Superconductivity: A Physics Rush

In science, "recent" usually means "in the last few years." In the search for high-temperature superconductivity it has come to mean "yesterday."

High-temperature superconductivity is the physicist's dream that now seems to be coming true – in a tremendous rush. The discovery of substances that lose all electrical resistance at manageable temperatures has been a goal of researchers for 75 years. The discovery last year of a new class of substances that become superconductors at around 30 kelvins, made by J. Georg Bednorz and K. Alex Mueller of the IBM Zurich Research Laboratory in Switzerland, triggered an avalanche that continues to intensify. The news has run to Japan, to China, to the United States, and the superconducting transition temperatures of new substances keep going up – 52.5 K, 94 K, 98 K (SN: 3/14/87, p.164).

Last week in New York City, one of the most extraordinary sessions of the American Physical Society ever held – it ran from 7:30 p.m. to 3:15 a.m. and played to an audience of thousands – addressed the latest progress in the field. This includes a claim to superconductivity at 125 K (still unconfirmed by others), from C. Politis of the University of Karlsruhe, West Germany, and a report of indications of superconductivity at 234 K by a group from the University of California at Berkeley and the Lawrence Berkeley Laboratory (Alex Zettl, Angelica Stacy and Marvin Cohen). The next day, at a press conference, Koichi Kitazawa of the University of Tokyo related that he had learned just in the last few days, from Japanese newspapapaper reports, that a group at Kagoshima University had found room-temperature (300 K) superconductivity, or at least they seem to have found the Josephson effect – a superconducting phenomenon – at room temperature.

The meeting also displayed superconducting tapes and rings made of the new materials, a first step toward technological application.

The pace has been breathless, and it seems to be still accelerating. The first materials found by Bednorz and Mueller, whose superconducting transition temperatures around 30 K are 10 K higher than any previously known, are now called "low-temperature superconductors," *sic transit gloria mundi*. Announcements are dated by the hour: A summary put out by AT&T Bell Labs carried the overline "UPDATE – noon, 3/19/87."

Superconductivity, which was discovered in 1911 by Heike Kamerlingh Onnes of the University of Leiden, in the Netherlands, first appeared in solid mercury at a temperature of 4.2 K, which happens to be the liquefaction temperature of helium. Over the years, slow and painstaking work gradually pushed up the maximum temperature of superconductivity. The late Bernd Matthias, one of the great people in the field, used to show a graph of this progress. According to Robert Dynes of AT&T Bell Labs, if physicists had continued to proceed at the rate shown on that graph it should have taken until 2190 to reach the 94 K temperature that is the highest well-confirmed result as of today.

Refrigeration is one of the great hindrances to practical use of superconductors. Those in technological use now require liquid helium for refrigeration. Helium is rare, requires refrigeration to 4.2 K and is not a particularly effective coolant. Liquid nitrogen, essentially liquid air, is cheap, easy to obtain, a much better coolant than helium and needs cooling to only 77 K, a much easier refrigeration technology. Several of the new materials are superconducting at liquid nitrogen temperature, and neither experimenters nor theoreticians have been predicting any ceilings.

Some of the physicists seem to think it won't be too long before the appearance of superconductors that work at temperatures accessible to household refrigerators. The "unusual drops in resistance" – as Marvin Cohen of the University of California at Berkeley described what his group found in a compound of yttrium, barium, copper and oxygen at 234 K – occur at a temperature equal to -38°F. If that should prove to be superconductivity, a cold winter day in Bemidji or International Falls could give outdoor superconductivity. If that sounds like a joke, Paul Chu of the University of

IBM

Bednorz (left) and Mueller.

Houston notes that 80 K is already ambient temperature on the shadow sides of both natural and artificial objects in space. Some of these substances could work without refrigeration in those environments.

Difficulty of fabrication is another hindrance to using superconductors. The ones in current use are all metals or metal alloys, and some of them are hard to work or have inconvenient mechanical properties. The new materials reported at the meeting are copper oxides containing rare-earth elements. P.M. Grant of the IBM Almaden Research Center in San Jose, Calif., whose group has deciphered the crystal structure of the yttrium-barium-copper oxygen compounds, reports that it is a perovskite – a crystal of a basically octahedral shape – that seems to be built of layers that are alternately conducting and insulating.

Theorists who spoke at the meeting seemed to agree that the presence of copper and oxygen and the chemical relationship between them is important for superconductivity, but whether the relationship involves planes of atoms or simply lines of them is not agreed. Again, the presence of rare earths seems important, and that is slightly paradoxical, as rare earths are magnetic, and magnetism and superconductivity have usually been incompatible.

Particularly striking is a compound discovered at Los Alamos (N.M.) National Laboratory (LANL) that includes gadolinium, a particularly magnetic rare earth. As James Smith of LANL pointed out, gadolinium is something physicists used to introduce into a superconducting material to see how much of it was necessary to destroy the superconductivity. Here gadolinium seems to enhance it.

Incidentally, rare earths are rare chemically but not geologically. As pointed out by Zhongxian Zhao of the Academica Sinica group in Beijing, which first found a 94 K superconductor, China has rich deposits of rare earths, and so technological development of these compounds would be good for the Chinese economy as well as a benefit for all humanity.

Most theorists who spoke at the meet-

Louis de Broglie, 1892-1987

Louis, Duc de Broglie, one of last survivors of the group of brilliant physicists who developed modern physics and quantum mechanics, died in Paris, March 19, at the age of 94. His first academic degree was in history, but then he turned to science and the philosophy of science, receiving a D.Sc. degree from the Sorbonne in 1924 for work in which he predicted the quantum mechanical wave-particle duality of matter. After experimental physics had confirmed his prediction, he received the 1929 Nobel Prize for physics for the work. De Broglie spent most of his life as a teacher at the Sorbonne and at the Institut Henri Poincaré, both in Paris. □