A detailed Qualitative Approach to the Cold Fusion Nuclear Reactions of H/Ni

By prof. Christos Stremmenos

After several years of apparent inaction, the theme of cold fusion has been recently revitalized thanks to, among others, the work and the scientific publications of Focardi and Rossi, which has been conducted in silence, amidst ironical disinterest, without any funding or support. In fact, recently, practical and reliable results have been achieved based on a very promising apparatus invented by Andrea Rossi. Therefore I want to examine the possibility of further development of this technology, which I deem really important for our planet.

Introduction

I will start with patent no./2009/125444, registered by Dr. Ing. Andrea Rossi. This invention and its performance have been tested and verified in collaboration with Prof. Sergio Focardi, as reported in their paper, published in February 2010 in the Journal of Nuclear Physics [1]. In that scientific paper they have reported on the performance of an apparatus, which has produced for two years substantial amounts of energy in a reliable and repeatable mode and they have also offered a theoretical analysis for the interpretation of the underlying physical mechanism.

In the history of Science, it is not the first time that a practical and reliable apparatus is working before its theoretical foundation has been completely understood! The photoelectric effect is the classic example in which the application has anticipated its full theoretical interpretation, developed by Einstein. Afterwards Einstein, Plank, Heisenberg, De Broglie, Schrödinger and others formulated the principles of Quantum Mechanics. For the interactive Nickel/Hydrogen system it would be now opportune to compile, in a way easily understood by the non expert the relevant principles and concepts for the qualitative understanding of the phenomenon. Starting with the behavior of electrically charged particles in vacuum, it is known that particles with opposite electric charge attract themselves and "fuse" producing an electrically neutral particle, even though this does not always happen, as for instance in the case of a hydrogen atom, where a proton and a electron although attract each other they do not "fuse", for reasons that will be explained later. On the contrary, particles charged with electric charge of the same sign always repel each other, and their repulsion tends to infinity when their distance tends to zero, which implies that in this case fusion is not possible (classical physics).

On the contrary, according to **Quantum mechanics**, for a system with a great number of particles of the same electric charge (polarity) it is possible that a few of them will fuse, as for instance, according to Focardi-Rossi, in the case of Nickel nuclei in crystal structure and hydrogen nuclei (protons) diffused within it, Although of the same polarity, a very small percentage of these nuclei manage to come so close to each other, at a distance of 10-14 m, where strong nuclear forces emerge and take over the Coulomb forces and thus form the nucleus of a new element, either stable or unstable.

This mechanism, which is possible only in the atomic microcosm, is predictable by a quantum-mechanics model of a particle put in a closed box. According to classical physics no one would expect to find a particle out of the box, but in quantum mechanics the probability of a particle to be found out of the box is not zero! This is the so called "tunneling effect", which for systems with a very large number of particles, predicts that a small percentage of them lie outside the box, having penetrated the "impenetrable" walls and any other present barrier through the "tunnel"! In our case, the barrier is nothing else but the electrostatic repulsion, to which the couples of hydrogen and nickel nuclei (of the same polarity) are subjected and is called Coulomb barrier.

Diffusion mechanism of hydrogen in nickel: Nickel as a catalyst first decomposes the biatomic molecules of hydrogen to hydrogen atoms in contact with the nickel surface. Then these hydrogen atoms deposit their electrons to the conductivity band of the metal (Fermi band) and due to their greatly reduced volume, compared to that of their atom, the hydrogen nuclei readily diffuse into the crystalline structure of the nickel, including its defects. At this point, in order to understand the phenomenon it is necessary to briefly describe the structure both of the nickel atom and the nickel crystal lattice.

