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Wild and wooly theories abound

On the rough road to explaining the 'impossible'

by Eugene Mallove

This is a modest attempt at the nearly impossible: an effort to explain in simple terms some of the complex physical mechanisms that have been proposed to account for cold fusion phenomena. For a general audience it is impossible to go deeper into these theories than to quote the arcane language of the theorists as they describe quantum-mechanical phenomena that are beyond ordinary experience. This will at least give a sense of what they are asserting.

Given that both large energy releases far beyond ordinary chemical explanation (hundreds of megajoules per mole of electrode) and anomalous nuclear products have been proved, many theorists have tried valiantly to explain cold fusion by means of solid state nuclear reactions producing in many cases (but not all cases) as yet incompletely discovered and understood nuclear ash. What is so striking about cold fusion, however, is that with very few exceptions —for example, the claims of one group of investigators to have found 4_{He} in amounts nearly commensurate with excess heat (1–4)— such nuclear products as have been found are not usually even close to being commensurate with the excess heat. Usually, the levels of nuclear products (neutrons, as an example) are over 10^9 times lower than they should be to explain watt-level excess heat (5). That mystery, indeed, has driven the passion of the cold fusion controversy (6). The nuclear products that have been found—neutrons, tritium, charged particles, and even the 4_{He}—are almost always far below the level required to explain the excess power by solid state nuclear reactions, with $E=mc^2$ energy conversion of the computed mass deficit assumed for the reaction.

Furthermore, to explain the excess heat in cold fusion appears to require an enhancement of the quantum-mechanical tunneling probability between mutually repelling hydrogen and deuterium nuclei by a factor of 10^{50} or more. How is this possible—or does tunneling really need to happen?

Types of theories

It is a daunting assignment to explain the bizarre phenomena of cold fusion, but dozens of theorists have tried. Usually a theorist attempts to explain only part of the list of phenomena, believing perhaps that the ignored part of the list will simply "fall out" of the theory when it is eventually refined. Perhaps this is the best that can be expected at the moment, without resorting to generalizations.

Attempts so far to explain the body of evidence claimed for cold fusion phenomena may be conveniently grouped into four categories:

1. Pathological science
2. Ordinary chemical energy release
3. Solid state nuclear reactions
4. "Something Else"—beyond nuclear reactions

The first, the so-called "pathological science" explanation, posits that all or virtually all of the experimental evidence derives from faulty experiments by self-deluded and even fraudulent scientists. This theory is unfortunately still widely held by many scientists. The idea of "pathological science" as applied to cold fusion has been given wide currency through electronic bulletin boards and lectures by physicist Dr. Douglas O. Morrison of CERN. The authors of three negative books on the history of cold fusion, Professor John R. Huizenga, Dr. Frank Close, and science journalist Gary Taubes[1] have also promoted the explanation of "pathological science." We need not comment further on this "theory," except to suggest that it has long since been demontrated false.

The second explanatory category suggests that cold fusion is a mis-interpreted release of ordinary chemical energy. While this possibility might have been a valid issue in the first months after March 23, 1989, there is now adequate proof from a host of experiments, which employ a variety of calorimetric techniques, that the energy releases cannot be attributed to ordinary chemical reactions. By ordinary chemical reactions, we mean the release of energy from materials in a cell (e.g. the hydrogen isotope- infused cathode) that would be of the order of 10 eV (electron volts) per atom or much less—typical chemical energy storage levels. In many cold fusion experiments, it is common now to observe energy releases in the range of hundreds to thousands of eV per atom.

We then reach another explanatory level, category 3: solid state nuclear reactions. This is the level of explanation favored by many "mainline" cold fusion researchers, such as Scott and Talbot Chubb, Peter Hagelstein, Giuliano Preparata, and Julian Schwinger. They suggest that if we search in the cathode lattice and in off gases, we will find nuclear "ash" commensurate with the excess heat. It is easy to understand why this category of explanation has wide appeal. First, nuclear products at low levels already have been proved to exist, and the thermal energy releases averaged over the entire cathode yield energy that cannot be due to chemistry. The basic idea is that maybe some kind of MeV-level (million electron volt-level) reactions are occurring and dumping their energies benignly into the metal lattice and adjacent fluid. Over the many cathode atoms, these multi-MeV nuclear level energy releases would average to hundreds to thousands of eV per atom, precisely what is found experimentally.

