Atomic evaporation in liquid helium

For the first time, a British research team has demonstrated that an individual heat pulse can eject a single atom from the surface of a liquid. This quantum evaporation process is the thermal equivalent of the photoelectric effect in which light, behaving like a stream of particles (photons), can knock electrons out of materials. In the newly observed "phonokinetic" effect, high-energy phonons (particle-like packets of waves that carry heat) eject atoms from a liquid surface.

In the July 28 NATURE, M.J. Baird and his colleagues at the University of Exeter in England report, "The interaction between the phonons and surface atoms is a one-to-one quantum process as has been conjectured by several authors but has not hitherto been demonstrated. ... Liquid [helium], therefore, is the first liquid in which we can understand evaporation at the atomic level."

The researchers used a bath of superfluid helium at 0.1 kelvin, a temperature low enough to ensure that the space above the liquid is an excellent vacuum. Thus, any liberated atom would move in a straight line with a negligible chance of being deflected before it is detected. An immersed heater produced a burst of phonons that traveled upward toward the liquid's surface. These phonons either reflected from the surface or knocked out atoms that could be detected by a sensitive instrument in the space above the liquid. The phonons and ejected atoms traveled along the same straight line.

The heater was always at a fixed distance below the detector, but the whole system could be raised or lowered, keeping the total path length constant. Baird's group was able to deduce the time taken for the phonons to go from the heater to the surface and for the ejected atoms to travel from the surface to the detector. They found that the phonon energy equaled the sum of the binding energy (the energy an escaping atom requires to overcome the forces that hold it to a liquid's surface) and the kinetic energy of the ejected atom.

John F. Allen of the University of St. Andrews in Great Britain, in the same issue of NATURE, comments, "What has been lacking has been the ability to produce an identifiable high-energy phonon to knock an identifiable atom from the liquid." This experiment clearly establishes "that we can speak of a phonokinetic effect which is the analogue of the photoelectric effect," he concludes. —*I. Peterson*

Vapor method yields elusive metallic glass

Iron and silver are like oil and water; they don't mix. In the past this presented difficulties for metallurgists wanting to produce an alloy from these elements. In separate but concurrent studies, researchers in both the United States and Japan have now found a way to fabricate an iron-silver (Fe-Ag) blend with a technique that should prove promising in the manufacture of other previously inaccessible alloys.

Since metallurgists usually rely on mixing in the liquid state to provide uniformity in alloys, a new method was needed to form blends such as Fe-Ag in which the elements are insoluble in the molten form. The "vapor-quench" technique has reportedly done the trick, according to physicists Chia-Ling Chien and Karl M. Unruh of Johns Hopkins University in Baltimore, Md. They report in the Aug. 1 PHYSICAL REVIEW that they were able to achieve a 50:50 Fe-Ag mix by vaporizing individual atoms off the surface of an Fe-Ag pressed-powder cake. A thin film of the blend was then deposited onto supercold metallic or polymer plates.

David J. Sellmyer, physics chairman at the University of Nebraska in Lincoln, predicts that the success of this technique will prompt other researchers to make additional artificial alloys. "It often happens that in making these materials you discover interesting new properties that haven't been seen before," he says.

Some material scientists are reserving judgment. David Turnbull, an applied physicist at Harvard University in Cambridge, Mass., feels that Chien and Unruh's result, if confirmed, would be highly significant but is concerned about the homogeneity of the new Fe-Ag alloy. "It may be homogeneous," he says, "but I would not be convinced without further tests showing that it is well-mixed with 50:50 compositions at the atomic level." Chien, however, remains confident that his sample is uniform to within 2 percent.

Chemical compounds, such as table salt, are mixtures of elements locked into a strict crystalline structure that specifies the exact ratio of one elemental concentration to the others. The components of alloys, however, are usually so atomically similar to one another that atoms of one element can substitute for another in a crystalline network, as they do in steel. As a result, alloys can be formed with a variety of compositions.

An amorphous solid, such as the new Fe-Ag glass and common glass, is an alloy that lacks the usual crystalline structure. The random arrangement of the atoms in amorphous metals results in physical properties quite different from those of crystalline alloys. These metallic glasses, as they are called, are often tougher, more corrosion resistant and more easily magnetized than their crystalline counterparts, giving them a variety of industrial applications (SN: 12/12/81, p. 380).

