Scientists who use microwave heating in experiments can control it better now

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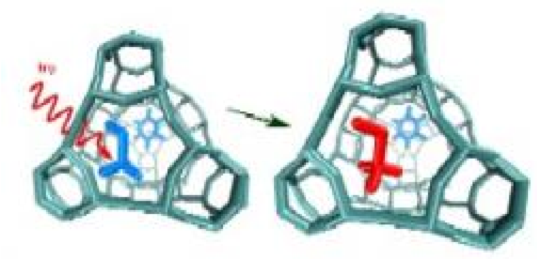

This is a schematic picture of a zeolite with methanol (foreground) and benzene (background), before (left) and after (right) irradiation with microwaves. It illustrates the selective heating of methanol, depicted on the right in red (hot). Cartoon courtesy of UMass Amherst

(PhysOrg.com) -- For at least 20 years, organic chemists and materials scientists have used microwaves as an alternative energy source to activate materials and break chemical bonds. However, though microwaves are clearly useful, scientists have remained largely in the dark on exactly how they provide special heating properties.

Now, an international research team including chemist Scott Auerbach at the University of Massachusetts Amherst has developed a new molecular-level probe to track how various components in a mixture absorb microwave energy to different extents. Results of their experiments conducted at the Institute Laue-Langevin, Grenoble, France, are reported in a recent issue of *Physics Review Letters*.

The research team also includes chemical engineer W. Curtis Conner, Jr. and chemistry graduate student Julian Santander, both of UMass Amherst, with others at the University of Lyon and the University of Edinburgh.

With the new tool, based on quasi-elastic neutron scattering, researchers can for the first time measure the effective temperature of components in a mixture to determine which part is hot and which is not. This technique has the potential to determine exactly how microwave heating speeds up chemical and material syntheses. "With this breakthrough, we’ve converted microwave heating from a mysterious tool to a well-understood and predictable method for promoting and speeding up materials synthesis," Auerbach says.

Most people using a microwave oven know that it warms unevenly and foods must be stirred before eating. This is because fat, proteins, water and minerals such as calcium in milk all absorb energy at different rates, Auerbach explains. The same is true for compounds and synthetic materials in laboratory experiments. But microwaves are widely used because they’re faster, more efficient and promote the chemical changes needed in modern materials science, while conventional heating does not, he adds.

"What we’ve done is to develop a technique for probing a material synthesis activated with microwaves. We blast the system with microwaves and neutrons at the same time. The neutrons act as the probe, bouncing off the system to tell us what’s going on with the temperature inside. It’s like a microscopic thermometer stuck into the system, giving a different temperature reading for each component in the mixture," Auerbach says.

In experiments, Auerbach and coworkers applied this new method to understand microwave heating of zeolites, which are materials with molecule-sized pores. At present, zeolites are used as catalysts for refining petroleum to high-octane gasoline. They also show promise for refining biomass into biofuels. Auerbach refers to the zeolite as "a hotel for molecules" such as benzene and methanol, which can rotate and vibrate in each room, or bounce from room to room. "We found from the neutron scattering that microwaves cause the molecules to rotate like mad, and bounce from room to room, but they do not vibrate much."

An expert in computer simulations of microwave-heated zeolites, Auerbach says by using such simulations, "It's almost as if we can shrink down to the size of an atom to watch this motion, figure out where the microwave energy is going and why it is so efficiently promoting the chemistry. It's a new kind of thermometer to use for the guest molecules."

He and colleagues did not get perfect agreement between laboratory experiments and computer simulations, he notes, but for broad characterization of zeolite host temperature, effective guest translational ("room to room") and spinning temperature, their results provide "very good agreement on the extent of selective heating."

Overall, the authors summarize that their work provides "the first unambiguous, microscopic evidence for athermal effects in microwave-driven zeolite-guest materials." With this advance, Auerbach suggests that microwave heating will be a "hot field for a long time to come."

Provided by University of Massachusetts Amherst

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