Introduction to the English Edition of –

Nuclear Transmutation: The Reality of Cold Fusion

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Introduction by Jed Rothwell

The announcement of cold fusion in March 1989 at the University of Utah was greeted with worldwide hysteria. Drs. Martin Fleischmann and Stanley Pons had claimed that an electrochemical cell with heavy water electrolyte and a palladium cathode put out so much excess energy that the mysterious phenomenon had to be nuclear, and was probably a process related to nuclear fusion. Newspapers and magazines said it might be a major scientific discovery with the potential to end the energy crisis and revolutionize society. For a few heady weeks the public took it seriously and waited anxiously for laboratories to replicate the results. Many scientists quickly took sides for or against cold fusion – mostly against. Then, by the end of the summer of 1989 the official word came, in an authoritative report written by a select panel of experts under the auspices of the Department of Energy: cold fusion was a bust. It did not exist. It was an experimental error. It could not be reproduced. Nearly every scientific journal, magazine and newspaper on earth reported this, and cold fusion abruptly dropped out of the headlines. The story, it seemed, was over. Actually, it had barely begun. Only a few thousand electrochemists in the world were qualified to do the experiments, and most of them were too busy or not interested in trying. In that autumn as public interest faded and the U.S. Department of Energy pronounced a death sentence, a small number of experienced scientists prepared serious, full-scale experiments. One of them was Tadahiko Mizuno, an assistant professor who had been doing similar electrochemical experiments for more than twenty years.

Mizuno wrote this short book about his work and personal experiences. It is the best informal account yet written about the daily life of a cold fusion researcher. It gives you a sense of what the job feels like. It is not intended to be technical. For technical details, the reader is invited to examine Mizuno's numerous scientific papers, some of which are listed in the references.

One event described here which is not described in the technical literature is an extraordinary 10-day long heat-after-death incident that occurred in 1991. News of this appeared in the popular press, but a formal description was never published in a scientific paper. [1] Mizuno says this is because he does not have carefully established calorimetric data to prove the event occurred, but I think he does not need it. The cell went out of control. Mizuno cooled it over 10 days by placing it in a large bucket of water. During this period, more than 37 liters of water evaporated from the bucket, which means the cell produced more than 84 megajoules of energy during this period alone, and 114 megajoules during the entire experiment. The only active material in the cell was 100 grams of palladium. It produced 27 times more energy than an equivalent mass of the best chemical fuel, gasoline, can produce. I think the 36 liters of evaporated water constitute better scientific evidence than the most carefully calibrated high precision instrument could produce. This is first-principle proof of heat. A bucket left by itself for 10 days in a university laboratory will not lose any measurable level of water to evaporation. First principle experiments are not fashionable. Many scientists nowadays will not look at a simple experiment in which 36 liters of water evaporate, but high tech instruments and computers are not used. They will dismiss this as "anecdotal evidence."

It is a terrible shame that Mizuno did not call in a dozen other scientists to see and feel the hot cell. I would have set up a 24-hour vigil with graduate students and video cameras to observe the cell and measure the evaporated water carefully. This is one of history's heartbreaking lost opportunities. News of this event, properly documented and attested to by many people, might have convinced thousands of scientists worldwide that cold fusion is real. This might have been one of the most effective scientific demonstrations in history. Unfortunately, it occurred during an extended national holiday, and Mizuno decided to disconnect the cell from the recording equipment and hide it in his laboratory. He placed it behind a steel sheet because he was afraid it might explode. He told me he was not anxious to have the cell certified by many other people because he thought that he would soon replicate the effect in another experiment. Alas, in the seven years since, neither he nor any other scientist has ever seen such dramatic, inarguable proof of massive excess energy.

Here is a chronology of the heat-after-death event:

March 1991. A new experiment with the closed cell begins.

April 1991. Cell shows small but significant excess heat.

April 22, 1991. Electrolysis stopped.

April 25. Mizuno and Akimoto note that temperature is elevated. It has produced 1.2×10^7 joules since April 22, in heat-after-death.

F. Nakano, "Mohaya hitei dekinai jyouon kakuyuugou [The reality of cold fusion can no longer be denied]," *Bungei Shunju*, September 1991

The cell is removed from the underground lab and transferred to Mizuno's lab. Cell temperature is >100 deg C.

April 26. Cell temperature has not declined. Cell transferred to a 15-liter bucket, where it is partially submerged in water.

April 27. Most of the water in the bucket, ~10 liters, has evaporated.

The cell is transferred to a larger, 20 liter bucket. It is fully submerged in 15 liters of water.

