroscopy) and his wife was interested in completing a master's degree with F. Albert Cotton (NAS, 1967) at MIT. So Verdier needed a job nearby. At Stockmayer's suggestion Verdier developed the first dynamic Monte Carlo simulation of polymers using a simple cubic lattice model. Stockmayer himself had essentially no programming ability, but was able to figure out how to relate the computer time, in cycles, to a physical time trough the translational diffusion coefficient. Verdier's simple model opened the door to what to what has become an enormous field of study.

By the late 1950s Stockmayer had become rather dissatisfied with his situation at MIT. He had some complaints about the way the department was being administered, but as he stated in his oral-history interview, more significant was his feeling that his research program was going stale, and the problems he was proposing to graduate students seemed unexciting either to them or to him. Stockmayer knew that he was a good teacher, however, so when a teaching-centered offer came from Dartmouth College, he accepted. It didn't matter to him that Dartmouth had no doctoral program in chemistry at the time because it did have good undergraduate students—and was much closer to the White Mountains, where he loved to hike.

Dartmouth

Stockmayer arrived at Dartmouth in March 1961 and spent the rest of his career there, serving twice as department chair (1963–67 and 1973–76). He officially retired in 1979, at what was then the mandatory retirement age of 65, but continued to teach and advise students part-time until 2002.

Shortly after Stockmayer had come to Dartmouth, he and Japanese postdoc Michio Kurata, who had moved with him from MIT, produced a gigantic 125-page review

Stockmayer in the teaching lab at Dartmouth.

article on viscosities and unperturbed dimensions of polymers for *Advances in Polymer Science*. After the review was published, Stockmayer discovered that they had made a serious error in calculating the dimensions of polyoxymethylene, and he hastened to publish a correction. But in another example of Stockmayer's sense of humor, rather than issuing it in his own name, he invented the pseudonym, Waldemar Silberszyc. Thus the three-page correction paper submitted to *Polymer Letters* was authored by Silberszyc, who expressly thanked Walter H. Stockmayer for a "useful soliloquy." And his mailing address was Stockmayer's post office box in Norwich, VT.[6] Waldemar Silberszyc was not finished, moreover, as a Stockmayer alter ego, and reappeared from time to time. For a few months in 1976, he was listed as a member of the editorial board of *Macromolecules*, and he was acknowledged in a 1981 publication by some Dartmouth colleagues. There are stories of letters from Silberszyc to various chemists, and he may even have been nominated to become department chair at Washington University in St. Louis. His affiliation eventually was revealed as the Northeast Poultry Analysis Institute in Norwich.

Stockmayer had little patience with pomposity and occasionally used practical jokes to prick the inflated egos of some of his colleagues. These jokes sometimes got him into trouble. For example, during his years at MIT there was an assistant professor in his department who had an extremely high opinion of himself and his work, which he would liberally broadcast. Stockmayer composed a fake letter, on the stationery of the *Journal of the American Chemical Society,* that extolled the virtues of this faculty member and invited him to be the next editor of the journal. Upon receiving the letter, the young professor showed it to the department head, who quickly realized who had actually written it. There were repercussions for Stockmayer, but he had made his point.

Dartmouth did not have a graduate program in chemistry until 1965, but Stockmayer attracted a series of excellent postdocs nevertheless. The first was John E. Hearst, who was

6 Silberszyc, W., and W. H. Stockmayer. 1963. Unperturbed dimensions of polyoxymethylene. *Polymer Letters* 1:577–579.

interested in biophysical chemistry and worked on the sedimentation of stiff polymers; he went on to a distinguished career at UC, Berkeley. The second Dartmouth postdoc was Hyuk Yu, who developed a theory of the dynamics of a once-broken rod and subsequently enjoyed a long career at the University of Wisconsin, Madison. Yu was primarily an experimentalist, but became a temporary theorist after he broke his leg skiing.

