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SAMUEL KING ALLISON

1900—1965

A Biographical Memoir by
ROGER H. HILDEBRAND

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BY ROGER H. HILDEBRAND

SAMUEL K. ALLISON began his professional life at a time of intense interest in the properties and interactions of X rays. His contributions to the field were immediately recognized by the scientific community and especially by A. H. Compton, who was responsible for bringing him back to his alma mater, the University of Chicago. It was also near the time when Cockroft-Walton accelerators and then Van de Graaff machines began producing beams of protons and deuterons. His contributions to nuclear and atomic physics, using these accelerators, were well recognized during his lifetime, but they have grown in significance with the emergence of new fields, especially nuclear astrophysics.

FAMILY AND EARLY YEARS

Allison always regarded himself as a product of the University of Chicago and its surrounding community, Hyde Park. He attended the John Fiske Grammar School and Hyde Park High School. His father Samuel Buell Allison was the principal of an elementary school in the Chicago Public School System. The family owned one of the first automobiles in the neighborhood. When school was out they would drive with their friends to the family summer home near Three Lakes, Wisconsin. There young Sam developed a love of the North Woods, which continued throughout his life and led in his adult years to strenuous canoe trips into the Canadian wilderness with friends, including his distinguished colleagues William H. Zachariasen and John H. Williams.

Allison enrolled in the University of Chicago in 1917. As he later reminisced for the benefit of his younger colleagues, it was a time when attendance at chapel was compulsory. He competed on the varsity swimming and water basketball teams while doing honors work in chemistry and mathematics. He was introduced to quantum theory by R. A. Millikan, one of the university's first great teachers, and graduated in 1921. Two years later he received his Ph.D. in chemistry under W. D. Harkins. His dissertation was on "Atomic Stability III, the Effects of Electrical Discharge and High Temperatures."

His performance in Harkin's laboratory earned him an appointment as a National Research fellow at Harvard (1923-25). From there he went to a fellowship at the Carnegie Institution in Washington (1925-26) and then to a faculty appointment at the University of California, Berkeley, where he advanced from an instructorship to an associate professorship (1926-30). While at Berkeley he married Helen Campbell. Their children Samuel and Catherine were born in Chicago after the family moved permanently to Hyde Park.

X RAYS

Except for a brief introduction to nuclear physics at the Cavendish Laboratory (to be discussed later), Allison's principal research from the time of his graduation until he returned to Chicago in 1935 at the invitation of A. H. Compton was in the properties and interactions of X rays by means of precision spectroscopy. It was a time when X rays were the primary means of studying the atom.

Allison later said that he was hired at Chicago because "the university needed a chemist, I was available, and the records showed that I usually operated well within my breakage allowance." A review by Robert S. Shankland gives a different perspective of Compton's invitation to Allison:

> In Professor Wm. Duane's laboratory at Harvard, [Allison] became involved in the famous controversy between Duane and Arthur H. Compton on the validity of the X-ray scattering experiments that were basic for the "Compton effect." Compton's now classic experiments conducted at Washington University in St. Louis had been challenged by several X-ray physicists, including C. G. Barkla and Bergen Davis, but especially by Duane, for they were in conflict with the accepted classical theory of X-ray scattering of Professor Thomson. Duane had interpreted the experiments carried on in collaboration with students in his laboratory as being adequately explained as "tertiary radiation" produced from carbon and oxygen in the box enclosing the X-ray tube by impact of photoelectrons ejected by the primary X rays. Compton, however, had explained his results by the quantum theory—by no means accepted at that time.
>
> When Allison joined Duane's group at Harvard, the experiments were repeated with greater care and precision, and the earlier results were shown to be due to secondary X rays produced by scattering of the primary beam by the walls of the box [1925]. When these definitive results were [obtained], Professor Duane strongly supported Compton's work at the next meeting of the American Physical Society. The close lifelong association of Allison and Arthur Compton began at this time.

The best-known result of the collaboration between Compton and Allison was their book *X Rays in Theory and Experiment* (1935), which served as an authoritative reference for many years. Much of Allison's major work in X rays was facilitated by his design and construction of a high-resolution double-crystal spectrometer. He chose John H. Williams, one of his first students at Berkeley, to be his collaborator in that project. Allison applied the instrument to measurements of unprecedented accuracy of the widths and intensities of X-ray lines. Among the results was his confirmation of the dynamical theory of X-ray diffraction by C. G. Darwin and P. P. Ewing. He provided the crucial measurements and pointed out fundamental errors in earlier theories. He also rendered a physical interpretation to relate the rather complex mathematical treatment to the experimental results.