April 30. Most of the water has evaporated; ~10 liters.

More water is added to the bucket, bringing the total to 15 liters again.

May 1. 5 liters of water are added to the bucket.

May 2. 5 more liters are added to the bucket.

May 7. The cell is finally cool. 7.5 liters of water remain in the bucket.

Total evaporation equals:

April 27	10 liters evaporated. Water level set at 15 liters in a new bucket.
April 30	10 liters evaporated. Water replenished to 15 liters
May 1	5 liters replenished.
May 2	5 liters replenished
May 7	7.5 liters remaining.

Thus, evaporation since April 30 is: 15+5+5-7.5=17.5 liters. Total evaporation is 37.5 liters. The heat of vaporization of water is 540 calories per gram (2,268 joules per gram), so vaporization alone accounts for 85 megajoules.

One aspect of the heat-after-death event seems particularly strange. It is as if the cathode is trying to maintain stasis inside the cell. After the external 60 watt heater was turned off, the heat-after-death reaction increased just about enough to compensate for the loss of external heat. This sounds like an instrument error. It prompted Mizuno to double check all instrument readings with meters attached directly to the sensors. As unbelievable as this sounds, it is a real phenomenon which others have observed. Stanley Pons noted that the cold fusion effect has a kind of "memory." After a perturbation, temperature tends to return to a fixed level. Perhaps this is not so strange. The physical configuration of deuterons in the metal controls the power level.

Tiny spots in the surface of the cathode are probably formed in what Edmund Storms of Los Alamos National Laboratory calls "a special configuration of matter" with highly active, densely packed deuterium. Until these spots change or disperse, the nuclear fuel being fed into the reaction remains constant, so the cell tends to return to the same power level. A chemical wood fire works the same way. You can partially douse a roaring fire. If the fire does not go out altogether and the wood remains in the same position, after a while it will start burning again and return to its former power level. Pons and Fleischmann used a three-minute pulse of heat to "kick" their cells from low level heat to the high level heat that rapidly increased to boil off. The heat was generated by joule heating from externally supplied power, but once the cathode was boosted into higher activity the external power could be withdrawn and the cathode continued to self-heat – thus "heat-after-death."

Metal undergoing cold fusion 'wants' to be hot and will keep itself hot, prolonging the reaction. When Mizuno put his cell in the bucket of water the reaction began to turn off, presumably because the water in the bucket cooled the cathode. It did not quench the reaction immediately because the cathode was fairly well insulated inside a large thermal mass. Later, the water in the bucket warmed up well above room temperature, ten liters of it evaporated, leaving the cell surrounded by air. The cell began to self heat again and it returned to its previously high level of activity. Storms thinks that in the special configuration, the deuterium diffusion rate is slower at high temperatures than usual. Normal Beta-phase palladium deuteride will de-gas more rapidly when it heats up. Storms thinks that when the temperature falls (or is lowered by a thermal shock), the deuteride converts to Beta-phase and begins rapidly de-gassing, and the cold fusion effect goes away.

Mizuno has often talked about the prehistory of cold fusion. Most great discoveries are visited and revisited many times before someone stakes a permanent claim. People sometimes stumble over a new discovery without even realizing what they see. Mizuno did his graduate and post graduate work on corrosion using highly loaded metal hydrides. His experiments were almost exactly like those of cold fusion, but they were performed for a different purpose. In retrospect, he realized that he saw anomalous events that may have been cold fusion. At the time he could not determine the cause, he did not imagine it might be fusion, and he had to leave the mystery unsolved. No scientist has time to track down every anomaly. I expect many people saw and disregarded evidence for cold fusion over the years. Mizuno makes a provocative assertion. He says that long before 1989 he wondered whether the immense pressure of electrolysis might produce "some form of fusion." He says: "This kind of hypothesis would occur to any researcher studying metal and hydrogen systems. It is not a particularly profound or outstanding idea. It never occurred to me to pursue the matter and research this further." He appears to downplay the role of Pons and Fleischmann. Perhaps he exaggerates when he says "any researcher" would think of it, but on the other hand Paneth and Peters and others did investigate this topic in the 1920s. It has been floating around the literature for a long time. Pons and Fleischmann deserve credit because they did more than merely speculate about it. They succeeded in doing the experiments to prove it. Perhaps cold fusion is self-evident in the way that many great discoveries are. An ordinary genius finds an obscure and difficult truth which remains obscure even after he publishes, except to other experts. A superlative genius makes a discovery that few other people imagined, yet which everyone later agrees is obvious in retrospect. When T. H. Huxley learned of the theory of natural selection, he reportedly exclaimed: "why didn't I think of that!"