Beyond category 3 there is an abyss, but one that cannot be ignored. The magic "something else" is appealing, since cold fusion has been so resistant to explanation as a purely nuclear process with commensurate nuclear products. What could that "Something Else" be? Known to this author are three theories of cold fusion that fit this category:

(1) The theory of Dr. Randell Mills of HydroCatalysis Power Corporation and Stephen Kneizys (7), which suggests that it possible for hydrogen atoms to have energy states below the ground state normally assumed in conventional quantum mechanics. This radical theory postulates that energy can be catalytically removed from hydrogen atoms during special electrolysis processes (or other processes), causing the hydrogen atoms (H or D) to "shrink" as the electron assumes a fractional quantum number energy state below $n=1$. This unusual theory of cold fusion suggests that the excess heat from cold fusion is not nuclear at all, but what one might call a kind of "super-energetic chemistry." The "ash" is postulated to be shrunken hydrogen atoms. The Mills theory suggests that these shrunken hydrogen atoms, by virtue of their dimension and charge distribution, which makes them look more like small neutral particles, can account for the nuclear effects seen in cold fusion. That is the claim, anyway, though most cold fusion investigators are highly skeptical, albeit very impressed that Mills et al have marshalled what seem to be incontrovertible experimental evidence for massive releases of excess energy from ordinary water systems with nickel cathodes. In recent times, Dr. Mills and his colleagues have assembled more direct proof of the existence of shrunken hydrogen atoms, which they dub "hydrinos." So the tide of opinion on this theory could change at any moment.

(2) The oscillating dynamical Jahn-Teller bond theory of materials scientist, Professor Keith Johnson of MIT (8), suggests that many of the nuclear products that have been seen in cold fusion are real, but do not explain the excess heat. Johnson originally put forth his theory in the spring of 1989, following the announcement by Pons and Fleischmann. At that time, he and his colleague Dr. Clougherty did not calculate the level of energy release, but suggested that such ex-

cess power might also be seen in light water systems. That was prescient. Today Johnson has radically increased his estimate of how much heat might be extracted from electrochemical systems. He now suggests that the amount of energy extractable from water is equal to the heat of vaporization of water, which is large. He suggests that with this kind of "energy conversion" promoted by hydrided metallic lattices, such as alloys of nickel and alloys of palladium, it will be possible to build "water engines" suitable for powering automobiles and much else.

On the other hand, Professor Johnson's hydrogen fuel, though astoundingly revolutionary, is millions of times less powerful than if nuclear reactions were at work. The Johnson theory, apart from its excellent insights into the workings of hydrided lattices, is not necessarily the full explanation because of its excess energy projections that appear to fall short of what is happening. Furthermore, how does one get 4_{He} or cold tritium out of such a process without relying on a mechanism to benignly suppress radiation into a thermal channel?

(3) Finally, we reach an extremely exotic theory—the possibility that cold fusion, in part, represents tapping of the vacuum zero-point energy (ZPE), which contemporary physics acknowledges pervades space, but which was presumed to be inaccessible technologically. One of the chief investigators of the possibility of the tapping of zero point energy, Dr. Hal Puthoff of the Institute for Advanced Studies, Austin, Texas, has not publicly promoted his ideas as an explanation of cold fusion. He has written numerous theoretical papers in reputable journals (e.g. *Physical Review*) on the implications of zero-point energy, and he has worked with Kenneth Shoulders to produce a series of experiments (which are backed up by more than a dozen U.S. patents, some of which have already been granted) that may suggest that zero-point energy can be tapped. This work appears to require the invocation of the well-established Casimir force to explain the ZPE energy extraction. Either that, or it is in error.

While being publicly coy about the possible implications of zero-point energy for cold fusion phenomena, Dr. Puthoff has written articles in *Speculations in Science and Technology* [9] and in *Fusion Facts*[10] that broadly hint about the possibility that ZPE may have something to do with cold fusion. Witness these remarks:

"If one could arrange to have an inexhaustible supply of such [Casimir] devices, and if it took less energy to make each device than was obtained from the Casimir-collapse process, and if the devices were discarded after use rather than recycled, then one could envision the conversion of vacuum energy to use with a net positive yield. Although almost certainly not achievable in terms of mechanical devices, a possible candidate for exploitation along such lines would be the generation of a cold, dense, non-neutral (charged) plasma in which charge condensation takes place not on the basis of charged plates being drawn together, but on the basis of a Casimir pinch effect. (Casimir pinch effects have been explored in the literature, not with regard to energy conversion, but in terms of semiclassical modeling of charge confinement in elementary particles, hadron bag models, etc.) Such an approach would constitute a 'Casmir-fusion' process, which in its cycle of operation would mimic the nuclear-fusion process.[9]

and . . .

