Replicable cold fusion experiment: heat/helium ratio

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Cold fusion effects have often been called 'unreliable', even by those convinced of their reality. The chaotic nature of material conditions, so far, has made ordinary reliability elusive. However, the Fleischmann–Pons experiment produces more than one effect, and two major ones are heat and helium. Miles, in 1991, measured both, and found that they were correlated, within an order of magnitude of the ratio expected from deuterium fusion. Miles was amply confirmed, and precision has increased. While there are outliers, there is no experimental evidence contradicting the correlation, and only the exact ratio remains in question. In this, we have direct evidence that the effect is real and is nuclear in nature; the mechanism remains a mystery well worth exploration.

Keywords: Anomalous heat, cold fusion, heat/helium ratio, replicable experiments.

Introduction

MICHAEL MCKUBRE, in his review of evidence in this special section, covers research into the original experimental 'cold fusion' report, anomalous heat. It is still common to see mention of 'cold fusion' accompanied by a claim that the experiments could not be replicated. Scientific papers are still being rejected solely because of the belief that cold fusion was disproved:

> Despite all details provided in the manuscript and the apparently rigorous procedure, I cannot recommend publication of the manuscript. The main reason is that the manuscript and the associated documentation target the rehabilitation of the cold fusion concept; unfortunately cold fusion has largely been disproved among the scientific community. (Anonymous reviewer, 2010, quoted by Hagelstein[1].)

However, since 1991, direct evidence has been available that the Fleischman–Pons heat effect (FPHE) is nuclear in nature, stronger than the indirect or circumstantial evidence (including unexplained heat) found by Pons, Fleischmann and others. Their experiment is difficult to replicate, and even in the hands of the experienced, results may be highly variable. One may search in vain for some protocol to produce reliable anomalous heat. However, science can handle unreliable effects, and may still determine their nature, through correlation, and this has been done with cold fusion.

The present article does not claim that any particular reaction mechanism is the source of the anomalous heat, only that helium is being proportionally produced, as shown in wide experimental confirmation (e.g. Figure 1)[2]. In this article, 'heat' refers to anomalous heat, heat measured but unexplained by known chemistry or power inputs.

Discussion

Cold fusion researchers often counter the 'non-reproducible' allegation by claiming that the calorimetry is good, pointing to many successful results, and, in addition, cite supporting evidence of some nuclear effect occurring, such as the formation of tritium and neutrons. This increases confusion, because there are many such effects reported but not confirmed, and different experiments seem to produce different effects. This is circumstantial evidence, and may not be enough to convince those reasonably skeptical that nuclear reactions are possible under the conditions of the FPHE. However, one of the original mysteries was the ash.

The reaction fuel was and is suspected to be deuterium, so what is the ash? Because the initial focus was on ordinary deuterium fusion, there were well-known products to look for. Half of the reactions would produce helium-3 and a neutron, and half would produce tritium and a proton. Neutrons and tritium are easily detected. While there are widespread reports of tritium at low levels, various transmutations, and neutrons at extremely low levels, none of these has been found to be even remotely commensurate with heat.

There is a rare branch from ordinary deuterium fusion, which produces helium-4 plus a gamma ray. That gamma ray is not observed with the FPHE.

Melvin Miles, one of the original reporters of replication failure, as covered in the 1989 US Department of Energy ERAB report[3] was, by late 1989, reporting heat[4]. In 1991, Miles announced that he had found helium correlated with heat in the evolved gas of electrolytic cold fusion cells[5].

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The levels of helium found varied with anomalous heat during the sampling period. (This is not a correlation with temperature. Temperature variation in low-power cold fusion cells is low; in some cases the temperature is held constant at an elevated level, excess heat being measured by the reduction in power necessary to maintain the temperature. In other cells, such as Miles' work, the temperature increase is low, no more than a few degrees Celsius, not enough to significantly affect leakage of helium.)

Ultimately, Miles reported 33 results from double-blind helium analysis. In 12 samples taken with no heat, none showed helium above measurement background. In 21 cells with heat, 18 showed helium and, generally, more the heat, more the helium produced[6]. (Of the three major outliers, one was a cell where calorimetry error was reasonably suspected. The other two involved the only Pd–Ce alloy cathode used.)

The helium found was roughly half of that expected, from measured heat, if the reaction were the conversion of deuterium to helium. The laws of thermodynamics require that this result be mechanism-independent[7].

Helium is effectively immobilized in palladium, trapped at grain boundaries; so helium formed in the bulk would remain there[8]. It is then reasonable to suspect that the helium is produced at or near the surface, instead of deep in the bulk, as some had originally expected. It is then reasonable to expect that roughly half of it will have birth momentum vector that takes it away from the material, and roughly half will implant and not be released.

Miles' early helium results were covered by John R. Huizenga in the second edition of his book, *Cold Fusion: Scientific Fiasco of the Century*. He wrote that, if confirmed, this solves one of the greatest puzzles of cold fusion, but then he added that it would probably not be confirmed, because the expected lethal levels of gamma rays were absent[9]. However, gammas are only required if the reaction is ordinary d–d fusion, producing helium. There are other possibilities.

