Fleischmann–Pons Experiment

Subjects: Physics, Particles & Fields
Contributor: HandWiki

The Fleischmann–Pons experiment was an investigation conducted in the 1980s by Martin Fleischmann of the University of Southampton and Stanley Pons of the University of Utah into whether electrolysis of heavy water on the surface of a palladium (Pd) electrode produces physical effects that defy chemical explanation. Of particular interest was evidence of "excess" (i.e. non-chemical) heat extracted from the deuterium fraction of common surface water which, if true, could have delivered the largest economic shock to the global energy industry since the Pennsylvania oil rush. On March 23, 1989, Fleischmann (then one of the world's leading electrochemists) and Pons reported their work via a press release from the University of Utah (who asserted ownership of the technology) claiming that the table-top apparatus had produced anomalous heat (understood as "excess" heat) of a magnitude they asserted would defy explanation except in terms of nuclear processes, which later came to be referred to as "cold fusion". In addition to the results from calorimetry, they further reported measuring small amounts of nuclear reaction byproducts, including neutrons and tritium. The reported results received wide media attention, and raised hopes of a cheap and abundant source of energy. Many scientists tried to replicate the experiment with the few details available. Hopes faded due to the large number of negative replications, the withdrawal of many reported positive replications, the discovery of flaws and sources of experimental error in the original experiment, and finally the discovery that Fleischmann and Pons had not actually detected nuclear reaction byproducts. By late 1989, most scientists considered cold fusion claims dead.

electrolysis calorimetry palladium

1. Background

Martin Fleischmann of the University of Southampton and Stanley Pons of the University of Utah hypothesized that the high compression ratio and mobility of deuterium that could be achieved within palladium metal using electrolysis might result in nuclear fusion.[1] To investigate, they conducted electrolysis experiments using a palladium cathode and heavy water within a calorimeter, an insulated vessel designed to measure process heat. Current was applied continuously for many weeks, with the heavy water being renewed at intervals.[1] Some deuterium was thought to be accumulating within the cathode, but most was allowed to bubble out of the cell, joining oxygen produced at the anode.[2] For most of the time, the power input to the cell was equal to the calculated power leaving the cell within measurement accuracy, and the cell temperature was stable at around 30 °C. But then, at some point (in some of the experiments), the temperature rose suddenly to about 50 °C without changes in the input power. These high temperature phases would last for two days or more and would repeat several times in any given experiment once they had occurred. The calculated power leaving the cell was significantly higher than the input power during these high temperature phases. Eventually the high temperature phases would no longer occur within a particular cell.[2]

In 1988, Fleischmann and Pons applied to the United States Department of Energy for funding towards a larger series of experiments. Up to this point they had been funding their experiments using a small device built with $100,000 out-of-pocket.[3] The grant proposal was turned over for peer review, and one of the reviewers was Steven Jones of Brigham Young University.[3] Jones had worked for some time on muon-catalyzed fusion, a known method of inducing nuclear fusion without high temperatures, and had written an article on the topic entitled "Cold nuclear fusion" that had been published in *Scientific American* in July 1987. Fleischmann and Pons and co-workers met with Jones and co-workers on occasion in Utah to share research and techniques. During this time, Fleischmann and Pons described their experiments as generating considerable "excess energy", in the sense that it could not be explained by chemical reactions alone.[2] They felt that such a discovery could bear significant commercial value and would be entitled to patent protection. Jones, however, was measuring neutron flux, which was not of commercial interest.[3][*clarification needed*] To avoid future problems, the teams appeared to agree to simultaneously publish their results, though their accounts of their 6 March meeting differ.[4]

2. Announcement

In mid-March 1989, both research teams were ready to publish their findings, and Fleischmann and Jones had agreed to meet at an airport on 24 March to send their papers to *Nature* via FedEx.[4] Fleischmann and Pons, however, pressured by the University of Utah, which wanted to establish priority on the discovery,[5] broke their apparent agreement, submitting their paper to the *Journal of Electroanalytical Chemistry* on 11 March, and disclosing their work via a press release[6] and press conference on 23 March.[3] Jones, upset, faxed in his paper to *Nature* after the press conference.[4]

Fleischmann and Pons' announcement drew wide media attention.[7] But the 1986 discovery of high-temperature superconductivity had made the scientific community more open to revelations of unexpected scientific results that could have huge economic repercussions and that could be replicated reliably even if they had not been predicted by established theories.[8] And many scientists were also reminded of the Mössbauer effect, a process involving nuclear transitions in a solid. Its discovery 30 years earlier had also been unexpected, though it was quickly replicated and explained within the existing physics framework.[9]

