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.

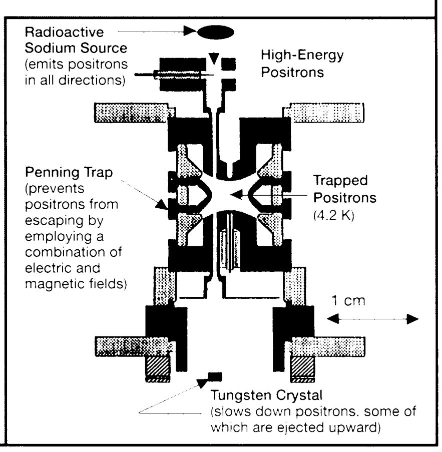
The researchers use radioactive sodium-22 as a source of high-energy positrons. Guided by strong magnetic fields, a fraction of these positrons strikes a tungsten crystal, which slows down the particles (see diagram).

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.

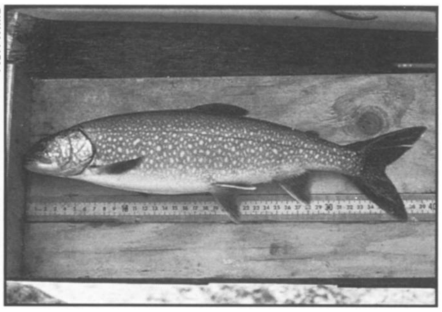
Kidd and her coworkers now report that among Yukon lakes receiving comparable toxaphene fallout from air, Laberge's fish eat more flesh and less insects, crustaceans, and plankton. This "is the sole reason for [their] elevated toxaphene concentrations," they conclude.

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 and into the water, observes Terry F. Bidleman, an environmental chemist with Canada's Atmospheric Environment Service in Downsview, Ontario. "But Karen Kidd's paper is showing clearly this is not the case—there's a strong food-chain factor which is likely to be quite different from lake to lake."

Her findings also explain the differential contamination of fish in remote, neighboring lakes in Ontario, notes David R.S. Lean with Environment Canada's National Water Research Institute in Apsley, Ontario. "The only difference [between the lakes] is in the food chain."

Lean says these recent findings of toxaphene throughout the Arctic and subarctic are scary because they "beg the question: If this was banned for so long and we're just finding it, how many things just as bad may be here that we haven't looked for?" *—J. Raloff*



Ken Mills

The fat that allows this lake trout to survive long winters also fosters the buildup of toxicants such as toxaphene.

Nicotine plays deadly role in infant death

As a result of studies associating smoking with miscarriage and sudden infant death syndrome (SIDS), pregnant women are usually advised by their doctors to kick the habit (SN: 3/11/95, p.151). A new study adds weight to that advice and explains how smoking may lead to SIDS.

A group of North Carolina researchers found that rats exposed to nicotine as fetuses were born without the ability to adjust to periods of oxygen deprivation, resulting in a rodent syndrome resembling SIDS. That finding could result in pregnant women being advised to forgo the nicotine patch as well as smoking.

"Perhaps pregnant women should be advised to go cold turkey," says study leader Theodore A. Slotkin of Duke University Medical Center in Durham, N.C.

The researchers gave pregnant rats nicotine in dosages representative of either moderate smoking (the equivalent of 10 cigarettes per day) or heavy smoking (40 cigarettes per day). Control animals received only water. The researchers then exposed the newborn pups to low oxygen concentrations similar to what they would experience if they suffered from sleep apnea, the transient cessation of breathing during sleep. One-third of the pups exposed to nicotine before birth died, while all of the control pups survived.

As the team reports in the July BRAIN RESEARCH BULLETIN, the nicotine-exposed pups that died failed to produce the stress hormones adrenaline and noradrenaline when faced with oxygen deprivation. Without this response, they couldn't maintain a normal heartbeat.

The results of prenatal exposure to nicotine continue after birth, says Slotkin. In humans, the nervous system develops throughout the first year of life. During that time, the adrenal glands, which produce the stress hormones, aren't fully integrated into the nervous system. In infancy, immature cells in those glands respond to low oxygen by producing a surge of stress hormones. Later, after nerve cells reach the adrenal glands and cause the cells to mature, the nervous system takes over control of hormone output.

Nicotine, by mimicking nervous system chemicals, forces the adrenal cells to mature prematurely, so they cannot secrete stress hormones without the go-ahead from the nervous system. The result, says Slotkin, is a child with "no defenses against low oxygen until nerves innervate his adrenal glands around his first birthday."

Slotkin's results may allow researchers to check adrenal function and identify infants likely to suffer from SIDS, says Marian Willinger of the National Institute of Child Health and Human Development in Bethesda, Md. *—L. Seachrist*

Feeding microbes to get rid of nitrates

Many sources of drinking water, polluted by fertilizers and other contaminants, contain high concentrations of nitrate, which studies have shown to cause cancer in humans. No simple method exists for removing nitrates, and groundwater rich in this contaminant has little use except on crops.

Now, researchers at the Department of Agriculture's Agricultural Research Service (ARS) in Fort Collins, Colo., say they may have a technique for reducing nitrate concentrations by supplying corn or soybean oil to microbes living in aquifers.

To survive, the microorganisms require carbon and either nitrate or oxygen to oxidize the carbon. Adding oil to nitrate-rich water provides a source of extra carbon that enables the microbes to make use of the abundant nitrogen, report William J. Hunter and Ronald F. Follett in the July AGRICULTURAL RESEARCH. Microbes convert most of their nitrate supply into harmless nitrogen gas.

Follett and Hunter tested their idea for groundwater cleanup by injecting oil into glass tubes containing sand and water from a polluted aquifer. The researchers then pumped the water slowly through the tubes. The water had 14 to 19 milligrams of nitrate-nitrogen (the nitrogen present in nitrates) per liter, which exceeds the safe concentration of 10 milligrams per liter, says Follett.

The oil became embedded in the sand, where it and the microbes formed an organic filter in the tube. Within 1 to 2 days of the oil infusion, the microbes began removing nitrates from the water that passed through the tube. As long as they had enough oil, the microbes kept nitrate concentrations to almost zero for the year-long experiment.

One gram of oil enabled the microbes to remove 260 milligrams of nitrate-nitrogen from 26 liters of water, the ARS team calculates.

An oil-based approach to removing nitrogen could have pitfalls, the scientists acknowledge. The microbe-oil filter could plug up pores in aquifers; make water taste or smell bad or be totally undrinkable; or pollute water with nitrites, a dangerous by-product of denitrification, they note.

The researchers hope to conduct field tests, in which they will either inject a mixture of oil and water near the base of a well or force oil down a well, says Hunter. They may also devise an above-ground water filter that uses oil.

"Overall, I think it's an intriguing concept," says Ralph S. Baker of ENSR Consulting, Engineering, and Remediation in Acton, Mass. However, "there's a lot of work to do to make something like this effective," he warns, citing particularly the concerns about clogging and nitrite production.

Battelle Memorial Institute, a research group in Richland, Wash., has a patent on a similar oil-based system for removing nitrates from water. A Battelle scientist, formerly with ARS, came up with the idea for the technology, but the institute has not formally tested it, says Glendon W. Gee of Battelle. The institute is looking for a commercial partner to help develop the system.

Other researchers have used bacteria to remove heavy metals and organic chemicals from damp soil. One group grows bacteria on blankets of coconut hull fibers that it then lays on contaminated areas (SN: 3/4/95, p.138). *—T. Adler*