Within days of the 1989 announcement Mizuno set to work on a "crude, preliminary" experiment. He built the cell in single afternoon, which is in itself astonishing. His purpose was to detect neutrons, which he along with everyone else in 1989 assumed would be the principal signature of the reaction. Months later it became clear that heat is the principal signature and neutrons appear sporadically. The neutron flux is a million times smaller in proportion to the heat than it is with hot fusion. His colleague Akimoto, an expert in neutron detection, soon convinced him that the instrumentation must be improved and the cell must be moved to a well-shielded location before meaningful results might be obtained. The underground laboratory housing the linear accelerator, close by on campus, was the ideal spot for the experiment, but it is hardly an ideal place for people. It is dark, dank, and unheated in winter, as Mizuno well knew from years of doing graduate research there. After weeks of operation, the experiment showed slight signs of generating 2.45 MeV neutrons. Mizuno decided to get serious.

Here we learn what real a scientist is made of. While the rest of the world rushed to judgment, Mizuno buckled down and began a second "serious" experiment. The preparations took eight months. Mizuno and a graduate student worked long days building and testing the cell, and preparing the anode, cathode, electrolyte, and controls. They planned to run at 100°C and 10 atmospheres of pressure, so they ran pressure tests at 150°C and 50 atmospheres, improving the seals and connections until they saw no significant pressure decline for days. Finally they were ready to begin the first test run. The hysteria was long past. The press and the establishment had dismissed cold fusion. Real experiments by people like Mizuno were getting underway. When these tests were finished and documented, a year or two later, they constituted definitive proof of tritium, excess heat and transmutation. It is tempting to think that the tragedy of cold fusion boils down to . . . a short attention span. If only *Nature,* the newspapers, the DoE and the American Physical Society understood that you cannot do a research project in a few weeks, they would have withheld judgment until Mizuno, Fritz Will, Melvin Miles and others published in 1990 and 1991.

In person, Mizuno is charming, self deprecating, optimistic and brimming with ideas. In the book he describes the dark side of the story: the frustration, the boredom, the endless guerrilla war with scientists who wanted to stop the research, and science journalists who appeared to thrive on the outpouring of supposedly negative results, and the fruitless battles to publish a paper or be heard at a physics conference. Research means years of hard work which must often be done in appalling circumstances: in an unheated underground laboratory, late at night, in Hokkaido's Siberian climate. Experiments must be tended to four times a day, from eight in the morning until eight at night, seven days a week, without a holiday or a weekend off.

He describes these travails, but he does not dwell on them, or the controversy and politics. He revels in the fun parts of cold fusion: the discovery, the sense of wonder, the rewards. Mizuno does not waste his time moping or worrying. He gets to work, he does experiments, he teaches and encourages students. The first 5,000 copy printing of this book sold out quickly in Japan. Mizuno was thrilled because, he told me, “undergrads are buying it, and calling me with questions.” He and I wanted to move the Sixth International Conference on Cold Fusion (ICCF6) out of the isolated mountaintop resort hotel in Hokkaido, back to the city of Sapporo, and into the grubby Student Union meeting hall on campus. We wanted to open up the conference and allow free admission to students.

We think that when engineering and physics majors drift into such conferences and realize what is happening, cold fusion will take off.

Despite the troubles, Mizuno remains confident that we will succeed in the end. The research will be allowed, papers will be published, rapid progress will be made. Others, like Fleischmann, are deeply pessimistic. Some of the best scientists in this field, including Storms, are deeply discouraged by the constant struggle and expense. They sometimes tell me they are on the verge of quitting. But Mizuno has never flagged, never doubted and never lost hope. As Storms says “we must have hope, we have no other resources in this field.”

Mizuno wants to make practical devices. He wants to improve reproducibility and scale up. He talks about the scientist’s obligation to give society something of value. He and Dennis Cravens are the only cold fusion scientists I know who say that. He succeeded in replicating the original Pons and Fleischmann palladium cold fusion in three experiments, but it was difficult and the reaction proved impossible to control, so he did not see much future in it. Instead of trying to improve the original experiment by repeating it many times with minor variations, the way McKubre, Kunimatsu and others have attempted, Mizuno decided to try other materials and other approaches. He is a one-man R&D consortium. Some may criticize him for trying too many things and spreading himself too thinly. As I see it, Mizuno is doing his share. The rest of the world is to blame for not following his lead. He worked on ceramic proton conductors for years, he published detailed information in professional, full-length papers, and he assisted Oriani by fabricating a batch of conductors for him (a week of difficult labor on Oriani’s behalf). No other scientist has been as cooperative, willing to share data, and willing to assist others replicate. If Mizuno has left jobs unfinished, others should have taken up these jobs.

