search & discovery

Soviet and US groups seek hydrogen's metallic phase

A group of Russian experimenters has recently reported (*ZhETF Pis. Red.* **5**, 286, 1972) that they may have produced metallic hydrogen at a pressure of 2.8 megabars; at the transition the density changed from 1.08 to 1.3 g/cm³. Last year a Livermore group reported on an apparently similar experiment in which they observed a pressure—volume point centered at 2 megabars and 1 cm³/g. Some people have predicted that metallic hydrogen might be metastable, and others that it would be a room-temperature superconductor.

The Russian experimenters, F. V. Grivorev, S. B. Kormer, O. L. Mikhailova, A. P. Tolochko and V. D. Urlin, work at an unknown Soviet institute, which some believe is defense-related. Although their paper does not give too much experimental detail, it does say that they measured the density of hydrogen by gamma radiography during isentropic compression by a cylindrical charge of high explosive. The explosive accelerates a shell that compresses gaseous hydrogen to high densities and pressures. To measure the diameter of the cavity containing the compressed hydrogen as the shell converges to the axis, Grivorev and his collaborators use a gamma-radiography device with a short exposure time; from the diameter of the cavity they determined the density of the hydrogen. They then varied the initial pressure of the gas and the parameters of the charge to determine the compressibility of hydrogen over densities between 0.45 and 1.95 g/cm³; values of pressure ranged from 0.4 megabars to 8 megabars.

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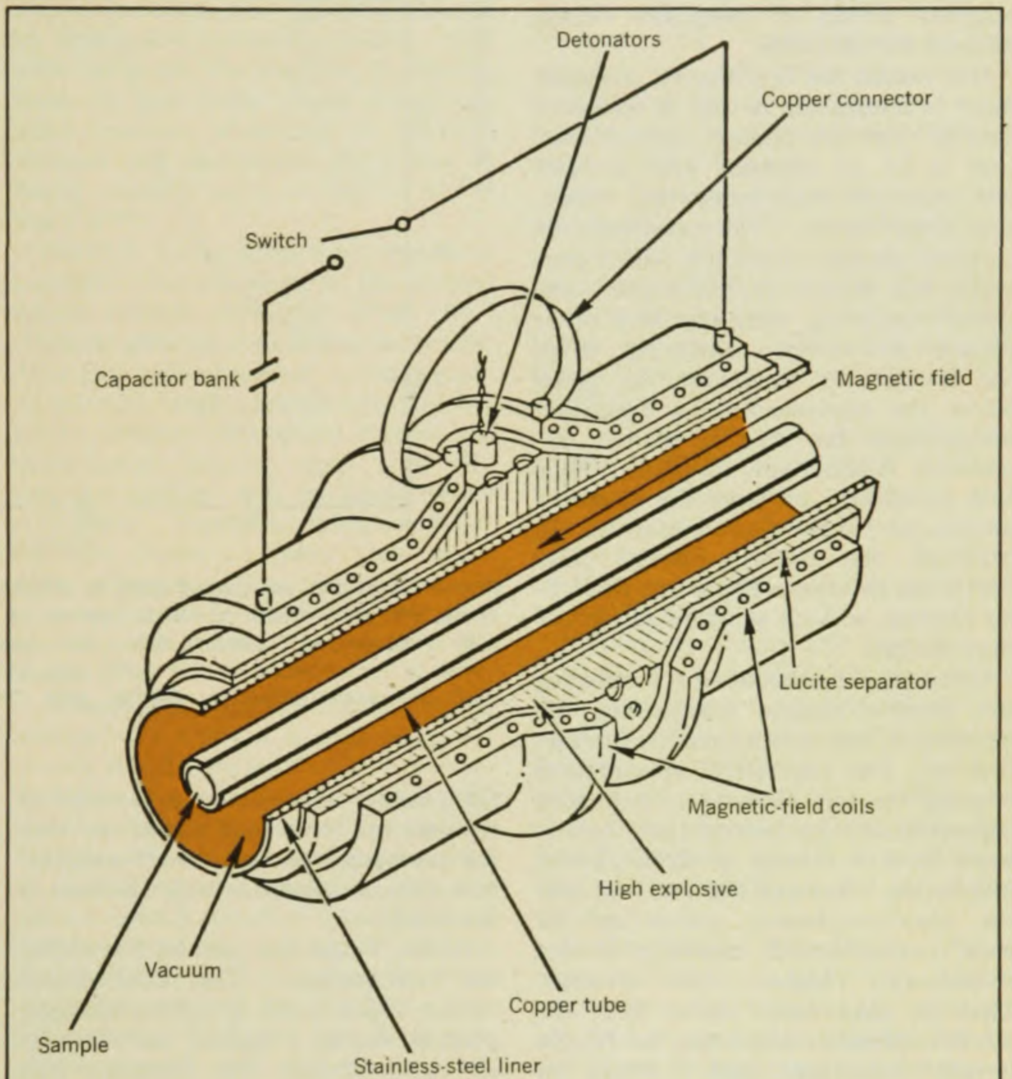

