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OBITUARY

CHARLES DUBOIS CORYELL

21 *February*, 1912–7 *January*, 1971

ON JANUARY 7, 1971, the field of nuclear chemistry lost one of its outstanding leaders and moving spirits when Professor Charles D. Coryell, of the Massachusetts Institute of Technology, died.

Professor Coryell was born and grew up in Los Angeles. He entered the California Institute of Technology in 1929, received his B.S. in Chemistry in 1932 and continued graduate work at Caltech, receiving his Ph.D. degree in 1935. He spent one year of his graduate work at the Technische Hochschule in München on an American–German Exchange Fellowship. For 3 years he worked as a Research Associate with Linus Pauling at Caltech before becoming an Instructor in Chemistry at the University of California at Los Angeles in 1938. In 1942, he took leave from U.C.L.A. to join the Metallurgical Laboratory of the University of Chicago, becoming a Section Chief in charge of radiochemistry of the fission products. He moved to the Clinton Laboratories at Oak Ridge, Tennessee in 1943, remaining there until 1946, when he was appointed Professor of Chemistry at M.I.T., where he remained until his death. He is survived by his wife, the former Barbara Buchman, and two daughters, Mrs. William Huber of Torrance, California and Mrs. Julie Ester Coryell of Seattle, Washington.

It is difficult in a short space to describe the character and accomplishments of such a complex and dynamic man as Charles Coryell. Perhaps he was best described by his former student, Jack Marinsky[1], as "one of the last of the renaissance men in an age of increased specialization". Just by glancing at Coryell's list of papers and the theses of his students, one is struck by the great diversity of fields in which he made important contributions. He began his scientific career in physical and inorganic chemistry with D. M. Yost and A. A. Noyes by studying electrode potentials of vanadium reactions and the reactions of divalent silver. With Linus Pauling, he made pioneering applications of physical chemistry methods to biochemical problems, specifically, magnetic studies of the structures of hemoglobin and its important complexes with oxygen, carbon monoxide and cyanide. The work is now more than thirty years old, but that area of investigation is still of considerable interest today as we become more concerned with the effects of air pollutants upon the oxygen-carrying capacity of the blood and related deleterious effects. Although Coryell was known primarily for his later work in nuclear chemistry, he continued his interest in these fields. During the middle 1960's he had an undergraduate research student working on divalent silver and, even more recently, he was giving advice and suggestions to a student at the National Magnet Laboratory who was performing additional magnetic studies of hemoglobin.

1. J. A. Marinsky, at the Memorial Service for Charles Coryell, 14 January 1971, M.I.T. Chapel, Cambridge, Massachusetts.

Coryell had an amazing ability quickly to assimilate the salient concepts of a new field and to start asking the right questions and seeking the correct answers. This trait was never more important than in 1942 when he was suddenly plucked from U.C.L.A. to join the Manhattan Project. In his own words, "I, a physical chemist with no experience with radioactivity, was made an instant nuclear chemist. This was a great nuclear transmutation, and I was in a highly excited state for a long time. I shared an office with Glenn Seaborg for several months and I and my growing group of fission-product chemists learned from him, Isadore Perlman and Spofford G. English. We also lifted ourselves by our own bootstraps as Edward L. Brady and Lawrence E. Glendenin can testify" [2]. Of this period, Glenn Seaborg recalls [3] that "during the summer of 1942 I gave a lecture course on nuclear chemistry and Charles was one of my students who, in his own words, 'worked long and late to prepare a respectable set of lecture notes to help newcomers to the Met. Lab'. As I recall, his excellent notes were reprinted by the thousands."

At Chicago and, later, at Oak Ridge, Coryell was Chief of the Section on Fission Products. His group was responsible for determining the nature of the many fission-product nuclides and determining their yields. It was at Oak Ridge that Coryell made some of his greatest contributions to nuclear and radiochemistry. His group designed and used the world's first "hot laboratory"—a building constructed exclusively for handling large quantities of radioactivity. Although it was designed for one curie of activity, their first request was to separate 100 curies of ^{140}Ba for the Los Alamos group. By adding some lead shielding and by recruiting help from soldier-chemists, they were able to ship 280 curies to Los Alamos on 18 September 1944.

