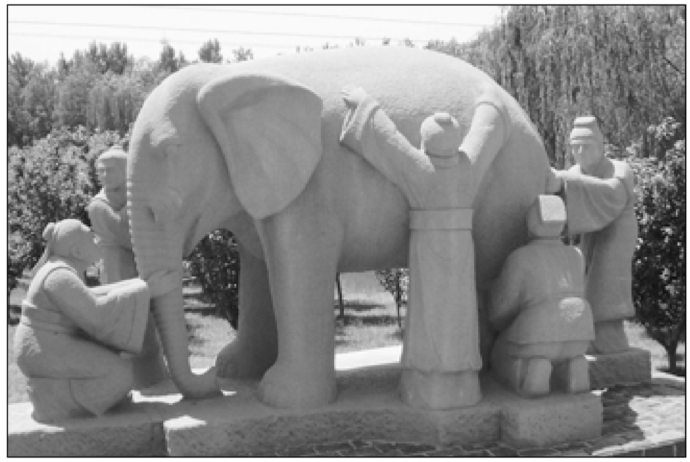
❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❷ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑ ❑

The Big Elephant and Blind Men

Xing Z. Li*

There were five blind men who tried to understand what an elephant was. The first touched the nose, and said that it was like a soft tube. The second touched the big ear, and said it was like a fan (ancient Chinese fans are made of a big piece of palm leaf). The third touched the big leg, and said it was like a pillar. The fourth touched the body, and said it was like a wall. The fifth touched the tail, and said it was like a rope. This Chinese fable tells us that after more than 20 years of experimental study of anomalous phenomena in metal hydrides (deuterides), we are supposed to integrate our knowledge about these phenomena and extract an image of this "big elephant." Infinite Energy initiated this discussion about the "elephant." Logically speaking, one should read the 162 papers in Storms' JCMNS paper, then comment on this new Storms paper. Nevertheless, I would like to support this initiative, and provide my imagination as a sixth blind after reading Storms' review.



I agree with Storms on the general statement that we are supposed to use assumptions as little as possible; then, we should avoid conflict with our consolidated knowledge of quantum mechanics, electrodynamics and thermodynamics. Early in 1989, we thought that the necessary product of any nuclear reaction between two positively charged particles was not necessarily a neutron, but charged particles (conservation of electrical charge). Then we started searching energetic charged particles using CR-39 (solid state track detectors) instead of using neutron detector in order to confirm any nuclear reaction. We also thought that there had to be some precursors before the anomalous phenomena appeared, because the anomalous phenomena could not appear in the normal crystal or any normal chemical environment. Therefore, thermal luminescence detector were used to detect any radiation from the metal deuterides because we believed that the precursor had to involve the movements of some charged particles during the loading processes, based on electrodynamics and thermodynamics. When Koonin published his calculation about the cross-section in *Nature*, and Peebles published his conclusion about "cold fusion" in his textbook on quantum mechanics, we noticed that both of them assumed tacitly "no resonance" before their calculations. If there was a resonance, then they were not allowed to throw away an important independent solution of the Schrödinger equation. Koonin and Peebles might argue that there was no evidence for the existence of such resonance. However, we might argue also that there was no evidence for them to allege "no resonance" because there was no such experimental data either. The beam-target experiments using accelerators could not reach such a low energy or such a sharp, narrow energy level. Therefore, the resonant tunneling was proposed to solve the first Huizenga puzzle—penetrating the Coulomb barrier.

