Organic Superconductor, Made Without Metals

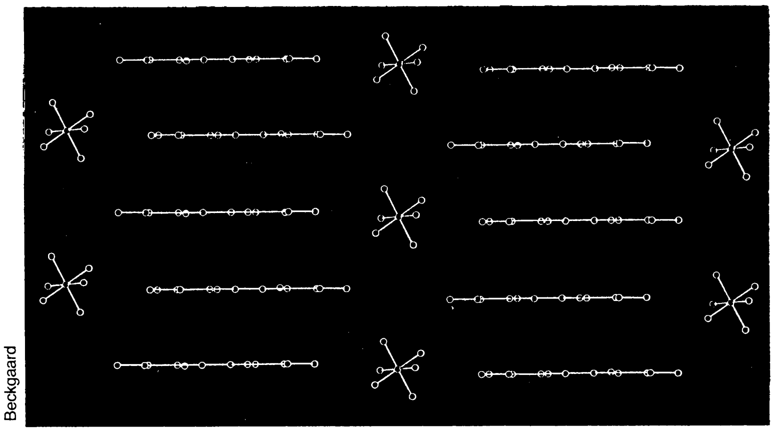
Heike Kammerlingh Onnes discovered superconductivity in 1911. Since then there has been a continuing search for new superconducting materials. Until now all that had been found were metals or metal compounds. Now there is a superconducting organic compound, one that has no metals in its composition. The demonstration of its superconductivity was reported at last week's meeting of the American Physical Society in New York by Denis Jerome of the University of Paris South in Orsay, France.

The search for new superconducting materials is motivated in part by technological desires, in part by the wish to demonstrate new physics. Superconductivity is the property of conducting an electrical current without resistance. Superconducting circuit elements do not dissipate energy in resistance heating. The saving is potentially tremendous.

The hitch is that any superconductor becomes superconducting only below a certain critical temperature, T_c. For all known superconductors T_c is within a few degrees of absolute zero. The only refrigerant that will cool things to those levels — below 20°K — is liquid helium, which is rare and difficult to work with.

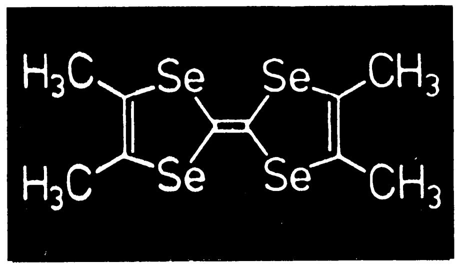
There are always dreams of room-temperature superconductivity, but most physicists would be happy just to get above the helium range. "What everyone wanted was to increase T_c to work with cryogenic fluid other than helium," says Jerome. "If you could work with hydrogen, it would be less expensive." It seemed that substances known as molecular conductors might have enhanced T_c. By an amendment to the usual theory of superconductivity, it seemed that the electrons responsible for superconductivity might interact with the whole molecule in molecular conductors instead of with the crystal lattice as they do in superconducting metals, and this could raise T_c.

For superconductivity to exist, the conduction electrons of the substance, which are normally single, must form pairs with oppositely directed spins. In pairs they can sail through the material unhindered by the attraction of the ions. Because negatively charged electrons repel each other, pairs can form only under the influence of an intermediary that converts the repulsion to a net attraction. In superconducting metals the intermediary is an interaction between the electrons and the vibrations of the crystal lattice (called phonons). In a molecular conductor vibrations of the whole molecule might theoretically be the intermediary. This would change the energy in such a way that higher critical temperatures than those customary for metals might result.



Beckgaard

In the organic superconductor TMTSF *molecules (below) form planar stacks held together by phosphorous hexafluoride molecules (section at left).*



"If you believe in theory," says Jerome, "and we don't believe too much — but a little bit."

