Note: Julian Schwinger (1918 - 1994) developed the theoretical basis for quantum electrodynamics, for which he shared the 1965 Nobel Laureate in Physics with Richard Feynman and Shin'ichiro Tomonaga. This talk was given on December 7, 1991, in Japan, at a celebration of Tomonaga's centennial birthday. See also: Schwinger, Julian, Cold Fusion Theory, *A Brief History of Mine,* on this website.

Cold Fusion—Does It Have a Future?

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Abstract. The case against the reality of cold fusion is outlined. It is based on preconceptions inherited from experience with hot fusion. That cold fusion refers to a different regime is emphasized. The new regime is characterized by intermittency in the production of excess heat, tritium and neutrons. A scenario is sketched, based upon the hypothesis that small segments of the lattice can absorb released nuclear energy.

Minasama. Ladies and Gentlemen

A totally unexpected phenomenon has been discovered in a certain field of science. It could have significant implications for the future of mankind, and especially for the Japanese. The overwhelming reaction of the experts in the field is rejection, based on the absence of other effects that are considered to be necessary companions of this new phenomenon. To quote one expert: "We know a lot about what happens. . . . We no longer have the latitude to say 'Well, some strange event occurred and generated those things.'" Nevertheless, this new possibility seems to have enough validity that one skeptic said: "It's hard to believe it. But there seems to be something to this." And he went on to say: "It should not be necessary, however, to understand the mechanism before embracing the concept. If a proven track record can be established . . . you have to believe it."

To which scientific field does all this refer? In view of the title of my lecture, the question may seem surprising. In fact, the object is *seismology*. The new phenomenon is the occurrence of electromagnetic effects just prior to the onset of an earthquake. The most striking event happened on 17 October, 1989. The apparatus of a team of radio detection specialists, which was situated in the Santa Cruz mountains of California, received an unprecedented blast of radio power. The strong signal continued for several hours, and then stopped, to be followed by the Loma Prieta earthquake that, last year, wreaked severe damage in the San Francisco area. Another kind of measurement seeks changes in electrical resistivity for ground currents. Scientists in Athens, Greece, have established a track record of 75% success in predicting earthquakes.

Of course – apart from the specific words of the quotation – all that I said before also applies to the phenomenon of cold fusion.

It is astonishing that there was an early precursor of the claim to have achieved cold fusion. Dated at the beginning of the Showa era, the German title of the paper is translated as "On the transformation of hydrogen into helium." At that time, neither the existence of the heavier isotopes of hydrogen, nor of the lighter isotope of helium, was recognized. If, indeed, they did produce helium, was it ^{4}He, or was it ^{3}He? Incidently, at just that time, Nishina Yoshio was at Niels Bohr's institute in Copenhagen. One can only wonder how he reacted to the bizarre claim.

On 23 March, 1989, the University of Utah, at Salt Lake City, threw a press party. Its purpose was to establish priority for patents on a new source of energy. The impetus was supplied by what seemed to be a rival group, down the road at Provo, Utah. The patent lawyers needn't have worried. The Provo people were investigating a very weak source of neutrons, which is only of academic interest. But, science filtered by patent attorneys is no longer science. Isn't it possible to establish a track record without reference to the initial claimants?

The National Cold Fusion Institute has provided a clearing house for reports that bear on the reality of cold fusion. As of August, 1990, 78 other groups, from all over the globe, have reported positive evidence, as conveyed by the detection of one or more of these indicators: excess heat, tritium, neutrons, γ-rays, ^{3}He. The standard response to such a list is: "Yes, but what about the much larger number of failures?" Does anyone really think that the scientific judgement is like an election, in which the majority carries the day?