When Huizenga proposed his second and third puzzles, he was using classical mechanics to discuss wave mechanics. Even if for the resonant tunneling at low energy he still assumed that a compound nucleus was formed first, and then it would decay into the reaction channel with the shortest lifetime. It was misleading, because it ignored the time necessary for a resonance process to build-up the wave amplitude in terms of constructive interference. The reaction channel with the shortest lifetime would not have enough time to build-up the wave amplitude. Only if the reaction channel has the proper lifetime can the resonance process enhance tunneling and result in nuclear reaction. As a consequence we realized that the resonant tunneling at low energy would not decay through the reaction channel with the shortest lifetime. Particularly, when the Coulomb barrier is thick and high, only the weak interaction channel would have the chance to construct a resonant tunneling and have a nuclear reaction. That is, the resonant tunneling would lead only to *neutrino* emission with no neutron or gamma radiation, because the strong interaction or electromagnetic interaction is too fast to allow any resonance process to build-up the amplitude of the probability wave for the low-energy penetration of the Coulomb barrier. The formation of a compound nucleus is equivalent to a "measurement procedure" in quantum mechanics. Huizenga separated a resonant tunneling process into two independent processes: compound nucleus formation and decay of compound nucleus. Then he concluded that gamma emission is the necessary product of resonant tunneling. Just like in the case of the famous double-slit diffraction experiment in quantum mechanics, if we measure the path of the electron at the position of the double-slits, we would interrupt the interference of the probability wave on the screen behind the double-slits. Unfortunately, *this important point of view has not yet been understood by everyone in our CMNS community.* This is the essential component of selective resonant tunneling.

When we accept the selective resonant tunneling to solve Huizenga's three puzzles by selecting the weak interaction channel, we might worry about the neutrino emission which would carry away most of the energy released in the nuclear reaction. Indeed, this would happen only if the nucleus—produced in accompaniment with the neutrino—was born in the ground state. If it was born in an excited state then most of the energy released in the nuclear reaction would still be kept by this excited state. The remaining problem is the decay of this excited nucleus. Usually, this excited nucleus would be supposed to decay through gamma-ray emission. Why don't we observe the gamma emission commensurate with the "excess heat"? The answer is that the internal conversion electron wins over the gamma emission due to the high nuclear spin and the dense nuclear energy levels in a resonant lattice.

We may use the nickel-hydrogen system as an example. In the Ni-hydride, ^{58}Ni+p might be in a resonance to form a ^{59}Cu-like state which would capture an electron to produce ^{59}Ni*+neutrino. This neutrino carries away only a small part of the reaction energy, because the excited ^{59}Ni* still have most of the reaction energy which would be transformed into "excess heat" later. The question is: Why doesn't this de-excitation energy appear as a single jump down from ^{59}Ni* to the ground state of ^{59}Ni? It appears as a series of small steps to chop this de-excitation energy into a series of small pieces of energy, ΔE. We learned from Defkalion's data, which was generously published during ICCF17 at KAIST. They have never observed any gamma emission beyond the range of 50 keV - 300 keV. This implies that the energy spectrum of ^{59}Ni* in the vicinity of (^{59}Ni*) is a dense distribution of energy levels. This would be in favor of an internal conversion process. In other words, the reaction energy in (^{59}Ni*) would go to the internal conversion electrons instead of gamma radiation. One more point in favor of this internal conversion process is the high spin of (^{59}Ni*) which was born during the resonant tunneling.

According to wave mechanics, the initial state of nickel-hydride is described by a wave function Ψ(^{58}Ni+proton in lattice) + $C\Psi$(^{59}Cu*)—the linear combination of (^{58}Ni+proton in lattice) and the copper. If there was no resonance, the coefficient, C, is very small, because the Coulomb barrier makes C exponentially small. When (^{58}Ni+proton in lattice) is in a resonance, the probability of appearance in state of Ψ(^{59}Cu*), $|C|^2$ is comparable with the probability of appearance in state of Ψ(^{58}Ni+proton in lattice), $1 - |C|^2$. Then, this initial state of nickel-hydride would transit to ^{59}Ni* in terms of electron capture process:

$$p + {}^{58}\text{Ni} + e \rightarrow {}^{59}\text{Ni}^* + \text{neutrino} + \text{part of total reaction energy}$$

As mentioned above, this neutrino would not carry away too much reaction energy, if ^{59}Ni* still keeps most of the reaction energy in it. Moreover, Defkalion scientists drive this electron into some Rydberg states using an electrical discharge process as a triggering method; hence, the electron in the left-hand-side of the equation might have a high orbital angular momentum, and would produce a ^{59}Ni* with high spin in the right-hand-side of the equation. This high spin would be in favor of the internal conversion process as well. Defkalion scientists observed very strong magnetic fluctuation after the electrical discharge triggering. It provides an evidence of a high spin state. Indeed, this Rydberg electron was necessary in order to have a good overlapping between the wave functions of the initial and final states.