Chien and Unruh's work is the first report of a concentrated metallic glass produced from a system of elements with no known compounds or crystalline alloys. The Fe-Ag glass is a "metastable" state, however, and if pushed to temperatures above about 250°C it will begin to separate and crystallize.

If iron and silver have such an aversion to each other, what binds the atoms together in the new metallic glass? Chien suspects that strong cohesive forces in iron may be responsible and that the silver atoms may simply be trapped between them. He remarks that this Fe-Ag alloy "puts on the defensive" the so-called micro-crystalline theories of amorphous solids, which imply that the presence of a metallic glass is linked to the existence of a crystalline counterpart. —*P.D. Sackett*

'Major milestone' in laser weapons tests

In the first successful tests of its kind, an airborne laser recently "defeated" missiles launched at it from another aircraft. The U.S. Air Force tests, announced July 25, marked completion of a series of experiments involving the Airborne Laser Laboratory. This flying test station, which the Air Force stresses is highly experimental and not a prototype weapon system, disabled five AIM-9 Sidewinder air-to-air heat-seeking missiles, causing them to veer off target and eventually crash-land.

The challenge was to target and track an incoming missile precisely so that the infrared (carbon dioxide gas) laser could continuously illuminate one point on the missile's exterior long enough to burn through and destroy its sensitive guidance components inside. Initial trials two years ago ended in failure. Even this time, the Airborne Laser Laboratory's first eight attempts were unsuccessful. Explains Major Sam Giammo of the Air Force Systems Command, "We'd fire one [Sidewinder], fine tune the equipment a little bit, then fire another." This was over a period of two weeks at the end of May. "But once we got the equipment calibrated," he said, "we were five for five."

The Air Force is calling the achievement "a major milestone" in its high-energy laser program. It is one of the most visible advances in research by the Department of Defense (DOD) on directed-energy weaponry. Although this particular effort began long before DOD outlined its Space Laser Program Plan last year, Giammo acknowledged the technology demonstrated in these tests would apply to other DOD laser programs.

Over the past year, DOD has expressed growing interest in laser weapons — particularly for defensive purposes; for use against incoming enemy missiles and for protection of important data-gathering

satellites in space. Describing his agency's new posture before the Senate subcommittee on strategic and theater nuclear forces earlier this year, Undersecretary for Directed Energy Weapons Major General Donald Lamberson said DOD currently expects to spend $900 million for research on space lasers during the next five years, prior to beginning expensive demonstrations in orbit. Roughly $600 million will go for programs to investigate the technical feasibility and cost effectiveness of using lasers in space. Three programs directed by the Defense Advanced Research Projects Agency (DARPA) — ALPHA, LODE, and TALON GOLD — will dominate these efforts.

Lamberson says ALPHA is investigating the prospects for high-powered mid-infrared-wavelength devices, though some shorter-wavelength laser systems are being looked at too. LODE is examining the feasibility of producing very large, precision mirrors to direct laser beams at their targets. It is also focusing on the difficulties of directing these beams at high brightness levels. TALON GOLD is concentrating on problems associated with locking a laser beam onto a moving target from space — a target that will likely be moving five or more times faster than the Sidewinders encountered in the recent Air Force tests.

The Army's role in the Space Laser Program is more modest. Focusing on ballistic-missile defense, it is chiefly investigating the extent to which missiles can be "hardened" (protected) against laser radiation. The Army is also concentrating on short-wavelength lasers, the type expected to prove most useful in space operations. For its part, the Air Force is studying the hardening of aircraft, satellites and other potential targets for their survival under an attack by enemy weapons, including lasers.

Responding to a growing public concern over the further militarization of space, DARPA Director Robert Cooper told the Congress on March 23 of this year, "We are conducting research and planning related to space weaponry, but I emphasize that no commitment has been made to acquire space-based weapons. And, we will proceed only if our national security is so threatened." —*J. Raloff*

Ozone: Selective force in plant evolution?

Scientists, spurred by the prediction that in the next decade stratospheric ozone may be partially depleted, are trying to learn how such a decrease might affect not only human health, but plant health too. One such study has led researchers to suggest that plants that originated at tropical and temperate latitudes display different levels of sensitivity to solar ultraviolet-B (UV-B) radiation, much of which is absorbed by the ozone layer before reaching the earth.

