LETTERS TO PROGRESS IN PHYSICS

Social Aspects of Cold Fusion: 23 Years Later

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The field of Cold Fusion, now called Condensed Matter Nuclear Science (CMNS), remains controversial. The original 1989 claim made by M. Fleischmann and S. Pons was that a chemical process in an electrolytic cell could initiate a nuclear reaction–fusion of two deuterium nuclei. More recent CMNS claims, made by experimental scientists, are: emission of charged nuclear projectiles during electrolysis; accumulation of ^{4}He; production of radioactive isotopes; and transmutation of elements. In the US, CMNS claims have been evaluated in two Department of Energy (DOE) investigations, in 1989 and 2004, as summarized in this article. These investigations did not lead to any resolution of the controversy. Scientists and adminstrators are not ideal; competition among them, as among other groups of people, tends to have both positive and negative influences.

1 Introduction

The so-called "scientific methodology", a set of norms developed to deal with difficulties, especially with mistakes and controversies, is well known. Most scientific mistakes are recognized when new results are discussed with colleagues, or via the peer review process. Occasional errors in published papers are subsequently discovered during replications conducted by other researchers. Scientific results, if valid, wrote Huizenga [1], must be reproducible on demand. "When errors are discovered, acknowledged and corrected, the scientific process moves quickly back on track, usually without either notice or comment in the public press." The scientific process, in other words, is self-corrective. The purpose of this presentation is to analyze an ongoing controversy about the so-called "cold fusion" (CF). The author of this article, and three other researchers, tried to verify one recent CF claim – emission of alpha particles during electrolysis. The results were negative, as described in [2]. Critical analysis of some CF claims, as illustrated in [3], can enrich nuclear physics courses, even at the undergraduate level.

Why is the CMNS controversy started in 1989 unresolved? Because CF claims are still not reproducible on demand, and because they conflict with accepted theories. A theory, in this context, is not just a hypothesis, or only a logical/mathematical argument. It is a logical structure that is known to agree with a wide range of already verified experimental data. Researchers know the rule–theories guide but experiments decide. But they are very reluctant to abandon accepted theories. To be reluctant means to insist on additional verifications of new experimental results. Referring to such situations, Huizenga wrote: "There are occasionally surprises in science and one must be prepared for them." Theories are not carved in stone; scientists do not hesitate to modify or reject theories when necessary. Rejecting a highly reproducible experimental result "on theoretical grounds" would not be consistent with scientific methodology. Unlike mathematics, science is based, in the final analysis, on experimental data, not on logical proofs.

2 The Original Claim

It is well known that two hydrogen nuclei can fuse, releasing energy. But this happens only at extremely high temperatures. At ordinary temperatures the probability of the reaction is practically zero, due to the well known coulomb repulsion of positive nuclei. This has been confirmed by reliable experimental data. But two scientists – Steven Jones, a physicist, and Martin Fleischmann, a chemist – independently speculated that this might not always be true. The term CF was introduced by them to identify the claimed fusion of hydrogen nuclei (ionized atoms dissolved in solid metals). The DOE supported Jones' work long before Fleischmann and his colleague Pons (F&P) applied for similar support. That is why the DOE asked Jones to evaluate the new research proposal. He was later accused (by the administration of Utah University) of stealing the idea of CF from F&P. Trying to establish priority, Utah University organized a press conference (March 23, 1989) at which the discovery of generation of nuclear heat in an electrolytic cell was announced to the world. The released heat was declared to be due to fusion of deuterium nuclei – ionized atoms dissolved in palladium. At that time Jones and his co-workers had already authored numerous peer-reviewed articles [4]. But their claim was not excess heat; it was emission of neutrons.

3 The First DOE Investigation

Most scientists immediately rejected claims conflicting with well-known facts and theories. But many attempts to replicate F&P's poorly-described experiments were made. Some attempts were successful (unaccounted heat was generated at rates close to one watt), while others were not [5]. That was the beginning of the controversy. Fleischmann and Pons wanted to study the CF phenomenon for another year or so but

were forced to announce the discovery by the university administrators [6]. They had no evidence that the measured heat was due to a nuclear reaction. The only thing they knew was that it could not be attributed to a known chemical reaction.

Suppose their experimental results had been described without any interpretation, and the phenomenon had been named "anomalous electrolysis". Such a report would not have led to a sensational press conference; it would have been made in the form of an ordinary peer review publication. Only electrochemists would have been aware of the claim; they would have tried to either confirm or refute it. The issue of "how to explain excess heat" would have been addressed later, if the reported phenomenon were confirmed. But that is not what happened. Instead of focusing on experimental data (in the area in which F&P were recognized authorities) most critics focused on the disagreements with the coulomb barrier theory. Interpretational mistakes were quickly recognized and this contributed to the premature skepticism toward their experimental data.