In *Fusion Facts* in September, 1991, Dr. Puthoff repeated the above statements in abbreviated form and continued: "In principle, if the energy used to generate the appropriate plasma conditions is less than the energy that one could recover from the plasma, then the result would be the efficient tapping of zero-point vacuum energy. Laboratory experiments are underway to investigate this possibility." [10]

The hydrided metallic lattice might be the site of that cold, dense plasma mentioned by Dr. Puthoff.

It is interesting to note that Professor Martin Fleischmann himself has recently suggested that nuclear reactions producing 4_{He} cannot be the whole story of what is going on in cold fusion:

"I think there is a wider set of nuclear phenomena. There is not just one phenomenon. This was apparent to Stan and me right from the beginning. We cannot account for the generation of neutrons, tritium, and heat by any one single process. There are several different processes, and these have to be investigated separately. This really leads to the helium-4 story. As long as we haven't accounted for all of the heat by the production of fusion products, we have to carry on with the search. This search will uncover many new phenomena. It could be that sufficient helium-4 will be found and this will be the whole story, but I doubt it. In my opinion, the creation of helium-4 by cold fusion is important, but to say that it explains everything is a simplification, even though it may be 99.9 percent of the story. Until the basics are established, we have to be careful that we have the whole story." (*21st Century Science and Technology*, Winter, 1992)

Solid state nuclear reactions

Solid state nuclear reactions are the mainline, "category 3" theories of cold fusion. To get solid state nuclear reactions to occur there are two basic requirements: (1) Surmount the huge electrostatic repulsion Coulomb barrier between positively charged reactant nuclei and (2) Dump the energy of the reaction into the metallic lattice so that it does not emerge as a lethal burst of radiation. That there is a mechanism for such energy dissipation in the lattice is clear from the existence of "cold" (low energy) tritium and 4_{He} without gammas, even without there being commensurate levels of either product corresponding to thermal releases. So, we must assume that cold fusion involves transfer of energy to the lattice, as the Chubbs, Hagelstein, Preparata, Schwinger and others propose, each in their own way.

Theories: An overview

What follows are brief summaries of what the various cold fusion theorists have said. Apologies to those many other outstanding theorists whose work I have not mentioned. This is an attempt to summarize a group of the better known theories, not to be exhaustive. In alphabetical order:

•Robert T. Bush[11]: "The Transmission Resonance Model and Alkali Hydrogen Fusion"

The "TRM" or Transmission Resonance Model of Robert Bush is inspired by the wave properties of matter. Bush conceives of a deuterium-infused metal lattice as an environment in which deuterium nuclei—"diffusons," as Bush calls them—may achieve a kind of quantum-mechanical resonance condition. This mathematical "transmission resonance condition" occurs, he suggests, "when an odd integral multiple of the average quarter wavelengths of the De Broglie waves of the diffusons match the potential well widths of the particles situated in the palladium deuteride (PdD) lattice." This, he claims, allows deuterons to get close enough to the lattice atoms to undergo nuclear reactions.

Bush in his 1991 paper claimed that his model could correlate many features of experimental data that had already been seen in cold fusion, such as the level of excess power versus current density. He also predicted that transmutations of elements would be seen in cold fusion experiments and that power levels on the order of 1 kW/cm³ would be reached. Both of these predictions have come to pass. He also suggested that, based on his theory, there was no fundamental reason why excess heat would not also emerge in light water systems.

Later experimental evidence convinced Bush that there could be nuclear reactions between alkali elements (Li, K, Rb, etc.) and hydrogen isotopes, including ordinary hydrogen. Bush claims to have evidence that the transmutation of these alkali elements is occurring in light water (e.g. K to Ca via the addition of a proton to K) at levels that explain the excess heat very well.

