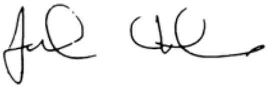

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JOHN W. CAHN

1928–2016

Elected in 1998

"For work on the kinetics and thermodynamics of phase transformations, interfacial phenomena, and quasi-crystals."

BY WILLIAM J. BOETTINGER,
CAROL A. HANDWERKER, AND FRANK W. GAYLE

JOHN WERNER CAHN, retired senior fellow of the National Institute of Standards and Technology (NIST), died in Seattle on March 14, 2016, at age 88.

After distinguished careers at General Electric in Schenectady, New York (1954–64), and at the Massachusetts Institute of Technology (1964–78), Cahn joined the National Bureau of Standards (later NIST) in 1977, where he stayed until his retirement in 2007. From 1985 until his death, he also held an affiliate faculty position at the University of Washington. His contributions to physical metallurgy and materials science and engineering, condensed matter physics, and mathematics are numerous and profound.

John Cahn was born Hans Werner Cahn on January 9, 1928, in Köln, Germany, to Lucy Schwartz, a medical X-ray technician, and Felix Cahn, a Jewish lawyer who actively opposed the Nazis. In 1933 the family fled to Amsterdam by way of the Black Forest and Belgium. John attended the Dalton School, where he learned the joy of independent exploration and the expectation of arguing with one's teacher.

Felix travelled to the United States and obtained a franchise to import American electric welding equipment and the business took the family to Italy for eight months in 1936–37 while

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John received his Dalton School lessons by mail. The family left Holland on September 17, 1939, for the United States, where they settled in New York City.

John attended Brooklyn Technical High School and then the University of Michigan. After a three-semester hiatus to serve in the US Army in postwar Japan, he graduated with a BS in chemistry in 1949. He earned his PhD in physical chemistry in 1953 from the University of California at Berkeley, studying the oxidation of hydrazine in aqueous solutions under the direction of Richard E. Powell.

At Berkeley, John met Anne Hessing. They married in 1950 and had three children.

John Cahn's trajectory into the field of physical metallurgy occurred in stages. At Berkeley he took an undergraduate course taught by Charles Kittel, became interested in the solid state, and realized that there should be a chemistry of solids to accompany the physics of solids. He then took a graduate course given by Ralph Hultgren on metallurgical thermodynamics and became fascinated by the many wonderful phenomena in solids that had no explanation.

From Berkeley he joined Cyril Stanley Smith as an instructor at the Institute for the Study of Metals at the University of Chicago. Smith had published his seminal paper, "Grains, Phases, and Interfaces: An Interpretation of Microstructure," in 1948. With Smith, John received his introduction to metallurgical microstructure and the influence of interface energy on the microstructure of solids at all scales. This marked his first exposure to the new field of thermodynamics and microstructure, which would prove to be his most fertile area of scientific discovery. There was more to thermodynamics than what he had previously learned, and he relished exploring the scientific concepts that linked them.

In 1954 John joined the Metallurgy and Ceramics Department at the GE Research Lab, where he was influenced by and collaborated with David Turnbull, John Hilliard, Ed Hart, and others. He was hired to perform experiments, but his lab was under construction so he had two years to roam the halls, discuss ideas with other staff, study, and focus on theory.

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He intentionally parked his car on the opposite side of the building from his office so that he could have impromptu conversations with his GE colleagues daily. The impact of these conversations on his view of how science could be done was evident throughout his career. For example, when asked in a NIST oral interview in 2013 how he became interested in reading the treatise *On the Equilibrium of Heterogeneous Substances* by J. Willard Gibbs, John said:

> Discussions with Ed Hart, the only theorist in that department, helped me understand how Gibbs did what he achieved. His derivations are usually rigorous, more complete and much simpler than what is in the textbooks. I became fascinated and then I really dug into Gibbs.
>
> The first time I tried to study Gibbs, I found him awfully pedantic, because he just worked out case after case after case. Then one day I was having a nonstandard problem that wasn't constant temperature and pressure and I couldn't get the answer. And then I found it in Gibbs. I said to myself 'Gibbs is useful,' but I didn't really understand how he was deriving these results.

During his time at GE, John became enthralled with many metallurgical topics to which he would return with new insight and vigor over the years. These topics included cellular and eutectoid precipitation at grain boundaries, the stereology of microstructure, and interface migration, including impurity drag. In a series of papers with John Hilliard, he developed the theory of nonuniform systems and formulated a nonclassical chemical diffusion equation that included a fourth derivative of concentration with respect to distance, the Cahn-Hilliard equation. This equation was used to describe phase transformations in a chemical miscibility gap called spinodal decomposition. The effects of elastic energy due to lattice parameter variation were included. An analytical solution to the equation for early time was found that conveyed the ideas easily. The concepts of spinodal decomposition have been applied to subjects ranging from metallurgy, ceramics, and polymers to cosmology.

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Of particular importance to him was determining how thermodynamic driving forces coupled to specific mechanisms to create the microstructure observed. That the energy decreased in a reaction must be true, but why did nature choose one path, and hence one microstructure, over another? Answering that question, and recruiting other researchers in the quest, was a unifying theme of his career.

