

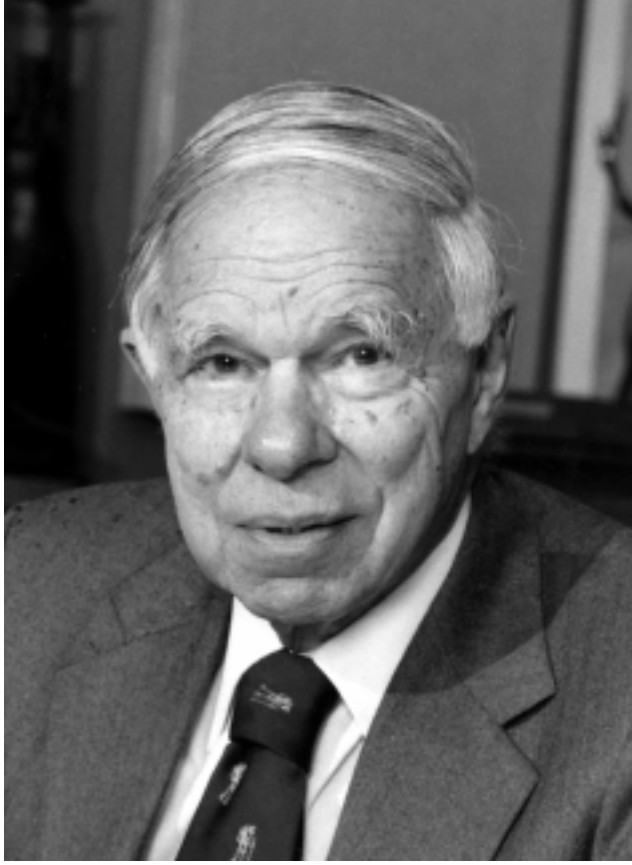
NATIONAL ACADEMY OF SCIENCES

GLENN THEODORE SEABORG
1912-1999

A Biographical Memoir by
DARLEANE C. HOFFMAN

Biographical Memoirs, VOLUME 78

PUBLISHED 2000 BY
THE NATIONAL ACADEMY PRESS
WASHINGTON, D.C.



Courtesy of the University of California Lawrence Berkeley Laboratory

GLENN THEODORE SEABORG

April 19, 1912–February 25, 1999

BY DARLEANE C. HOFFMAN

GLENN T. SEABORG WAS a world-renowned nuclear chemist, educator, scientific advisor to 10 U.S. presidents, humanitarian, and Nobel laureate in chemistry. He is probably best known for his leadership of the team that in 1941 accomplished the first chemical separation and positive identification of plutonium and his “revolutionary” actinide concept (1944) in which he placed the first 14 elements heavier than actinium in the periodic table of elements as a *5f* transition series under the lanthanide *4f* transition series. He went on to be codiscoverer of 9 elements beyond plutonium, culminating in 1974 in the production of element 106, later named seaborgium in his honor.

Seaborg was also well known as an educator and for his tireless efforts to improve U.S. science education at all levels. He served as chancellor of the University of California at Berkeley from 1958 until 1961 when he was called by President-elect John F. Kennedy to chair the U.S. Atomic Energy Commission, a position he held until 1971. Seaborg led the negotiations resulting in the limited nuclear test ban treaty prohibiting the testing of nuclear devices in the atmosphere or under the sea, approved by the U.S. Senate in 1963. He strongly supported the use of nuclear energy as

a source of electricity, and led delegations to some 63 countries, including the Soviet Union to promote the peaceful uses of atomic energy.

1912-1942: EARLY LIFE, EDUCATION, AND MARRIAGE

Glen Theodore Seaborg was born of Swedish ancestry in Ishpeming, Michigan, a small iron-mining town on the Upper Peninsula of Michigan. His father, Herman Theodore Seaborg, whose parents had come from Sweden to Ishpeming in their youth and met and married there in 1872, was born in 1880 in Ishpeming. His mother, Selma Olivia Eriksson (changed to Erickson), was born in Grängesberg in the southern Dalarna region of Sweden, and came to Ishpeming in 1904, when she was seventeen years old. Glen's parents met at a picnic on Swedish Midsummer's Day (June 24, 1908) and were married three years later on Swedish Midsummer's Day (June 24, 1911). Glen was born in Ishpeming on April 19, 1912; his only sibling, Jeanette, was born two years later.