"You need a molecule which can be polarized and has internal modes of vibration," says Jerome. Molecular conductors entered physics in 1972 with the famous organic compound TTF-TCNQ. This had a promising relation between temperature and conductivity. "An understanding of electronic principles allowed synthesis of a new compound, TMTSF-DMTCNQ," says Jerome. It had better properties. Finally came $(TMTSF)_2PF_6$, the idea for which came from Klaus Beckgaard of the H.C. Oersted Institute in Copenhagen. It becomes superconducting below 0.9°K and under a pressure of 12 kilobar. It doesn't seem immediately practical, but it shows that "superconductivity in organic matter ... exists ...," as Jerome says. He believes $(TMTSF)_2PF_6$ is the precursor of a family of superconducting organics, some of which will not need the pressure, and some of which will show critical temperatures perhaps up to 40°K. □

Sweet medicine: Tiny pumps and packets

The hypodermic needle, the capsule and the spoonful of medicine are on their way out, according to polymer chemists. Drugs of the near future will be supplied in more convenient vehicles that will provide a constant level of therapeutic agent over long periods of time. A few such medicinals are already on the market (SN: 2/17/79, p. 102). A variety of new strategies were described last week at the meeting of the American Chemical Society in Houston. Some are in clinical trials, while others are barely off the drawing board.

One device, already tested on patients, is a portable system to deliver drugs intravenously to ambulatory patients. It has allowed persons receiving cancer chemotherapy to leave the hospital and participate in work and sports, while receiving continuous drug treatment. The system, which was developed by the Alza Corp. of Palo Alto, Calif., consists of a thin catheter that remains inserted into a vein and a drug-containing cartridge that can be changed daily. The drug is introduced into the vein under constant pressure from the cartridge's elastomeric reservoir. Alejandro Zaffaroni, president of Alza, says the device has been licensed for use beginning next year.

To deliver drugs orally, Alza scientists have developed an elementary osmotic pump that the patient swallows. Essentially it is a shell made of cellulose esters and filled with crystalline material. Water gradually passes through the polymer shell and dissolves the contents, which are pumped by osmotic pressure out through a tiny hole made by a laser in the shell. Zaffaroni says the shell remains intact in the stomach and intestines until it is eliminated from the body. It can pump its contents continuously for many days, although it would remain in the digestive tract only for about 24 hours. Working with pharmaceutical companies, Alza is attempting to put a variety of drugs into such pumps. Theophylline and an anti-inflammatory drug are already under development. The system allows drugs to be taken only once or twice a day instead of more frequently and provides much smaller fluctuations of drug level in the blood, Zaffaroni says.

An injectable contraceptive is another project receiving much attention at Alza and elsewhere. The Alza scientists have developed a system in which the contraceptive drug is bound within a matrix of a hydrophobic material, a polyorthoester. As the surface of the matrix erodes, the hormone is gradually released. In the first clinical trials, among women in Sweden, one administration provided a constant level of the contraceptive hormone for six months.

Another approach to long-term contraception was presented by Gopi N. Gupta of Cornell University Medical College. Gupta and colleagues have developed a rice-size pellet containing 85 percent contraceptive hormone and 15 percent cholesterol, consolidated by a heat fusion technique. In monkeys, pellets under the skin gave a burst of drug and then a steady rate for three months. Gupta says that this method, similar to one used for delivering hormones for other treatments, has the advantage that the pellet dissolves completely into the hormone and a natural body component, cholesterol. Using the subcutaneous pellet, the effective daily dose of hormone is only one-tenth that of conventional oral contraceptives.

Biodegradable implants for a variety of drugs are the goal of scientists at Arthur D. Little, Inc. in Cambridge, Mass. Kenneth R. Sidman reports success with a small drug depot made of copolymers of L-glutamic acid, a naturally occurring amino acid. After the drug is released, the depot disintegrates into the amino acid and is metabolized completely. Sidman says these polymers can release a wide range of drugs. He is currently developing a pellet that releases a contraceptive for about a year after implantation. Other scientists are working on a depot for releasing a narcotic antagonist for use in anti drug abuse programs. Another team is using the pellets to provide a growth stimulant for livestock. Sidman predicts that clinical trials of a number of L-glutamic acid copolymer depots will begin within five years.