The characteristics that seem to be common to all successful cold fusion experiments are: (1) Intermittency—the production of heat, of tritium, of neutrons, comes in bursts, switching on and off at random. (2) Irreproducibility—seemingly identical cells vary widely in their ability to "turn on." It may not be too much of an exaggeration to say that, early in April, 1989, everyone – including those who, like myself, had to look up the meaning of enthalpy – had thrown together and electrolysis apparatus and was waiting for dividends. After a few weeks, with no reward, they quit in disgust, and denounced it all as incompetence, or fraud. Their votes are irrelevant.

Reproducibility is often cited as a canon of science. And so it is, in established areas. But, early in a study of a new phenomenon that involves an ill-understood macroscopic control of a microscopic mechanism, irreproducibility is not unknown. That was so at the onset of microchip studies. It also appeared in the initial phase of the discovery of high temperature superconductivity, which, by the way, is a prime example of "embracing the concept" without having "to understand the mechanism."

What is it about cold fusion that seems to enrage a substantial number of physicists? The people who have spent a lot of money on hot fusion would doubtless echo: "We know a lot about what happens. . . . We no longer have the latitude to say 'Well, some strange event occurred and generated those things.'" To be specific, this is how their preconceptions work: (1) In hot fusion, the union of two deuterons, to form ^{3}He and a neutron, proceeds at about the same rate as the formation of a triton and a proton. But the emission of neutrons from palladium electrodes immersed in heavy water occurs at a rate around the insignificant background level. Conclusion:

No neutrons—no cold fusion. (2) The two cited reactions are the only important ones in hot fusion. There is no independent source of excess heat. Conclusion: Incompetence. (3) Given the essential absence of neutrons, what of the claims for substantial tritium production? Conclusion: Fraud. (4) At the low energy of cold fusion, the penetrability of the Coulomb barrier is so overwhelmingly small that nothing could possibly happen. Conclusion: Stupidity.

The next item of the hot fusioneer's creed are responses to suggested cold fusion mechanisms: (5) Very soon after 23 March, 1989, it was proposed that excess heat is produced by the formation of ground state ^{4}He in the DD fusion process. Response: Where is the accompanying γ-ray of roughly twenty million electron volts? (6) Then came the recognition that excess heat might be dominated by HD, rather than the DD reaction. Heavy water unavoidably contains some fraction of a percent of light water. The fusion of a proton with a deuteron produces ^{3}He. Response: Where is the accompanying γ-ray of roughly five million electron volts? (7) The HD reaction is a source of heat and of ^{3}He, but not of neutrons or tritium. The latter must come from the DD reaction. What happens if two fusing deuterons populate, not in the ground state, but the first excited state of ^{4}He? That excited state is unstable against decay into a triton and a proton. It is *stable*, however for decay into a neutron and ^{3}He. Here, then, is a mechanism to account for the great disparity between neutron and triton production—the ratio is about one in a hundred million—that seems to be characteristic of cold fusion. Response: Where is the accompanying γ-ray of about four million electron volts?

So stands the indictment of cold fusion. The defense is simply stated: The circumstances of cold fusion are not those of hot fusion.

It is a standard operation procedure, in hot fusion work, to represent the reaction rate as the product of two factors: the barrier penetration probability, which involves only the Coulomb repulsion; and, the intrinsic reaction rate, which is dominated by nuclear forces. But, at the very low energy of cold fusion, one is dealing, essentially, with a single wavefunction, which does not permit such factorization. The effect of Coulomb repulsion cannot be completely isolated from the effect of the strongly attractive nuclear forces. This is a whole new ballgame. It is, so to speak, a sumo tournament restricted to the maku-no-uchi, indeed, to the yokuzuna.

The wavefunctions for a low energy proton and deuteron, and for a low energy pair of deuterons, are effectively dominated by zero relative angular momentum. They are states of even orbital parity. The intrinsic parities of all relevant particles—neutron, proton, deuteron, triton, ^{3}He, ground state, and first excited state of ^{4}He—are also positive. So, the normally dominant process of electric dipole radiation is forbidden; it requires a parity change.