After coming to Dartmouth, Stockmayer himself moved into a new area of research—the study of the dielectric relaxation of polymers—that engaged him in a superb interplay between theory and experiment. Stockmayer and his colleagues showed that while the component of the dipole parallel to the chain backbone relaxes through the global chain motions, the perpendicular component relaxes through a local high-frequency mechanism. But when the chains are short enough, the global motions and local mechanisms compete. Stockmayer also did some work on chain dynamics, using nuclear magnetic resonance, with postdoc Alan Anthony Jones.

In 1968, Stockmayer took on a different responsibility when he became an associate editor of *Macromolecules,* a newly created journal of the American Chemical Society (ACS). Because there was some dissatisfaction in the polymer-science community with the existing journals devoted to the subject, Stockmayer and numerous others felt the need for a high-quality journal that would publish articles on polymers in a timely manner and be affordable to individual subscribers. Stockmayer was part of the original editorial team, and he continued to serve *Macromolecules*—with a three-year break from the journal (during the 1970s) when he was department chair—until 1994. As an editor, he was known for his scientific insight, fairness, and arch sense of humor.

In fall 1972, Stockmayer spent a sabbatical at the Dutch State Mines in Geleen, Holland, where he worked with Ronald Koningsveld on polymer thermodynamics. Together they wrote a book titled *Polymer Phase Diagrams*, which was published by Oxford University Press in 2001 with Eric Nies as the third coauthor. Nies was much appreciated, as Stockmayer readily admitted he was "no great whizbang" in getting things published and Koningsveld, a perfectionist, was even slower.

Because Koningsveld was an accomplished pianist and composer, Stockmayer suggested that he write some music—for two pianos, based specifically on polymer themes—that they could play together. The result was *Polymer Music: Suite for Two Pianos in Six (Short) Movements,* which was dedicated to Stockmayer. The six movements were titled (1) Random Coils and Crosslinks, (2) Polypentenamer and Phantom Networks, (3) Holes in Polymer Liquids and Theories, (4) Fluctuations, (5) Folding Chains, and (6) Helical Duet.

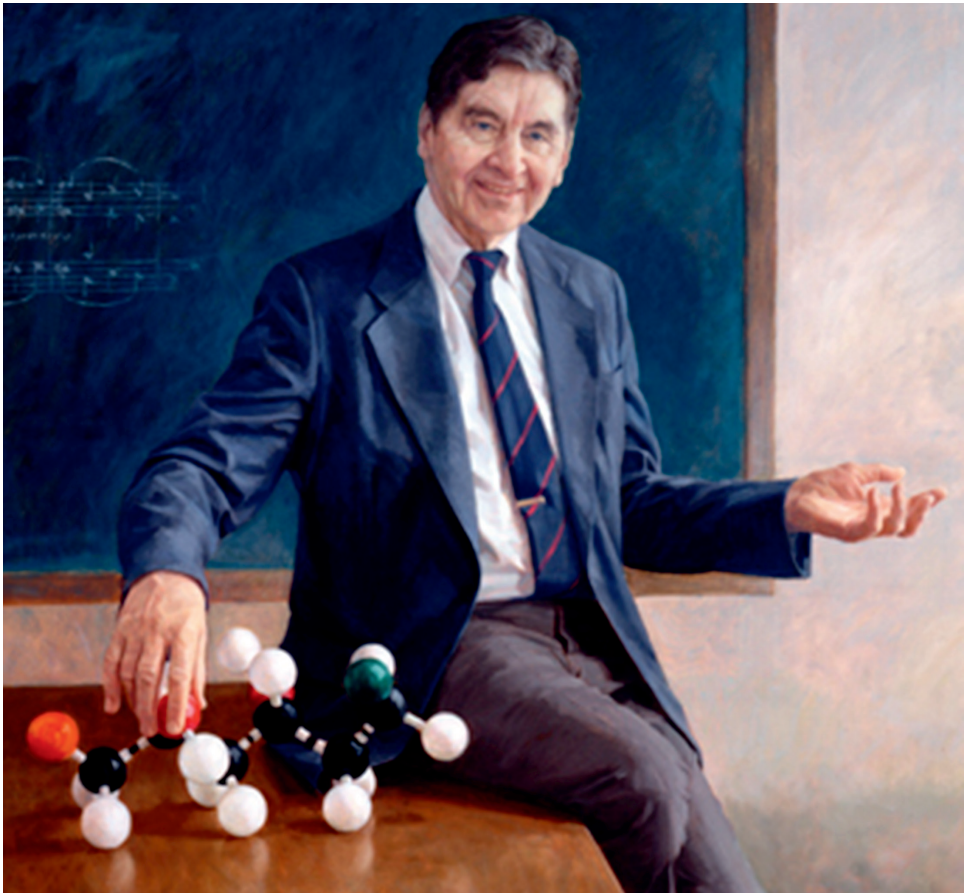
Stockmayer took his final sabbatical leave during the 1978–79 academic year, his last year as an active member of the Dartmouth faculty. He spent that period in Freiburg, on the edge of the Black Forest. There he collaborated with Walther Burchard and his student Manfred Schmidt on dynamic light scattering, an area that Stockmayer continued to pursue after returning from Germany. Burchard was quite ill during that year and spent considerable time in the hospital so Stockmayer took his lectures in polymer physical chemistry in German. He was helped out by the students who provided the words that he didn't know.