•Talbot Chubb and Scott Chubb[12]: "The Ion Band State Theory"

This uncle and nephew physicist team from the U.S. Naval Research Laboratory addresses the quantum-mechanical behavior of charged particles in a periodic metal lattice, such as palladium. The Chubbs say that the Coulomb barrier to fusion does not exist in the particular lattice configuration which they have in mind. They write, "When energetically favored, charged particles in a crystal lattice [such as positively charged deuterium nuclei, D^+] assume a non-chemical configuration that matches the periodicity of the lattice, as described by Bloch wave functions." They say that because kinetic energy dominates over potential energy in the Schroedinger equation that led to these mathematical "Bloch functions," the wave functions overlap and facilitate fusion of deuterons to 4_{He}.

How does energy emerge benignly rather than as lethal 23.8 MeV gamma rays? They say that the energy is released over a volume of the lattice, rather than at a point. They suggest that the rules of quantum mechanical transfer of energy and momentum in a lattice—for "small to moderate size crystals"—prevent the ejection of high energy radiation.

As for the heat from ordinary water, the Chubbs think that it derives from the 150 ppm of deuterium in natural water that undergoes this ion band state fusion in Ni via the same D + D reaction that they postulate for the palladium-heavy water system.

- Peter L. Hagelstein[13]: "Coherent and Semi-Coherent Neutron Transfer Reactions"

MIT Professor Peter Hagelstein was among the first theorists in the cold fusion field to speculate about coherent nuclear reactions in the lattice, which would require cooperative behavior among metal lattice atoms both to promote the reactions and to liberate heat rather than lethal ionizing radiation. His theoretical framework evolved considerably from the early days in which he, like the Chubbs, was also suggesting 4_{He} as the nuclear ash. Now Hagelstein believes that the prototypical reaction involves the transfer of a neutron from one nucleus to another, which is mediated by low frequency electric or magnetic fields. He says that these transfers occur between a donor nucleus to "virtual continuum states," followed by capture of the "virtual neutron" by an acceptor nucleus. It is a physical tour de force, many say, to have these "virtual neutrons" wander very far from a donor nucleus to be "accepted" by another nucleus.

Hagelstein is convinced that the reactions responsible for the heat are of nuclear origin, but that they are not fusion reactions per se. The neutron transfer reactions that Hagelstein postulates create not only the excess heat, but also side reaction products, such as cold tritium, 4_{He}, and the various isotope shifts and element transmutations that have been observed. The neutron might go, as an example, to another deuterium nucleus, to a 6_{Li} nucleus, to a 10_B nucleus, or to a Pd nucleus.

- Keith Johnson and D. Clougherty[8]: "Dynamic Jahn-Teller Oscillations"

The oscillating Jahn-Teller bond theory of materials scientist, Professor Keith Johnson of MIT and Dr. D. Clougherty[8], suggests that many of the nuclear products that have been seen in cold fusion come from the overlap of atomic wave functions brought about by the special Jahn-Teller bonds in hydrided metal lattices of palladium and nickel and their alloys. The nuclear reactions occur by enhancing tunneling probability between deuterium nuclei or between deuterium and heavier nuclei.

Johnson and Clougherty, however, do not believe that these nuclear reactions explain the excess heat. Johnson suggests that the amount of energy extractable from water is equal to the heat of vaporization of water, which is large and technologically extremely useful.

The theory postulates a common quantum mechanical origin of both the well-known superconductivity and the excess heat effects in hydrogen/deuterium in palladium. These effects both arise from an interstitial network of "delocalized H-H/D-D ss-bonding molecular orbitals at the Fermi energy." The dynamical Jahn-Teller oscillations of the protons or deuterons are "optical phonons," which the theory says gives rise to the superconductivity at low temperature and excess heat at higher temperature.

- Frederick Mayer and John Reitz[14]: "The Hydron Theory"

One of the most unusual and creative theories of nuclear reactions in solids was put forth by two Michigan physicists, Drs. Fred Mayer and John Reitz, one of whom—Mayer, has long been involved in the hot fusion program, specifically inertial confinement fusion or laser fusion. In May, 1991, Mayer and Reitz proposed that an unusual short-lived resonance between an electron and the proton of the hydrogen nucleus could make hydrogen or an isotope of hydrogen momentarily look like a neutral particle. This "hydron," whose lifetime might be only a few tens of nanoseconds (billionths of a second), could react with other atomic nuclei in metal lattices.