The announcement of a new purported clean source of energy came at a crucial time: adults still remembered the 1973 oil crisis and the problems caused by oil dependence, anthropogenic global warming was starting to become notorious, the anti-nuclear movement was labeling nuclear power plants as dangerous and getting them closed, people had in mind the consequences of strip mining, acid rain, the greenhouse effect and the Exxon Valdez oil spill, which happened the day after the announcement.[10] In the press conference, Chase N. Peterson, then the president of the University of Utah, Fleischmann and Pons, backed by the solidity of their scientific credentials, repeatedly assured the journalists that cold fusion would solve environmental problems and would provide a limitless inexhaustible source of clean energy using only seawater as fuel.[11] They said the results had been confirmed dozens of times and they had no doubts about them.[12] In the accompanying press release Fleischmann was quoted saying: "What we have done is to open the door of a new research area, our indications are that the discovery will be relatively easy to make into a usable technology for generating heat and power, but continued work is needed, first, to further understand the science and secondly, to determine its value to energy economics."[6]

3. Response and Fallout

Although the experimental protocol had not been published, physicists in several countries attempted, and failed, to replicate the excess heat phenomenon. The first paper submitted to *Nature* reproducing excess heat, although it passed peer-review, was rejected because most similar experiments were negative and there were no theories that could explain a positive result;[13][14] this paper was later accepted for publication by the journal *Fusion Technology*. Nathan Lewis, professor of chemistry at the California Institute of Technology, led one of the most ambitious validation efforts, trying many variations on the experiment without success,[15] while CERN physicist Douglas R. O. Morrison said that "essentially all" attempts in Western Europe had failed.[16] Even those reporting success had difficulty reproducing Fleischmann and Pons' results.[17] On 10 April 1989, a group at Texas A&M University published results of excess heat and later that day a group at the Georgia Institute of Technology announced neutron production—the strongest replication announced up to that point due to the detection of neutrons and the reputation of the lab.[18] On 12 April Pons was acclaimed at an ACS meeting.[18] But Georgia Tech retracted their announcement on 13 April, explaining that their neutron detectors gave false positives when exposed to heat.[19] Another attempt at independent replication, headed by Robert Huggins at Stanford University, which also reported early success with a light water control,[20] became the only scientific support for cold fusion in 26 April US Congress hearings.[21] But when he finally presented his results he reported an excess heat of only one degree celsius, a result that could be explained by chemical differences between heavy and light water in the presence of lithium.[22] He had not tried to measure any radiation[23] and his research was derided by scientists who saw it later.[24] For the next six weeks, competing claims, counterclaims, and suggested explanations kept what was referred to as "cold fusion" or "fusion confusion" in the news.[4][25]

In April 1989, Fleischmann and Pons published a "preliminary note" in the *Journal of Electroanalytical Chemistry*.[1] This paper notably showed a gamma peak without its corresponding Compton edge, which indicated they had made a mistake in claiming evidence of fusion byproducts.[26] Fleischmann and Pons replied to this critique,[27] but the only thing left clear was that no gamma ray had been registered and that Fleischmann refused to recognize any mistakes in the data.[28] A much longer paper published a year later went into details of calorimetry but did not include any nuclear measurements.[2]

Nevertheless, Fleischmann and Pons and a number of other researchers who found positive results remained convinced of their findings.[16] The University of Utah asked Congress to provide $25 million to pursue the research, and Pons was scheduled to meet with representatives of President Bush in early May.[16]

On 30 April 1989, cold fusion was declared dead by the *New York Times*. The *Times* called it a circus the same day, and the *Boston Herald* attacked cold fusion the following day.[29]

On 1 May 1989, the American Physical Society held a session on cold fusion in Baltimore, including many reports of experiments that failed to produce evidence of cold fusion. At the end of the session, eight of the nine leading speakers stated that they considered the initial Fleischmann and Pons claim dead, with the ninth, Johann Rafelski, abstaining.[16] Steven E. Koonin of Caltech called the Utah report a result of "*the incompetence and delusion of Pons and Fleischmann,*" which was met with a standing ovation.[30] Douglas R. O. Morrison, a physicist representing CERN, was the first to call the episode an example of pathological science.[16][31]

On 4 May, due to all this new criticism, the meetings with various representatives from Washington were cancelled.[32]

From 8 May only the A&M tritium results kept cold fusion afloat.[33]

In July and November 1989, *Nature* published papers critical of cold fusion claims.[34][35] Negative results were also published in several other scientific journals including *Science*, *Physical Review Letters*, and *Physical Review C* (nuclear physics).[36]

