TODAY'S HEADLINES

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SONOCHEMISTRY

SINGLE-BUBBLE MICROREACTORS

Chemistry quantified in a cavitating bubble; fusion likely out of reach

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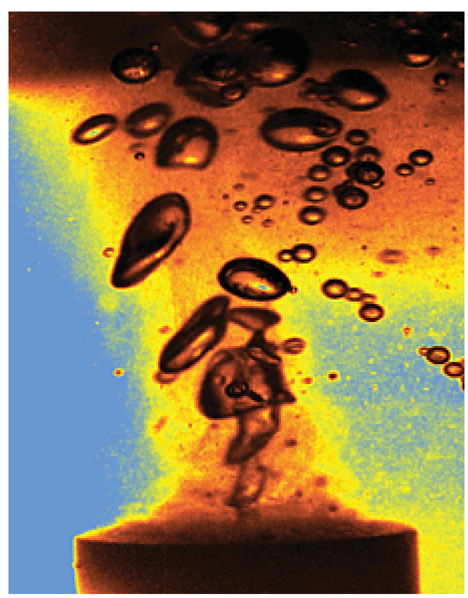
Using sensitive fluorescence spectroscopy, chemists at the University of Illinois, Urbana-Champaign, have made the first direct measurements of energy dissipation and reaction rates inside an isolated bubble in water driven to violent size oscillations by high-intensity ultrasound. The results of postdoc Yuri T. Didenko and chemistry professor Kenneth S. Suslick suggest that a cavitating bubble could be thought of as a high-temperature, high-pressure microreactor and have important implications for future work on ultrasound-driven chemistry [*Nature,* **418,** 394 (2002)].

However, Didenko and Suslick conclude that the endothermic reactions limit the temperatures that can be achieved inside a cavitating bubble. The maximum temperature for single-bubble cavitation is generally expected to be below 20,000 K--far less than the 1 million K needed for the tabletop "bubble fusion" in a cavitating deuteroacetone system that was reported in a controversial *Science* paper earlier this year (C&EN, March 11, page 11). The extraordinary conditions needed to initiate nuclear fusion will be very difficult to obtain by single-bubble cavitation in a volatile liquid such as



SONOCHEMISTRY A titanium rod vibrating at 20 kHz gives rise to a cloud of cavitating bubbles that emit flashes of light and house an array of chemical

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water or acetone, Suslick says, although the possibility of fusion in molten salts or liquid metals cannot be ruled out.

reactions.
KENNETH SUSLICK/KENNETH KOLBECK PHOTO

As cavitating bubbles collapse, they emit flashes of light, a process known as sonoluminescence. In addition, a flurry of chemical activity has been hypothesized to occur inside. Although chemical reactions have been indirectly observed, quantitative analysis of the products has proven difficult because of the tiny amount of reacting gas inside a single bubble. The Illinois chemists' experiments have now overcome this obstacle.

Gases that diffuse into the expanding bubble from the surrounding liquid are thought to become ionized under the high temperature generated by the bubble's collapse. Excited-state molecules and the recombination of the separated electrons and ions give rise to the light emission. During this recombination, the original N_2, O_2, and H_2O molecules present have been predicted to re-form as hydroxyl radicals, nitrogen oxides, and other species. The hydroxyl radicals, in turn, are expected to react with organic molecules in the water or to dimerize to H_2O_2.

By direct correlation from the fluorescence spectra, Didenko and Suslick were able to measure the number of photons emitted and the yield of OH and NO_2^- in a 10-µm cavitating bubble. The data were used to calculate the energy balance of the collapsing bubble.

Most of the system's potential energy is converted into mechanical energy that is imparted to the liquid, the researchers find. The remaining energy is converted to heat, chemical reactions, and light, with the energy going into the chemical reactions 100 times greater than that going into light emission.

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