Schematic of Livermore magnetic-compression device. The high explosive is detonated and implodes the stainless-steel liner shortly after a 60-kG magnetic field is applied; the field serves to transfer momentum from the outer cylinder to the inner cylinder. The magnetic-field intensity increases, and a pressure is generated on the hydrogen sample.

Phonon linewidths measured by neutron scattering

Two Brookhaven experimenters, John D. Axe and Gen Shirane, have used inelastic neutron scattering to detect the influence of the superconducting energy gap upon phonon lifetimes in Nb_3Sn. Speaking at the January meeting of the American Physical Society in New York, Axe said their results yield estimates of the superconducting energy gap and the size and anisotropy of the electron-phonon coupling. Axe and Shirane feel that their method of using inelastic neutron scattering will be useful in studying low-lying electron excitations in superconductors.

Many people believe that by increasing the electron-phonon interaction one can achieve better superconductivity properties—higher transition temperatures, higher critical fields and so on. At the same time, however, there is concern that by turning up the electron-phonon interaction the lattice may become unstable under these additional kinds of forces, as has been pointed out by Bernd Matthias (University of California, La Jolla). One way to increase the effectiveness of the electron-phonon interaction is by rethat is, to work out a three-dimensional map of the positions of the 50 or so proteins and the nucleic acids that form the macromolecular ribosome complex. They would take the deuterated form of the ribosome, separate it into its constituent proteins and RNA, hydrogenate two of the proteins, then reassemble the ribosome. Neutron diffraction can then give the distance between the two nondeuterated proteins; repeating the process for all the remaining protein pairs would lead to a three-dimensional map of the structure. The experiments on ribosomes are now in a preliminary stage, and Caspar and Michael Moody plan to use similar methods for other macromolecules.

Improvements. The major limitations to neutron diffraction as a tool in molecular biology now appear to be those of source strength and instrumentation. Among the techniques currently being explored[1] are beam focusing through graphite monochromators, better beam pipes, and a multidetector ("hedgehog") counting system, now being built for the high-flux beam reactor in Grenoble (see PHYSICS TODAY, September 1972, page 17). Alternatively, monochromators could be eliminated and a time-of-flight method used to analyze the pattern produced by the entire neutron spectrum. —MSR

References

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The Livermore group, Ronald S. Hawke, D. E. Duerre, J. G. Huebel, R. N. Keeler and H. Klapper, reported an apparently similar experiment last March at the High Pressure Physics and Planetary Interiors Conference in Houston. They determined that liquid hydrogen had a volume of 1 cm^3/g at a pressure of about 2 megabars but they say they did not determine if it was transformed into a metal. Hawke says that pressure-volume measurements alone (with their associated errors) are not capable of pinning down the metallic transition pressure. "We have a point in the ballpark of the metallic equation of state, but I'm reticent to say that proves it's metallic hydrogen." Livermore hopes in the very near future to have a direct electrical measurement of the hydrogen metal transition; that is, they will measure the electrical conductivity as the sample changes from an insulator to a metal.