This picture of selective resonant tunneling and the following weak interaction process is similar to Bethe's early work in 1938 when he explained the origin of solar energy in terms of

$$p + p \rightarrow \text{deuteron} + e^+ + \text{neutrino}$$

He was using the overlapping of wave function between (p+p) and deuteron (p+n) states as well. In our case, there are two new points: 1) the metal-hydride replaces the configuration of (proton beam + proton target); 2) The production of a positron is replaced by electron capture because there is not enough energy defect. The common feature is that a proton has been transformed into a neutron both in our case and in Bethe's calculation. The necessary energy, 782 keV, is provided by the binding energy. There is no "heavy electron" involved at all. We did not invoke "heavy electron" to provide the necessary energy for a process of $p + e^- \rightarrow n +$ neutrino, and we did not invoke "heavy electron" to transform reaction energy into emission of the infrared ray, because the high spin and dense energy levels are in favor of energy transfer from an excited nucleus to internal conversion electrons in many steps.

What is the necessary condition to have this resonant tunneling? It is the existence of an energy level of ^{59}Cu*, which coincides with the energy level of (^{58}Ni + the proton in the lattice potential well). We cannot control the nuclear energy level in ^{59}Cu*, nor in ^{58}Ni, but we may control the energy level of a proton in the lattice well in terms of boundary condition and shape of lattice well. The potential well in the lattice may be adjusted by the density of electrons and the lattice constant. In the past 20 years, a lot of methods were tried to adjust the lattice potential well, such as superwave, ultrasonic wave, RF-wave, electrical discharge, electrical loading, gas loading, laser heating, electrical heating, pressure jump (pumping), additive doping (catalyst), etc. Because this resonance is very sharp, it is almost impossible to meet this resonance condition in a steady state; we may tune the metal-hydride system by a temperature or density gradient and a negative feedback mechanism to reach a self-sustaining state. This is the most difficult part of the experiment. However, we understand that electron density plays an important role in the lattice well, and the metal surface is the location where electron density changes rapidly. That is why the surface or the crack is in favor of this resonant tunneling. The same reasons may lead to the interface of different metals or metal-oxides in favor of resonant tunneling. The interface between α and β phases of metal-hydrides is the location where the lattice constant varies. Hence, we may predict that the resonant tunneling might appear near the interface between α and β phases of metal-hydrides as well.

The negative feedback mechanism plays a key role in reaching a self-sustaining resonant tunneling state; however, the only feedback factor we have known is temperature. The reaction heat would increase the temperature of the system. If the temperature increment drives the system away from resonance and reduces the reaction rate, then we may have a negative feedback mechanism. We noticed that in Defkalion's experiment, they have to trigger the system manually ten times every hour. Their negative feedback mechanism is not as good as that in Fleischmann and Pons' heat after death experiment where the dried system was kept in 100°C for three hours. We may guess that the hydrogen (deuterium) flux plays an important role there.

Now we may answer the question: Why do we need the powder of nickel instead of nickel rod? Because the weak interaction has a coupling constant of $10^{-4}sec^{-1}$, it would provide a power of 1 MeV/10^5 sec per nickel nucleus in resonance. If only the nuclei in the surface layer would be in resonance, then the excess power would be much less than 10 kW in a piece of 50 gram nickel block. We have to break the nickel block into nickel powder, then we may have enough surface to supply the 10 kW power. As we understand, the nickel nuclei on the surface would be burnt in the resonance processes; then, we need more new surfaces to keep a constant power in six months. Fortunately, most hydrogen-storage metals (palladium, nickel and their alloys) would be broken into smaller pieces during the cycles of absorption and desorption. When we put these numbers (100 Angstrom thickness of surface layer, 10 kW, 50 gram nickel, etc.) into calculation we may find that the size of the nickel powder is in good agreement with the size in their patent.

