Optical Molasses: Atoms in the Deep Freeze

A gas of free atoms can get a lot colder than anyone had thought, according to recent experiments using lasers to cool atoms. Careful measurements show that such laser systems can slow down sodium atoms to produce a gas with a temperature of roughly 43 microkelvins, a fraction of a degree above absolute zero. This temperature is well below the theoretical cooling limit of 240 microkelvins predicted for laser cooling.

"We believe that we have produced the coldest [three-dimensional] gas ever observed," William D. Phillips of the National Bureau of Standards (NBS) in Gaithersburg, Md., and his colleagues report in the July 11 PHYSICAL REVIEW LETTERS. Lower temperatures have been achieved only among atoms confined to a narrow, essentially one-dimensional beam.

The results also indicate that the generally accepted theory of laser cooling is faulty and must be modified. "We were astounded by these results because the cooling limit is something that has been accepted as applying to the kinds of systems that we were studying," Phillips says. Research groups at Stanford and the University of Colorado and in Paris have now confirmed the NBS findings.

Laser cooling begins with the firing of precisely tuned laser light into the face of an onrushing beam of sodium atoms. For each photon of laser light absorbed, the atoms slow down by a certain amount (SN: 3/23/85, p.183). After the atoms have been slowed sufficiently, they are moved into a region of "optical molasses." Here, six crisscrossing laser beams create an environment that makes the sodium atoms behave as if they were suspended in a viscous fluid, in effect confining the sodium atoms for a time (SN: 6/21/86, p.388). In a typical experiment, the optical molasses has a volume of 1 cubic centimeter and contains about 10 million atoms moving at an average speed of 10 centimeters per second, a five-thousandth of their speed at room temperature.

Theory predicts that the gas temperature achieved depends on a balance between the cooling effect of the laser beams and the heating produced by the emission of photons from the atoms. This balance sets the cooling limit. Early experiments by the NBS team and other groups produced temperatures very near the predicted cooling limit.

"This is always a danger when making measurements," Phillips says. "There are lots of things that can affect the accuracy of your measurements, and you tend to look harder for them when you're not getting the answer you expect. In this case, it was initially satisfying to get the same result that everybody else was getting and the one that was predicted by theory. For a little while, it escaped our attention that there was something really fishy going on."

But the researchers observed enough inconsistencies in subsequent results that they decided to try the experiments again with improved temperature measurements and a more detailed look at the effect of subtle shifts in laser frequency. That led to the observation of atoms at 43 microkelvins and suggested that the theory of laser cooling had to be revised.

Steven Chu of Stanford University and a group at the Ecole Normale Supérieure in Paris have independently come up with similar explanations for the NBS results. The original theory assumed laser cooling was associated with a simple transition between two different energy levels in a sodium atom. In reality, these energy levels can split into sublevels in the presence of a magnetic field or a laser-induced electric field. Because the electric field within the optical molasses is not uniform, atoms moving about encounter varying electric fields and interact in a complex way with the laser beams. As a consequence, the atoms are slowed down more than expected.

"It's a new way of cooling that had not been anticipated in any theory," Chu says.

"At this point, those explanations need to be viewed as preliminary but very promising," says Phillips. "They seem to explain most of the features of the results that we see. But I'll be a lot more satisfied when they predict something that we haven't measured yet. Then we can measure it to see if, in fact, that's the case."

In laser-cooling applications such as atomic spectroscopy or the study of low-energy atomic collisions, the colder the atoms, the better. "Optical molasses is the standard starting point for just about anyone's laser-cooling experiments," says Chu. "Now we have a better [lower-temperature] starting point." *—I. Peterson*

A radical role for dietary fish oils

Numerous recent studies in animals and humans link consumption of marine fish and their oils with a decreased risk of heart disease. But the mechanisms accounting for these associations have remained unclear. Now biochemists at the Cleveland Clinic Research Institute report evidence suggesting a possible explanation of how fish oils may reduce artery-clogging atherosclerosis. And the surprise is that free radicals (reactive oxygen species) — and not the oils' highly touted omega-3 fatty acids — may lie behind the oils' beneficial effects.

One factor contributing to the development of atherosclerotic lesions is the proliferation of smooth-muscle cells near the interior surface of arteries. Previously, Paul E. DiCorleto and colleagues at the University of Washington in Seattle showed that endothelial cells, which make up the interior surface of arteries and veins, produce a biological factor — known as PDGFc — that promotes the growth of smooth-muscle cells. In the July 22 SCIENCE, Paul L. Fox and DiCorleto, now at the Cleveland Clinic, report fish oils can inhibit PDGFc formation. And the inhibition of this protein was selective, Fox notes: With the exception of PDGFc, the cultured cells' protein synthesis was normal.

"What we're now speculating," Fox says, "is that the production of this growth factor in humans might be inhibited by eating fish oil." If that's true, he adds, then it's also possible that the growth of smooth-muscle cells might fall, limiting atherosclerosis development.

What tends to distinguish marine-fish oils from other fats is their high level of omega-3 fatty acids. However, "while we can't yet preclude that the effect we saw is due to omega-3, we feel rather strongly that oxidation is responsible," Fox told SCIENCE NEWS. One reason, he explains, is that safflower oil — a fat containing almost no omega-3 — also suppressed PDGFc formation, although with only a tenth or twentieth the potency of fish oil. Safflower oil is mildly susceptible to oxidation, however, and fish oil extremely so. Moreover, when antioxidants were added to the cells cultured with fish oil, PDGFc production was normal.

William Lands, who studies the biochemistry of atherosclerosis at the University of Illinois at Chicago, calls the findings "very interesting." However, Lands adds, one has to question how relevant these findings are to modeling fish oils' role in the body, where antioxidants can abound. That's true, Fox concedes. He adds, however, that there is still some question about the levels of antioxidants present in the arterial wall. And that, he notes, is where their research suggests PDGFc production might be affected. *—J. Raloff*