WARTIME ACTIVITIES

During the war years Allison took on a series of responsibilities. He was a consultant to the National Defense Research Council (October 1940 to January 1941) and then was a member of the Uranium Committee of the Office of Scientific Research and Development (January 1941 to January 1942). In January 1942 he became director of the Chemistry Division of the Metallurgical Laboratory, then chairman of the Project Council, and finally director of the laboratory (June 1943 to November 1944). This was the laboratory that first achieved the controlled release of nuclear energy (December 2, 1942).

Alvin Weinberg, once a student in Allison's class in electricity and magnetism and later director of Oak Ridge National Laboratory, was among the scientists in the Metallurgical Laboratory. At a memorial service for Allison in 1965 he described Allison's work in the laboratory in these words:

> Sam Allison's contribution to the controlled release of nuclear energy went much beyond holding people's hands and submerging his own technical aspirations to the interest of his country and of mankind. He did the earliest experiments on the multiplication of neutrons in a beryllium-moderated chain reactor here at Chicago even before the Metallurgical Laboratory was begun. [His relatively small exponential pile came closer to the critical value, $k = 1$, than was achieved by the Fermi group, then at Columbia.] This work has remained of fundamental interest, and serves now as the basis for certain major lines of nuclear reactor development both in the United States and abroad. His was the first experimental group at the newly formed Met Lab, and indeed was the nucleus of the wartime lab [around which grew] the final 3,000-man institution.

Weinberg described Allison's administrative burdens in the laboratory as follows:

> The laboratory had its giants—Enrico Fermi and Arthur Compton, and Leo Szilard, and Eugene Wigner; it had its pessimists and bureaucrats; and it had a lot of somewhat bewildered young people undertaking their first scientific jobs. It was Sam Allison who, with his extraordinary patience and insight, kept this disparate crew focused on the main job, which was to achieve success ahead of the Nazi competitors.
>
> If the project was faced with a technical crisis, as when the multiplication factor appeared too small to sustain a chain reaction, or when the canning of the uranium slugs seemed to be impossible; or if the project was confronted with a personnel crisis as when the most senior and desperately needed physicist handed in his resignation, it was always Sam Allison upon whom much of the burden fell, and it was he, with his gentle and appropriate humor and technical knowledge who saved the day.

By the end of 1944 the center of activity moved to Los Alamos and Allison was called on to go there as chairman of the Technical and Scheduling Committee (November 1944-January 1946). When the first atomic device was exploded in the desert at Alamogordo, New Mexico, in July 1945, it was Sam Allison's voice that was heard counting down the last seconds before the explosion. That countdown received a great deal of attention in descriptions of the event, and Allison joked that he became famous for his ability to count backwards. In a ceremony at the University of Chicago on January 12, 1946, he was awarded the Medal of Merit by Major General Leslie R. Groves. President Harry S. Truman signed the citation.

POSTWAR SCIENTIFIC LEADERSHIP

The Medal of Merit ceremony marked the end of his official duties at the Metallurgical Laboratory and the beginning of a new phase of public service, administrative accomplishment, and scientific success. He was an eloquent and effective spokesman in the drive for civilian control of atomic energy and a staunch defender of individuals under attack during the “Red scare” led by Senator McCarthy.

Allison became the first director of the Institute for Nuclear Studies (now the Enrico Fermi Institute), a peacetime successor to the Metallurgical Laboratory and among the first interdisciplinary institutes. The Institute for Nuclear Studies was formed on the conviction—inspired by the wartime example—that physicists, chemists, and astrophysicists could benefit by working together. Among the senior members were Enrico Fermi, Willard Libby, Joseph and Maria Mayer, Leo Szilard, Edward Teller, Harold Urey, and later S. Chandesekhar and Gregor Wentzel. The younger faculty included Richard Garwin, Marvin Goldberger, Murray Gell-Mann, Yoichiro Nambu, Eugene Parker, John Simpson, Nathan Sugarman, Anthony Turkevich, and Valentine Telegdi. The students of that era included James Cronin, Jerome Friedman, T. D. Lee, Jack Steinberger, and C.-N. Yang. It was an array of talent seldom, if ever, matched by any laboratory in any decade.

