Fusion Breakthrough?

Scientists working at the University of Utah claim to have found a fusion method that proceeds at room temperature and which could open the way to easily produce fusion power, but so far no one has offered a scientific explanation of what is going on

TWO RESEARCHERS WHO SPENT $100,000 of their own money to fund an experiment that "had a one in a billion chance of working" say they have found a sustainable room-temperature nuclear fusion reaction that may provide a virtually limitless source of clean, inexpensive power. As *Science* went to press, a number of efforts were under way to verify the results, but the astonishing claim had not been independently verified. The report from the University of Utah was complicated by news from Brigham Young University that researchers there have seen a similar fusion process but many orders of magnitude smaller.

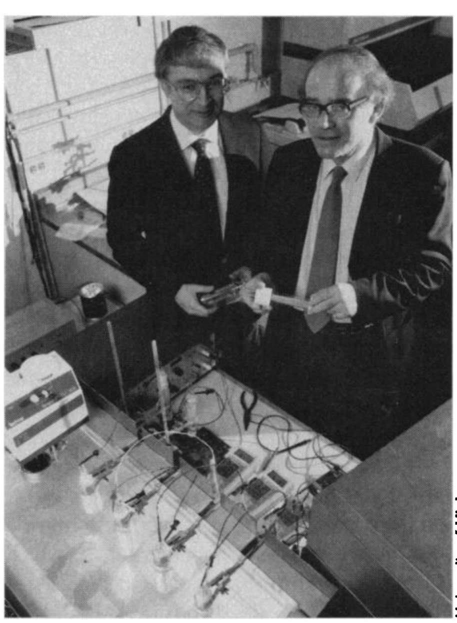
The Utah fusion process is done in small cells that are little more than glass test tubes filled with heavy water—water in which normal hydrogen is replaced by deuterium, the isotope of hydrogen whose nucleus has one proton and one neutron. The cells contain two electrodes hooked up to a battery, and one of the electrodes is made of palladium, which absorbs deuterium. It is in the palladium electrode that the fusion supposedly occurs.

"Our indications are that the discovery will be relatively easy to make into a usable technology for generating heat and power," said co-discoverer Martin Fleischmann, "but continued work is needed, first, to further understand the science and secondly, to determine its value to energy economics." Fleischmann, a professor of electrochemistry at the University of Southampton in England, collaborated with Stanley Pons, chairman of the Department of Chemistry at the University of Utah.

Most scientists were extremely skeptical of the claim announced 23 March at a University of Utah press conference, but were unwilling to reject it out of hand because both Pons and Fleischmann are well-respected researchers. As fusion theorist Kim Molvig of the Massachusetts Institute of Technology put it, "I'm willing to be open-minded, but it's really inconceivable that there's anything there."

Surprisingly, independent results indicate that there really might be something there, although these results see it only at a much smaller scale. A group led by Steven Jones of Brigham Young University said it has solid evidence of fusion reactions taking place in a system similar to the one at the University of Utah. According to members of both teams, the groups became aware of each other's work late last year and had agreed to submit papers to *Nature* simultaneously on 24 March. The press announcement violated one of the terms of the agreement, Jones said, so he submitted his group's paper on 23 March. Pons submitted his paper the next day. Pons said the decision to publicize the results before submitting a paper to *Nature* was influenced by rumors circulating about the work, patent considerations, and the fact that he had already had a paper on the work accepted by another journal. The University of Utah has applied for a patent on the fusion process.

The key difference between the results of the two teams—and the one on which most attention is likely to be focused—is that Pons and Fleischmann measure a heat output a billion times larger than can be explained by the fusion that Jones reports. Where is all that heat coming from? One scientist familiar with the work said, "It's either an altogether new process which will have to be identified, or it's sloppy electrochemistry."


