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# Science heats up

By GREG KLINE

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Astronomers can't poke a thermometer in the sun's mouth, or elsewhere, to take its temperature, so they use light.

That is, they extrapolate the temperature from the relative intensity of the lines in the spectrum of light from the sun and other stars, essentially the variations in the colors or wavelengths of light they give off.

University of Illinois researchers have applied a similar technique to tiny gas bubbles in liquid that are formed, grown, isolated and collapsed by ultrasound and found something hot. Real hot.

The temperature inside a single collapsing bubble is more than 26,000 degrees – about three times hotter than the surface of the sun.

And that's just at the outer regions of the bubble. It's probably even hotter at the center and a violent shock wave likely accompanies the bubble's collapse as well, UI Professor Ken Suslick said recently.

No need to avoid the UI Chemical & Life Sciences Lab, where Suslick and doctoral student David Flannigan do their work, however. The hot spot and shock wave are on the same very small scale as the bubbles with which they work. The minireaction also is contained by being centered in and surrounded by a flask of otherwise cold liquid, Suslick said.

The light emitted with the high heat inside is another matter. It's bright enough to see in the hallway outside the darkroom where Flannigan does the experiments, even with the room lights turned on, Flannigan said.

"It hurts to look at it sometimes," he said.

Bright enough to measure the temperature of the reaction, which had never been done with a single-bubble collapse before. Suslick and Flannigan

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reported their results in the journal Nature this month. The National Science Foundation and the Defense Advanced Research Projects Agency have supported the work.

In addition to being a first, the study has attracted attention because some scientists at Oak Ridge National Laboratory have previously reported evidence of nuclear fusion in such sonoluminescence, or "sound-into-light," bubble-collapsing experiments.

The Oak Ridge claim, released in 2002, was widely disputed, and the UI researchers reported no such result in nature.

Suslick, a UI chemistry professor, said earlier attempts to measure the temperature of a single-bubble collapse failed largely because they employed water.

Water has a high vapor pressure, which in this case means a lot of water molecules get inside a bubble and absorb much of the compressive force, resulting in the spectrum of light emitted being poorly delineated.

Suslick's lab had been testing substitute liquids and liked the looks of sulfuric acid because it has a low vapor pressure and emits a light pattern nearly 3,000 times as brilliant as water.

Flannigan first uses ultrasound to vibrate the flask of liquid and create a standing wave that pushes a single bubble to the center. Suslick likened it to throwing a rock in a pond, only with the ripples circling inward instead of outward.

Once the bubble is centered, the UI researchers turn up the ultrasound, the force of which collapses it.

"When you compress a gas, you get heating," Suslick said. "Anybody who's pumped up a bicycle tire knows that."

As the bubble collapses, the reaction actually yields plasma – charged gas and the stuff of which stars are made – and the UI researchers use a spectrophotometer to measure the light emitted in the process. It's a device similar to those used by astronomers, in conjunction with telescopes, to measure light from distant stars, Suslick said.

In our everyday lives, the light emitted by plasmas is the basis of fluorescent lighting and plasma TV screens, among other things.

Likewise, the ultrasound the researchers employ is the same tool used for medical procedures, but at a different frequency and intensity.

The use of ultrasound to collapse bubbles – called "acoustic cavitation" – by Suslick and colleagues is more than a hot academic exercise.

They can use the high-energy, high-temperature reactions not only to produce light but also to produce unusual chemical materials and nanoscale structures. A nanometer is a billionth of a meter, about 200,000 times smaller than the diameter of a human hair.

For example, they've already created hollow nanospheres of a material, molybdenum-disulfide, which appears to be a superior catalyst for removing polluting sulfur compounds from gasoline, and box-shaped crystals with spherical voids inside. Such tiny vessels might be useful, say, for delivering drugs to a specific place in the body.

"There are all kinds of chemical applications for ultrasound," Suslick said. "Every bubble is (potentially) a separate nanoreactor."

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## Science heats up

N-G photo by John Dixon

Doctoral student David Flannigan, left, and Ken Suslick, UI professor of chemistry, sit next to a spectrophotometer in a darkroom at the Chemical & Life Sciences Lab on Friday March 4, 2005. The pair use the machine to measure the light spectrum and get a temperature reading from single bubbles collapsed with ultrasound.



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