Squeezed hydrogen turns semi-metallic

For years, scientists have tried compressing hydrogen until it becomes a metal. Current theory predicts that a sufficiently large pressure should collapse the two-atom molecules of hydrogen, breaking them into a tightly packed collection of individual atoms and freeing electrons from their designated shells to conduct electricity. Achieving such a metallic state for the simplest atom would provide a great advance in basic physics. In the bargain, metallic hydrogen holds promise as a high-temperature superconductor and as a fuel for nuclear fusion.

Now, two scientists from the Carnegie Institution of Washington in Washington, D.C., report seeing the first glimmer of their long-awaited goal. Ho-Kwang Mao and Russell J. Hemley observed changes in their hydrogen samples indicating that, if not already metals, these samples have at least reached an important intermediate state as semiconductors, or semi-metals. They presented their finding earlier this month at the American Geophysical Union meeting in Baltimore.

The researchers achieve a pressure comparable to that near the center of the earth by squeezing materials between two gem-quality diamonds in a "diamond anvil." The device works by concentrating a force over a small area, the way a high-heeled shoe painfully concentrates a person's weight on a stepped-on toe.

Ten years ago, Mao and Peter M. Bell used the diamond anvil to compress hydrogen into a new kind of crystalline solid at 1.7 megabars, or 1.7 million times atmospheric pressure (SN: 3/10/79, p.156). Now they can reach 2.5 megabars. At this pressure, when the researchers peer through the transparent diamonds, they see the hydrogen turn opaque. This indicates the sample is becoming metallic, explains Mao, because electrons of semiconductors and conducting metals absorb visible light. The team cannot yet test the sample directly for electrical conductivity, but Mao says they expect to eventually develop this capability.

Mao and Hemley say they have little idea what metallic hydrogen might be like — it could even be a liquid. Their work should improve scientists' understanding of the planets Jupiter, Saturn, Uranus and Neptune, which may have metallic-hydrogen cores. In addition, the possibilities of a superior superconductor or a new fusion source remain open. While fusion efforts have failed to produce more energy than put in, Mao says, a more compact hydrogen starting material could help boost efficiency. *— F. Flam*

Vitamin E fights radicals — again and again

For years, researchers have puzzled over why adults appear to need so little tocopherol, better known as vitamin E. While the body employs this vitamin daily to fend off potentially damaging attacks by many potent reactive chemicals, known as free radicals, tissue levels of the vitamin are usually quite low. And adults never seem to show signs of deficiency — even while eating diets containing little or no tocopherol. New experiments now suggest why: Certain membranes within cells can recycle the vitamin by rearming it with the vital ammunition lost in its defensive salvos.

Free radicals, possessing an unpaired electron, wreak major damage by oxidizing — robbing an electron from — a protein or other nearby molecule. They also threaten to set in motion a self-perpetuating chain reaction as each electron they rob transforms a molecule into an electron-hungry radical itself. Vitamin E, the body's premier antioxidant, stops this destructive chain of oxidizing reactions by donating an electron.

In the process, vitamin E also becomes a radical, but a relatively nonreactive and benign one. Vitamin E radical was thought to just decay away, but studies over the past decade have suggested otherwise. To resolve the issue, Lester Packer and his coworkers at Lawrence Berkeley (Calif.) Laboratory recently fed high vitamin-E diets to rats for three weeks, enriching tocopherol levels in their mitochondrial membranes to 20 times normal. These membranes are the main site of oxygen consumption — and therefore, Packer reasoned, a likely site of vitamin-E rejuvenators.

After isolating these membranes, the researchers scanned them spectroscopically and for the first time directly observed vitamin-E radicals in biological materials. Next, they subjected their soup of membranes and vitamin-E radicals to an electron-donating chemical and watched as the membranes' "respiratory system" began shunting electrons around. Before long, enzymes in this system transformed the radicals back to vitamin E.

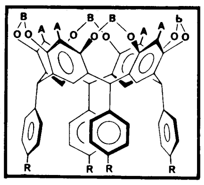
Packer's finding, while not surprising, confirms that vitamin E is recycled in living systems, says Paul B. McCay at the Oklahoma (City) Medical Research Foundation. McCay's own work, with microsomal membranes, suggests glutathione — not the respiratory system — donates vitamin-rejuvenating electrons there. Other studies indicate that elsewhere, including the eye (SN: 5/20/89, p.308), vitamin C may play a similar role. In other words, McCay says, "every subcellular membrane may have its own [vitamin-E recycling] mechanism."

— J. Raloff

Building up better synthetic receptors

From a small molecule's point of view, they're creatures with jellyfish-like tentacles and gaping, sticky mouths. From a chemist's perspective, they're fascinating molecular assemblies — synthetic receptors known as cavitands — suited for basic research, but also promising for medical and agricultural uses.

"You start with oddities, and if you're lucky you end up with something practical," says chemist Donald J. Cram of the University of California, Los Angeles. In the May 10 JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, he and three UCLA colleagues report making a new type of cavitand that has two differently shaped cavities. Earlier versions had only one, bowl-like cavity. Last year, Cram reported linking two bowl assemblies to make the first "molecular cells," which he also calls carcerands because small molecules get trapped inside when the bowl rims meet.



Cram et. al.

Generic cavitand with fused bowl- and box-shaped cavities. A, B and R are sites for chemicals to fine-tune the molecule's features.

The new cavitands contain two outward-opening cavities fused bottom to bottom, one shaped like a box and the other like a bowl. The researchers can fine-tune the shapes and dimensions of the cavities by linking various chemical groups to their rims. In the same way, they can "dial in" the degree of solubility of the cavitands, and they hope to adorn the rims with catalytic groups to trigger specific chemical reactions.

Some of the two-cavity cavitands host the same molecular "guests" in each cavity; others host different guests in the bowl and box. One version remains empty despite the availability of guests. "It's very rare to have a vacuum," remarks Cram. "We're puzzled by it."

Cram expects next to build new carcerands by linking a pair of box cavities to make an elongated box with a bulge in the middle. Compared to the carcerands Cram described last year, the box-shaped interiors of carcerands made with the new cavitands should be inviting to a different variety of guests, he says.

"All of this is related to how enzymes work," remarks chemist Ronald Breslow of Columbia University. Cram envisions using cavitands and carcerands to shuttle drugs to diseased cells, as slow-release pesticide delivery systems, and as novel liquid crystals in which the carcerands crystallize in place while their molecular prisoners are free to respond to electric fields. *— I. Amato*

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