Current Comments

A Tribute to Harold Urey

Number 49 December 3, 1979

I remember how I felt when I first saw Harold Urey's picture on the cover of *Chemical & Engineering News (C&EN)* in 1972.[1] Harold had just been awarded the Priestley Medal, which is given annually by the American Chemical Society to recognize distinguished service to chemistry. It is considered the greatest honor in American chemistry and Harold Urey is certainly one of the world's great scientists. When I glanced at Urey's photograph in *C&EN*, I could distinctly see *Science Citation Index® (SCI®)* volumes on the book shelf an arm's length behind him. This pleased me, and I pointed it out to Urey in a letter to him.[2] I'm sure it pleased him too. He has been on ISI®'s Board of Directors since 1962, and has been a member of the Editorial Advisory Board of the *SCI* and *Current Contents® (CC®)* for nearly 15 years.

Joshua Lederberg first introduced me to Harold Urey in 1959. Since then Harold has provided many useful suggestions, a lot of good advice, and much needed moral support. I have also appreciated the warm hospitality of Harold and his wife, Frieda. Last spring, a small ISI delegation visited the Ureys. We promised to return this spring when the desert is in bloom.

It was especially gratifying that Harold could tell me often that the *SCI* was "exceedingly useful." Over the years he introduced *SCI* to many colleagues and friends. This sort of boost from a man of his brilliance and honesty was helpful to ISI in its formative years. As a matter of fact, I used Harold's paper on "Lifelike forms in meteorites," published in *Science* in 1962, as a prime example of the "power" of citation indexing in one of the earliest brochures we produced.[3] The citation for this paper has remained a very useful search key for the field of study it represents.

Urey's concern with information retrieval problems demonstrates his remarkable versatility. In addition to winning accolades as a research scientist, Urey has been honored for his teaching ability and praised for his social awareness. He pursues his gardening hobby with the dedication of a career horticulturist. It is a special privilege to be acquainted with Harold Urey. So I want to provide a profile of some of the achievements of this genius.

Harold Urey was born in Walkerton, Indiana, on April 29, 1893. He received his BS in chemistry with a major in zoology from the University of Montana in 1917. His experience during World War I is described in a biographical note that was submitted to the Nobel Prize Committee: "When the United States entered the World War he went to Philadelphia to help in the manufacture of war materials. He regards this experience as most fortunate, for it convinced him that industrial chemistry was not to be his major interest, and definitely directed him toward academic work."[4] After the war Urey returned to the University of Montana where he held the post of instructor of chemistry until he entered the University of California in 1921 to work on a doctorate in chemistry.

At the University of California at Berkeley Urey studied under Gilbert N. Lewis, well-known for his major contributions to the knowledge of the atom's structure. Urey has often acknowledged the profound influence which his professors had upon his scientific career, and Lewis is one of those that he has noted in particular.[5] (p. XII)

Urey received his PhD in chemistry in 1923. His dissertation focused on the properties of diatomic gases.[6]

Immediately upon receiving his PhD, Urey was given a two-year fellowship from the American-Scandinavian Foundation to go to the Institute for Theoretical Physics in Copenhagen. There he continued his studies, this time under the stimulating influence of Niels Bohr, whose work on atomic structure was recognized in 1922 with the Nobel prize for physics.

When he returned to the US in 1924, Urey became a research associate in chemistry at Johns Hopkins University in Baltimore, Maryland. He remained at Johns Hopkins until 1929. During this time he collaborated with Arthur Ruark on the book *Atoms, Molecules, and Quanta*, which was published in 1930.[7] This work was a major contribution to the fields of physics and chemistry. At the time of its publication, the physical sciences had just been revolutionized by the theory of quantum mechanics. *Atoms, Molecules, and Quanta* paved the way for a link between that new area of abstract mathematical physics and the whole field of chemistry.[8]

These years were very special ones for Harold Urey. On June 12, 1926 he and Frieda Daum were married at her father's home in Lawrence, Kansas. Their daughter Elizabeth was born in 1927, Frieda Rebecca in 1929, Mary Alice in 1934, and their son John Clayton in 1939. The Urey children have inherited their parents' energy and intelligence. Today all four have homes, careers, and children of their own.