Ishpeming had typical sections that were nearly all Swedish and it was in one of these that the Seaborgs lived. Since Glen's father was fluent in Swedish and it was his mother's native tongue, the Swedish language was spoken in the home, and he learned to speak and understand Swedish before English. He started kindergarten in the High Street School in Ishpeming in September 1917 and continued there through the first three grades. Glenn was nicknamed "Lanky" because he was so much taller than his classmates.

When he was ten years old, the family moved to Home Gardens, now a part of South Gate, near Los Angeles, California. (At this time he changed the spelling of his name from "Glen" to "Glenn.") This move to California was made primarily because his mother wanted to broaden her children's horizons beyond the limited opportunities avail-

able in Ishpeming. But Glenn Seaborg never forgot his roots in Ishpeming and was always very proud of his Swedish ancestry. Unlike in Ishpeming, where his father would have been guaranteed employment for life as a machinist in the iron works, in California his father never found permanent employment in his trade, and the family finances were in rather poor condition. Glenn early on earned his own spending money by taking paper routes, mowing lawns, and performing other odd jobs.

Glenn attended high school in the Los Angeles suburb of Watts and developed a special interest in chemistry and physics, which he attributed to his inspiring high school chemistry and physics teacher, Dwight Logan Reid. Seaborg graduated as valedictorian of his class in 1929. He first obtained work in a warehouse as a stevedore and then found summer employment as a night laboratory assistant in the Firestone Tire and Rubber Company to earn money for his freshman year at the University of California, Los Angeles (UCLA). This made it just barely possible for him to enter UCLA in the depression year of 1929, since it was a tuition-free public university and he could live at home and commute with friends some 20 miles to UCLA. He also worked at a variety of jobs to help earn his way. He decided to major in chemistry rather than physics because he felt it would provide him with more career opportunities if he were unable to find a position as a university teacher. During his last year, he became particularly interested in the exciting new developments in nuclear physics and chemistry. After receiving his A.B. degree in chemistry in 1933, he stayed on a fifth year (1933-34) to take a number of courses in physics, which had just that year been started at the graduate (master's degree) level. Because graduate work had not yet been instituted in the Department of Chemistry, he then went to Berkeley to pursue graduate work in

chemistry, hoping to work near the great Professor Gilbert Newton Lewis, dean of the college of chemistry, and the rising young nuclear physicist Ernest Orlando Lawrence, who invented the cyclotron in the early 1930s, for which he received the Nobel Prize in physics in 1939.

Seaborg described the atmosphere that existed at the University of California at Berkeley (UCB) when he entered as a graduate student in August 1934 as “exciting and glamorous,” and he took formal courses in chemistry from many eminent professors. Seaborg earned his Ph.D. in chemistry in the spring of 1937 with a thesis on the inelastic scattering of fast neutrons. It was the depth of the Depression and suitable positions were difficult to find, but he was soon asked by Lewis to stay on at Berkeley to serve as his personal research assistant. Together they published several papers; Seaborg always regarded Lewis as one of the scientific geniuses of our time and often expressed his admiration for him as his great teacher and mentor. In 1939 Seaborg became an instructor at Berkeley and in 1941 he was promoted to assistant professor. During this period he collaborated with the physicist J. J. (Jack) Livingood to use the newly completed 37-inch cyclotron to produce and discover several dozen new isotopes. Many of these, including iodine-131, are still widely used in nuclear medicine procedures. These experiences as a “radioisotope hunter” led eventually to the exploration of the transuranium elements, his life-long research interest.

During Seaborg’s graduate years and later, he closely followed the developments from Enrico Fermi’s group in Italy, which was bombarding uranium with neutrons and producing what they thought were transuranium elements, and the research of Otto Hahn, Lise Meitner, and Fritz Strassmann in Berlin on these so-called transuranium elements. These results were widely discussed in Berkeley at the weekly nuclear

seminars and physics journal club meetings. In January 1939 the exciting news of the discovery of nuclear fission by the Berlin Group came through to Berkeley by word of mouth. Edwin M. McMillan and Philip H. Abelson then set out to study the fission process in bombardments of uranium with neutrons at Berkeley's new 60-inch cyclotron. Quite unexpectedly, they produced and identified the first "real" transuranium element, which they chemically separated and identified as element 93, for which they proposed the name neptunium. McMillan then began a search for the next heavier transuranium element (atomic number 94), but was soon called to wartime research at the Massachusetts Institute of Technology. Seaborg received McMillan's permission to continue this search. In February 1941 Seaborg led a team consisting of fellow instructor Joseph W. Kennedy and Seaborg's first graduate student, Arthur C. Wahl, in performing the first chemical separation and positive identification of plutonium. It was produced as the isotope plutonium-238 in deuteron bombardments of uranium. Soon after, the new isotope plutonium-239 was produced and was found to be highly fissionable. (Because of potential military applications in nuclear weapons, these results were voluntarily withheld from publication until 1946, after World War II.) These discoveries led to the U.S. decision to undertake a crash program to develop nuclear reactors for plutonium production to be used in the U.S. atomic bomb project. In April 1942 Seaborg took a leave of absence from Berkeley to go to the University of Chicago Metallurgical Laboratory to direct the work on the chemical extraction and purification of the plutonium produced in the reactors.