But the significance of CF, if real, was immediately recognized. Some believed that ongoing research on high-temperature fusion, costing billions of dollars, should be stopped to promote research on CF. Others concluded, also prematurely, that such a move would be opposed by "vested interests" of mainstream scientists. Responding to such considerations, the US government quickly ordered a formal investigation. A panel of scientists, named ERAB (Energy Research Advisory Board), and headed by John Huizenga, was formed to investigate CF in 1989. The final report, submitted to the DOE several months later, interfered with the normal development of the field. It should be noted that ERAB scientists investigating the CF claims were not personally involved in replications of experiments. Their report [7], based on visits to several laboratories rather than participation in experiments, can be summarized by the following statements:
Conclusions:

1. There is no evidence that a nuclear process is responsible for excess heat.
2. Lack of experimental reproducibility remains a serious concern.
3. Theoretically predicted fusion products were not found in expected quantities.
4. There is no evidence that CF can be used to produce useful energy.
5. The CF interpretation is not consistent with what is known about hydrogen in metals.
6. The CF interpretation is not consistent with what is known about nuclear phenomena.

Recommendations:

7. We recommend against any extraordinary funding.
8. We recommend modest support for more experiments.
9. We recommend focusing on excess heat and possible errors.
10. We recommend focusing on correlations between fusion products and excess heat.
11. We recommend focusing on the theoretically predicted tritium in electrolytic cells.
12. We recommend focusing on theoretically predicted neutrons.

Note that only one conclusion (item 2) refers to CF experiments. Conclusion 4 is about anticipated practical uses of CF while the remaining four conclusions (1, 3, 5, and 6) are about various aspects of the suggested interpretation of experimental results. Instead of focusing on reality of excess heat critics focused on the fact that the hypothesis was not consistent with what was known about hot nuclear fusion. The same observation can be made about recommendations. Only one of them (item 9) refers to possible errors in experiments. Items 7 and 8 refer to future funding while items 10, 11, and 12 refer to what was expected on the basis of the suggested hot-fusion interpretation. It is clear that the ERAB observations were based mostly on "theoretical grounds,"and not on identified errors in experimental data. Recommendations about future financial support for CF were very important. But they were ignored by the DOE. Support for CF research practically stopped in 1989. Another result of the first DOE investigation was that editors of some scientific journals stopped accepting articles dealing with CF research. Why was the scientific methodology of validation of claims – theories guide but experiments decide – not followed by the DOE-appointed scientists? Why did "rejections on theoretical grounds" prevail?

4 The Second DOE Investigation

The second DOE investigation of CF was announced in March 2004, nearly 15 years after the first one. Links to three online documents related to that investigation – Conference Agenda, Meeting Agenda, and DOE CF Report – can be found in [8]. The six most important scientific questions, based on new experimental claims, were:

a) Is it true that unexpected protons, tritons, and alpha particles are emitted [9, 10] in some CF experiments?
b) Is it true that generation of heat, in some CF experiments, is linearly correlated with the accumulation of ^{4}He and that the rate of generation of excess heat is close to the expected 24 MeV per atom of ^{4}He [9, 11]?
c) Is it true that highly unusual isotopic ratios [9, 12] have been observed among the reaction products?
d) Is it true that radioactive isotopes [9, 13] have been found among reaction products?
e) Is it true that transmutation of elements [10, 14] has occurred?

f) Are the ways of validating of claims made by CF researchers (see conference reports presened at [16, 17, 18]) consistent with accepted methodologies in other areas of science?

A positive answer to even one of these questions would be sufficient to justify an official declaration that cold fusion, in light of recent data, should be treated as a legitimate area of research. But only the (b) question was addressed by the selected referees [8]. They were asked to review the available evidence of correlation between the reported excess heat and production of fusion products. One third of them stated that the evidence for such correlation was conclusive. That was not sufficient; the attitude of the scientific establishment toward cold fusion research did not change.

5 Conclusion

The CF controversy is unprecedented in terms of its duration, intensity, and caliber of adversaries on both sides of the divide. Huizenga and Fleischmann were indisputable leaders in nuclear science and electrochemistry. CMNS researchers are mostly also Ph.D. level scientists. The same is true for those scientists who believe that the announced discovery of CF was a "scientific fiasco". We are still waiting for at least one reproducible-on-demand demonstration of a nuclear effect resulting from a chemical (atomic) process. In the case of CF the self-correcting process of scientific development emphasized by Huizenga has not worked. This fiasco seems to be due to the fact that scientists appointed to investigate CF claims did not follow the rules of scientific methodology.

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