Since about half of the heavy-mass fission products are rare earths, Coryell and his group necessarily became heavily involved in rare-earth radiochemistry, which, of course, entailed a great deal of ion-exchange work, a field in which Coryell has had many important contributions throughout the remainder of his career. During the course of these experiments in 1945, he and his students, J. A. Marinsky and L. E. Glendenin, discovered and characterized isotopes of element 61, about which there had previously been much confusion and a number of incorrect "discoveries" [4]. In 1949 the element was officially designated "Promethium", a name originally suggested by Grace Mary Coryell, who died in 1965. With characteristic modesty, Coryell refused authorship on the paper announcing the discovery of the element, insisting that "his contribution had not been sufficient for this. He explained, as well, that his name would detract attention from us (Marinsky and Glendenin)" [1].

In 1947, Coryell and Nathan Sugarman edited *Radiochemical Studies: The Fission Products*, a massive report on the discoveries and studies of the vast num-

2. Charles D. Coryell, Remarks of 19 May 1970 upon receiving the A.E.C. Citation, Cambridge, Massachusetts.
3. Glenn T. Seaborg, Remarks of 19 May 1970 at the A.E.C. Award ceremony for Charles Coryell.
4. Coryell later showed via his β-decay energetics that $_{61}$Pm and $_{43}$Tc both fail to have any stable isotopes in part because of positive values of $\pi-\nu$, i.e. the greater instability of unpaired protons than unpaired neutrons in certain mass regions following nuclear shell closures, see his publication Ref. 47 below.

ber of nuclides observed as products of fission. One of Coryell's major contributions to nuclear science appeared in Paper Ref. 52 of that volume, by L. E. Glendenin, Coryell and R. R. Edwards (Ref. 38 in list of papers below). On the basis of independent yields of only four fission products, they deduced the major features of nuclear charge distribution in fission. Now that independent yields of one hundred or more products have been measured, their original hypotheses have had to be modified in the light of the new data, but their basic concepts remain essentially valid.

Another major contribution resulting from the fission-product work was Coryell's systematics of β-decay energetics (paper Ref. 47 below), based on principles of the Weizsacker mass equation. In the years since his 1953 publication, many computerized, megaparameter mass equations have appeared, but I have found none which more consistently predicts the masses of unstable species than Coryell's simple treatment.

Coryell readily perceived that his predictions of nuclear masses were of great significance in the development of theories for nucleosythesis of the elements, an area in which he made several important suggestions. His paper on "Chemistry of Creation of the Heavy Elements" (Ref. 69 below), based on his address upon accepting the 1960 American Chemical Society Award for Applications of Nuclear Chemistry, is the most lucid and exciting paper I have read in that field.

Coryell's interest in nucleosynthesis and rare earths carried him into the area of meteorite research. He made the important suggestion (paper Ref. 76) that distributions of rare-earth abundances in rocks and minerals could best be interpreted if fluctuations due to nucleosynthesis were removed by normalization to a standard, in particular, an average of several chondrite meteorites. With minor modifications, that method continues to be a most useful interpretive tool today in the analysis of returned lunar samples.

These are but a few of the high spots of Coryell's many contributions to science. In addition to the works for which he is tangibly credited, he was the stimulator and catalyst of many other projects and concepts of his students and associates. He had the most free-running imagination of any person that I have known. As with any creative thinker, some of his original thoughts were soon shown to be incorrect, but many were successful and some of the intellectual seeds planted during his lifetime may yet bear fruit. I recall one occasion when he was looking at an X-ray spectrum of fission products. What he saw led him to postulate the existence of "positron capture", i.e. as an alternative to β^- decay, an electron–positron pair is created and the positron is captured by the nucleus. The data certainly did not prove the case or even suggest it to ordinary minds, but who knows?—maybe it will someday be found!