In July 1984, Fixman and Yu organized a Stockmayer 70th Birthday Symposium in cooperation with the Dartmouth Chemistry Department. Although Stockmayer's birthday had been in April, the symposium was held the weekend after the Gordon Conference on Polymer Physics, thereby attracting a greater number of participants. The Dartmouth meeting featured talks by Stockmayer's scientific children, grandchildren, and collaborators, along with social events. To honor his love of limericks, several colleagues composed verses for the occasion. For example, his former student and colleague, Robert Cleland, wrote:

I know a statistical mechanic
For whom polymer chains writhe in panic.
He's the cream of the cream,
And he skis like a dream,
His piano sometimes sings in Chopin-ic.

Consulting

During his early years at MIT, Stockmayer began a consulting relationship with the central research division of E. I. Dupont de Nemours and Company that lasted more than 50 years. DuPont had been interested in hiring him full-time, but he felt he did not have the temperament to be an industrial chemist; so he suggested that they employ him as a consultant, and they agreed. Stockmayer often said that he learned more from consulting with DuPont than he ever gave them. Beginning in 1950 he consulted for a few years for the American Chicle Company, which made chewing gum. The company was having trouble getting an acceptable low-molecular-weight polyvinylacetate from suppliers, so they decided to manufacture it themselves and hired Stockmayer to help get the plant running. He also consulted for Humble Oil Company and the U.S. Army Picatinny Arsenal.



An oil portrait of Stockmayer, painted by Sarah Belchetz-Swenson, that now hangs in Dartmouth's chemistry building.

Awards

In addition to the awards already mentioned, Stockmayer received the Stas Medal from the Société Chimique de Belgique (1955), the ACS Award in Polymer Chemistry (1966), the Peter Debye Award in Physical Chemistry of the ACS (1974), the High-Polymer Physics Award of the American Physical Society (1975), the Humboldt Senior Scientist Award of the Alexander Humboldt Foundation (1978), a Service Award from the Division of Polymer Chemistry of the ACS (1987), the Theodore Williams Richards

Medal of the Northeastern Section of the ACS (1988), the Polymer Chemistry Division Award of the ACS (1988), the Society of Plastics Engineers International Award (1991), the William Proctor Prize of Sigma Xi (1993), and the Hermann Staudinger Prize of the German Chemical Society (2001)—the only non-German ever to be so honored. In 1987, President Ronald Reagan presented Stockmayer with the National Medal of Science. Stockmayer was awarded honorary doctorates by the Université Louis-Pasteur (1972), Dartmouth College (1983), and the University of Massachusetts, Amherst (1996). He was named an honorary member of the Society of Polymer Science of Japan (1991) and an honorary fellow of Jesus College, Oxford University (1976). Stockmayer also delivered numerous named lectures around the world.

