HENRY TAUBE
30 November 1915 — 16 November 2005
Through a lifetime of increasingly broad and significant experiments and discoveries, Henry Taube became the world’s premier mechanistic inorganic chemist (one who focuses on reaction pathways and reaction mechanisms produced during inorganic chemical changes). In his first faculty appointment, he examined the oxidation–reduction reaction and identified questions that could only be answered through precise experimentation. He then focused on the chemistry of transition metal complexes, laying out the details of what he called ‘inner sphere electron transfer’. He went on to compile a broad range of findings, leading to the elevation of inorganic chemistry to a major field of study.

Taube earned bachelor’s and master’s degrees at the University of Saskatchewan and a PhD from UC Berkeley. After receiving his doctorate in 1941, he took a position as an instructor at Cornell University, where he remained until 1946. He then joined the faculty of the University of Chicago, where he carried out seminal investigations of the electron transfer reactions between metal ion complexes. In 1962 he moved to Stanford, where he continued studies of electron transfer mechanisms. He also twice served as chair (1972–74; 1978–79) of the Stanford Department of Chemistry and subsequently was appointed the Marguerite Blake Wilbur Professor in 1976. He formally retired from the faculty in 1986, but continued as an active scientist long afterward.

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Early life and education

Henry Taube was born in Neudorf, Saskatchewan, on 30 November 1915. His parents were ethnic German farmers who escaped from Russian-controlled Ukraine in 1911 for Canada. They settled initially in Winnipeg, Manitoba, where his father worked as an unskilled labourer. After four years they moved to Neudorf, where his father worked as a farm hand and his mother cleaned houses. Henry remembered that the family lived in a rented sod hut when he was born. Eventually, the family was able to rent a farm near Grenfell, Saskatchewan, which is where Henry spent his childhood. Given his background, it was not surprising that Henry occasionally referred to himself as ‘just a farm boy from Saskatchewan’ (Creutz et al. 2006). He became a US citizen in 1942.

In an interview, conducted in 2003 but published in 2005 (Ford 2005), Henry was asked about the people who had influenced his career and its future development. He said:

My father was self-taught and was known to nearly every one as ‘Honest Sam Taube.’ He always kept his word and I felt that he had a large influence on my life and science. Although I’ve often been disappointed by ideas I had that didn’t work out, I learned not to fool myself, and not see things that weren’t there at the disregard of the science.

Henry’s first language was Low German, and his early education was in a one-room schoolhouse. His father wanted his children to have a better life. At age 13, Henry was sent to Luther College in Regina for his secondary education. His initial thought about a career was to become a minister. But after coming across Darwin’s teachings when he was a 15, he found that he had to make a change. He had a real interest in English literature, which was promulgated by his high school physics teacher. Unfortunately, he lost the financial support from his family in his second year at Luther College, after the stock market crash of 1929. He was still able to stay on at Luther, however, because his chemistry teacher persuaded the school to appoint him as a helper in the laboratory, a remarkably important step forward for scientific research.

After Luther, Henry attended the University of Saskatchewan, in Saskatoon, where he registered in chemistry and earned both BSc and MSc degrees. His research advisor was John Spinks, who would later become president of the university. Henry noted that his university stay included interactions with future Nobel Chemistry Laureate Gerhard Herzberg (FRS 1951), and remembered with relish the quality and clarity of Herzberg’s lectures on atomic spectroscopy and nuclear physics. After finishing his degrees at Saskatchewan, he still was not fully committed to chemistry but decided to attend graduate school at the College of Chemistry at the University of California in Berkeley.