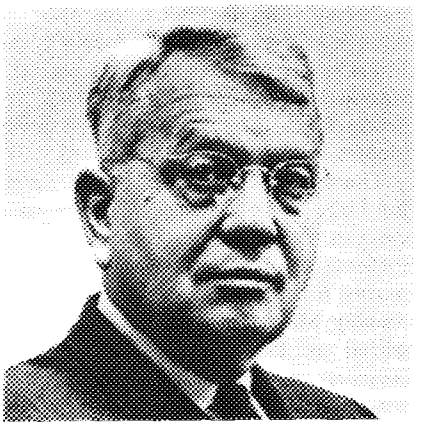
Urey was appointed associate professor of chemistry at Columbia University in 1929 and full professor in 1934. His work at Columbia led to the Nobel prize that same year. To this day, Harold considers deuterium to be his most important discovery.[9] His Nobel lecture was published in the German journal *Angewandte Chemie*.[10] He was elected to the National Academy of Sciences in 1935.

Urey and other researchers had for quite some time suspected the existence of *heavy hydrogen*, but these theoretical predictions had yet to be verified. At Columbia in 1931 Urey studied the atomic spectrum of a sample of liquid hydrogen and discovered the presence of heavy hydrogen: about one part in 5,000 of the ordinary hydrogen. Ordinary hydrogen, atomic weight 1, contains one proton, one electron, and no neutron; heavy hydrogen, atomic weight 2, contains, in addition, one neutron. He called this new isotope *deuterium*, from the Greek word meaning second.

No doubt the most far-reaching impact of Urey's discovery was that it confirmed the occurrence of *heavy water*. Heavy water is the combination of heavy hydrogen and oxygen: deuterium oxide (D_2O). It is used to slow the activity of neutrons, and for this reason heavy water became important in atomic research. Urey continued his work on the chemical properties and separation of isotopes until World War II.

During World War II he became director of the uranium separation project of the Substitute Alloys Materials Laboratory (SAM) at Columbia, charged with the problem of separating the isotopes of uranium for the atomic bomb project. After the war he was awarded the Congressional Medal for Merit for his contributions to the production of fissionable material.

Urey joined the Fermi Institute for Nuclear Studies at the University of Chicago in 1945. For seven years he was Distinguished Service Professor of Chemistry, and during his last six years at Chicago (1952-1958) he held the posi-



Harold Urey

tion of Martin A. Ryerson Distinguished Service Professor of Chemistry.

Like so many others who worked on the atomic bomb, Harold Urey had ambiguous feelings about its ultimate use. While at Chicago he joined other scientists who worked hard to defeat a bill which would have put future atomic research into the hands of the military.[11] Subsequently the Atomic Energy Commission was formed.

The label "nuclear studies" may be misleading as to the focus of Urey's work during his time at the University of Chicago. When Urey went from Columbia to Chicago, his research on thermodynamics and isotopes continued. However, his remarkably wide-ranging investigations reached into paleontology, geochemistry, and astrophysics.

During a seminar, Urey suggested a chemical origin of life. Later, three of his students undertook to confirm this suggestion experimentally. Each of these students, Harmon Craig, Stanley Miller, and G. J. Wasserburg, is now a respected scientist in his own right. And all of them are members of the National Academy of Sciences.

At Chicago, Urey became interested in studying ancient climates by quantitative methods. He and his student Cesare Emiliani examined the paleotemperatures of the oceans. Emiliani has continued this work at the University of Miami. Urey published with other researchers who were studying paleotemperatures.[12,13] Two of these researchers, S. Epstein and H.A. Lowenstam, are now at the California Institute of Technology, Division of Geology and Planetary Science in Pasadena.

Also while at Chicago, Urey published numerous papers on the abundances of the elements in the solar system. He and research chemist Hans Suess cooperated on an extensive study of this matter.[14,15] One of their papers, "Abundances of the elements in planets and meteorites," published in *Handbuch der Physik* in 1958, remains highly cited with 221 citations from 1961-1979. The abundance tables which Urey and Suess set up have undergone some revision, but they are largely still accepted today.

In 1952 Urey published *The Planets: Their Origin and Development.* The book has been called "a tour de force which will surely stand as one of the classics of science."[5] (p. XVI) It was the first methodical chronology of the origin of the solar system, setting the stage for the field of cosmochemistry (sometimes referred to as "planetary geochemistry") and making Urey a leader in it. *The Planets* is by no means a subjective or reflective work. Urey's studies of the origins of the solar system (involving chemical composition, heat balances, etc.) were as quantitative as possible given the available data.

Harold Urey was a founding member of the faculty of the campus of the University of California of San Diego at La Jolla in 1958. Urey's work has made the chemistry department there a leading center in the field of cosmochemistry. Urey remains the "star" of the department, although poor health has recently prevented him from overseeing laboratory activity or conducting discussion sessions with graduate students.

Everyone who knows Harold Urey is familiar with his incredible devotion to his work. But he has never been closeted away in a laboratory or office,

never out of touch with the world. Harold Urey allows his brilliance to range over social and political issues as well as scientific questions, and he is outspoken on such topics.