University of Utah

Fusion in a test tube. *Pons, left, and Fleischmann with their electrochemical fusion cells.*

Fusion occurs when two atoms are combined into one, generally with a release of energy. For example, two atoms of deuterium can fuse into a helium-3 atom (whose nucleus has two protons and one neutron) plus an extra neutron. The reaction releases energy because less binding energy is needed to hold together the protons and neutron of the helium-3 nucleus than is needed to hold together two nuclei of deuterium. Fusion researchers hope to harness the energy of large numbers of fusion reactions to generate power, analogous to the way nuclear power plants harness atomic fission, but with less radioactive waste.

The fusion of two deuterium nuclei will take place automatically if they are brought close enough together. However, the positive electrical charges of the protons cause the nuclei to repel each other, so some way must be found to move them together. The sun, whose heat and light are generated by fusion taking place in its core, does this by brute force—the tremendous heat and pressure at the center of the sun overwhelm the electrical repulsion and push the hydrogen nuclei close enough together to fuse. Here on Earth, the 35-year-old effort to turn fusion into a power source also has concentrated on brute force—in one case applying powerful lasers to heat the hydrogen, and in a second using massive magnets to hold it in place. It is a difficult technological feat, and although the first breakeven reaction—one that releases as much energy as is put in—is expected in the next year or two, even the most optimistic predictions do not see commercial fusion power for another 30 years.

The alternative to this brute force method is finesse—finding some clever way to convince the two nuclei that they do not dislike each other quite so much. Jones at Brigham Young, for instance, has done this with muons, short-lived atomic particles similar to electrons but 200 times more massive. The negatively charged muons form psuedo-molecules with pairs of hydrogen nuclei, bringing them close enough together that they can fuse. Muon-catalyzed fusion takes place at much lower temperatures than magnetic confinement fusion, but so far it takes more energy to make the muons than is produced from the fusion.

The Fleischmann/Pons fusion technique also uses finesse, but in this case the catalyst is palladium metal. The palladium-catalyzed fusion proceeds as follows:

Two electrodes, one of palladium and one of platinum, are inserted into a container of heavy water. Lithum hydroxide is dissolved in the water in order to provide the ions to carry a current between electrodes. Then a voltage is placed across the two electrodes, with the platinum electrode serving as the anode (positive terminal) and the palladium the cathode (negative terminal). The current through the water causes electrolysis—the separation of the heavy water into oxygen, which collects at the platinum electrode, and deuterium, which collects at the palladium electrode.

Palladium has the well-known property of absorbing a lot of hydrogen, so the deuterium gradually builds up inside the palladium cathode. Pons estimated that the electrodes in his cells contain two or more deuterium atoms for every palladium atom. Once the deuterium builds to a sufficient level, which takes 10 hours or so, the palladium electrode begins to give off heat—a lot of heat, in fact, compared with the electrical input. The best performing cell, Pons said, had a 4.5-watt thermal output generated by a 1-watt input. The fact that the cell is putting out more energy than it is taking in implies that something is going on inside the cell.

Pons and Fleischmann say that this something is fusion. "This generation of heat continues over long periods and is so large that it can only be attributed to a nuclear process," Fleischmann said. Some of the cells have run for several hundred hours with a steady heat output. As further evidence of fusion, the researchers point to the presence of neutrons with energy of 2.5 million electron volts—precisely the energy that is to be expected of neutrons produced in the $D + D \rightarrow He^3 + n$ reaction. They have also detected helium-3 and tritium (the isotope of hydrogen with a proton and two neutrons), both of which are fusion by-products. Helium-3 is only produced by the fusion of two deuterium atoms.

Palladium-assisted fusion works for two reasons, Pons said. One is that the deuterium nuclei inside the palladium do not repel each other as strongly as they do in free space, and thus they approach each other closely enough to have a reasonable probability of fusing. In addition, the confinement parameter—a measure that combines how densely packed the atoms are with how long they are held—is much higher than has been achieved in magnetic confinement fusion, Pons said. This means that there are enough deuterium atoms held in a small enough space that many fusions take place, generating a detectable amount of heat.