There are actually two Livermore programs that are measuring hydrogen's properties at high density. Both are dynamic methods: relatively fast shock compression and relatively slow isentropic compression using a strong magnetic field. The latter method (suggested by Francis Bitter in 1965), which Hawke and his collaborators use, is deliberately made slow enough (about 10 microsec) that no shock waves are generated in the sample.

Hawke and his colleagues use two concentric conducting cylinders that surround a cylinder of liquid hydrogen; the outer cylinder is four inches in diameter and the inner one is 0.5 inches in diameter. The outer cylinder is driven inward with high explosives shortly after a 60-kG magnetic field is applied between the cylinders; the field serves to transfer momentum from the outer to the inner cylinder. Because flux is conserved, as the area of the interior goes down, magnetic-field intensity increases, going up to 10 MG in about 10 microsec. The field squeezes on the smaller cylinder, generating a pressure on the hydrogen sample. The hydrogen compression time is long enough (much longer than in the shock experiments) that sound can traverse the sample several times, so that the compression is isentropic.

The experimenters make a 0.2-microsecond flash x-ray exposure before the experiment and during it. By comparing the sample-tube diameter before and after they obtain the volume compression. The pressure is calculated with a magnetohydrodynamic computer code.

The initial volume of the sample was 14.1 cm^3/g, so that the volumetric compression was about 14. Pressure goes as high as 3.5 megabars and then relaxes in about 0.5 microsec to 1.5 megabars.

Theoretical predictions for the transition density, Grivorev and his collaborators say, range between 0.5 and 1 g/cm^3 while the pressure value ranges between 0.25 and 18 megabars. Hawke told us that the best theoretical estimate for a lower limit on the pressure is 1.7 megabars with an error bar of −0.3; an upper limit is very difficult to obtain, he says. This calculation is based on recent shock-wave results from Livermore and Los Alamos. Neil Ashcroft (Cornell) has predicted that the most likely transition pressure is 1.6 megabars.

There are also attempts to achieve metallic hydrogen with static presses. One effort is at Cornell, where Arthur Ruoff is trying to obtain 3 megabars with a static press. He recently did a calculation based on plasticity theory that shows that several megabars can be obtained using steel or sintered tungsten carbide. A proposed program, at the University of Maryland, is headed by Ian Spain. In the Soviet Union Leonid Vereschagin at the Institute of High Pressure Physics has discussed a 10-story-high static press, which is apparently intended to make large sintered diamonds. However he also plans to use the press to reach 2–3 megabars and attempt to make metallic hydrogen. Unlike the dynamic experiments, the static experiments would allow one to recover the metallic hydrogen if it is metastable and if they are capable of reaching the transition pressure. Vereschagin, using a different static press, said he has so far been able to reach 2.5 megabars (compared to the 2.8 megabars reported in the dynamic experiment by Grivorev and his collaborators) with a stiff sample. Hawke notes that the hydrogen is elastically very soft and must be studied at cryogenic temperatures, making it much more difficult to reach the required pressure.

If metallic hydrogen turns out to be metastable, it would of course be very useful to have metastable deuterium in particular. One can envision applications in weapons, controlled fusion and laser fusion. And the possibility some theorists have raised that metallic hydrogen could be a room-temperature superconductor has certainly evoked interest in making the substance. Even astrophysicists are interested in metallic hydrogen because it is possible that it occurs in the interior of Jupiter and Saturn and in white dwarfs.

To use metallic hydrogen on earth may be very tricky indeed. As Hawke told us, the stored energy in metallic hydrogen is very high, 30–40 times greater than that of TNT, so that if metallic hydrogen is metastable it will be extremely dangerous. —GBL

Report reviews studies of mid-Atlantic ridge

A new report, *Understanding the Mid-Atlantic Ridge,* has been issued by the National Academy of Sciences. The report outlines an orderly approach to a comprehensive study of the Mid-Atlantic Ridge. It reviews present knowledge and hypotheses, states major unsolved problems and possible methods of solution, and presents outlines of recommended programs, including general priorities of the programs, coordination of necessary joint projects, and estimates of new funds and facilities required. □