Family and personal life

Stockmayer married Sylvia Kleist Bergen in 1938, a marriage that lasted until her death in 2002. Sylvia had been working as a fashion model for Jordan Marsh, a Boston department store, and came to know some MIT people—including a colleague of Stockmayer's in the MIT chemistry department, who introduced Sylvia and Walter. Concerning his attraction to Sylvia, Walter said, "How could you resist a beautiful woman who could get into and out of her clothes that fast?" They had two sons, Ralph, (born in 1943) and Hugh (1945), eight grandchildren, and, at the time of Walter's death, one great-grandchild. Sylvia had been quite involved in public affairs and environmental issues, including service as state president of the League of Women Voters of Vermont. In several of the locales where they had lived, the Stockmayers belonged to Unitarian Universalist congregations, most recently in Norwich, VT.

Sylvia and Walter Stockmayer.

Outside science, Stockmayer's principal interests were music and hiking. He played the piano his entire life and performed with various amateur ensembles at and around Dartmouth. He was particularly fond of music from the romantic period, notably Brahms. He would also sometimes perform at professional meetings. At the Michigan Molecular Institute's International Symposium on Polymer Melt Dynamics in 1987, the entertainment for the evening banquet was a duet with Stockmayer on piano and Zimm on clarinet. Zimm began the program by saying that they might be a bit rusty because they had not played together since about 1948! Stockmayer also loved operas, particularly those of Richard Wagner, and he tried to attend opera performances when he traveled.

Stockmayer at a White Mountains shelter.

And Stockmayer loved the White Mountains of New Hampshire. After passing the age of 70, he finished climbing all of the chain's 4,000-foot peaks for at least the second time. Those who climbed with him can attest to enthusiasm for the outdoors and his generous spirit; one small indicator was that he usually packed a flask of Old Grand Dad to share at the summit of a peak. Stockmayer was a lifelong member of the Appalachian Mountain Club and for many years served on the committee that compiled the *AMC White Mountain Guide*; he was responsible for writing and updating the Mt. Carrigan section of the book. After his death, his family scattered his ashes on the summit of Mt. Carrigan. Stockmayer had been assiduous about maintaining the trail system's huts and shelters; in response to one request to maintain and improve a particular remote shelter, he installed an electrical outlet and posted a warning not to exceed the power rating of a mythical turbine in a nearby stream—another example of his wry sense of humor.

Stockmayer died at his home in Norwich, VT, on May 9, 2004.

Reflections

Walter H. Stockmayer was one of a small number of scientists who pioneered the use of physical chemistry to explore the properties of macromolecules. He was able to combine theory and experiment in creative ways to solve complex and important problems. He will be particularly remembered for his seminal contributions to gelation theory, his work in elucidating the effects of molecular weight on polymer solubility, and his contributions to the theory of light scattering in multicomponent systems. But his published work was only the tip of the iceberg. Stockmayer was a mentor and inspiration to generations of younger scientists, including the authors of this memoir. Many of his graduate students and postdocs went on to outstanding careers in academia and industry. Uncountable are the times he provided a crucial insight to a student or colleague and then politely declined to become a coauthor. Beyond his contributions as a mentor and colleague, Stockmayer was always a caring friend. When you talked to him, he always asked about your nonscientific life and remembered details about your family and other personal interests. For Stockmayer you were a human being first, a scientist second.

