The chemistry of superconductivity

The unprecedented rate of evolution — some would say revolution — in high-temperature superconductivity has catalyzed the physical sciences as few topics have since the World War II effort to harness the atom. In recent weeks, researchers have been abandoning sleep and home life to collaborate across disciplines and among laboratories in an all-out rush to understand why certain new copper oxides lose all electrical resistance at the "high" (above liquid-nitrogen) temperatures of 77 to 90 kelvins and beyond (SN: 3/28/87, p.196).

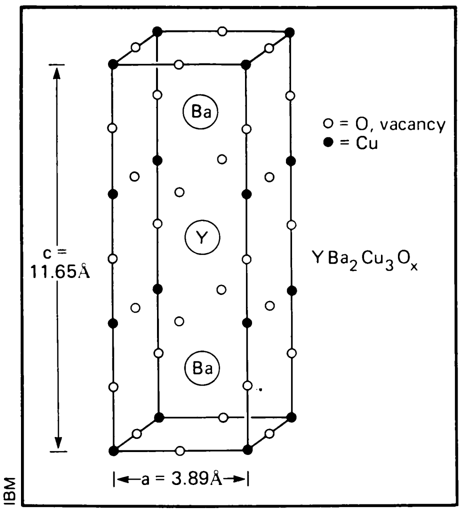
With only 10 days' planning, researchers presented a tutorial on the chemistry of these materials at the American Chemical Society's spring meeting in Denver last week. It was an important forum, according to Arthur Sleight of E.I. duPont de Nemours in Wilmington, Del., since the properties of and the production techniques for high-temperature superconducting materials "have largely been discovered through solid-state chemistry."

Sleight reports finding a new attribute associated with oxide superconductors. Previously, only one or two electrons were found occupying the essential ingredient's — say niobium's — d-orbital, or outermost subshell of electrons. In the new 90+K materials, where copper appears to be the essential element, there are nine. This suggests a new range of materials that may qualify for substitution, he says — those whose d-orbital is "nearly filled" instead of "nearly empty."

The first announcement of a 90+K superconductor — the highest-temperature material at which electrical resistance has been demonstrated to cease — was made by physicist Paul Chu and his colleagues (SN: 3/14/87, p.164). But no sooner had Chu begun circulating preprints on the work than chemists joined the fray. The Chu preprint arrived on a Friday, recalls Edward M. Engler of IBM Almaden Research Center in San Jose, Calif., and by Monday "at least a dozen laboratories that we knew of [had] made it [the material]."

All they had to go on was a one-sentence description of the Chu material's ingredients. But within a week of playing with the material, Engler says, "we [at IBM] found that the major phase in the superconducting component of the yttrium/barium/copper-oxide material is a variation of a well-known class of inorganic structures called perovskites [see diagram]." After identifying the chemical structure of the superconducting component out of the complex mix of crystals that formed, they developed a recipe for producing it in pure form.

His group got the highest "critical" (superconducting) temperatures from recipes whose starting ingredients had been "cooked" in pure oxygen instead of air, then cooled slowly. "This sensitivity to [production] conditions appears to be related to the amount and ordering of oxygen in the material," he says.



Left: One of first "usable," current-carrying superconducting perovskite wires, undergoing tests. Right: Basic structure of superconducting perovskite.

Thomas Mason, a solid-state chemist from Northwestern University's Materials Research Center in Evanston, Ill., has been developing some of the first "phase diagrams" — a mapping of which recipes, based on the same starting ingredients, produce stable materials — for the constituents used in the new 90+K superconductors. From these diagrams, materials designers can make more informed variations in their recipes for the next generation of superconductors.

Since Chu's first announcement, researchers have developed more than 20 new 77+K superconductors, which are being fashioned into crude but usable shapes — such as wires for magnets, and thin films for electronics applications.

— J. Raloff

Oodles of 'noodles' found in galaxy

Most people — including most astronomers — would consider stars to be the most common components of a galaxy. Now, a group of astronomers has found strange new objects, called "compact structures in the interstellar medium," that, by statistics at least, should prove to be more numerous than stars.

"Compact" means that these objects are about as big as the earth's orbit around the sun, and therefore larger than all but the biggest stars. They are, however, much smaller than the clouds that previous observations have detected in interstellar space. They reveal their presence by diffracting the radio waves coming from distant quasars. Ralph L. Fiedler, Brian K. Dennison and K.J. Johnston of the Naval Research Laboratory in Washington, D.C., and Anthony Hewish of Mullard Radio Astronomy Observatory in Cambridge, England, report the discovery in the April 16 NATURE.

The finding came from a program of daily observations of 36 quasars over a period of seven years. The data show that certain quasars undergo what seem to be sharp occultations: Their radio intensity drops off sharply, remains down for a month or so, then rises sharply again. It's as if a blob of ionized matter moved between the observer and the quasar. The objects move too fast to be near the quasar — to be that far away, they would have to go at 500 times the speed of light — so the observers conclude they are in our galaxy. Previous observers didn't see them, Fiedler says, because they didn't observe the same quasar at close enough intervals.

If the objects are roughly spherical, each one contains about the mass of an asteroid. But they could be elongated shapes, "more like noodles," Fiedler says. How they form, how long they last and what they may become are all open questions. If they last any length of time, something must supply the energy to maintain them in an ionized state. That too is a mystery. From the five instances so far found, the observers estimate that these objects may prove to be 500 or 1,000 times as numerous as stars.

Other astronomers are "very excited" by the discovery, Fiedler says, and are going to look at their favorite quasars for the same effect. His group plans to extend their observations to 400 quasars. If they find some good candidates, he says, they can then get some very long baseline interferometry done, to elucidate fine details of the structure of these objects.

— D. E. Thomsen