In the interview noted above (Ford 2005), Henry recounted the story of how he wound up at Berkeley:

That was arranged by the Department Chair at Saskatchewan, Professor Thorvaldsen, who took an interest in me. It turns out that he knew G. N. Lewis [ForMemRS 1940; dean of the College of Chemistry] from their being students together at MIT. When they parted, Lewis had told him that any student he recommended would be accepted for graduate study at Berkeley. So, this is what happened in my case; he took it upon himself to recommend me to Berkeley. . . . When he called me into his office, I was frightened, since I knew that he really had a fear of mercury poisoning and I was using mercury in the laboratory. . . . I was quaking in my boots. It didn’t help when he looked at me rather sternly and said ‘Mr. Taube, please sit down.’ Then he said ‘I’ve heard
from Professor Lewis that you are going to Berkeley.’ I myself had been thinking about going to Columbia to do my Ph.D. with Louis Hammett.

Instead, Henry ended up at Berkeley, where chemists such as Lewis, W. F. Giauque, J. H. Hildebrand and W. M. Latimer, as well as his PhD mentor, W. C. Bray, were on the faculty and where he earned his PhD in 1940.

The environment for Henry at Berkeley was exactly what he needed. He noted that the faculty shared their ‘enthusiasm for their subject matter and their frankness in admitting their own limitations and their willingness to learn from others’.

There was little pretence for impressing others. The calibre of the people and the place spilled over into Henry and the way he conducted his own research. That became clear in later conversations with his former students and colleagues. With the benefit of a drink or two, Henry occasionally talked about his student days at Berkeley, where he became deeply interested in chemistry, in part because of the stimulating environment created by its faculty.

**Cornell University 1941–1946 and University of Chicago 1946–1962**

With his PhD in hand, Henry joined the chemistry faculty at Cornell University in 1941. His early research at Cornell and throughout the 1940s was characterized by investigations on the kinetics and mechanisms of oxidation–reduction reactions, initially those of the main group nonmetals. In the beginning, hydrogen peroxide and ozone were key substrates (2)*. In his research, a key and characteristic feature was the identification of important issues needing to be resolved that could be dealt with by using dynamical studies to elucidate the mechanistic details about how they occurred.

Henry departed Cornell in 1946 to take a post at the University of Chicago, where he turned his skills and capabilities toward a new, long-term theme, the chemistry of transition metal complexes, including a significant and long-term interest in redox reactions. One of his first interests was in the details of how ligand substitution reactions occurred in metal complexes. With that theme in mind, he spent the large part of a Guggenheim Fellowship during the late 1940s in a return to the chemistry library at Berkeley, reviewing all that was known about these substitution reactions. The result was a memorable 1952 article in *Chemical Reviews* (5) in which he highlighted the details of metal complex, ligand substitution reactions. This article provided a framework for interpreting changes in rates and showed that they were induced by changes in the electronic configuration at the metal. As a follow-up, his analysis of the data provided a direct lead into the design of a series of truly elegant experiments that elucidated, in detail, how electron transfer reactions occur between transition metal complexes in solution.

In one experiment, which helped define the area, he investigated the mechanistic details of how electron transfer occurs. The initial phases were telling in their simplicity. The strongly reducing, aquated chromium(II) complex $\text{Cr}^{2+}$, which was known to undergo rapid ligand exchange, was mixed with a solution of the substitution-inert, hexa-coordinate cobalt(III) complex $\text{Co(NH}_3\text{)}_5\text{Cl}^{2+}$. A key to the experiment was that upon oxidation to Cr(III), the chromium product becomes unreactive toward loss of ligands while the Co(II) product

* Numbers in this form refer to the bibliography at the end of the text.
rapidly loses its ligands to the surrounding solvent, giving an aquated Co(II) ion. In Henry’s test tube experiment, the deep green of the Cr(III) complex Cr(H$_2$O)$_5$Cl$_2^{2+}$ appeared in solution immediately after mixing. Therefore, since Cr$_{\text{(aq)}}^{2+}$ is ‘labile’ and Co(NH$_3$)$_5$Cl$_2^{2+}$ and Cr(H$_2$O)$_5$Cl$_2^{2+}$ were ‘inert’ to ligand substitution, the chloride ion must have been transferred from cobalt(III) to chromium(II) during the redox step. As shown in equation [1], this result demonstrated that the electron transfer reaction must have occurred when the chlorine ligand was bridging the two metal centres. Henry called this process ‘inner sphere electron transfer’ (6, 7, 14).