While much honored for his accomplishments, Stockmayer was remarkably humble. Fixman remembered a conversation during a hike when Stockmayer, thinking of some award that he, or perhaps Fixman, had won, asked, "How long are we going to be able to keep up this swindle?" More routinely, for a number of years when members of the Dartmouth chemistry faculty met to eat bag lunches together, Stockmayer could be counted on to make the conversations fun and information-packed, given his amazing memory and deep fund of knowledge about a great many things besides chemistry and physics. So there would be times when he would have something to add to the conversation that was really arcane, something that other members of the department would either have forgotten or never heard of. On such occasions, he would preface his remarks with, "As you remember," to imply that they knew as much as he did.

Stockmayer treated everyone from undergraduates to senior faculty with respect and was always generous with his time and wisdom. For example, when one of the authors of this memoir (JK) was a beginning assistant professor who had been assigned to teach a graduate course in the physical chemistry of polymers, Stockmayer sent him a set of lecture notes from the course he had given in Boulder some years before, along with other helpful advice. Stockmayer was a great scientist, a gifted teacher, and a remarkable human being. He enriched the lives of all he touched.

SOURCES AND REFERENCES

Stockmayer was interviewed by Jeffrey L. Sturchio and Peter J. T. Morris in August 1986 and January 1992 as part of the Oral History Program of the Chemical Heritage Foundation; the transcript (nearly 100 pages) is available from the foundation, and the authors made good use of it. The joint article by Stockmayer and Bruno H. Zimm, "When Polymer Science Looked Easy," published in 1984 by the *Annual Reviews of Physical Chemistry* (35:1–21) was another valuable source, as were Stockmayer's papers, which are archived in the Dartmouth College Library. Additional sources included "Walter Hugo Stockmayer 70" by R. Koningsveld and M. Fixman, published in 1984 by *Macromolecules* (17:507–508) and "Walter Hugo Stockmayer" by M. Fixman, H. Yu, and J. E. G. Lipson, published in 2004 by *Physics Today* (57[12]:84).

At the time of his death in February 2016, Fixman was writing what was to become this biographical memoir. Jeffrey Kovac was asked to complete the project and has benefited from the extensive files and notes that Fixman had accumulated, which were provided by his son Andy. The stories attributed to Fixman come from these notes. Although this cannot be the memoir that Fixman would have written, it is appropriate that he be included as a co-author.

This memoir was enhanced by the recollections of several of Stockmayer's colleagues, students, and postdocs, including Roger H. Soderberg, David M. Lemal, Marc Mansfield, Robert Cook, and Gerald Wilemski. The source of the candid photographs was Fixman, the formal portrait was provided by the Dartmouth College Library, and the photo of the painting was provided by the artist, Sarah Bechetz-Swenson.

NOTES:

1. Kurt Vonnegut. 2000. *Breakfast of Champions.* London: Vintage. 228.
2. W. H. Stockmayer, G. M. Kavanagh and H. S. Mickley. 1944. The Thermodynamic Properties of Gaseous Sulfur Trioxide. *J. Chem. Phys.* 12:408-412.
3. J. V. Gaven, W. H. Stockmayer and J. S. Waugh. 1963. Self-Diffusion and Impurity-Controlled Proton Relaxation in Liquid Ethane. *J. Chem. Phys.* 38:227-235.
4. W. Silberszyc and W. H. Stockmayer. 1963. Unperturbed Dimensions of Polyoxymethylene. *Polymer Letters.* 1:577-579.

SELECTED BIBLIOGRAPHY

1941 Second virial coefficients of polar gases. *J. Chem. Phys.* 9:398–402.

1943 Theory of molecular size distributions and gel formation in branched chain polymers. *J. Chem. Phys.* 11:45–55.

1945 Distributions of chain lengths and compositions in copolymers. *J. Chem. Phys.* 13:199–207.

1949 With B. H. Zimm. The dimensions of chain molecules containing branches and rings. *J. Chem. Phys*. 17:1301–1314.

1950 Light scattering in multi-component systems. *J. Chem. Phys.* 18:58–61.

With H. Jacobson. Intramolecular reactions in polycondensations. I. The theory of linear systems. *J. Chem. Phys.* 18:1600–1605.