Fleischmann and Preparata paid attention to the word "coherence." Twenty years of experiments gradually revealed the importance of "coherence." We already knew that even if a single nucleus jumped down to the ground state step-by-step through a series of dense nuclear levels, it would not produce the directional X-rays. However, Karabut observed directional X-rays in their electrical gas discharge experiments. Defkalion scientists observed strong magnetic field fluctuation in the order of 1.8 Tesla when the magnetic field of discharge current was 1 Tesla. A lot of triggering mechanisms involve the various waves. These all are reminding us that this anomalous nuclear process is not in a single beam-target configuration; it should be a collective "coherent" motion of protons and nickel nuclei. Indeed, we understand that the resonance between the nuclear level and the lattice level is a very sharp resonance due to the very long lifetime, and no modern accelerators would be able to provide such a low-energy beam of protons with enough current density and sharp enough in energy distribution. The "coherence" in the lattice is just a way to put protons on such a sharp energy level and provide the negative feedback mechanism to keep protons in resonance. We have to consider a group of protons in "coherence." Only a blind man with wide open arms would be able to tell the size of the elephant. A blind man using his single palm would never have the right answer.

To summarize, I agree with Storms' use of the term "resonance," which is the essence of the theory. An anomalous heat phenomena cannot appear in or at the normal chemical lattice. It seems that a triggering mechanism is necessary. It seems also that some additives are necessary as well. A surface location meets the conditions for resonance, and the crack is the right place to have surface. However, the essential point is the conditions for resonance.

Our main disagreements are as follows: In wave mechanics, we are supposed to think of the probability wave function only until the "measurement" is done. The physical quantities appear only after the "measurement." Before the "measurement," we might think only of the overlapping of the wave functions. The resonant tunneling and electron capture means:

(1) The coefficient C in wave function, $\Psi(^{58}\text{Ni}+\text{proton in lattice}) + C\Psi(^{59}\text{Cu}^*)$, increases greatly.

(2) The overlapping between $\Psi(^{59}\text{Cu}^*)$ and $\Psi(^{59}\text{Ni}^*)$ reaches it maximum. Then we may predict that the process of resonant tunneling and electron capture is possible even if the Coulomb barrier is very high and thick between the proton and nickel nucleus. The proton is transformed into a neutron in terms of electron capture, and the necessary energy 782 keV is provided by the binding energy of $^{59}\text{Ni}^*$. In wave mechanics, the whole process is not separable. The energy conservation is abided as a whole. Only in classical mechanics may we ask where the 782 keV is to transfer a proton into a neutron before penetrating the high Z Coulomb barrier.

We have to wait for more experimental data. At the Pontignano workshop in April 2012, the evidence of copper (~30%) was present. In 2011, it was said in Sweden that the copper (~30%) was found in nickel powder after six months operation of E-Cat. In 2012, it was said in Switzerland that there was no copper as a nuclear product in the E-Cat. At ICCF17 in 2012, Defkalion published their mass spectroscopy data in detail. Very little copper (0.053 ± 0.007%) was found there. Hopefully, we may see the definite answer in 2013.

Reviewers of this paper were asked if "a clear statement of assumptions is required of any proposed theory." Yes, we are supposed to make the assumptions as clear as possible; however, Koonin and Peebles did not mention the assumption of "no resonance" because they did not consider it as an assumption. Therefore, we have to figure out the assumption by ourselves sometimes.

Recently lithium battery fires in aircraft induced a discussion on the possible reason of the fire. Because lithium-6 has a low lying resonance energy level, but lithium-7 does not, it is advisable to analyze the ratio of isotope abundance in the batteries. Replacing the natural lithium with depleted lithium (*i.e.*, lithim-7 only) in a lithium battery might be a better option instead of using a Ni-Cd battery.

About the Author
Dr. Xing Zhong Li is Professor Emeritus in the Department of Physics at Tsinghua University. He has Ph.Ds in theoretical nuclear physics and plasma physics. Dr. Li has studied hot fusion for 30 years, and cold fusion for 24 years. He was a visiting scientist at MIT Plasma Fusion Center (1984-1985) and the Chairman of ICCF9 (2002, Beijing). Dr. Li was awarded the Preparata Medal in 2005.

*Email: lxzdmp@gmail.com