to add neutrons to the plutonium nucleus until it beta decayed to a new element with the atomic number 95. The other option was to use helium ions from the 60-inch Crocker Laboratory cyclotron in Berkeley to make a new element with the atomic number 96. He used both methods and eventually was successful in creating both new elements—americium and curium.

But in the late 1940s, there were two big problems that affected research into the transuranic elements. One was that the relatively primitive instruments were not very sensitive. The other was that, although the chemistry of plutonium was well-known by then, that of the new elements was completely unknown. These factors meant that little progress had been made after many months of effort. Finally, Glenn made a big breakthrough when he formulated his theory that the transuranic elements were part of an actinide series, and, because they were trivalent in aqueous solution, they could be chemically separated from the plutonium target material. His theory of a rare earth–like series required a major realignment of the periodic table, and for many years the Seaborg hypothesis was fought by other chemists. In the end, his actinide theory was vindicated, especially after his insight made possible the chemical identification of elements up through element 103, which was later dubbed lawrencium.

His work in the transuranium field led inexorably to the Nobel Prize in Chemistry in 1951 and thence to service outside the laboratory, where he soon proved himself equal to the challenge. From 1958 to 1961, he served as chancellor of the University of California, Berkeley, and then, in 1961, President Kennedy asked him to be the chairman of the US Atomic Energy Commission (AEC). That position launched his career into the arena of world politics. For ten years and while serving under three presidents—Kennedy, Johnson, and Nixon—Glenn worked diligently at the AEC. He participated in the negotiations that led successfully to a complete worldwide ban on the atmospheric testing of nuclear weapons. Of more far-reaching consequence, though, was his espousal, both while chairman and thereafter, of a comprehensive test ban treaty.

Though his AEC job was a very demanding one, Glenn always had time to talk about the science that was dearest to his heart, the transuranium elements. It was because of Glenn that AEC's National Transplutonium Program was launched in 1961 and carried through to the point where the heaviest elements would become available for various kinds of chemical and physical research. It was also thanks to Glenn that our current knowledge of these rare elements is very extensive. Furthermore, it was his sponsorship of the very expensive production of large quantities of pure plutonium-244 that led to the use of ^{244}Pu as the target material in the production of one putative atom of element 114 by a joint Russian–American team at the Joint Institute for Nuclear Research in Dubna, Russia, in January 1999. If confirmed, this achievement will mark the discovery of the first truly superheavy element.

When he returned to Berkeley in 1971 after the long stint in the Washington jungle, it would have been understandable if he had settled down into a less hectic existence—but that was not to be. He immediately plunged into the academic routine, and one of his greatest joys became teaching the freshman chemistry class. For that, he had to study hard to bring himself up to the very high standards that he had decided a teacher should have. Besides his teaching duties, he supervised the PhD research of more than 65 students. He founded and became the first director of the Lawrence Hall of Science in 1982. He wrote more than 500 scientific articles and numerous books. Because he had an acute sense of history, he somehow also found the time to edit his valuable, extensive, and marvelously detailed journals, which he had kept faithfully throughout his long career. He was truly overwhelmed when, in 1994, his colleagues proposed that element 106 be named Seaborgium, and he claimed that that was an even greater honor than the Nobel Prize!

The accompanying picture of Glenn was taken a few months before the stroke that would prove fatal by Pier Addone, the inventor of the PEP-II, the "asymmetric B factory" completed late in 1998 by the LBL/SLAC team.

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Gerhard Herzberg

Gerhard Herzberg, winner of the 1971 Nobel Prize in Chemistry for "his contributions to the knowledge of electronic structure and geometry of molecules, particularly free radicals," died on 3 March at his home in Ottawa, Canada.

Born in Hamburg, Germany, on 25 December 1904, Herzberg was ten when his father died, but scholarships made it possible for young Gerhard to attend the local *gymnasium*. Later, a Hamburg industrialist supported his further education at the Technical University of Darmstadt.

After earning his doctorate in engineering physics at Darmstadt in 1928, Herzberg was a postdoctoral fellow at the University of Göttingen, where, during one of the most exciting periods in the history of physics, the newly developed quantum mechanics was being applied to atomic and molecular physics. He joined Max Born's group for six months, working on theory with Walter Heitler, and then spent six months with James Franck's experimental group.

At Göttingen, Herzberg met Friedrich Hund, who kindled his interest in molecular-orbital theory. Herzberg made an important early contribution to the field with his theory of bonding and antibonding electrons. This innovation led to an invitation from John Lennard-Jones to spend the academic year of 1929 at the University of Bristol in England. He returned to Darmstadt in 1930, and, through his research over the next four years, he won recognition as one of the pioneers of molecular spectroscopy.

After the Nazis came to power in 1933, Herzberg, whose wife Luise (also a distinguished spectroscopist) was Jewish, began looking for positions abroad with the help of emergency committees in London and Zurich. Opportunities in North America not only were scarce because of the Great Depression, but were also much sought after by a large number of academic refugees from Europe. Eventually, in 1935, Herzberg was invited to join the University of Saskatchewan in Saskatoon, Canada, as a guest professor funded by the Carnegie Corp.

At Saskatchewan, proving himself to be an excellent and caring lecturer, he was soon given a permanent appointment. He spent ten happy years there, and carried out important research on molecules of astrophysical interest, while completing two of his molecular texts.

In 1945, he joined the faculty of the University of Chicago's Yerkes Observatory, where he formed a lifelong friendship with Subrahmanyan Chandrasekhar. Herzberg founded a spectroscopy laboratory that housed a long absorption–path system to duplicate the spectra of planetary atmospheres.