At a luncheon in the Shoreland Hotel announcing the creation of the institute, Allison fired the opening gun in the struggle against continuation of military censorship, when he said, “We are determined to return to free research as before the war. If secrecy is imposed on scientific research in physics, we will find all first-rate scientists working on subjects as innocuous as the colors of butterfly wings.” This speech, delivered at the founding of a prominent institute, caught the attention of a wide audience and was credited with hastening the re-establishment of open scientific inquiry.

NUCLEAR AND ATOMIC PHYSICS

Allison’s contributions to nuclear physics began in the mid-1930s while he was visiting the Cavendish Laboratory as a Guggenheim fellow. In a paper presenting the results of his "Experiments on the Efficiencies of Production and the Half-Lives of Radio-Carbon and Radio-Nitrogen," he thanked "Dr. J. D. Cockroft for instruction in the use of the high-voltage apparatus at the Cavendish Laboratory [and] Lord Rutherford for permission to work in the laboratory."

When he returned to Chicago he built his own Cockroft-Walton accelerator in Eckhart Laboratory, home of the Physics Department. He soon had some five students measuring the energies of particles produced in lithium targets bombarded with protons and deuterons. Just as this work was achieving its initial success it was interrupted by war.

When he was free to return to the field, he reconstructed the accelerator in the new Research Institutes Building, which had just been built to house the Institute for Nuclear Studies. He called his accelerator the "kevatron" to emphasize its modest peak energy (400 KeV) at a time when his associates were building machines in the million- and then billion-volt range with names like "cosmotron" and "bevatron." The kevatron stood on the basement floor of the building, extended through a very large hole in the first floor, and reached almost to the level of the second floor. Access to the ion source was by way of a plank thrown across the gaping hole some 10 feet above the basement floor. His students tell of hair-raising adventures in coping with that feature of the laboratory. The high-voltage apparatus was operated from an adjacent room with a haywire but smoothly efficient rig of mirrors, pulleys, and strings culminating in an array of broomsticks—you turned the brooms that pulled the strings that worked the levers that made the beams.

The research had two objectives: the study of low energy nuclear reactions induced by light projectiles (protons, deuterons, helium ions, lithium ions) and the elucidation of the phenomena associated with the interaction of atomic and ionic beams with matter, in particular the energy loss and the capture and loss of electrons by the beam particles. A by-product of the research effort was the development of sophisticated apparatus for the production of monoenergetic beams of particles and for the precise measurement of their energy.

Allison's postwar studies of low-energy nuclear reactions in light nuclei were concerned at first with the energy release as determined by measurement of the kinetic energy of the reaction products. These studies included measurements of the energy levels of unstable reaction products, such as ^{7}Be, ^{13}B, ^{15}C, and ^{17}N. These light nuclei and the reactions leading to their formation later proved to be of great cosmological significance because of their role in the production of stellar energy and in nucleosynthetic processes.

In the kevatron, Allison's projectiles were protons or deuterons; the targets were lithium, beryllium, and boron. The reaction products were studied with his electrostatic or magnetic analyzers. Later, Allison acquired a 2-MeV Van de Graaff accelerator, which he equipped to accelerate lithium ions to energies sufficient to cause nuclear reactions in light nuclei. With his modest apparatus, first the kevatron and then the Van de Graaff, he was an early pioneer in a field of research that would later be known as "heavy ion physics." His projectiles were too light to qualify as heavy ions by modern standards, but they were heavier than could be found in other laboratories of that era.

Edwin Norbeck, then one of Allison's students, described the venture into lithium projectiles as follows:

> By 1953 it was difficult to come up with good nuclear physics experiments that could be done with a low-energy accelerator. I remember a brainstorming session he had arranged to uncover promising projects. The conclusion of the meeting was that any new experiment would be difficult,