Even newer approaches to drug delivery are being investigated by Robert Langer of the Massachusetts Institute of Technology. All drug-plastic implants so far developed can only deliver drugs at constant or decreasing rates, Langer says. He recently has begun exploring a system that can release drugs at increased rates on demand. He adds small magnetic beads to the plastic of an implant and finds that a magnetic field can boost drug release by a factor of three. Langer suspects the magnetic field causes a "squeezing" of channels in the plastic, forcing out more drug. Such controlled release could be useful in cases in which increased drug release from an implant was desired during specific parts of the day or, for contraception, during specific periods of the menstrual cycle. □

Mt. St. Helens comes to life


Wide World

Sunday morning surprise: Mt. St. Helens sends up a cloud of smoke and ash.

Stretching from northern California through Oregon and Washington, up into southern Canada, the Cascade mountain range forms a bony spine along the western edge of the United States. Hikers, mountaineers and weekend vacationers are fondly familiar with the names Mts. Lassen, Shasta and Jefferson; the Three Sisters, Mt. St. Helens, Mt. Hood; Mts. Adams, Baker and Rainier, and, of course, Crater Lake. But most of the hikers tend to forget that these mountains are actually volcanoes, and that any of them could erupt at any time.

Last week "could" became "is" and many weekend mountain climbers turned into weekend geologists. The real geologists found themselves with a live volcano, the first in the continental United States to erupt since Mount Lassen in northern California dirtied up the surrounding countryside in 1915. Mt. St. Helens, the 9,677 ft. volcano in southwestern Washington State, has become active again.

Mt. St. Helens is 50 miles northeast of Portland, Ore., and only 30 miles due east of the Trojan nuclear power plant. It is a typical composite volcano — made of alternating layers of ash flows and lava — and has been compared in beauty to Mt. Fuji in Japan. It is one of the youngest of the Cascade volcanoes and the most active. In the last 500 years alone the mountain has erupted on an average of once very 100 years. The last episode began in the 1830s and continued sporadically — and sometimes spectacularly—until 1857.

The latest episode began March 20, when seismologists at the University of Washington in Seattle detected swarms of microquakes centered under the mountain. The frequency and intensity of the quakes increased over the next five days until by March 25 the seismometer near the volcano was saturated with quakes. Between 4 p.m. and 10 p.m. that evening, reported U.S. Geological Survey seismologist Craig Weaver, "We had 23 quakes larger than magnitude 4 on the Richter scale, an average of 4 per hour."

From that maximum, the earthquakes diminished in intensity if not frequency through March 26, and by that evening the number of quakes had dropped. Scientists, however, were not writing Mt. St. Helens off yet. A reduction in earthquakes often immediately precedes a volcanic eruption, and there was no reason that it couldn't be the case here.

Volcanologists didn't have to wait long to find out. On Thursday, March 27, the volcano erupted with a loud bang at 12:30 p.m. Ash and smoke began pouring from a newly blasted crater at the mountain's top, and soon Mt. St. Helens's east flanks were covered with a fine dusting of volcanic ash. Since then the mountain has remained active with only occasional pauses. Several mud slides have occurred as the glaciers and snow pack on the mountain began melting from the heat. The first crater, about 1,000 feet from the summit and about 300 by 450 feet in diameter, has been joined by a second crater about 30 feet away. Both craters, which lie in the crater scar from the 19th century activity, continue to widen and by Tuesday, April 1, had fused with one another to form one large opening. Steam explosions continue to come from the craters, sending columns of ash and smoke as high as 15,000 to 20,000 feet above sea level. Dust from the plume has been spotted settling to the ground as far as away as Spokane, about 300 miles to the northeast.

So far, USGS scientists report no evidence of juvenile, or newly formed, magma in their samples. This means, says one, that the volcano is still in the "throat-clearing" stage — spewing out old material. A University of Idaho geologist, however, claims to have found evidence for fresh magma. Charles R. Knowles re-