As soon as the decision was made in March 1942 that Seaborg should move to Chicago for work on the plutonium project, he immediately proposed to Helen Lucille

Griggs (then E. O. Lawrence's secretary), who he had been dating since the fall of 1941, and she accepted. The understanding was that he would soon come back to Berkeley and they would be married. In June 1942 Seaborg did return from Chicago to Berkeley and took Helen to visit his parents in South Gate. He then persuaded her to return with him to Chicago by train, promising they would be married en route. They disembarked from the train at Caliente, Nevada, and were subsequently married at Pioche, Nevada, on June 6, 1942, but not without some interesting "misadventures." These have been charmingly described by Helen Seaborg. (See Helen's account quoted by Seaborg in his preface to the book *The Transuranium People: The Inside Story* by D. C. Hoffman, A. Ghiorso, and G. T. Seaborg, pp. 42-44.) Helen and Glenn's marriage was to last for more than 56 years and Seaborg often fondly referred to Helen as "his best discovery of all," an assessment with which I totally agree!

They had six children: Peter Glenn, who died in 1997, Lynne Annette Seaborg (Mrs. William B. Cobb), David Michael, Stephen Keith, John Eric, and Dianne Karole, all of whom survive Glenn. Helen was his constant companion and advisor and accompanied him on most of his many trips, faithfully attending the scientific and other symposia in which he was involved. I personally was always most gratified to have her support in the audience when I spoke at some of these meetings.

1942-1961: SEPARATION OF PLUTONIUM AND
DISCOVERY OF ELEMENTS 95-102

Seaborg headed the Metallurgical Laboratory chemistry group, which was responsible for devising plant processes for chemical purification of plutonium for the World War II Manhattan Project to develop an atomic bomb. Remark-

ably, these plant procedures, which were developed and later used in the manufacture of kilograms of plutonium at Clinton, Tennessee, and Hanford, Washington, were devised on the basis of experiments with milligrams or less of plutonium. This represents a scale-up of more than six orders of magnitude, leading to much initial skepticism about the success of the project! By 1944 the process chemistry for plutonium was essentially worked out, and Seaborg and his coworkers began attempts to produce and identify the next transuranium elements with atomic numbers 95 and 96 (americium and curium). They were unsuccessful until Seaborg came up with the actinide concept of heavy-element electronic structure in which the 14 elements heavier than actinium (atomic number 89) are placed in the periodic table of elements as a *5f* transition series under the lanthanide *4f* transition series. A new periodic table incorporating this concept was published in *Chemical & Engineering News* in 1945. It was viewed as a "wild" hypothesis because at that time it was commonly believed that thorium, protactinium, uranium, neptunium, plutonium, and the following elements should be placed as the heaviest members of groups 4 through 10. But Seaborg postulated that the heavier actinides, like their lanthanide counterparts, would be extremely difficult to oxidize above the trivalent oxidation state. This concept was verified when chemical separations based on separating elements 95 and 96 as trivalent homologues of the lanthanides were successfully used in 1944 to separate and identify these new elements, subsequently named americium and curium.

After the end of World War II in May 1946, Glenn Seaborg returned to Berkeley from Chicago as full professor of chemistry, bringing with him some of his associates, including Isadore Perlman, Burris B. Cunningham, Stanley G. Thompson, and Albert Ghiorso. In the following years up to

1958, Seaborg, Thompson, Ghiorso, and coworkers, including many graduate students and postdoctoral fellows, went on to synthesize and identify the next six transuranium elements with atomic numbers 97 through 102. The first of these, berkelium (97) and californium (98), were produced at the Berkeley 60-inch cyclotron in 1949-50. Shortly thereafter, in 1951, Seaborg and McMillan shared the Nobel Prize in chemistry for their research on the transuranium elements. Seaborg, who was only thirty-nine years old at the time, still remains the youngest winner of this honor.