Three years later, he returned to Canada to establish a molecular spectroscopy laboratory at the National Research Council of Canada (NRCC) in Ottawa, which was expanding its activities after World War II. Having seized the opportunity with enthusiasm, he soon assembled a team of young spectroscopists, who all later

GERHARD HERZBERG

became leaders in their specialty branches. Distinguished scientists and postdoctoral fellows from around the globe came to work at the lab, which was so successful that it was cited at the Nobel awards ceremony as the undisputed center for molecular spectroscopy. Herzberg remained at the NRCC in Ottawa until he retired in 1994.

Here we can summarize only some of the highlights of Herzberg's 70 years of active research. His main contributions to atomic physics include fundamental problems, such as the nuclear spin of nitrogen-14 and helium-3 and Lamb shifts in the ground states of deuterium, He, and Li^+.

During their time together in Darmstadt, he and Heitler concluded, from the alternation of intensities in the rotational Raman spectrum of molecular nitrogen, that ^{14}N had integer spin and followed Bose statistics. That was in 1929—three years before the discovery of the neutron and at a time when the N nucleus was thought to have an odd number of fermions (14 protons and 7 electrons) and to follow Fermi statistics.

Other early contributions included a seminal paper with Edward Teller on the theory of vibrational intensities in electronic transitions (1933), the recognition that molecular bond lengths depend on the nature of neighboring bonds (1937), and determinations of the dissociation energies of the molecules O_2, C_2, and H_2.

Following a meeting at Yerkes in 1941 and discussion with Teller, Herzberg and Alexander Douglas identified three previously unknown spectral lines as being due to CH^+ by reproducing the spectrum in the laboratory at Saskatchewan. This was the first interstellar molecular ion to be discovered and one of only three interstellar molecules to be identified before the wave of identifications by radio astronomy that began with the OH radical in 1963 and the NH_3 molecule in 1968.

One of the fruits of Herzberg's Yerkes sojourn was the laboratory observation of the infrared absorption spectrum of H_2 due to the electric quadrupole moment of the molecule. This spectrum, which was subsequently observed in emission in Jupiter, Saturn, and Uranus, provides a powerful means to study the hot gas in objects such as planetary ionospheres, circumstellar atmospheres, planetary nebulae, and superluminous galaxies. Herzberg was also the first to discover, in 1952, extraterrestrial H_2 in Uranus and Neptune by reproducing planetary pressure-induced spectra of H_2 in the laboratory.

In the early 1950s, Herzberg developed and applied flash photolysis. In this technique, parent molecules are split by intense pulses of light into short-lived fragments whose absorption spectra are recorded on a photographic plate. The technique's high sensitivity led to the discovery at the NRCC of the spectra of a number of important free radicals—including, NH_2, HCO, CH_3, CH_2, C_3, and BH_2, of which CH_3 and CH_2 are particularly important in organic chemistry.

In 1963, Herzberg and Christopher Longuet-Higgins published a paper on the adiabatic electronic wavefunction's change of sign—an early example of a geometric phase—which occurs when the wavefunction is transported round a point of degeneracy.

For much of his career, Herzberg was fascinated by the diffuse interstellar bands, whose source had long been an enigma to observational astronomers. He was a strong proponent of the idea that the bands are due to molecules in the gas phase, an idea initially down played in preference to interstellar dust grains, but now gaining acceptance as more observations are made.

Since his earliest work on hydrogen, Herzberg had hoped to find the emission spectrum of H_3^+, whose observation in the laboratory would be an invaluable tool in the search for H_3^+ in the interstellar medium. Instead, in 1979, he found the spectrum of neutral H_3. In this electron recombination spectrum, a positive ion picks up an electron and then cascades down through the Rydberg states to the ground state, which is unstable and falls apart. Herzberg's original goal, the spectrum of H_3^+, was found by one of us (Oka, who was in Herzberg's group at the time), and has recently been observed in molecular clouds and the diffuse interstellar medium.

From 1969 to 1994, birthday conferences were held every five years to celebrate Herzberg's friendship and achievements. The unwavering enthusiasm of the participants was evidence of the continuing vigor of the various branches of science to which Herzberg had contributed so much. At the first of those conferences, his appointment as Distinguished Research Scientist at NRCC was announced, and at the next, the creation of the Herzberg Institute of Astrophysics at NRCC. Though he received many awards, medals and honorary degrees during his lifetime, Herzberg was probably proudest of the spectroscopy laboratory he established in Ottawa in the late 1940s.

When the NRCC became a target for government economies, he was always ready to speak out against bureaucracy and in defense of basic science. He was also a strong advocate of the rights of dissidents in authoritarian countries.

In his prime, Herzberg was notable for the energy and excitement that he brought to his field, and he was an outstanding lecturer—clear, well-organized, and with a knack for choosing the right amount of detail. On a broad range of spectroscopic problems in physics, astrophysics, and chemistry, he brought to bear a keen and lively research interest and became a father figure for workers in the field of spectroscopy. This status was no doubt enhanced by his monograph, *Atomic Spectra and Atomic Structure* (still in print after 62 years), and by his three-volume *Molecular Spectra and Molecular Structure* (1939, 1946, 1966), which became the bible for researchers in the field.

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Robert Green Sachs

Robert Green Sachs, a distinguished theoretical physicist and outstanding scientific administrator, died in Chicago on 14 April of complications following surgery.

Sachs was born in Hagerstown, Maryland, on 4 May 1916. He did both undergraduate and graduate work at Johns Hopkins University, where he went directly from two years of undergraduate study to the PhD program in physics. He earned his PhD in 1939 under the supervision of Edward Teller and Maria Goeppert Mayer for work