It is well known that the nickel atom is not so simple as the hydrogen atom, as its nucleus consists of dozens of protons and neutrons, thus it is much heavier and exerts a proportionally higher electrostatic repulsion than the nucleus of hydrogen, which consists of only one proton. In this case, the electrons, numerically equal to the protons, are ordered in various energy levels and cannot be easily removed from the atom to which they belong. Exception to this rule is the case of electrons of the chemical bonds, which along with the electrons of the hydrogen atoms form the metal conductivity band (electronic cloud), which moves quasi freely throughout the metal mass.

As in all transition metals, the nickel atoms in the solid state, and more specifically their nuclei, are located at the vertices and at the centre of the six faces of the cubic cell of the metal, leaving a free internal octahedral space within the cell, which, on account of the quasi negligible volume of the nuclei, is practically filled with electrons of the nickel atoms, as well as with conductivity electrons.

It would be really interesting to know the electrons' specific density (number of electrons per unit volume) and its spatial distribution inside this octahedral space of the crystal lattice as a function of temperature.

Dynamics of the lattice vibration states

Another important aspect to take into consideration in this system is the dynamics of the lattice vibration states, in other words, the periodic three dimensional normal oscillations of the crystal lattice (phonons) of the nickel, which hosts hydrogen nuclei or nuclei of hydrogen isotopes (deuterium or tritium) that have entered into the above mentioned free space of the crystal cell.

It could be argued that the electrons' specific density and its spatial distribution in the internal space of the crystal structure should be coherent with the natural frequencies of the lattice oscillations. This means that the periodicity of the electronic cloud within the octahedral space of the elementary crystal cell of Nickel generates an oscillating strengthening of shielding of the diffused nuclei of hydrogen or deuterium which also populate this space.

I believe that these considerations can form the basis for a qualitative analysis of this "NEW SOURCE OF ENERGY" and the phenomenology related to cold fusion, including energy production in much smaller quantities and various reaction products.

Shielding of protons by electrons

In the Focardi-Rossi paper the shielding of protons provided by electrons is suspected to be one of the main reasons of the effect, helping the capture of protons by the Ni nucleus, therefore generating energy by fusion of protons in Nickel and a series of exothermic nuclear reactions, leaving as by-product isotopes different from the original Ni (transmutations). Such shielding is one of the elements contributing to the energetic efficiency of the system. From this derives the opportunity, I think, to focus upon this shielding, both to increase its efficiency and to verify the hypothesis contained in the paper of Focardi-Rossi. Of course, what we are talking of here is a theoretical verification, because the practical verification is made by monitoring the performance

of the apparatus invented and patented by Andrea Rossi, presently under rigorous verification by many independent university researchers.

In my opinion, the characteristics of the shielding of the proton from the electrons should be defined, as well as the "radiometric" behavior of the system.

In other words, the following two questions should be answered:

1. Which is the supposed mechanism that overcomes the powerful electrostatic repulse (**Coulomb barrier**) between the "shielded proton" and the Nickel nucleus?
2. For what reason there is almost no radiation of any kind (experimental observation), while according to the Focardi and Rossi's hypothesis there should have been some γ radiation (**511 KeV**) produced by the predicted annihilation of the β+ and β- particles that are being created during the Fusion?

I believe that some thoughts based on general and elementary structures, data and principles of universal scientific acceptance, might shed some light to this exciting phenomenon. More specific, I refer to **Bohr's hydrogen atom, the speed of nuclear reactions (10-20 sec) and the Uncertainty Principle of Heisenberg.**

I will take Bohr's hydrogen atom as a starting point (figure 1a), which stays at its fundamental state forever in the absence of external perturbations, due to De Broglie's wave, accompanying the sole electron.