Elements 99 and 100 were most unexpectedly produced in the debris from the first thermonuclear device, which was designed and tested by the Los Alamos Scientific Laboratory on Eniwetok Atoll in the South Pacific on November 1, 1952. Its huge yield of some 10 megatons created such an instantaneous high neutron flux that at least 17 neutrons were captured by the ^{238}U in the device. Seaborg's group at Berkeley was the first to separate and obtain evidence for these new elements, working together with scientists from Argonne National Laboratory and Los Alamos to confirm these results. The group proposed the names einsteinium and fermium for these elements in honor of the great scientists Albert Einstein and Enrico Fermi. Professor Seaborg and coworkers then produced mendelevium (101) in 1956 using the 60-inch cyclotron and nobelium (102) in 1958 using the heavy ion linear accelerator at the Berkeley Radiation Laboratory. According to the actinide hypothesis, it was expected that nobelium should have a relatively stable 2+ state by analogy with ytterbium, which can be reduced from 3+ to 2+ with strong reducing agents. However, it was found that not only is the 2+ state of nobelium achievable, it is the most stable oxidation state of nobelium in aqueous solution.

During the period 1946-58, Seaborg served as director of

the Nuclear Chemistry Division and in 1954 became an associate director of the Berkeley Radiation Laboratory. In addition to the research on the production and chemical properties of the transuranium elements, the division discovered dozens of new isotopes and furnished much of the data on alpha-particle radioactivity and nuclear energy levels needed for the evolution of modern theories of nuclear structure.

Seaborg also began to broaden his horizons to national public service and served from 1947 to 1950 on the first General Advisory Committee to the Atomic Energy Committee. Consistent with his lifelong interest in athletics, he accepted Chancellor Clark Kerr's invitation to serve as Berkeley's faculty athletic representative from 1953 to 1958 and played a leading role in organizing the Athletic Association of Western Universities. When Kerr became president of the University of California in 1958, Seaborg was asked to serve as chancellor, which he did until 1961, when President-elect John F. Kennedy asked him to come to Washington, D.C., to chair the U.S. Atomic Energy Commission.

1961-1971: THE WASHINGTON, D.C. YEARS

Seaborg and his family moved to Washington, D.C., somewhat reluctantly, but he was eager to accept this new challenge as chairman of the U.S. Atomic Energy Commission (AEC), and he was granted a leave of absence from the University of California. Seaborg's tenure from 1961 to 1971 was longer than any other chairman's and spanned the presidencies of John F. Kennedy, Lyndon B. Johnson, and Richard M. Nixon. Seaborg led the negotiations resulting in the limited nuclear test ban treaty prohibiting the testing of nuclear devices in the atmosphere or under the sea, which was approved by the U.S. Senate in 1963. He strongly supported the use of nuclear energy as a source of electricity

and led delegations to some 63 countries, including the Soviet Union, to promote the peaceful uses of atomic energy. During the Johnson and Nixon administrations, the AEC played a significant role in the negotiation of the non-proliferation treaty and took the lead in instituting national and international safeguards to assure that nuclear materials were not diverted from peaceful uses to weapons purposes. He was a strong advocate of a comprehensive test ban treaty. As AEC chairman he continued his interest in transuranium element research and the National Transplutonium Production Program was established at the High Flux Isotope Reactor, which was commissioned at the Oak Ridge National Laboratory in the mid-1960s. That reactor and its associated transuranium processing facility were essential to the production of rare heavy-element isotopes used in the synthesis of new heavy elements and in heat sources for space exploration. Other radioactive isotopes for applications in biology, nuclear medicine, and industry were also produced. During his tenure the support for basic research in the physical sciences, biology, and medicine nearly doubled. Seaborg also became very interested in the improvement of teaching in science and mathematics and in attracting young people to careers in science.