Mizuno concentrates on the rewards, the progress, the heady sense of excitement, the breathtaking possibilities. If progress has been slow, it has been real, and the scope of the research has broadened immeasurably. In 1989 we thought we had stumbled onto one isolated uncharted island. It turned out we have discovered a whole new continent. No wonder our exploration of it is taking longer than we expected. Over the years I have asked many scientists where cold fusion may be taking us and how big the discovery might be. Only Martin Fleischmann has shown a deep understanding of how many ramifications it may have.

Mizuno describes few moments of epiphany. There are moments of excitement, but most of the triumphs are long expected, and a good result does not mean much until you make it happen again, and again after that. There are few revelations. The scientists do not suddenly grasp the answer. They gradually narrow down a set of possibilities. Often the same possibilities are examined, discounted, and then reconsidered years later. Recently, Mizuno, Bockris and others have increasingly focused on so-called "host metal transmutations," that is, nuclear reactions of the cathode metal itself. The cathode metal was inexplicably neglected for many years. The term "host metal" is misleading. It was an unfortunate choice of words. It implies that the metal acts as a passive structure, holding the hydrogen in place, cramming the deuterons or protons together. The metal is a host, not a participant. The hydrogen does the work. Now, it appears the metal itself is as active as the hydrogen. The metal apparently fissions and fusions in complex reactions. Now the task is to think about the metal, and not just the hydrogen. Theory must explain how palladium can turn part of itself into copper and other elements with peculiar isotopes.

One of the few "Eureka!" events in this book is the moment when Mizuno and Ohmori saw the scanning electron microscope images of the beautiful lily-shaped eruptions on the surface of Ohmori's gold cathodes. This was visual proof that a violent reaction takes place under the surface of the metal, vaporizing the metal and spewing it out. Later, these vaporized spots were found to be the locus of transmutation. Around them are gathered elements with an isotopic distribution that does not exist in nature. The only likely explanation is that these isotopes are the product of a nuclear transmutation.

Mizuno describes the wrong directions he has taken, the dead ends, the mistakes. For years he ignored the most important clue: the host metal transmutations. He did not check the composition of the used cathodes. After his first big success produced tritium and spectacular heat-after-death, he opened the cell to find the cathode was blackened by something. He thought it must be contamination, and he was disappointed that his painstaking efforts to exclude contamination had failed. After puzzling over it for a long time he scraped the black film off the cathode with glass, and prepared the cathode for another run. Years later he realized that this black film was probably formed from microscopic erupted structures similar to those on Ohmori's cathodes. He says in retrospect he was throwing away treasure. Even Mizuno, an open minded, observant and perceptive scientist, has to be hit over the head with the same evidence many times before he realizes it is crucial. Other people are worse. Mizuno was blind for a long time; other cold fusion scientists remain blind to this day. They are unwilling to do simple tests that might reveal the nature of the reaction. IMRA is a sad example. Informed sources say IMRA researchers never performed an autoradiograph on a used cathode.

A recurring theme in this book is money. Mizuno frets, schemes and struggles to reduce expenses. He worries about the consumption of heavy water at $8 or $10 per day. He does not reveal in the book why these trivial expenses bother him so much: most of the money comes out of his own pocket. University discretionary funding allotted to professors in Japan does not begin to cover the expense of cold fusion research. It would be called “noise level funding” in the U.S., or “sparrow’s tears” in the Japanese idiom. Most of the other professors at Hokkaido remain hostile toward this research, and unwilling to allocate more money for it, so Mizuno often pays for equipment, materials, travel expenses and so on himself. Over the years the research has cost him tens of thousands of dollars, which is a great deal of money for a middle-class Japanese family. Cold fusion research consumes a constant flow of new equipment. The Japanese scientific establishment and the university barely tolerate this research. Still, Mizuno is better off than he would be at most U.S. universities, which have essentially banned this research.

Mizuno describes the dank, underground laboratory. He does not mention that his own laboratory is the size of a broom closet and so crammed with equipment you can barely fit in the door. The roof leaks. A large sheet of blue plastic is suspended over the corner of the room, funneling the rain water down to a sink and away from the computers, meters, power supplies and complex, delicate, beautiful handcrafted experimental apparatus, made of aluminum, stainless steel, platinum, palladium, gold and silver.

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