As stated before, in contact with the metal, these atoms lose their fundamental state, as their electrons are being transmitted to the conductivity band. These electrons, together with the "naked nuclei" of hydrogen (protons), form a freely moving cloud of charges (plasma at a degenerate state) inside the crystalline lattice. That cloud is being defused through the surface to the polycrystallic mass of the metal, covering empty spaces of the non-canonical structure of the crystalline lattice, as well as the tetrahedral and octahedral spaces between the molecules. As a consequence, the crystalline structure is covered by "**delocalized plasma**" (degenerate state), which is consisted by protons, electrons produced by the "absorbed atoms" of hydrogen, as well as by the electrons of the chemical valence of Nickel of the lattice, at different energy states (Fermi's band). (Fig. 2)

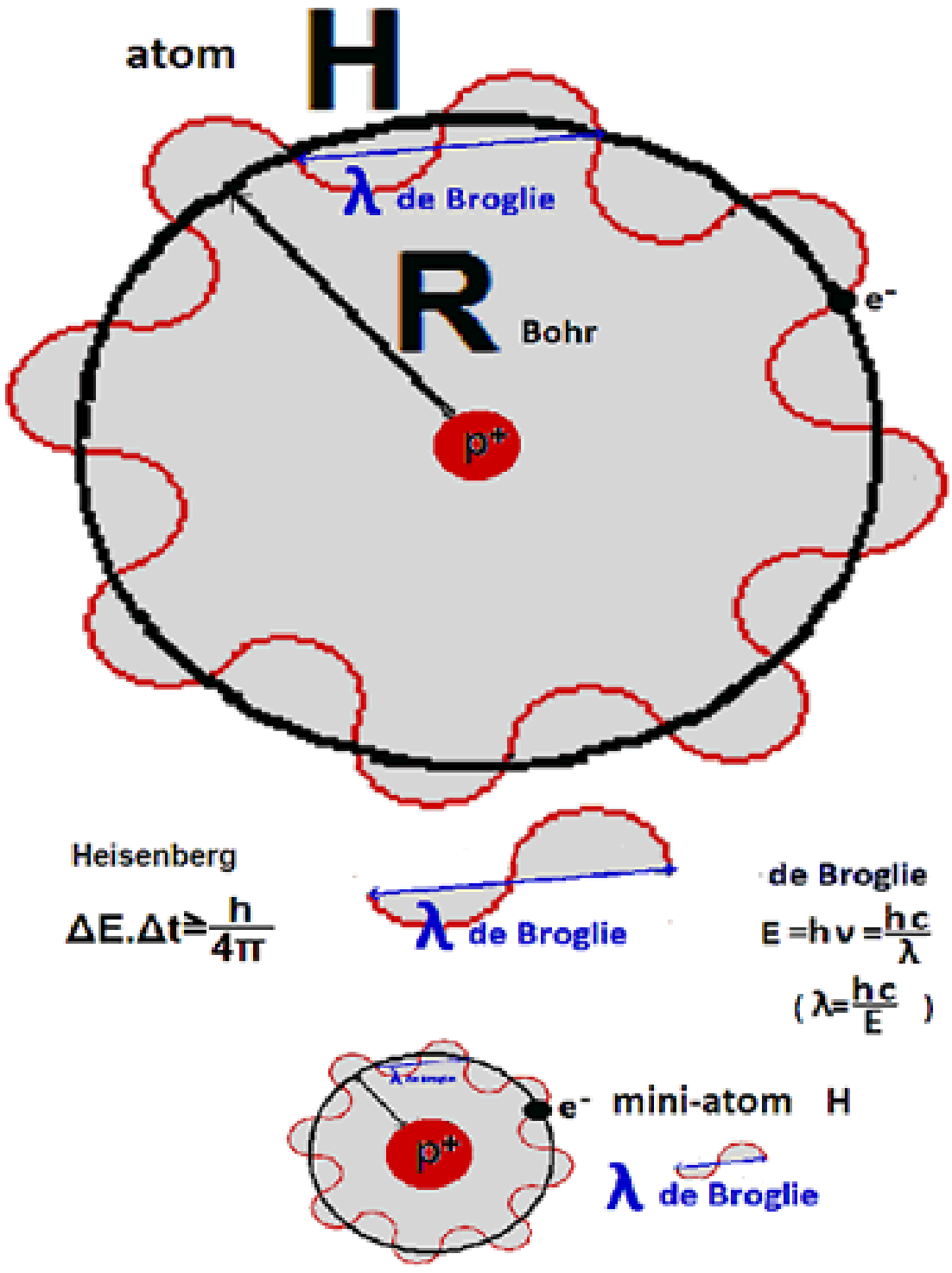
atom H
λ de Broglie
R Bohr
e-
p+
Heisenberg
ΔE.Δt≥h/4π
λ de Broglie
de Broglie
E =hν =hc/λ
(λ=hc/E)
e- mini-atom H
p+
λ de Broglie