- Giuliano Preparata[15]: "Quantum Field Theory of Superradiance"

After the Utah announcement, Preparata and his colleagues were among the first to speculate about how cold fusion could occur in palladium lattices. Since then, Preparata has further developed his theoretical ideas and has analyzed many of the other cold fusion theories. He finds these other theories wanting because, he says, they do not consistently and effectively overcome the two central problems of cold fusion, which he lists as: (1) Dealing with the Coulomb barrier between deuterons in a lattice and (2) Making D-D fusion take place in a palladium lattice differently than in a vacuum to get high levels of heat without accompanying lethal radiation. Preparata is first to admit that his ideas do not explain every experimental aspect of cold fusion, but he considers his approach to be the best starting point. His theory is very complex and carefully considered, but it is not amenable to simplified description.

Preparata speaks of "coherence domains," in which charges in the lattice oscillate in phase around equilibrium positions with well-defined amplitude; this is coherent oscillation. There is an oscillating "electron plasma," a "palladium nuclei plasma," and a "deuterium plasma." He says that his superradiance method describes the plasmas "by a quantum wave field" that is time-dependent. Preparata shows how all this works to enhance the tunneling probability by tens of orders of magnitude (10^{30} or more) over what one might normally expect, so that the cold fusion effects that are observed are accounted for.

Preparata manages to find another billion-fold enhancement of the tunneling probability by positing that a single deuteron added to the lattice actually "sees" the assembly of deuterons in the lattice within a coherence domain as a "single quantum mechanical wave function." After fusion, the electron plasma disperses energy benignly in the lattice. Preparata manages to calculate an excess heat release that is in the right regime of the original Pons-Fleischmann experiment.

- Julian Schwinger[16]: "Nuclear Energy in an Atomic Lattice"

Nobel laureate Julian Schwinger has been a prominent defender of boldness and openness in speculating about the mechanisms of cold fusion. He thinks the process is certainly nuclear. Among other bold conjectures of Schwinger, he was first to consider whether cold fusion might represent a nuclear reaction between D and H, H being present in trace amounts in heavy water. For that matter, D is also present obviously in ordinary water, so this may tie in with the appearance of excess heat in Mills-type experiments. This reaction would produce 3_{He}, for which not too many experimenters have searched. He says that the "asymmetry" of the HD reaction over DD enhances HD. This, he says, might be the origin of the disproportionate ratio of tritium to neutron emission in cold fusion.

Schwinger's main line of theoretical investigation is the transfer of energy from nuclear reactions to coherent vibrations in the metal lattice. He also sees the lattice acting to suppress the Coulomb repulsion between hydrogen species—"to overcome it with an energy of attraction that significantly ameliorates the effect of Coulomb barrier penetration."

Schwinger writes, "It may be that a microscopically large—if macroscopically small—region attains a state of such lattice uniformity that it can function collectively in absorbing the excess nuclear energy that is released in an act of fusion."

Schwinger posits that an initial energy "fluctuation" occurs at one part of a uniform metal-hydrogen lattice. This transfers energy from a fusion—(H+D) or (D+D)—and transfers it via intense "phonon" vibrations. Schwinger says this leaves the reacting pair of nuclei in a "virtual state of negative energy." He suggests that if the final reactant product state, say 3_{He} as in the case of (H + D), is close to the magnitude of energy in the "virtual state of negative energy," this will be a "resonance" and the Coulomb barrier will not have to be suppressed. He even speculates about the "causal order" of the reaction, emphasizing that unlike the vacuum "the lattice is a dynamical system, capable of storing and exchanging energy."

In one of his papers, after he describes the "indictment of cold fusion" by the skeptics, Schwinger comments in his inimitable economical style, "The defense is simply stated: the circumstances of cold fusion are not those of hot fusion."

- Akito Takahashi1[7]: "Multi-Body Fusion"

Akito Takahashi, a Japanese hot fusion physicist and now cold fusion experimenter and theorist, has made many waves in the cold fusion field. His has conducted repeatable, simultaneous measurement of low-level neutron emissions and excess heat production in specially configured D_2O-Pd/Pt cells.

To explain cold fusion phenomena, Takahashi proposed a controversial multi-body fusion process, which requires deuterium nuclei at lattice sites within palladium to come together and create unusual nuclear reactions involving more than two reacting nuclei. At high loading of D into the Pd lattice (D/Pd > 1.0), multiple deuterons at so-called octahedral sites ("o-sites") may occasionally simultaneously fall into the so-called tetrahedral sites ("t-sites") throughout the lattice. Three, four, or even five deuterons may react simultaneously in a t-site. Takahashi suggests that "strong electron screening" may act momentarily when deuterons "fall into" the t-site.

