Observing individual molecular reactions

Molecular reactions happen fast: In a billionth of a second, two molecules can collide, intermingle, and merge, giving rise to a new chemical product. In fact, the trading of atoms or electrons between molecules takes place so quickly that scientists can only estimate the true reaction speed.

Now, Maryanne M. Collinson and R. Mark Wightman, chemists at Kansas State University in Manhattan and the University of North Carolina at Chapel Hill, respectively, have come up with a novel system enabling chemists to detect and monitor single molecular events.

By focusing on a small number of reactive molecules confined in a tiny place, the chemists can, in effect, observe reactions as they happen.

Their report appears in the June 30 SCIENCE.

The scientists placed a dilute solution of 9,10-diphenylanthracene (DPA) molecules, which fluoresce when chemically stimulated, into a minuscule, lightless reaction vessel only one-fiftieth the size of an average living cell. By applying a mild electric pulse across two tiny electrodes, each only a few micrometers in diameter, the researchers created positively and negatively charged DPA ions.

The ions float freely in solution, seeking out oppositely charged partners. When they meet, they react, emitting a single photon. By using an instrument capable of counting single photon emissions, the scientists can track each molecular coupling.

As expected, the rate of photon emissions corresponded to the rate predicted by theory. "The apparatus detected about four photons per microsecond, " Wightman says. "That's what we expected, according to the statistics. But what's interesting here is that, ordinarily, there's no way to observe each molecule react. Here you actually *see* it happen."

Allen Bard, a chemist at the University of Texas, Austin, points out that this technique could lead to other methods for detecting small numbers of molecules in solution, an application that could prove useful to analytical chemists and molecular biologists.

To develop the new technique further, Wightman says, he will test it on other molecules to see how well it works for monitoring various types of chemical reactions.

"One of the virtues of this method is its simplicity," Wightman says. "I like low-tech experiments." *— R. Lipkin*

Trapping and storing frigid antimatter

When electron meets positron, the two particles promptly annihilate each other, disappearing in a puff of radiation. So trapping and storing positrons—the positively charged, antimatter counterparts of electrons—in the midst of ordinary matter is a delicate operation.

Now, researchers have developed a convenient technique for capturing and chilling positrons in an environment suited to the production of antiatoms. This achievement represents a key step toward creating antihydrogen, which consists of a positron orbiting a negatively charged antiproton nucleus.

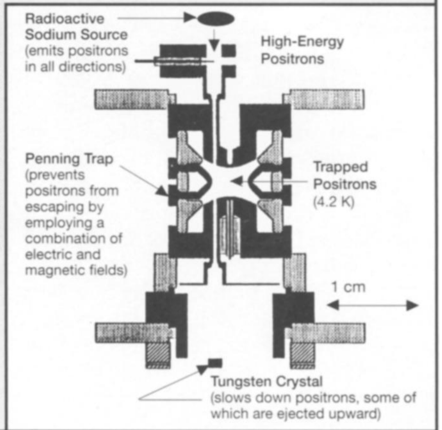
Physicists Gerald Gabrielse, L.H. Haarsma, and K. Abdullah of Harvard University describe their method in a paper to be published in PHYSICAL REVIEW LETTERS.

The researchers use radioactive sodium-22 as a source of high-energy positrons. Guided by strong magnetic fields, a fraction of these positrons strikes a tungsten crystal, which slows down the particles (see diagram).

Rebounding from the crystal, some of these slow-moving positrons enter a trap created by a web of electric and magnetic fields. This trap confines the particles to a small volume, which is as free as possible of stray atoms.

Gabrielse and his coworkers have stored up to 35,000 positrons in this high-vacuum environment at a temperature of 4.2 kelvins.

The researchers have already developed a similar apparatus for trapping and cooling antiprotons. To create antihydrogen, they need to increase the number of trapped positrons by a factor of at least 10, then bring together the laggard positrons and antiprotons so they can snare each other. *— I. Peterson*



L.H. Haarsma et al./PHYS. REV. LETT.

Apparatus for trapping positrons.

Fishy clues to a toxaphene puzzle

In 1991, Canada banned angling at the seemingly pristine Lake Laberge in its Yukon Territory, citing dangerous concentrations of the banned pesticide toxaphene in the lake's fish. Because the catch from neighboring waters carried barely detectable amounts of toxaphene, suspicion fell on illegal dumping of this highly toxic chemical.

It now appears the problem evolved quite legally, a Canadian team reports in the July 14 SCIENCE. Aerial transport of toxaphene—perhaps from as far away as Russia—and the especially carnivorous diet of the lake's fish appear to explain Laberge's toxaphene crisis.

Toxaphene was used widely throughout North America for decades to rout insects, weeds, even unwanted fish. But worried by its apparent carcinogenicity, toxic effects on nontargeted species, and persistence, the Canadian and U.S. governments each initiated a phaseout of the chemical in 1982.

In the Northern Hemisphere, volatile pesticides tend to leapfrog slowly toward the Arctic—wintering in soil or water until warm weather revolatilizes them and they resume their northward march. The puzzle, then, was not how toxaphene could have reached Laberge, but why it hit this lake so hard.

Karen A. Kidd of the Freshwater Institute in Winnipeg, Manitoba, found the answer by studying two stable isotopes of nitrogen. Because animals tend selectively to retain nitrogen-15 over nitrogen-14, predators that feed on older, larger prey—those at the top of the food chain—will accumulate proportionately more nitrogen-15.

Toxic chemicals passed along through the diet also concentrate most quickly in animals at the top of the food chain. And because so many pollutants, like toxaphene, become stored in fat, they accumulate most efficiently in animals that must fatten up to survive hard winters, as the subarctic Laberge fish do.

Kidd and her coworkers now report that among Yukon lakes receiving comparable toxaphene fallout from air, Laberge's fish eat more flesh and less insects, crustaceans, and plankton. This "is the sole reason for [their] elevated toxaphene concentrations," they conclude.

Why are Laberge fish so piscivorous? Because of recent overfishing at the lake, the fish that survive may face fewer competitors for the juvenile fish they prefer to eat, suspects coauthor David W. Schindler, an ecologist at the University of Alberta in Edmonton.

Many people had assumed that the accumulation of toxic chemicals in fish is governed by what falls out of the air