$$\text{Co}^{III}(\text{NH}_3)_5\text{Cl}^{2+} + \text{Cr}_{\text{(aq)}}^{2+} \rightarrow \left\{ (\text{NH}_3)_5\text{Co}^{III}\text{-Cl-Cr}^{II}_{\text{(aq)}} \right\}^{4+} \rightarrow \left\{ (\text{NH}_3)_5\text{Co}^{II}\text{-Cl-Cr}^{III}_{\text{(aq)}} \right\}^{4+}$$ [1]

Elucidating the details of electron transfer was a major accomplishment, but Henry’s contributions to mechanistic inorganic chemistry were far more broadly based. His many findings were both significant and extensive. Early in his career, he and his group were the first to determine coordination numbers, geometries and stabilities of solvated metal ions, all of which provided a critical understanding for the solution chemistry of transition metal ions (4). He and his group were also the first to utilize paramagnetic metal complexes as nuclear magnetic resonance shift-reagents (10), and they made some of the first observations on the importance of ion-pairing in the reactivity of metal complexes (8). They carried out studies on photochemical reactions in solution (1) and were among the earliest users of isotopes in the elucidation of reaction mechanisms (9). Of particular importance was Henry’s use of oxygen-18 to establish that oxidation–reduction reactions could occur by oxygen-atom transfer (3).

**Stanford University 1962–1986**

Henry took his last academic posting at Stanford University in 1962 and remained there until his retirement in 1986. In the late 1960s he conducted a series of experiments with his (late) student, Carol Creutz, focusing on the chemistry and properties of the soon to be famous, ‘Creutz–Taube’ ion \(\{(\text{NH}_3)_5\text{Ru(pz)}\text{Ru(NH}_3)_5\}^{5+}\), with pyrazine (pz) as a bridging ligand between the two ruthenium centres. Given the mixed-valence form of the complex with two identical metal centres and electronic coupling across the bridge, a major question was how do you describe the electronic distribution? Was it localized with one ruthenium in the +2 oxidation state the other in the +3 oxidation state, delocalized, or something in between (13, 14)? Henry’s experiments in this area were part of a much more extensive study on the redox and spectroscopic properties of ruthenium ammine complexes, and later of osmium ammine complexes. He and his group explored a number of important issues, including the existence of an extended reactivity involving osmium ammines and unsaturated ligands, including molecular nitrogen (N$_2$) as a coordinated ligand (11, 12). He and student Dean Harman discovered an extensive reactivity between osmium amines and a variety of unsaturated organic ligands in a series of experiments that lie at the interface between traditional coordination chemistry and organometallic chemistry (15).

Henry’s major contributions to research have been summarized elsewhere, including an extensive 2006 retrospective published in the journal *Inorganic Chemistry* (Creutz et al. 2006). In looking back, it is clear that his contributions were fundamental to the development of inorganic chemistry as an important field of study. His timing and his ability to investigate...
and understand issues of importance for chemical reactivity of transition metal complexes in solution were extraordinary. When he began, little was known in quantitative detail about the area, but he became the master. He had the creativity and quantitative insight needed to help build it into the discipline that it is today. With the importance of transition metal complexes, and their reactivity in chemical systems, which range from biological oxidation–reduction mechanisms to industrial catalysis, the broadly based impact of his studies continues to be enormous.

Personal life

His list of scientific accomplishments was truly impressive, but there were other things that characterized Henry, which were relished by those of us who knew him well. It was abundantly clear to his many friends and colleagues, and especially to his many students and postdoctoral fellows, that he was a genuinely warm and interesting person (figure 1). As a mentor, he made chemistry and the discovery of new phenomena not only challenging and stimulating, but fun. He created a research environment in which the key was the identification of issues of importance and how to solve them. He was even known to bet a bottle of wine or whisky on the potential outcome of an experiment, and pay off when, rarely, he was the loser.