He is a member of the Union of Concerned Scientists, a group of 2,300 scientists including six other Nobel laureates, who in 1975 petitioned the White House to decrease the production of nuclear power plants. The Union of Concerned Scientists asks for suspension of atomic power plant exports to other countries and a slowdown of production of plants inside the United States, but does not call for the end to nuclear power.[16] These scientists explain their position by noting safety questions, the need for a national plan to dispose of nuclear wastes, and a concern that the worldwide spread of nuclear power could cause a spread of nuclear weapons. The 1975 petition stated that while it was no mistake to attempt to use nuclear power for peaceful purposes, "it was a serious error in judgment to devote resources to nuclear development to the virtual exclusion of other alternatives."[17]

Another example of Urey's social and political awareness is a moving statement he made in the late 50s concerning America's future. His conclusion is even more timely today: "...We will settle down to understand our faults and shortcomings and do what needs to be done to correct the situation. But what needs to be corrected? Our security system? Nonsense! Our support for science? I believe not in any immediate way.... The real problem that faces the country is a long-term one. It is a problem of the proper education and inspiration of our youth."[5] (p. VII)

It is unfortunate that all intellectually curious young people can't come in direct contact with a mind like that of Harold Urey's. Certainly his students would attest to the fact that he solved the "problem of proper education and inspiration" for them. Harold Urey has had many honors bestowed upon him, including the Research Institute of America Silver Medal (1935/1960), the Franklin Institute Medal (1943), and the National Medal of Science (1964). But praise from former students probably pleases him more than any award.

There are continual words of praise for Urey at colloquia and in informal campus conversations. Some former students put their praise into more enduring forms. In 1964 Harmon Craig, Stanley Miller, and G. J. Wasserburg edited a book of papers entitled *Isotopic and Cosmic Chemistry*.[5] This well-cited work (185 citations in the *SCI* 1964 to 1979) is dedicated to Harold Urey in a preface filled with admiration, respect, and affection. A new laboratory at the Coral Gables, Florida, campus of the University of Miami was dedicated in 1974 by Cesare Emiliani to his former professor: "The Harold C. Urey Laboratory for Isotopic Paleotemperature Research."

Citations have sometimes been called "rewards" to authors for their additions to the world's knowledge. In this sense, citation itself is indeed a form of praise. Harold Urey's work just during the period from 1961-1979 was cited over 3,000 times. And this does not include papers on which he was listed as a second author. During that time, his most-cited work, with 337 citations, was *The Planets*.[18] This is by no means a surprise. The field of cosmochemistry has expanded dramatically in the last two decades under the influence, both direct and indirect, of the US space program. Urey essentially defined this field in *The Planets*, and it is good to see that credit continues to be given where credit is due, i.e., to his fundamental statements.

"The thermodynamic properties of isotopic substances," published in the *Journal of the Chemical Society* in 1947, was cited 238 times from 1961-1979. That alone qualifies it as a citation classic. Similarly "The composition of the stone meteorites and the origin of the meteorites," published in 1953 (co-

authored by Harmon Craig) in *Geochimica et Cosmochimica Acta,* received 191 citations. "The vibrations of pentatomic tetrahedral molecules," written with C.A. Bradley and published in *Physical Review* in 1931, is also a classic. Craig, Miller, and Wasserburg point out that even this early paper made advances toward cosmochemistry. They comment that "many papers have since been written on this problem, all using the formalism of Urey and Bradley, and the results have not changed and their conclusion still stands."[5] (p. XVI)

Urey's papers introducing and describing his Nobel prizewinning discovery were heavily cited in the three decades before the *SCI* started. We won't know how much and where until we go back to complete the *SCI* for those years. However, "A hydrogen isotope of mass 2," which appeared in the *Physical Review* in 1932, received only about 32 citations between 1961 and 1979. While this is much more than the average paper will ever receive, it probably illustrates the obliteration phenomenon. This occurs with many fundamental discovery or method papers that become part of the common wisdom of everyone working in the field.

While classics in the arts and humanities may continue to be cited for centuries, it is the inexorable fate of scientific works that they fade into history. Since Harold Urey's collective work continues to be cited quite heavily it will be a long time before his work is totally obliterated. When future historiographers write about science in the 20th century, Urey will be one of the giants on whose shoulders so many have stood. This essay is a small token of my enormous love and respect for Harold Urey. It's not only a privilege to pay tribute to a personal friend; it is also a special pleasure to acknowledge a person who, while juggling the demands of family, teaching, and research, succeeded magnificently at all three while revolutionizing 20th century science.

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