Fig.1b

In this system, if one considers the probability of the creation **inside the crystalline lattice** of temporary (not at the fundamental state) **"pseudo-atoms" of hydrogen with neutral charge**, for example at a time of the order of 10^-17 sec, then that possibility is not completely ill-founded. (Fig 1b)

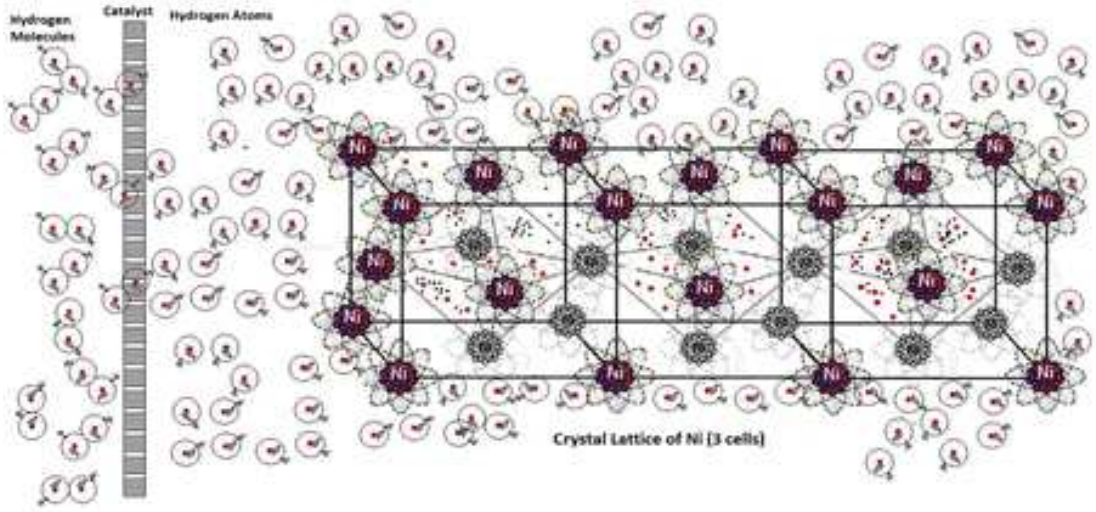

Fig.2

According to the Uncertainty Principle of **Heisenberg**, the temporary atoms of hydrogen will cover during that small time interval **Δt**, a wide range of energies **ΔE**, which means also a wide range of **atomic diameters** of temporary atoms, satisfying the **De Broglie's condition**. A percentage of them (at fist a very small one) might have diameters smaller than **10^-14 m, which is the maximum active radius of nuclear reactions**. In that case, **the chargeless temporary atoms, or mini-atoms, of hydrogen** together with high energy but short lived electrons, are being statistically trapped by the Nickel nuclei at a time of **10^-20 sec**. In other words, the high speed of nuclear reactions permits the fusion of short lived **but neutral** mini-atoms of hydrogen with the Nickel nuclei of the crystalline lattice, as during that short time interval **the Coulomb barrier (of the specific hydrogen mini-atom) does not exist**.

Afterwards, it follows a procedure similar to the one described by Focardi and Rossi, but instead of considering the capture of a shielded proton by the **Ni*58*** nucleus, we adopt the hypothesis of trapping a neutral temporary atom, or a mini atom, of hydrogen (with a diameter less than **10^-14 m**) which transforms the **Ni*58*** nucleus into **Cu*59*** (copper/59, short lived isotope*).