Earlier research also has shown that plants now living at different latitudes vary widely in their tolerance to ultraviolet-B radiation. The amount of UV-B that reaches the earth is linked to the thickness of the ozone layer because stratospheric ozone absorbs most of the invisible light before it touches the planet. Plants growing in tropical latitudes, where natural levels of UV-B are the highest on earth, are more resistant to the radiation than plants in temperate latitudes, where most of the world's food crops are grown. Botanists Alan Teramura of the University of Maryland in College Park, and Martyn Caldwell of Utah State University in Logan, report that the degree of tolerance to UV-B is related to the level of the radiation at the time specific plants evolved. The ozone layer and its effect on UV-B, they say, may have been a selective factor in plant evolution.

In field studies and controlled experiments, 90 agricultural plant species were exposed to UV-B. At first the researchers could not identify a common factor within plant families that makes the plants more or less resistant to the radiation. But when the researchers considered where the plants originated, they found that three times as many crops that evolved in temperate latitudes in the Near East, Northern China and Mesoamerica (roughly north central North America to Nicaragua) were adversely affected by the same level of UV-B as crops that evolved in tropical latitudes in mid-Africa, Southeast Asia and South America. Teramura and Caldwell assert that naturally occurring UV-B has been an "important selective force in the evolutionary history of these agricultural species."

The plants with low resistance to UV-B are particularly vulnerable, the scientists found, because increases in UV-B radiation inhibit their photosynthesis, result in smaller plant size and smaller leaf area, and reduce yield and yield quality. Soybeans, for instance, fare poorly when UV-B levels are too great. The crop is cultivated because its seeds contain high proportions of oils and proteins. Some varieties, Teramura says, produce less oil and protein when exposed to levels of UV-B that are outside the tolerance ranges of the plants.

It is estimated that the protective layer of stratospheric ozone may be depleted from 5 to 9 percent in the next decade, primarily due to human use of chlorofluorocarbons in refrigerants and other industrial applications (SN: 4/10/82, p. 244). The increase in UV-B radiation would be disproportionately large at temperate latitudes, scientists say, with a 19 percent increase in the amount of UV-B radiation capable of affecting plant biology.

—*C. Simon*

Sex switch stimulated by size

In the lonely hearts club of coral reef fish, when the going gets tough, the tough change sex. Many fish are hermaphroditic, but most species change sex because they lack a nearby mate. For the first time, researchers have now found at least one species that bases its sex on the relative size, not the sex, of its neighbors.

Female saddleback wrasse *(Thalassoma duperrey)* can change to male. While smaller fish of either sex stimulate a female to switch, larger fish inhibit such a change. "Basically, if you put two of these fish together, only the bigger one will become a male," says Milton Diamond of the University of Hawaii in Honolulu.

As a result, the larger fish are usually male, either by birth or by subsequent sex change. On the reef, a relatively small female is likely to encounter males. But if the proportion of larger fish drops, a female would find more mates if she changed sex. "Since fish are considered to be fairly highly evolved, this brings up a number of philosophical implications," says Diamond. "The social situation of these animals determines their sexual physiology and behavior."

Like most fish, the dull green saddleback wrasse has no detectable sex chromosomes, yet when it reaches sexual maturity, it produces either sperm or eggs. "The initial sex is probably determined by multiple sites on different chromosomes," says Robert M. Ross, of the Hawaii Institute of Marine Biology in Kaneohe. "This makes the wrasse very sexually labile." Females can later stop producing eggs and start producing sperm. This protogynous (female first) sex change takes two to three months and is non-reversible. Since the wrasse cannot produce both sperm and eggs simultaneously, it cannot fertilize itself. Says Ross, "Virtually all females eventually become males, given the right social conditions."

To determine those conditions the Hawaii group studied isolated females, and females placed with one to three smaller, sexually mature fish. As reported in the Aug. 5 SCIENCE, the lone females continued to produce eggs, as did those in pens with larger saddleback wrasse or smaller fish of another species. But females that were the largest of their species changed sex even if the smaller fish were male.

In species that live in Harems, removing the dominant male prompts the largest female to switch sex. But the social structure of the promiscuous saddleback, which breeds in temporary pairs or swarms, is less clear-cut. "You can't usually tell a male from a female by color," says Ross. "The size ratio of nearby fish may be the best clue to sexual strategy."

—*S. Steinberg*