1971-99: RETURN TO BERKELEY

Seaborg returned to Berkeley in 1971 and was appointed university professor of chemistry by the regents of the University of California. He continued to teach until 1979 and supervised the Ph.D. research of more than 65 students. In 1982 he became the first director of the Lawrence Hall of Science, which he founded. He served as associate director at large of the Lawrence Berkeley National Laboratory until his death in 1999. He was active in many international organizations for fostering the application of chemistry to

world economic, social, and scientific needs. He continued to speak out for better education in science and mathematics and was appointed in 1998 to the Commission for the Establishment of Academic Content and Performance Standards by California Governor Pete Wilson. In addition to the 1951 Nobel Prize in chemistry, he received a host of other honors and awards. These include selection in 1947 as one of America's ten outstanding young men by the U.S. Junior Chamber of Commerce; election to the National Academy of Sciences in 1948; American Society of Swedish Engineers' John Ericsson Gold Medal in 1948; AEC's Enrico Fermi Award in 1959; 1971 Nuclear Pioneer Award of the Society of Nuclear Medicine; Order of the Legion of Honor of the Republic of France, Decoration, 1973; 1979 Priestley Medal; Swedish Council of America's Great Swedish Heritage Award in 1984; University of California's 1986 Clark Kerr Medal; National Science Board's 1988 Vannevar Bush Award; 1991 National Medal of Science; and many other major awards from the American Chemical Society; 50 honorary degrees from various universities and election to a dozen foreign national academies of science. Seaborg is listed in the *Guinness Book of World Records* for having the longest entry in *Who's Who in America!*

The name "seaborgium" for element 106 was officially approved by the International Union of Pure and Applied Chemistry in 1997, an honor that Seaborg cherished more than the Nobel Prize. He held more than 40 patents, authored more than 500 scientific articles and numerous books, including his journals, which he faithfully kept throughout his career. These formed the basis for a number of books, including an autobiography published in 1998 entitled *A Chemist in the White House: From the Manhattan Project to the End of the Cold War*.

Seaborg was active in the American Chemical Society

throughout his career, serving as its president during its centennial year of 1976. One of his last accolades was being voted one of the top 75 distinguished contributors to the chemical enterprise over the last 75 years by the readers of *Chemical & Engineering News*. It was this award that he accepted at a huge ceremony and reception at the August 1998 American Chemical Society meeting in Boston the evening before his stroke.

Glenn loved to hike, and he and Helen laid out an interconnected network of 12-mile trails in the East Bay Hills above Berkeley extending to the California-Nevada border that forms a link in a cross-country trek of the American Hiking Society. Glenn was also a strong supporter of the Berkeley athletic program. Football was his favorite spectator sport and he liked to point out that during his tenure as chancellor the Berkeley football team went to the Rose Bowl!

SOME PERSONAL REMINISCENCES

Glenn Seaborg had a tremendous influence on me—both before and after I met him. Of course, as a nuclear chemist, I knew of his leadership in the legendary discovery of plutonium in 1941, the development of the actinide concept, his receipt of the Nobel Prize in 1951, and the discovery of 8 more transplutonium elements by 1958. It was not until his tenure as chairman of the AEC (1961-71) that I actually began to learn first hand about the “real” person behind these awesome accomplishments. One of my early vivid memories of him was from the 1969 Welch Conference on “The Transuranium Elements—The Mendeleev Centennial,” which I attended. He presented the opening lecture on “From Mendeleev to Mendeleevium”; he gave the evening address commemorating the twenty-fifth anniversary of the discovery of americium and curium, he slipped out during one lunch hour to visit the M. D. Anderson

Hospital to see the program to develop the use of californium-252 for cancer therapy; and he introduced all the speakers and presided at all the sessions, except for the final day, when he was at the Manned Spacecraft Center at 5 a.m. to observe the deployment by our astronauts on the moon of the SNAP-27 (plutonium-238) generator to power the instrument package to be left there. He was also instrumental in seeing that scientists from the Soviet Union were included on the program. The breadth of his interests, his skill in communicating with both scientists and the general public and press, and his energy in doing all this even while he was AEC chairman still boggles my mind!

In 1971 while I was at the Los Alamos Scientific Laboratory (now Los Alamos National Laboratory), I became better acquainted with him when my colleagues and I found minute quantities of primordial plutonium-244 in nature. He was immediately interested in our progress and announced it during his trip to Europe for the United Nations Conference on Peaceful Uses of Atomic Energy. We kept in touch after that, especially after I was appointed in 1974 to be a member of a committee of the international unions of pure and applied chemistry and of physics to consider competing claims to priority of discovery of elements 104 and 105 by Berkeley and Dubna (Soviet Union) scientists, and I visited Berkeley several times. Later, in 1976, we had many long discussions both in person and by telephone concerning the drafts and wording of an article on criteria for the discovery of new chemical elements, which was published in *Science*. In 1978-79 I spent a sabbatical year as a Guggenheim fellow in Berkeley with his group, leaving a few months early to return to Los Alamos as leader of the Chemistry-Nuclear Chemistry Division. I frequently returned to Lawrence Berkeley National Laboratory for experiments on spontaneous fission and searches for superheavy