It follows the predicted "**β decay**" of the nuclei of the short lived isotope of copper, accompanied by the emission of **β+ (positrons)** and **β-** (perhaps the electrons of the mini atoms trapped inside that nucleus during the fusion). These particles are being annihilated with an emission of **γ** radiation (two photons of **γ** of energy 511 KeV each, for every couple of **β+** and **β-**).

In other words, whoever has experimented with this system should have suffered the not-so-harmless influence of those radiations, but that never happened. The radioactivity measured at the experiments is almost zero and easily shielded.

In any case, a rigorous, in my opinion, theoretical approach for the interpretation of that phenomenon with quantum mechanical terms, would give clear quantitative answers to the above stated models. With my Colleges of theoretical chemistry, we are already planning to face

the problem using the time-depended quantum mechanical perturbation theory, bearing in mind the following:

1. The total **wave function** (of the nucleus and the electrons) of temporarily, non-stable states.
2. The total time-depended Hamiltonian, for temporarily states.
3. Searching for the **resonance conditions** at that system.

Such an approach had a successful outcome at a similar problem of theoretical chemistry and we hope that it will be valid in this case as well.

Let's go back to the intuitive, with ideal models, approach, in order to give a qualitative explanation for the (almost) absent radiations of the system, by using:

- First of all the **Boltzmann's distribution** (especially at the asymptotic area of high energies).
- **The photoelectric effect**
- **The Compton effect**
- **The Mössbauer effect**

We have already mentioned that from the temporary mini atoms of hydrogen, the ones with diameter less than **10^-14 m**, have a larger probability of fusion. But, in order for them to be created, high energy bond electrons should exist at the "delocalized plasma" of the crystalline lattice.

1. Boltzmann's statistics:
There are reasons to believe that the H/Ni system, at first at temperatures of about 400-500oC, contains a very small percentage of electrons in the "delocalized plasma" with enough energy to create (together with the diffused protons), according to the wave-particle duality principle, the first temporary mini atoms of hydrogen, that will trigger the fusion with the nickel nuclei and the production of **high energy γ photons** (511 KeV).

2. Photoelectric Effect:
It is not possible, the HUGE amount of energy (in kW/h), that the Rossi/Focardi reactor produces, as measured by unrelated scientists in repeated demonstrations (at one of them by the writer and his colleagues, Fig 3), to be created due to the **thermalization** of the insignificant number of γ photons at the beginning of the reaction.