Takahashi suggests that the "chaotic" cold fusion results for tritium, heat, charged particles, neutrons, and 4_{He} can be explained by this multi-body fusion process. He also proposes how mixtures of H and D, as in ordinary water cold fusion experiments, yield heat and the two forms of helium through multi-body fusion of H and D. He has recorded high energy charged particle emissions from ion beam-loaded metals that he says supports his multi-body fusion theory.

Sonoluminescence and cold fusion

Sonoluminescence (SL), like cold fusion, is a very strange phenomenon that has been resistant to explanation. It has been treated much more politely than cold fusion in the scientific press, because since its discovery there has never been any question about the reality of light emission from collapsing bubbles in fluids. The phenomenon of light emission from cavitation bubbles dates back to 1934.

Physics Nobel laureate Julian Schwinger, whose interest in cold fusion predates his involvement with the theory of sonoluminescence, gave talks at the University of Pennsylvania and at MIT in the fall of 1991 At that time he made what might be called a "metaphoric comparison" between cold fusion and sonoluminescence[18]. He traced the history of sonoluminescence, pointing out that the 1934 work assumed (of course) that the emitted light in SL was incoherent, hence this was incoherent SL. In 1970, he said, the possibility of coherent SL arose when SL was first seen with no attendant cavitation noise—just the light. In 1990, Professor Seth Putterman and Bradley Barber at UCLA, proved that sonoluminescence could arise from a single cavitation bubble if the acoustic field were designed properly in frequency and amplitude.[19–21]

Photomultiplier analysis of the SL light revealed pulses of light rather than continuous light, each pulse emitted in less than 50 picoseconds, said pulses tracking the acoustic period. The period of the acoustic waves, by contrast, was on the order of 10^{-4} seconds. Each pulse consisted of about 10^5 blue wavelength photons.

From the outset, Schwinger apparently viewed sonoluminescence as a manifestation of a "dynamical Casimir effect." The static Casimir effect is the well-established attractive force between two very closely spaced conducting plates in a vacuum. This is how Schwinger described the general mechanism of coherent SL:

"A bubble in water is a hole in a dielectric medium. Under the influence of an oscillating acoustical field, the bubble expands and contracts, with an intrinsic time scale that may be considerably shorter than that of the acoustical field. The accelerated motions of the electromagnetic field create a time-dependent, dynamical, electromagnetic field, which is a source of radiation. Owing to the large fractional change in bubble dimensions that may occur, the relation between field and source could be highly nonlinear, resulting in substantial frequency amplification." [18]

Cold fusion and sonoluminescence were metaphorically linked, according to Schwinger, because "the great disparity between atomic and nuclear energy scales," which are of the order of 10^7 different. In sonoluminescence, the energy scale of the bubble and the light emission is on the order of 10^{11} times different. Note that the time scales of the acoustic waves and the light pulses in sonoluminescence are also of very different scales; the pulse width is some 10^7 times smaller than the acoustic wave period. Schwinger has gone on to perform further theoretical assessments of sonoluminescence, linking it to the Casimir effect[23–25].

Though acoustic stimulation of cold fusion appears to have been a generic concept that arose soon after March 23, 1989 (virtually every conceivable method of activating the process was proposed!), there seems to have been no public link made between cold fusion and sonoluminescence until Julian Schwinger's 1991 talks. However, Dr. David Deak of New York City had privately examined the prospects for actually triggering cold fusion phenomena using sonoluminescence.[22] The link between cold fusion and sonoluminescence, he believes, is more direct than anyone had imagined. Roger Stringham has conducted many successful ultrasonically-triggered cold fusion experiments ("micro fusion" from cavitation, he calls it), which were reported at ICCF4. The temperature reachable at the surface of deuterium-contacted metals under ultrasonic triggering probably exceeds 1,600°C. This means that practical energy producing devices are within reach.

Postscript

Even with the various theories of reaction and energy deposition within lattices, we are still faced with the possible severe conundrum of the lack of nuclear ash commensurate with the excess heat. Where is the balance of the thermal energy to come from which is not accounted for by the observed ash? Perhaps it will require a combination of theories to explain cold fusion: the postulate of simultaneously acting mechanisms on different scales of time and energy. Cold fusion seems a difficult enough problem to require that.

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