In 1964 John joined the faculty at MIT, where he taught courses in physical metallurgy and phase transformations and supervised numerous PhD students. He also began his long-term collaborations with Ryo Kikuchi on chemical ordering and antiphase domain walls, and with Jean Taylor in interface thermodynamics, crystal growth, and grain boundary motion. With Francis Larché, he studied the effect of coherency stress on phase equilibria expanding the thermodynamics of solids to include the full stress tensor. He considered the nature of interfaces between liquid and crystal, exploring the constraints that thermodynamics placed on alloy solidification far from equilibrium. He studied liquid phase sintering and the thermodynamics of chemically ordered phases. With Sam Allen he developed the Allen-Cahn equation to describe the motion of antiphase boundaries in chemically ordered phases. He invented a vector thermodynamics of anisotropic surfaces, and described simultaneous phase separation and chemical ordering reactions.

In early 1977 John's wife, Anne, accepted a position in President Carter's administration in the Arms Control and Disarmament Agency, working under Paul Warnke in Washington. John went to work as a visiting scientist at the National Bureau of Standards during an extended sabbatical from MIT. He permanently joined NBS as a scientist in the Center for Materials Science in 1979 and was named one of three initial Senior NBS Fellows in 1984.

At NBS/NIST, John's eclectic range of research topics expanded to areas such as critical point wetting and diffusion-induced grain boundary migration as he continued work on the effect of stress on phase transformations, grain boundary

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faceting, grain growth by mean curvature, ordering, and antiphase boundaries on face-centered cubic lattices.

Although his appointment was at the NIST level, he considered the Metallurgy Division his home. He conducted weekly bag-lunch seminars with NIST staff and his many visitors. These often lasted hours, and led to days and months of discussion of particularly interesting and difficult points. Through these seminars and their aftermath, John contributed significantly to the spirit and intellectual climate of the organization, by both creating joy in the pursuit of the unknown and establishing the degree of rigor and open discourse needed for real scientific progress. The experience could be intimidating: to be treated as a peer by John Cahn, and at the same time to be told there were gaping holes in one's understanding that had to be corrected, was humbling. It was this rigor, coupled with his joy in sharing the pursuit of knowledge, that made John a colleague, friend, and mentor to generations of materials scientists, mathematicians, and engineers.

John found great stimulation in the vast array of problems in metallurgy. He especially enjoyed the use of metallurgical micrographs and other experimental evidence to stimulate new research or abandon old ways of thinking; he was never one to limit himself to only one way of thinking about problems.

One of his favorite books was *The Structure of Scientific Revolutions* by Thomas Kuhn (University of Chicago Press, 1962). John thereby knew of the challenges of establishing new paradigms in science. His detailed description to Dan Shechtman on the experimental rigor necessary to "prove" the existence of quasicrystals embodied this awareness as he and Shechtman challenged long-established laws of crystallography. As a consequence, the announcement of quasicrystals in late 1984 was met by "immediate worldwide acceptance, excitement, and confirmation" by the scientific community, as evidenced by the special session on quasicrystals at the American Physical Society's March meeting in 1985, a special symposium at the fall meeting of the Metallurgical Society

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(TMS), and more than 300 papers on quasicrystals submitted by the end of that year.

John's love of creating new knowledge with others can be seen in how he led the NIST scientific staff in quasicrystal research. From the core group with Shechtman, Denis Gratias, Bob Schaefer, Leonid Bendersky, and Frank Biancaniello, John called the NBS community together in early 1985 to develop a plan to throw all of NBS's intellectual weight and measurement science into the study of quasicrystals. The team responded by creating seminal work on structural and compositional ranges over which quasicrystals existed, discovering new classes of quasiperiodic structures, developing a six-dimensional approach to understanding "quasicrystallography," formulating new approaches to simplify working with six-dimensional structures, and much more. John's vigorous defense of quasicrystals against public attacks by Linus Pauling was based on the underlying science and experimental evidence, and was quickly substantiated as the field of quasicrystals grew.

John's awards included a Guggenheim Fellowship at the University of Cambridge (1960–61), the Dickson Prize of Carnegie Mellon University, the Michelson and Morley Prize of Case Western Reserve University, the American Society of Metals (ASM) Sauveur Award, the NBS Stratton Award, the Rockwell Medal, the Harvey Prize from the Israel Institute of Technology, and Gold Medals from Acta Metallurgica, the US Department of Commerce, and the Japan Institute of Metals. He received the 1998 National Medal of Science presented by President William J. Clinton, the 2001 Emil Heyn Medal from the German Metallurgical Society, the Franklin Institute's 2002 Bower Award, and the 2011 Kyoto Prize in Materials Science. He was a fellow of both ASM and TMS and a member of the National Academy of Sciences, National Academy of Engineering, and American Academy of Arts and Sciences.

He gave the Metallurgical Society's Institute of Metals Lecture and the Materials Research Society's von Hippel Lecture. He received an honorary ScD from Northwestern University and doctor honoris causa from the Université d'Évry in France. He

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published more than 260 papers and was a visiting professor at universities in Israel, China, Taiwan, Iran, and Sweden.

John had a brilliant mind and a warm heart. In addition to his own research, he stimulated, motivated, and mentored scientific colleagues at NIST and all over the world. Wherever he worked he created an atmosphere of excellence that raised the standards of the research of everyone around him and led to new science and its application. His personal warmth was evident in his day-to-day interactions with colleagues at work, his genuine interest in the lives of his colleagues and their families, and the dinners and parties he hosted with Anne at their home. His spirit remains alive in his friends, students, and colleagues.

John is survived by Anne; their children Martin, Andrew, and Lorie; and six grandsons.

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