Measurements by Jones's group verify that palladium-catalyzed fusion takes place, but only on a scale that is about 1 billion times smaller than what Pons and Fleischmann claim. Johann Rafelski, a theoretical physicist at the University of Arizona who works with Jones, said the group has detected fusion neutrons in a palladium electrolysis system "at a level which is very modest." The group has used a very sophisticated neutron counter—much more sensitive than Pons and Fleischmann have used—which leaves little doubt that fusion is taking place, he said.

Jones added that his group has seen metal-catalyzed fusion in a variety of metal electrodes, and that palladium is not one of the better performers. "Titanium works much better than palladium," he said.

So the University of Utah group and the Brigham Young group agree that room-temperature fusion does take place inside the palladium electrode. That result seems solid. "There is no doubt in my mind about the fusion in palladium," said one scientist familiar with the work. But the bigger question, and the one on which the two groups disagree, is how much heat is generated by fusion inside the electrode.

Where is the heat coming from? One scientist said, "It's either an altogether new process, or it's sloppy electrochemistry."

The Brigham Young group sees no heat comparable to the Utah results. In fact, Rafelski pointed out that to generate that much heat from deuterium fusion alone, the fusion cells would also produce so many neutrons that "they'd all be dead."

Pons agrees. "The deuterium-deuterium process is not the process that is responsible for all the heat." The number of neutrons detected indicates that this fusion process accounts for only about one-billionth of the heat released, he said. In other words, the fusion that Jones detected is going on in the cell but it is not the source of the heat.

So where is all the heat coming from? Pons said he and Fleischmann think they know, but they are not ready to say. It is coming from a fusion reaction, he said, but one that does not produce neutrons. There are a number of other substances in the palladium besides deuterium that could be involved, such as tritium and lithium, he pointed out.

The two of them originally tried the experiments because they had seen anomalies in certain processes—Fleischmann in separating hydrogen and deuterium isotopes and Pons in isotopic isolation in electrodes. Together they came up with a theory and decided to test it using their own funds. "We thought we wouldn't be able to raise any money since the experiment was so far-fetched," Pons said. (On 2 March, the Department of Energy did approve a $322,000 grant application for the research.)

Jones and colleagues had completely different reasons for looking for fusion in metals. One of them was the success of muon-catalyzed fusion, Rafelski said, which suggested the idea of using metals to bring deuterium nuclei close enough to fuse. A second was the observation by Russian physicist B. A. Mamyrin in 1978 of anomalies in the concentrations of helium-3 and helium-4 in metals.

Several laboratories were trying to reproduce the Utah results as *Science* went to press. Hans Hendel at Princeton Plasma Physics Laboratory said, "We did it on Friday [24 March], and we understand that a number of other labs also tried, and it hasn't worked in any case." However, most of these labs were looking for neutrons. If Pons and Fleischmann are correct and the heat is produced by a fusion process that does not release neutrons, these tests are useless.

If Pons and Fleischmann have indeed discovered a sustainable room-temperature fusion reaction that does not produce neutrons, it could be revolutionary. The two major problems with current schemes for fusion power, aside from their technological difficulty, are the expense in building the equipment to do fusion at very high temperature and pressure and the radioactive by-products created by neutrons. The new method seemingly would sidestep both of these. Still, as the recent work on high-temperature superconductors has shown, there can be much work between scientific discovery and commercial application.

If the heat observed in the cells results from something besides fusion—a chemical reaction taking place in the palladium, for instance—then the brouhaha over fusion power will have obscured a smaller, but still quite interesting scientific discovery. The work of Jones and colleagues, if verified, indicates that a small but measurable amount of deuterium-deuterium fusion can take place in palladium and other metals. Although the effect that Jones sees is too small to generate power, it is enough to answer some long-standing geological questions about the relative abundance of helium-3 and helium-4. ■ ROBERT POOL