Coryell was an important pillar of the world-wide nuclear chemistry community. After the exciting productive war-time years at Oak Ridge, he returned to academic life, taking several of his Oak Ridge scientists and "soldier-chemists" to M.I.T. where, with the help of J. W. Irvine, Jr. and cooperation of nuclear physicists, he established one of the world's great nuclear chemistry laboratories. With sponsorship and cooperation of the A.E.C., they built a productive research group, but the most important product was people. A majority of U.S. nuclear chemists in universities and national laboratories received part of their training either in the M.I.T. group or in Seaborg's laboratory in Berkeley, not to mention the many foreign students and postdoc's. Coryell was involved in the founding of the Gordon Research Conference in Nuclear Chemistry, serving as co-chairman (with Seaborg) at the first conference in 1952 and as chairman in 1953. The great stimulation of that conference that continues today undoubtedly results in part from the tone of free inquiry which Coryell encouraged during its formative years. He was also on the editorial board of This Journal which has served the nuclear-inorganic field so well over the years. On May 19, 1970, in an impressive ceremony at M.I.T. in the presence of about 300 of Coryell's friends from around the country, Chairman Seaborg of the A.E.C. presented him with an A.E.C. Citation:

> "For his distinguished contributions to the Nation's atomic energy program in the field of fission products research and radiation chemistry while serving as section chief in the chemistry division of the Metallurgical Laboratory and the Clinton Laboratories from 1942 to 1946; for his outstanding research, in cooperation with L. E. Glendenin and J. A. Marinsky, which led to the identification in 1945 of promethium, the rare earth element with atomic number 61; for his sound judgment and guidance as a consultant to the Oak Ridge and Brookhaven National Laboratories and the Los Alamos Scientific Laboratory; and for his continuing service to research and education as professor of chemistry at the Massachusetts Institute of Technology."

Coryell was also honored as a Fellow of the American Academy of Arts and Sciences, the American Physical Society, the American Association for the Advancement of Science and the American Nuclear Society.

Coryell had a great reputation as a researcher, but Charles (as he was called by all who knew him) was above all a teacher. I was not formally a student of his, but in a broader sense, all of us who associated with him were his students. One's impression of him as a teacher were of great interest and excitement, and of great disorganization. But, in retrospect, most students found that they had come away from their contact with him bearing far more insight than they realized at the time. If it is possible for one to teach "creativity", I believe Charles Coryell did so.

Charles' greatest strength as a teacher was his concern and affection for his students—he was not just their teacher, but their father-confessor and friend as well. This was particularly true of the graduate students—he made them feel they could do anything and I'm sure he felt they could. In numerous cases, he had confidence in "his boys" long after the rest of us had given up on them. Sometimes he was wrong, but more often he was vindicated, and a talented young scientist was kept from the scrap heap by his faith.

Being a friend of Charles was not something one could take lightly, as much was required of one—hour–long' phone conversations, automobile rides with him to Vermont so that one could serve as a sounding board for his ideas. And of the best students and closest friends, he demanded the most. But no one begrudged these services, as they were a part of a student's educational process and Charles always repaid their favors many times over.

Charles always enjoyed having lots of people around him. I particularly picture him sitting there reading students' theses—inch by inch, and page by page, preferably with the student sitting next to him so they could argue about each scientific idea and split infinitive. It didn't make any difference how far afield the student's thesis was from Charles' major interests, he went over all of them with care, learning something from each of them and making a contribution to each.

Charles was very interested in peoples and customs of foreign countries and in the improvement of international relations at personal and scientific levels. He was always quite fascinated with foreign languages and alphabets. Many times following his 1953–1954 sabbatical at the Weizmann Institute in Israel, he would add a greeting in Hebrew when writing to his friends or outline a lecture with Hebrew characters. Before he went to the Institute du Radium in France in 1962, he spent many hours with a French professor, Robert Koch, in order that he could give his lectures there in French. Lesser men would not have attempted it, but Charles was bold enough to try it, despite the fact that he later observed that many in his audiences came to hear his French instead of the radiochemistry.

Charles made strong efforts to bring people of diverse backgrounds and ideas together. He firmly believed that if he could get everyone talking to each other, we could solve the world's problems. Under his influence, historic rivals such as Turks and Greeks, Pakistanis and Indians, and Arabs and Israelis became close friends. He participated in several organized attempts at enhancing world peace. He was one of the leaders in the presentation of a petition from the scientists at Oak Ridge via A. H. Compton to President Truman requesting that the atomic bomb be demonstrated to the Japanese and not dropped on them. He led the fight to assure civilian control of the atomic bomb. His confrontation of General Groves was a high point of the successful lobby of the scientists[1]. He aided Pauling in the circulation and collection of signatures on the 1958 petition to the United Nations which called for an immediate ban on nuclear weapons testing. Charles strongly defended Pauling against detractors who dismissed the petition (much of which was later embodied in the 1963 Limited Test-Ban Treaty) as a subversive plot. Charles was a participant in the third Pugwash Conference in Vienna in 1958. He participated strongly in the affairs of the Federation of American Scientists, the United World Federalists and the Committee for a Sane Nuclear Policy.