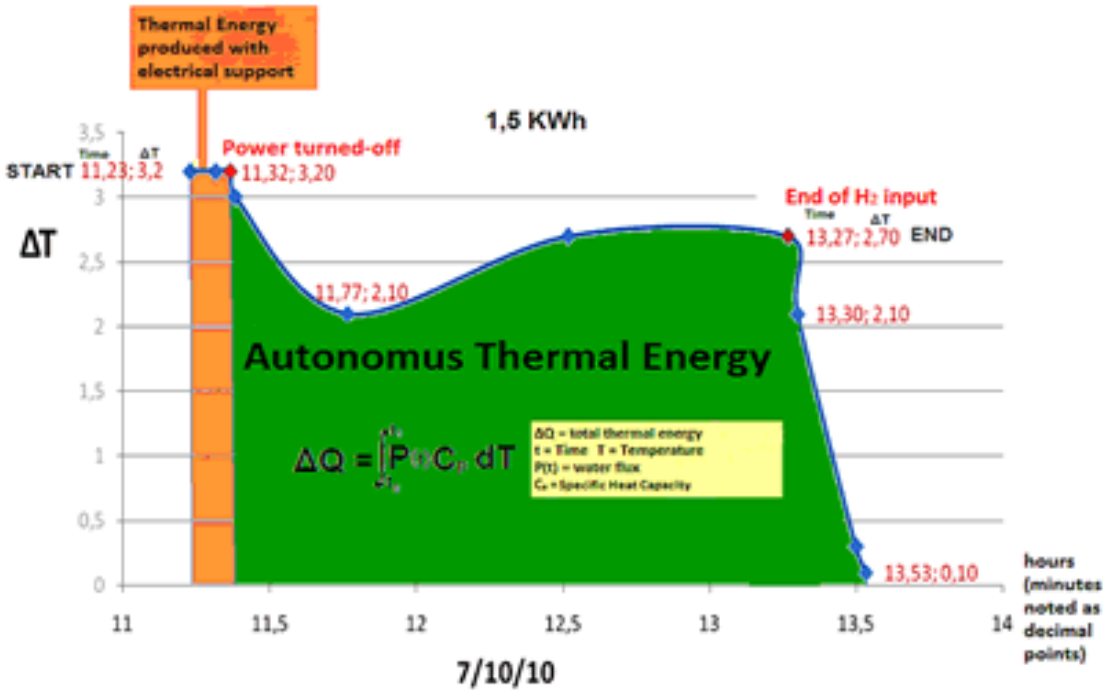

Fig.3

I believe that, as stated above, these photons are the trigger of fusion at a multiplicative series, **based on the photoelectric effect inside the crystalline structure**.

The two γ photons can **export symmetrically (180°)** two electrons from the nearest Nickel atoms. The stimulation, due to the high energy of γ, concerns electrons of internal bands of two different atoms of the lattice and has as a prerequisite the absorption of **all the energy of the photon**. A small part of that energy is being consumed for the export of the electron from the atom and the rest is being transformed into kinetic energy of the electron (thermal energy).

The result of that procedure is to enrich the "delocalized plasma" with high energy electrons that will contribute multiplicatively (by a factor of two) at the progress of the cold fusion nuclear reactions of hydrogen and nickel and at the same time transform the hazardous γ radiation into useful thermal energy.

3. The Compton Scattering:
It gives the additional possibility of multiplication, this time due to secondary photons **γ**, in a wide range of frequencies, as a function of the angular deviation from the direction of the initial photon of **511 keV. That has as a result the increase of the export of electrons, due to the photoelectric phenomenon at the crystalline mass, in many energy/kinetic levels, which gives an additional possibility of converting the γ radiation into useful thermal energy**.

4. The Mössbauer effect:
It gives another possible way of absorbing the γ radiation and transforming it into thermal

energy. It is based on the principle of conservation of momentum at the regression of the new **Cu*59*** nucleus/ from the emission of a γ photon. Relative calculations (Dufour) showed that this mechanism has an insignificant (1%) contribution.

It follows that, according to given data, the Photoelectric phenomenon and the Compton Effect, could explain the absence of radiations in the Focardi-Rossi system, which, from the amount of producing energy versus the consumption of Ni and H2, as well as from the experimental observation of element transformations, lead undoubtedly to the acceptance of hydrogen cold fusion.

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References:
(1)www. journal-of-nuclear-physics.com /Focardi Rossi/ (A new energy source from nuclear fusion)

* I believe that the phasmatometric tracing of copper is the most definitive sign of nuclear fusion: From the relative bibliography (HANDBOOK OF CHEMISTRY AND PHYSICS, 66TH edition), it follows that the stable non radioactive isotopes of nickel are the following five:

58, 60, 61, 62 and **64**. These, when fused with a hydrogen nucleus, are being transmuted relatively to **Cu-59, Cu-61, Cu-62, Cu-63** and **Cu-65**. From these isotopes of copper only the last two (**Cu-63** and **Cu-65**) are not radioactive, i.e. they are stable. The other three**Cu-59, Cu-61, Cu-62**, are being transmuted again to Nickel, with an average life expectancy of some hours and the most unstable Cu-59 in 18 seconds.

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