Henry’s impact on his students and research collaborators was an important part of what he did, and how he did it. When asked in interview about his secret for inspiring students, his response was (Ford 2005):

I think students feel that I really want to understand. They like to participate in the generation of new knowledge. I tried to introduce them to questions not answers. I was willing to learn from the facts.

Many of his students and research collaborators, including both of the authors of this memoir, were strongly influenced by his role as a research advisor. All benefited from their interactions with him and the research environment that he created. His laboratory was a magnet for talented graduate students and postdoctoral research fellows. It attracted senior visitors from around the USA and from other countries, especially Brazil, Australia and Denmark, and those interactions led to some very significant interactive science.

As a person, Henry was many things. It is clear that he was a world-class scientist, but he was also very much at home talking about gardening, opera, politics, mystery novels, baseball and even tennis. He was also an avid collector, and loved to rummage through thrift shops for possible items of interest. At one point, he had a world-class collection of old phonograph records, specializing in tenors. He also enjoyed collecting obscure items. His list of collectables included espresso coffee pots, antique blowtorches and old bottles.

Henry took great delight in sharing his enthusiasms with others. Socially, he loved a good martini. Once, with one of the authors a visitor at the Taube’s, Henry overfilled his glass. He then dropped to his knee for a drink, which brought his lovely wife, Mary, to exclaim ‘Henry Taube! What in the world are you doing?’ When the visitor commented that he saw the glass was overfilled, Mary commented ‘Oh, I thought he was genuflecting to his martini.’ In response, Henry said, ‘it was a bit of both.’

Henry was an infinite source of chemical wisdom and of continued advice for his colleagues and collaborators. When once asked what advice he would give to young scientists, he offered
Figure 1. Henry with some of his colleagues at the Oesper Symposium, Cincinatti, October 1986. From left: David Richardson, Tom Meyer, Carol Creutz, Henry Taube, Jim Sullivan, James Espenson, Ed Deutsch, Stephan Isied and Harold Friedman. (Image provided by Thomas Meyer, copyright unknown.) (Online version in colour.)

the following (Ford 2005): 'My advice is to keep your eye on the ball and don’t be persuaded by your wishes. We all have ideas that we would like to prove to be correct, but we have to learn that we are limited.'

Henry published more than 80 research papers in refereed journals after his retirement and consulted with the company Catalytica, where he contributed to seminal studies on the catalytic activation of methane (16). His final paper, number 412, appeared in 2003, when he was 87 years old. He died on 16 November 2005.

AWARDS

The importance of Henry’s scientific contributions was highlighted in a 1983 news release upon his being awarded the Nobel Prize in Chemistry (The Royal Swedish Academy of Sciences 1983). The release stated: ‘There is no question that Henry Taube has been one of the most creative research workers of our age in the field of coordination chemistry throughout its extent.’ The implications of what he accomplished continue today. Looking toward the future, he anticipated molecular-level electronic devices, the exploitation of the redox properties of excited states, and the utilization of electrochemical processes at the device level.
In addition to the Nobel Prize, 1983 was an especially good year for Henry; he collected the National Academy of Science Award in Chemistry and the Robert Welch Award in Chemistry. Henry was the recipient of nearly every major award in chemistry. In 1977 President Jimmy Carter bestowed on him the National Medal of Science ‘in recognition of contributions to the understanding of reactivity and reaction mechanisms in inorganic chemistry’ (National Science Foundation 1976). He was also a recipient of the American Chemical Society (ACS) Award in Inorganic Chemistry (1981), the ACS Award for Distinguished Service in the Advancement of Inorganic Chemistry (1967) and, in 1985, the Priestley Medal, the highest award of the ACS.

Acknowledgements

The portrait photograph is from the author Thomas Meyer’s personal collection.

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