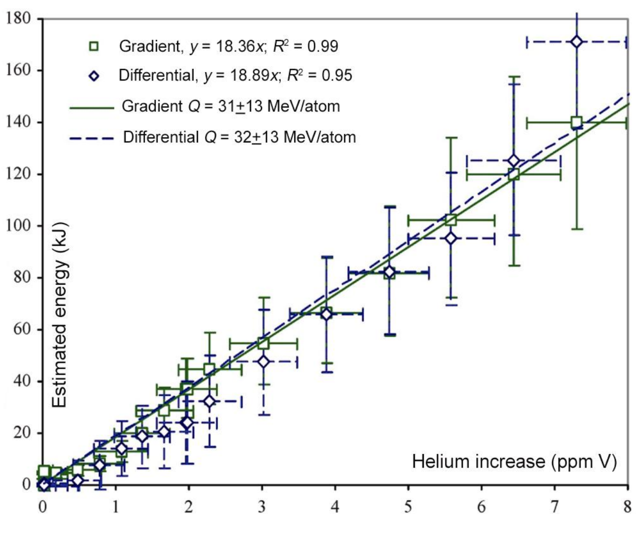

Figure 1. Anomalous energy versus measured helium[2].

Miles was amply confirmed. For a review of the literature, see Storms[10,11]. In his recent book[12], Storms adds more, reporting work from 30 groups. Over 80 experiments are covered, including more than 20 where there was no heat and no helium (light hydrogen controls or 'dead cells', cells that show no heat in spite of being treated similar to heat-producing cells). There is a solid body of research supporting the heat/helium correlation.

Michael McKubre at SRI International has measured heat/helium ratio the most precisely, to date[13–15], at 23 MeV/^{4}He ± 10%. The theoretical value for deuterium conversion to helium is 23.8 MeV/^{4}He, if there is no loss of helium or loss of heat (as through radiation).

This is a reliable, reproducible and reproduced experiment, even though the individual tests are not reliable as to the amount of heat produced. As helium is a nuclear product, it is direct evidence that the FPHE is nuclear in nature.

Critique of Miles' work was published, with response[16–19]. None of the responses correctly addressed the correlation[20]. Critics have focused on claims that the calorimetry may be incorrect, or that the helium may be leakage. Either one of these could seem possible. No plausible explanations have been advanced for the correlation, nor the ratio being close to the fusion value, a remarkable coincidence. There is no substantial contrary experimental evidence.

Atomic counts of helium found in the FPHE experiments are roughly a million times higher than those of tritium, which, in turn, are roughly a million times higher than neutrons[21]. We may say, then, that 'cold fusion', at least with the FPHE, is a process that converts deuterium to helium, with no other major confirmed effects. We can call it 'fusion' because it produces a fusion product, not because the mechanism is what is known as fusion. The mechanism is a mystery.

Cold fusion was, then, confirmed as to resulting heat and nuclear product, in work first announced 23 years ago, and that confirmation was itself confirmed by multiple research groups around the world. This is a reproducible experiment: set-up conditions where the FPHE may be expected in some fraction of experiments, measure heat and helium, and determine the ratio. Modern cold fusion protocols commonly show more than half of the experiments with anomalous heat. Null results (no heat, no helium) confirm the correlation, though not the ratio.

When McKubre at SRI made the measurement that was closest to the theoretical fusion value, he had repeatedly loaded and deloaded the cathode, plus anodic reversal was used, in an attempt to flush out helium[22]. Apicella *et al.* also used 'anodic erosion' to release additional helium, in a rough confirmation of this approach[23]. Anodic reversal may dissolve the surface of a palladium cathode, releasing helium trapped there. In both cases the results moved toward the theoretical value, from values that indicated roughly 40% of helium had been trapped.

Conclusions

It is clear from the data available in the literature that the phenomenon of heat and helium correlation is replicable. While some attributes of this phenomenon are consistent with d–d fusion (e.g. ^{4}He production and the energy associated with the heat), many of the other features expected from d–d fusion are not observed in these experiments (e.g. detection of high-energy gammas, nor substantial neutrons and charged particles). The mechanism of production of ^{4}He and the correlated heat generated is not understood. The fact remains that it is an interesting phenomenon which needs more detailed experimentation and requires new theoretical approaches.

Cold fusion is real, and it is time that serious work is funded to study the conditions of cold fusion and other correlated effects, gathering the evidence needed to understand it.

If agencies or decision-makers are still in doubt about the reality of the effect, then the first work to fund would be more accurate measurement of the heat/helium ratio, perhaps following McKubre or Apicella *et al.*[24].

Beyond that, identifying and confirming the nuclear active environment (Storms' term, the specific local structure or condition that allows the reaction) would take us forward[25]. There is work by Dennis Letts, following a prediction by Peter Hagelstein, that appears to show reliable control of the reaction with dual laser stimulation tuned to beat frequencies in the terahertz region[26]. There are many clues in an abundant exploratory literature, and a great deal to confirm and nail down.

For physicists, this is a mystery to address and resolve, and an exciting opportunity. How are these results possible? Is new physics involved, or merely some set of unanticipated conditions? Beyond that, are there possible practical applications?

Notes and references

Where available, links are provided to free-access documents. Some references not otherwise freely available are to papers, published in mainstream journals, in the 'Britz collection', a bibliography with reviews, at http://www.dieterbritz.dk/fusweb/papers. Further coverage of this topic, as well as corrections and criticism, will be available or linked from http://en.wikiversity.org/wiki/Cold_fusion/Excess_heat_correlated_with_helium

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