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### Arnold M. Karo

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neutral-beam injectors.

In his roles as investigator, program manager, graduate research supervisor and friend, Bob impressed everyone with his understanding, patience and stimulating intellect. He is warmly remembered by his students and colleagues.

KLAUS BERKNER  
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Lawrence Berkeley Laboratory  
Berkeley, California

LAWRENCE RUBY  
Reed College  
Portland, Oregon

## Robert Hugh Cole

Robert Hugh Cole, professor emeritus of chemistry at Brown University, died on 17 November 1990 at the age of 76. He was known for his seminal contributions to the chemical physics of dielectrics.

While an undergraduate at Oberlin College, Bob wrote his first research paper with his older brother, Kenneth, an established physiologist. Their collaboration continued for ten years and yielded publications on what is now called the Cole-Cole plot. This method of representing dielectric data has been used since its development in 1941 to yield analytical forms for the frequency dependence of the dielectric permittivity.

Following his graduation from Oberlin in 1935, Bob went to Harvard University as the only experimenter (as far as we know) to work with John van Vleck. After getting his PhD in 1940, Bob was appointed an instructor in physics at Harvard, but he left the following year for Woods Hole Oceanographic Institution as a research supervisor in the Underwater Explosives Research Laboratory. He later became a trustee of Woods Hole. His first book, *Underwater Explosions*, published in 1948, was based on his research there.

Because of Bob's expertise in dielectric phenomena, the chemistry department of Brown University recruited him in 1947 as an associate professor, even though Bob's formal training in chemistry was limited to just one course. He was made chair in 1949 and was promoted to full professor two years later.

In 1960 Bob was named the Jesse H. and Louise D. Sharpe Metcalf Professor of Chemistry, the position he held until he retired in 1985. He also served as chair of several Gordon Research Conferences devoted to dielectric phenomena and the physics and chemistry of liquids, and he organized a symposium in 1963 in

honor of Peter Debye.

Paramount in Bob's research on the gas phase were the precise measurements of permittivity that revealed the negative dielectric virial coefficient of helium in addition to producing some of the most reliable multipole moments of both polar and non-polar molecules. His measurements on the solid hydrogen halides elucidated the differing molecular rotations in their various solid phases. A notable example of his work on liquids is the experimental confirmation of the Hubbard-Onsager kinetic depolarization theory with the dielectric measurements of sulfuric acid.

A few of Bob's contributions to precision measuring techniques include the transformer ratio arm admittance bridge, the low-frequency amplifier bridge and a cyclic expansion method for the measurement of both the dielectric and *PVT* second virial coefficients. For the last 15 years he was one of the leaders in the development of time-domain spectroscopy theory and measurements. His contributions to the theory of dielectrics are evidenced by his papers on linear dielectric theory, correlation function theory and the Kerr-effect relaxation in axially symmetric polar molecules.

Bob always wanted to learn more, and he believed in learning through research. He held dual citizenship in his field as an experimenter and a theorist, and he succeeded in being at its frontier until his death. We shall remember him and miss him as a warm friend and colleague and a superb scientist.

JOHN BERBERIAN  
St. Joseph University  
Philadelphia, Pennsylvania  
PEDER ESTRUP  
Brown University  
Providence, Rhode Island

## Arnold M. Karo

Arnold M. Karo died on 16 June 1991 at age 63, after a yearlong battle with leukemia. He was a theoretical chemist and solid-state physicist with the chemistry and materials science department at Lawrence Livermore National Laboratory.

Karo received bachelor of science degrees in both chemistry and physics from Stanford University in 1949 and his PhD degree in physical chemistry from MIT in 1953. Following a period of employment on the research staff of the solid-state physics division of MIT's Lincoln Laboratory, he spent two years with the US Army Chemical Corps at the Dugway Proving

Ground, Utah. During that time he was also associated with the University of Utah as a lecturer in the department of chemistry. In 1955 he joined the solid-state and molecular physics group in the department of physics at MIT as a postdoctoral fellow.

In 1958 Karo joined Livermore as a theoretical chemist and solid-state physicist. While there he did pioneering work in atomic and molecular orbital theory; the solid-state physics of specific lattice dynamic models; the theoretical investigation of infrared absorption and Raman scattering properties of crystals, leading to the first detailed calculations relating structure in the observed spectra to critical features of the phonon densities of states; and the development of techniques used in quantum chemistry in calculations of the electronic structure of molecules. He also organized and headed a theoretical chemistry group.

More recently Karo worked on the vibrational relaxation of hydrogen molecules upon impact with a cold metal surface and the recombination of hydrogen molecular ions on surfaces into vibrationally excited hydrogen molecules. This work has been crucial to understanding the kinetics of hydrogen (deuterium) negative-ion generators.

In parallel with this later work Karo pioneered in the application of molecular dynamics to the study of shock-induced behavior in condensed matter, including initiation and detonation phenomena in energetic (explosive) materials.

Karo's capabilities as a scientist were matched by his human qualities. The term "gentleman" seems to come first to most colleagues' minds when asked to describe him, and he did much of his work as part of several long-term collaborations. A result of one such collaboration, with John Hardy, was the book *The Lattice Dynamics and Statics of Alkali Halide Crystals*.

All of us will miss Arnold and the insight he provided—both in scientific matters and in our relations with our fellow humans. One always anticipated with pleasure a scientific discussion with him in his office or by telephone, or a social evening in his home. It is hard to realize that this is no longer possible.

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