> either because it required high precision, had a low cross-section, or used exotic beams or targets. After this meeting Prof. Allison and I met in his office to discuss the situation. He recalled seeing an article, published many years earlier in *Review of Scientific Instruments*, that described a method for making a beam of lithium ions:
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> The authors, J. P. Blewett and E. J. Jones, had produced lithium ions by heating the lithium aluminum silicates, spodumene and beta-eucryptite, on a filament of platinum gauze. Eucryptite gave twice as much lithium current as spodumene. Allison contacted friends who were geologists and soon we had some spodumene, a semiprecious jewel, and then some alpha-eucryptite. These natural minerals gave good ion currents, but soon we were making our own beta-eucryptite using separated isotopes.
>
> We put the source in a Van de Graaff accelerator and brought out a 1.2-MeV ^{7}Li beam. This was more difficult than it sounds, but Allison had a good solution to every problem that arose. When the big day came to bring out the beam, we had a variety of detectors. If there were any nuclear reactions at such a low energy we wanted to be sure that we would not miss them. We had a gamma ray detector and a neutron survey meter. We used a thick target of LiF in a chamber with a thin window on one side. Outside the thin window we had a phototube coated on the end with a ZnS phosphor and covered with a thin aluminum foil.
>
> When the beam hit the target I was pleased to see lots of gamma rays and neutrons, but what caught Prof. Allison's attention were the charged particles. He put a sheet of paper in front of the ZnS and found only a slight reduction in the counting rate. He commented that such a large number of high-energy protons could only come from the reaction ^{7}Li(^{7}Li,p)^{13}B. He then noted that the only trouble with that explanation was that the nucleus ^{13}B [was not supposed] to exist.

The discovery of this nucleus was only the beginning. It was soon followed by further studies of lithium-induced nuclear reactions. The study of reactions with lithium beams was a new branch of nuclear physics. Even with a maximum beam energy of only 2 MeV, the Van de Graaff accelerator could be used to study reactions of ^{6}Li and ^{7}Li with all of the stable isotopes of Li, Be, B, C, N, and O. The lithium ions produced nuclei far from stability, of which ^{13}B was the first example. Reactions observed at energies near or below the Coulomb barrier included “fusion-like” processes such as ^{7}Li(^{7}Li,p)^{13}B and ^{9}Be(^{7}Li,p)^{15}C and “stripping or transfer” processes such as ^{9}Be(^{7}Li,^{8}Li)^{8}Be. Measurements of the products of various reactions made it possible to determine the masses of the ground and low-lying excited states of ^{12}B, ^{13}B, ^{15}C, and ^{17}N. The last of his nuclear studies involved elucidation of the mechanisms of complex reactions such as ^{6}Li + ^{6}Li yielding three alpha particles, and investigation of the role of intermediate nuclei (e.g., ^{8}Be) in these reactions.

Using data on ^{9}Be(^{7}Li,^{8}Li)^{8}Be from an experiment by Norbeck et al. at the University of Minnesota, Allison calculated the neutron density out to 40 fm. The words “halo nuclei,” now in common use, did not appear until much later.

Allison introduced the precision techniques he had developed for nuclear reaction spectroscopy to study the interaction of particles with matter. He commented that everyone wanted quantitative information about the passage of beams through matter, but no one wanted to make the measurements. Using the apparatus developed for precise determination of the energies and products of nuclear reactions he and his associates were able to measure the changes in energy, the “stopping power,” and the charge-changing cross-sections as a function of energy, ionic species, and stopping material. The early work on the energy loss of slow protons, deuterons, alpha particles, and Li^{6} nuclei passing through thin aluminum and gold films was pioneering and established Allison and his collaborators as the leaders in this field. The work was extended to gaseous targets. The results of the measurements of cross-sections for electron capture and loss in hydrogen and air were outstanding. This work was followed by extensive studies of helium ions in gasses where neutral atoms and both the singly and doubly charged ions coexist. The work was then extended to 2-MeV lithium.

In this atomic beam work Allison was without peer. The review article "Passage of Heavy Particles Through Matter" by Allison and Warshaw (1956) was the definitive work on stopping powers for at least a decade. The measurements of atomic capture cross-sections became important in applications, such as neutral injection into plasma machines and production of H^- ions in tandem Van de Graaff machines.

In the experiments on light nuclei it was often necessary to subtract a background due to a contamination of the targets by decomposed pump oil. Allison identified the unwelcome scattering nuclei by measuring the difference in energy between the incident and recoiling projectiles. That experience led him to suggest to his colleague Anthony Turkevich that this technique could be used to analyze surface materials where conventional chemical analysis was not feasible.

Turkevich and his colleague Anthony Tuzzolino built an instrument on this principle using the recently developed silicon detectors. Their scattering analysis instrument was carried to the moon on the last three *Surveyor* missions and made the first chemical analyses of the lunar surface. More recently, a successor to that instrument built by Tom Economu has analyzed the surface of Mars.

