MATERIALS SCIENCE

Superconductor high spurs wave of physics

Researchers strive to reproduce and understand zero-resistance material that works at a record high temperature.

BY EDWIN CARTLIDGE

Hydrogen sulfide — the compound responsible for the smell of rotten eggs — conducts electricity without any resistance at a record high temperature of 203 kelvin (−70 °C), reports a paper published on 17 August in *Nature*[1].

The work is a step towards finding a long-sought room-temperature superconductor. The first results were released on the arXiv preprint server in December[2]; more followed in June[3]. Both have already sparked a wave of follow-up calculations and experiments, not to mention excitement.

The discovery is "historic", says physicist Fan Zhang of the University of Texas at Dallas, adding that its impact will be "far ranging". A superconductor that works at room temperature could improve electricity generation and transmission, as well as giving a boost to current uses of superconductivity, such as in the huge magnets used in medical imaging machines. In a News & Views article[4] that accompanies the *Nature* paper online, Igor Mazin of the Naval Research Laboratory in Washington DC describes the finding as "the holy grail of superconductors".

The results are the work of Mikhail Eremets, Alexander Drozdov and their colleagues at the Max Planck Institute for Chemistry in Mainz, Germany. They find that when they subject samples of hydrogen sulfide to extremely high pressures — around 1.5 million atmospheres (150 gigapascals) — and cool them below 203 K, the samples display the classic hallmarks of superconductivity: zero electrical resistance and a phenomenon known as the Meissner effect, in which a material is placed in an external magnetic field but there is no field inside the sample, unlike in normal materials.

DEFYING CONVENTION

Other scientists are intensely interested in the result because it was achieved without using exotic materials such as copper-containing compounds called cuprates, says physicist Christoph Heil of the Graz University of Technology in Austria. Until now, these have held the record for the highest superconducting temperature — 133 K (−140 °C) at ambient pressure and 164 K (−109 °C) at high pressure.

Many scientists had assumed that superconductivity at temperatures of more than a few tens of kelvins required such materials. But Heil says that the pressurized hydrogen sulfide seems to be a 'conventional' superconductor — vibrations in the material's crystal lattice drive electrons to form 'Cooper pairs' that can flow through the crystal without resistance. And in calculations reported in April[5], Matteo Calandra of the Pierre and Marie Curie University in Paris and his colleagues found that the results could indeed be explained using a modified version of the conventional theory of low-temperature superconductivity based on lattice vibrations.

For others, such theoretical analyses are superfluous until the result by Eremets and co-workers is confirmed experimentally by independent teams. Several are working towards that goal, including Katsuya Shimizu of Osaka University in Japan and his colleagues, who have seen the loss of resistance in pressurized hydrogen sulfide, but have yet to observe the Meissner effect. Meanwhile, three Chinese groups and one US team contacted by *Nature* say that they have yet to confirm either the electrical or magnetic effects.

If Eremets and colleagues are proved right, then other compounds that pair hydrogen with, for instance, platinum, potassium, selenium or tellurium instead of sulfur may also be good candidates for high-temperature superconductivity, according to several other research groups. Taking a different tack, Zhang in Dallas and Yugui Yao of the Beijing Institute of Technology in China predict[6] that substituting 7.5% of the sulfur atoms in hydrogen sulfide with phosphorus and upping the pressure to 2.5 million atmospheres could raise the superconducting transition temperature all the way to 280 K, which is above the freezing point of water. ■

1. Drozdov, A. P., Eremets, M. I., Troyan, I. A., Ksenofontov, V. & Shylin, S. I. *Nature* http://dx.doi.org/10.1038/nature14964 (2015).
2. Drozdov, A. P., Eremets, M. I. & Troyan, I. A. Preprint at http://arxiv.org/abs/1412.0460 (2014).
3. Drozdov, A. P., Eremets, M. I., Troyan, I. A., Ksenofontov, V. & Shylin, S. I. Preprint at http://arxiv.org/abs/1506.08190 (2015).
4. Mazin, I. *Nature* http://dx.doi.org/10.1038/nature15203 (2015).
5. Errea, I. *et al. Phys. Rev. Lett.* **114,** 157004 (2015).
6. Ge, Y., Zhang, F. & Yao, Y. Preprint at http://arxiv.org/abs/1507.08525 (2015).