elements. Glenn was still taking graduate students at that time, ultimately being advisor for 65 Ph.D. students. However, he wanted to ensure that heavy-element research would continue at Berkeley. He and his colleagues convinced the faculty of the Berkeley Chemistry Department, and then me, that I should return in 1984 as professor of chemistry and succeed him as group leader of the heavy-element nuclear and radiochemistry group. Thus began a very close association for more than 15 years. I learned so many things from him just by observing how he ran the weekly brown bag lunches with his graduate students and later mine—listening with great interest as they described their research progress. He asked insightful and penetrating questions, but not in a threatening manner, made suggestions, and frequently went to visit the labs late in the day to see what was going on. He also hosted many undergraduate research students. He was devoted to education and student training and would prepare as carefully for lectures to freshman chemistry classes as for presentations to prestigious assemblages of scientists.

Glenn was very concerned with history and had kept a diary or journal since he was eight years old. After his return to Berkeley from Washington in 1971, he continued the tremendous undertaking of putting them into book form, which occupied him and several helpers for many years. His journals also formed the basis for books on his years as chancellor at Berkeley, as chairman of the AEC, and many other topics. On the rare occasions that he did not remember something that one of us might ask about he would look it up in his journals. He had a fabulous memory and was able to synthesize and apply and keep track of what he knew so it could be applied to the situation at hand. One might almost say in the parlance of our time that he was a “parallel processor”!

Seaborg had previously organized and published the proceedings of symposia commemorating the twenty-fifth anniversaries of the discoveries of the individual transuranium elements. In 1990 he decided that a symposium must be held to commemorate the fiftieth anniversary of the first chemical separation and proof of the discovery of plutonium on February 23, 1941. He asked me to help plan and organize this grand undertaking and we worked very closely on the project. Quite appropriately, at the symposium banquet in February 1991 the announcement of the initial establishment of the Glenn T. Seaborg Institute for Transactinium Science at Lawrence Livermore National Laboratory was made by its former director and Seaborg Ph.D. student (in 1951) Roger Batzel. The institute is devoted to the study of the transactinium elements with special emphasis on the education and training of future generations of scientists in heavy-element research.

Glenn Seaborg's legacy as a citizen-scholar was also commemorated by the establishment in 1998 of the Glenn T. Seaborg Center for Teaching and Learning Science and Mathematics and the new Seaborg Science Complex. They are located at Northern Michigan University in the Upper Peninsula, not far from his birthplace in Ishpeming. Their stated mission is to reach out to children young and old to invite them to share the excitement of learning that Seaborg held so dear.

Glenn continued to travel and lecture widely in the United States and abroad; I never ceased to marvel at his energy and ability to keep going. He maintained an active interest in issues such as the first studies of the chemical properties of the transactinide elements (atomic number > 103), the search for superheavy elements, science education, the nuclear test ban treaty, non-proliferation and the use of nuclear power, as well as hiking and sports. What a wonder-

ful advisor and resource he was, one I almost came to take for granted!

Our final collaborative effort, together with Albert Ghiorso, resulted in a book entitled *The Transuranium People: The Inside Story* published in late 1999. Of course, in typical fashion, he had his sections completed long ahead of time with appropriate figures and pictures, but Al and I worked long and hard to get all our pictures in and have him read our final texts. Somehow I was obsessed with getting this project completed and sent to the publisher before we left for the August 1998 American Chemical Society national meeting in Boston at which he suffered the stroke and fall that led to his death. One of my great regrets is that he did not live to participate in the joy of discovery of the new superheavy elements 118, 116, and 114 by our Heavy Element Nuclear and Radiochemistry Group in May 1999 (Ninov et al. in 1999).

In spite of his legendary accomplishments, Glenn Seaborg always had time for family members, colleagues, students, and even non-scientists who wanted to visit with him. We have lost a treasured advisor, colleague, mentor, resource, and friend. But he will live on through his prolific writings and in the cherished memories of the hosts of students, scientists, colleagues, and lay people that he influenced.

I would like to close this memorial by quoting from his statement upon being appointed the Berkeley chancellor in 1958.

There is a beauty in discovery. There is mathematics in music, a kinship of science and poetry in the description of nature, and exquisite form in a molecule. Attempts to place different disciplines in different camps are revealed as artificial in the face of the unity of knowledge. All literate men are sustained by the philosopher, the historian, the political analyst, the economist, the scientist, the poet, the artisan and the musician.

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