Charles was a friend of young struggling institutions. He was a member of the Board of Trustees of Windham College in Putney, Vermont from 1963 to 1969. In June, 1968, he established the Grace Mary Coryell Foundation, in memory of his late wife, to give financial aid to the college. He was an incorporator and member of the Board of Directors of Mark Hopkins College from 1964 to his death. He had close associations with the Middle-East Technical University in Ankara, Turkey and went there on a site visit for the Ford Foundation in 1968.

It is probably difficult for anyone who did not know Charles Coryell to see how any person could pack so many things into a short span of 58 years. For one thing, his time scale was accelerated by a factor of about four relative to that of most people—he talked fast and thought even faster. He also had one of the most unusual memories of any person I have known. Beyond that, his life was never compartmentalized—he was simultaneously a scientist and a man of peace, a teacher and friend, a linguist and a benefactor. I knew him best as the guiding spirit of a great laboratory. Those of us who worked with him knew that we had to take second place in the students' affections, but no one was ever jealous—we appreciated his uniqueness and shared the students' affection for him. He set a tone of openness and cooperation among students of different groups and Departments, being strongly interdisciplinary long before it was fashionable. We always discussed our work quite openly with each other and with visitors to the laboratory.

Since 1966, Charles had been fighting for his life against cancer. I've never seen a person face such a serious condition with more outward optimism and courage than he displayed. He became quite knowledgable about his condition and the treatment of it with heavy radiation doses and chemotherapy. In true scientific fashion, he became very interested in recent studies of ^{67}Ga concentrations in tumors as well as results of trace-element measurements on his own diseased and healthy tissue as determined by neutron activation analysis by his former student Chung-Wai Tang, now of the Cancer Research Institute of the Deaconess Hospital in Boston.

I very much regret that M.I.T. has no legacy of that great laboratory which, at its height, had four faculty members (besides Coryell and Irving, Professor W. B. Walters and myself), four research associates, 12–15 graduate students and several undergraduate research students. The laboratory was dismantled during Charles' last years and this great man, who so loved people, was left almost isolated in his laboratory. He does, however, leave a legacy all over the United States and the world, wherever the 60+ Ph.D. students and many post-doc's from the laboratory and the countless undergraduates who were his students now enhance his memory by carrying on work in nuclear chemistry and related fields under principles, scientific and otherwise, they learned from him.

Charles' friends and family have established a Memorial Fund in his name at M.I.T. to provide a scholarship for a "deserving student, at any level, whose work would combine a study of basic biochemical and/or physiological processes with possible practical medical applications toward a cure for cancer". Donations for the fund may be sent to Mr. Frederic W. Watriss, Assoc. Treasurer, M.I.T., Cambridge, Massachusetts 02139.

I wish to thank Mrs. Alberta Wyluda, J. A. Marinsky, W. B. Walters, W. H. Zoller, Linus Pauling, James Fasching, Earl K. Hyde, Robert Epple, Justin Bloom, Glenn Seaborg and Mrs. Constance Gordon for their help in preparing this tribute.

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DOCTORAL THESES SUPERVISED BY PROFESSOR CHARLES D. CORYELL

At U.C.L.A.

Theodore Vermeulen, I. The physical and structural chemistry of ferrihemoglobin fulminate and thiocyanate. II. Conjugated systems and modern color theory (June 1942).

Thurston Skei, A kinetic investigation of the reaction of substituted ethylene dibromides with potassium iodide (August 1942) W. G. Young, co-supervisor.

Edward H. Frieden, The equilibria of amino acids with formaldehyde (August 1942) M. A. Dunn, co-supervisor.

At M.I.T.

Raymond R. Edwards, Chemical effects of nuclear transformations (September 1948).

Warren B. Lewis, Isotopic exchange by electron transfer between complex ions (September 1948).

Lawrence E. Glendenin, The distribution of nuclear charge in fission (September 1949).