In August 1989, in spite of this trend, the state of Utah invested $4.5 million to create the National Cold Fusion Institute.[37]

The United States Department of Energy organized a special panel to review cold fusion theory and research.[38] The panel issued its report in November 1989, concluding that results as of that date did not present convincing evidence that useful sources of energy would result from the phenomena attributed to cold fusion.[39] The panel noted the large number of failures to replicate excess heat and the greater inconsistency of reports of nuclear reaction byproducts expected by established conjecture. Nuclear fusion of the type postulated would be inconsistent with current understanding and, if verified, would require established conjecture, perhaps even theory itself, to be extended in an unexpected way. The panel was against special funding for cold fusion research, but supported modest funding of "focused experiments within the general funding system."[40] Cold fusion supporters continued to argue that the evidence for excess heat was strong, and in September 1990 the National Cold Fusion Institute listed 92 groups of researchers from 10 different countries that had reported corroborating evidence of excess heat, but they refused to provide any evidence of their own arguing that it could endanger their patents.[41] However, no further DOE nor NSF funding resulted from the panel's recommendation.[42] By this point, however, academic consensus had moved decidedly toward labeling cold fusion as a kind of "pathological science".[43][44]

In March 1990 Dr. Michael H. Salamon, a Utah physicist, and nine co-authors reported negative results. University faculty were then "stunned" when a lawyer representing Pons and Fleischmann demanded the Salamon paper be retracted under threat of a lawsuit. The lawyer later apologized; Fleischmann defended the threat as a legitimate reaction to alleged bias displayed by cold-fusion critics.[45]

In early May 1990 one of the two A&M researchers, Kevin Wolf, acknowledged the possibility of spiking, but said that the most likely explanation was tritium contamination in the palladium electrodes or simply contamination due to sloppy work.[46] In June 1990 an article in *Science* by science writer Gary Taubes destroyed the public credibility of the A&M tritium results when it accused its group leader John Bockris and one of his graduate students of spiking the cells with tritium.[47] In October 1990 Wolf finally said that the results were explained by tritium contamination in the rods.[48] An A&M cold fusion review panel found that the tritium evidence was not convincing and that, while they couldn't rule out spiking, contamination and measurements problems were more likely explanations,[49] and Bockris never got support from his faculty to resume his research.

On 30 June 1991 the National Cold Fusion Institute closed after it ran out of funds;[50] it found no excess heat, and its reports of tritium production were met with indifference.[51]

On 1 January 1991, Pons left the University of Utah and went to Europe.[51][52] In 1992, Pons and Fleischman resumed research with Toyota Motor Corporation's IMRA lab in France.[51] Fleischmann left for England in 1995, and the contract with Pons was not renewed in 1998 after spending $40 million with no tangible results.[53] The IMRA laboratory stopped cold fusion research in 1998 after spending £12 million.[54] Pons has made no public declarations since, and only Fleischmann continued giving talks and publishing papers.[53]

Mostly in the 1990s, several books were published that were critical of cold fusion research methods and the conduct of cold fusion researchers.[55] Over the years, several books have appeared that defended them.[56] Around 1998, the University of Utah had already dropped its research after spending over $1 million, and in the summer of 1997, Japan cut off research and closed its own lab after spending $20 million.[57]

4. Revival and LENR

In the mid-1990s there was heated debate among scientists that promoted the room-temperature fusion and those who observed that isotopic shifts and heavy-element transmutations pointed not to fusion but to some sort of neutron-induced reaction.

In 1997, theorist Lewis Larsen looked at some of this data and suspected that a neutronization process was occurring in low-energy nuclear reactions (LENR). Physicist Allan Widom joined Larsen's team in 2004, and in 2006 they published a theory in the *European Physical Journal C – Particles and Fields.*

The Widom–Larsen theory is consistent with existing physics and has nothing to do with fusion. Their theory explains nuclear reactions based on creation of ultra-low-momentum neutrons and their recapturing. The reaction rate are based on collective many-body interactions and not on few-body interactions that had been presumed for Fleischmann–Pons experiment.

Many scientific reports, some of them published in respectable peer-reviewed journals, show that LENRs can produce local surface temperatures of 4,000–5,000 K and boil metals (palladium, nickel and tungsten) in small numbers of scattered microscopic sites on the surfaces of laboratory devices. In other words, Fleischmann and Pons misunderstood their own experiment but did not engage in sham science as they were accused of. Ultimately, although their experiment did not show what Fleischmann and Pons thought it did, it prompted new exciting venues of research that may highly expand applications of theoretical particle physics[58].

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