1953 With B. H. Zimm and M. Fixman. Excluded volume in polymer chains. *J. Chem. Phys.* 21:1716–1723.

1955 With L. D. Moore, M. Fixman, and B. N. Epstein. Copolymers in dilute solution. I. Preliminary results for styrene-methyl metharcrylate. *J. Poly. Sci.* 16:517–530.

1962 With P. H. Verdier. Monte Carlo calculations on the dynamics of polymers in dilute solution. *J. Chem. Phys.* 36:227–235.

1963 With M. Kurata. Intrinsic viscosities and unperturbed dimensions of long-chain molecules. *Advances in Polymer Science* 3:197–312.

1964 With M. E. Baur. Low-frequency electrical response of flexible-chain molecules. *J. Am. Chem. Soc.* 86:3485–3489.

1971 With K. Solc. Kinetics of diffusion-controlled reactions between chemically asymmetric molecules. *J. Chem. Phys*. 54:2981–2988.

1972 With W. Gobush, H. Yamakawa, and W. S. Magee. Statistical mechanics of wormlike chains. I. Asymptotic behavior. *J. Chem. Phys.* 57:2839–2843.

1973 With S. F. Edwards. The equation of state of materials intermediate to rubbers and glasses. *Proc. Roy. Soc.* (London) A 332:439–442.

1974 With R. Konningsveld, J. W. Kennedy, and L. A. Kleintjens. Liquid-liquid phase separation in multicomponent polymer systems. XI. Dilute and concentrated polymer solutions in equilibrium. *Macromolecules* 7:73–79.

1976 With A. A. Jones and R. J. Molinari. Low-frequency dielectric response of poly (ε-caprolactone) in dilute solution. *J. Poly. Sci.: Polymer Symposia* 54:227–235.

1979 With W. Burchard. Quasi-elastic light scattering by rigid macromolecules. *J. Chem. Phys.* 70:3138–3139.

1980 With J. A. Guest, K. Matsuo, and U. W. Suter. Chain dimensions and dipole moments of poly(tert-butyl vinyl ketone). *Macromolecules* 13:560–564.

With W. Burchard and M. Schmidt. Influence of hydrodynamic pre-averaging on quasi-elastic scattering from flexible linear and star-branched macromolecules. *Macromolecules* 13:580–587.

1983 With K. Matsuo. Conformational properties of perfluoroalkane chains. VII. Carbon-13, fluorine, and proton spin-lattice relaxation of poly(decamethylene perfluorosebacate) in solution and the local mobility of the fluorocarbon chain. *J. Phys. Chem.* 87:2911–2914.

1986 With S. Mashimo, P. Winsor IV, R. H. Cole, and K. Matsuo. Conformation and dynamics of poly(olefin sulfones) in solution. I. High-frequency dielectric relaxation and carbon-13 NMR relaxation. *Macromolecules* 19:682–686.

With A. Z. Akcasu, B. Hammouda, and G. Tanaka. First cumulant for chains with constraints. *J. Chem. Phys.* 85:4734–4743.

With G. V. Schulz. Revival and modification of an ancient osmotic pressure equation. *Makromol. Chem.* 187:2235–2239.

1990 With R. Koningsveld and E. Nies. Phase behavior of ordered polymer solutions. *Macromol. Chem., Macromol. Symp.* 39:1–18.

1991 Thermoreversible gelation via multichain junctions. *Macromolecules* 24:6367–6368.

1994 With G. Tanaka. Thermoreversible gelation with junctions of variable multiplicity. *Macromolecules* 27:3943–3954.

1997 With J.-F. Joanny and H. Benoit. Does compressibility affect the results obtained by small-angle neutron scattering? *Macromol. Symp.* 121:95–96.

2001 With R. Koningsveld and E. Nies. *Polymer Phase Diagrams.* New York: Oxford University Press.