Jack A. Marinsky, Ion-exchange equilibria and radiochemical studies (September 1949).
Harold F. Plank, Chloro-complexes of tetravalent tellurium (June 1950).
Lionel S. Goldring, The ionization constant of nitric acid (June 1950).
Joseph T. Benedict, Separation of zirconium and hafnium by ion exchange (September 1950) W. C. Schumb, co-supervisor.
Arthur W. Fairhall, Transmutations involving nuclear isomerism (December 1951).
William W. Harvey, Some properties of composite metal films (January 1952) H. H. Uhlig, co-supervisor.
Harold G. Richter, Photofission of uranium (September 1952).
Donald R. Wiles, A study of fission-yield fine structure (February 1954).
John W. Winchester, Fission yields in the region of mass numbers 103–131 (September 1955).
Richard C. Fix, Beta ray energetics and nuclear systematics (September 1956).
John M. Alexander, Jr., Charge distribution in the fission of uranium and thorium induced by deuteron and neutron bombardment (February 1957).
Arthur M. Poskanzer, Solvent extraction of inorganic complexes (September 1957).
David H. Freeman, Anion exchange studies (February 1958).
Chester E. Gleit, Fission products in the valley region: Beta-transition systematics (September 1948).
John T. Wasson, Scintillation-spectroscopy study of short-lived fission-products (September 1958).
Patrick Del Marmol, Medium energy deuteron and alpha fission of U^{235} (February 1959).
Arthur C. Herrington, The effect of prompt neutron emission on the fission products of U^{235} (June 1959).
William R. Pierson, Radiochemical studies: Br^{78} and short-lived Ru–Rh fission-product chains (September 1959).
Bernd Kahn, Anion exchange study of the oxidation states of the halogens, including astatine (February 1960).
Morton Kaplan, Nuclear shell effects in fission: Yields of krypton isotopes from the deuteron and alphas bombardment of heavy nuclei (February 1960).
Emanuel Yellin, Valley yields in deuteron fission (June 1960).
Carl F. Buhrer, Some properties of bismuth perovskites (February 1961) A. R. von Hippel, co-supervisor.
Carl F. W. Ekman, An investigation of some of the properties of divalent silver (June 1961).
Kurt W. Kreiselmaier, A calorimetric study of ion-exchange resins (June 1961).
John W. Chase, Lanthanum, europium and dysprosium distributions in igneous rocks and minerals (February 1962) J. W. Winchester, co-supervisor.
Robert C. Lange, The chemistry of polonium (February 1962).
Richard D. Fink, Charge and mass distribution in nuclear fission (September 1962).
Henry C. Griffin, The decay of Ru^{107}, Rh^{107}, Ru^{108} and Rh^{108} (September 1962).
Howard A. Storms, Independent fission yields of some xenon isotopes (September 1962).
Demetrios G. Sarantites, Independent yields of isomers in fission (February 1963).
Evan T. Williams, Resolution of the 55-sec fission-product bromine activity (June 1963).
Chung-Wai Tang, Decay schemes of the cadmium-117 isomers (December 1965).
Alan M. Ehrlich, Rare earth abundances in manganese nodules (March 1968) J. W. Winchester, co-supervisor.
Donald H. J. Hnatowich, The decay of ^{111}Ag, ^{113}Ag, and ^{115}Ag (July 1968).
John F. Wild, Decay-scheme study of 9·6-d ^{125}Sn and anion-exchange behavior of astatine (October 1968).
James L. Fasching, Nuclear-charge distribution in thermal-neutron fission of ^{235}U and the decay scheme study of ^{144}Ce (May 1970).
Hasan N. Erten, Short-lived fission products: Iodine, antimony, bromine (December 1970).

LIST OF PAPERS OF CHARLES D. CORYELL

I. *Book*

C. D. Coryell and N. Sugarman (editors) *Radiochemical Studies: The Fission Products*. Vol. 9, Div. IV of the National Nuclear Energy Series, McGraw-Hill, New York, (1951).

II. *Research papers*

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2. C. D. Coryell, *Tabellen des Funken- und Bogenspektrums des Eisens nach G. Scheibe*, Teil III (Wellenlängen von 6400–9206 AE), Press of R. Fuess, Berlin-Steglitz (1935).
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