If the γ-rays demanded by the hot fusioneers are greatly suppressed, what agency does carry off the excess energy in the various reactions? One must look for something that is characteristic of cold fusion, something that does not exist in the plasma regime of hot fusion. The obvious answer is: the lattice in which the deuterium is confined.

Imagine, then, a small but macroscopic piece of the lattice absorbs the excess energy of the HD or DD reaction. Please—I beg of you—do not rise in high dudgeon to protest that this is impossible because of the great disparity between atomic and nuclear energy scales. That is a primitive reaction to what may be a very sophisticated mechanism. And do not forget the failure of theory to predict, and then to account for the phenomenon of high temperature superconductivity. I advance the idea of the lattice playing a vital role as a *hypothesis*. Past experience dictates that I remind you that a hypothesis is not something to be proved mathematically. Rather, it is a basis for correlating data and for proposing new tests, which, by their success or failure, support or discredit the validity of the hypothesis. It is the essence of the scientific method.

Intermittency is the hallmark of cold fusion. It incorporates irreproducibility as a circumstance in which the time intervals between bursts significantly exceed the duration of the observations. Intermittency is the ultimate rebuttal to the charges of fraud in the tritium production. Externally introduced tritium maintains an essentially constant counting rate. There is no resemblance to the switching on and off of the observed bursts. Does the lattice hypothesis have a natural explanation for intermittency?

One needs information about the lattice structure of deuterided palladium. The experts say that "We know a lot . . ." but that knowledge does not include what happens in the important regime of heavy deuteron loading. There is, however, a theoretical suggestion that, in the circumstance of heavy loading, a pair of new equilibrium sites comes into existence within each lattice cell. The equilibrium separation for that pair is significantly smaller than any other such distance in the cell.

It would seem that a close approach to saturation loading is then required for effective fusion to take place. But, surely, the loading of deuterium into the palladium lattice does not occur with perfect spatial uniformity. There are fluctuations. It may happen 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. And that energy can initiate a chain reaction as the vibrations of the excited ions them into closer proximity. So begins a burst. In the course of time, the increasing number of vacancies in the lattice will bring about a shut-down of the burst. The start-up of the next burst is an independent affair.

This scenario raises an interesting question: Would the efficacy of room temperature cold fusion be enhanced significantly by further lowering of the ambient temperature? Lower temperature would presumably decrease somewhat the probability of the initial fusion. But, it should increase the probability of forming and maintaining the lattice structure against the destructive onslaughts of thermal agitation. Experiment must supply the answer.

I find it both amusing and tragic that the members of a panel, investigating the charge of fraud in tritium production by cold fusion, dismissed the charge as "unlikely" and "much less probable than that of inadvertent contamination or other unexplained factors in the measurement." That the "unexplained factors" might be the reality of cold fusion was not admitted. Why? Because "critics questioned the results, saying that the tritium was not accompanied by other fusion byproducts. . . ." It is the old story. If a significant flux of neutrons is not observed, there cannot be any tritium, even though one finds tritium with a signature that differentiates it both from external and internal contamination.

The pressure for conformity is enormous. I have experienced it in editors’ rejection of submitted papers, based on venomous criticism of anonymous referees. The replacement of impartial reviewing by censorship will be the death of science.

Does cold fusion have a future? I have little hope for it in Europe and the United States – the West. It is to the East, and, specifically to Nihon, that I turn. The willingness that the Japanese have displayed, of foregoing short term rewards for greater long term successes, should be a key ingredient in this endeavor.

Indulge me in a fantasy, not of the future, but of the past. I should like to think that, if cold fusion had been a burning topic a few years before 1951, as well it might, Nishina would have recognized that was a subject for open minded research—not suppression. And, in view of the physioco-chemical nature of this subject, that he would have thrown all the resources of the institute of physical and Chemical Research—into the study and development of cold fusion. Dare one hope that a dream of the past also contains a glimpse of the future?

Domo arigato gozaimasu. Thank you very much.