STUDENTS

Among Allison's major interests was the training of Ph.D. candidates in the techniques of research. Today many of his students pursue distinguished careers, in some cases working in fields far removed from their thesis problems. They recall his gift for making hard things clear and his emphasis on putting effort where it counts, a point he drove home with a turn of phrase: "If it's not worth doing, it's not worth doing well." His numerous overseas contacts resulted in a flow of foreign students and postdocs. George Morrison, a postdoc who played a leading role in the work with lithium at the Van de Graaff, relates, "In Looking back, I have to say that my period at Chicago was the most rewarding and enjoyable research time of my life. . . Lithium beams, even at 2 MeV were opening up new physics and there was Sam himself—encouraging, ebullient, luminous, and larger than life."

James Cronin began working in Allison's laboratory when he was still uncertain about what sort of physics to do, and Sam Allison's personality played a dominant role in his decision to do a thesis on nuclear physics. He says, "Sam was easy to work with, but [he] had his subtle ways of pushing his students. One Christmas, while I was away visiting my family, Sam built a proportional counter detector for my thesis experiment. It was done complete with a flowing gas system and a preamplifier. This showed his impatience with my slowness (and even reticence) to build this particular piece of equipment."

On Memorial Day weekends Allison brought his students and staff to his cabin in the North Woods. Everyone was expected to help clear brush and windfall accumulated over the winter, and Leo Herzenberg was among those who learned on those occasions to paddle a canoe, catch a fish, and wield an ax. Recalling an incident that was typical of Sam Allison's style, Herzenberg recounts, "One of the graduate students was attempting to cut down a small tree. He kept swinging the ax with much energy but hardly scratching the bark with each stroke. After a while he just stood there, covered with sweat, with a look of extreme frustration. Allison came over, took the ax, and with a single seemingly effortless swing cut right through the tree. The student stood there, mouth wide open, and asked, “How did you do that?” Allison, replied, “Fifty-seven years of experience!”

LAST YEARS

Allison went to Culham, England, near Oxford, in 1965 as the U.S. delegate to the Plasma Physics and Controlled Nuclear Fusion Research Conference sponsored by the International Atomic Energy Agency. He died there of complications following an aortic aneurism on September 15, 1965. In a memorial service at Chicago, William H. Zachariasen commented on Allison’s last years and on the character of his life in words that provide a fitting conclusion to this memoir.

> Despite heavy demands on his time by other duties in postwar years, Sam continued as an active scientist and teacher. But the combination of administrative duties and personal research taxed his strength in increasing measure as he grew older. When he resigned as director of the Fermi Institute in 1957, he felt relieved and looked forward with anticipation to many years of fruitful scientific inquiry under less stressful conditions. However, two years [before his death] his colleagues in the Fermi Institute appealed so strongly to Sam’s sense of duty that he reluctantly agreed to serve yet another term. Surely . . . a younger man should have been found to do the job so that Sam, who had already given so much unselfish service, could have been spared this burden.
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> Sam had a good life. He was at peace with himself and with the world, and he had much happiness at home and in his work. He had a simple approach to his research. The only motivation was the job and excitement of satisfying intellectual curiosity. He had no thought of other rewards. However, . . . Sam was pleased and somewhat surprised that fellow scientists had such high opinions of his work. While he tended to belittle his own accomplishments, he was most liberal in praising those of other workers in the same field . . . [He was] a great and noble man.

I AM GRATEFUL TO many of Allison’s friends, family members, students, and colleagues who have contributed material to and commented on drafts of this memoir. Among these are James Cronin,

Carol Herzenberg (Caroline Littlejohn)), Leo Herzenberg, Tanera Marshall, George Morrison, Paul Murphy, Edwin Norbeck, Gilbert Perlow, John Schiffer, John Simpson, and Anthony Turkevich. I have used copies of the tributes by H. L. Anderson, R. S. Shankland, A. Weinberg, J. H. Williams, and W. H. Zachariasen, and excerpts from anonymous notes, possibly by N. Sugarman, found in the files of the Enrico Fermi Institute. I have also used material from a booklet "Samuel K. Allison: The Frank P. Hixon Distinguished Service Professorship," edited by C. Daly (University of Chicago Development Office). I have given all of the documents used in preparing this memoir to the Special Collections Department of the University of Chicago's Joseph Regenstein Library, which was an additional source.

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