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Review

A Review of Experiments Reporting Non-Conventional Phenomena in Nuclear Matter Aiming at Identifying Common Features in View of Possible Interpretation

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Abstract: The purpose of the present paper is to clarify, as far as it is possible, the overall picture of experimental results in the field of non-conventional phenomena in nuclear matter published in the scientific literature, accumulated in the past few decades and still missing a widely accepted interpretation. Completeness of the collection of the experiments is not among the aims of the effort; the focus is on adopting a more comprehensive and integral approach through the analysis of the different experimental layouts and different results, searching for common features and analogous factual outcomes in order to obtain a consistent reading of many experimental evidences that appear, so far, to lack a classification in a logic catalogue, which might be compared to a building rather than a collection of single stones. Particular attention is put on the issue of reproducibility of experiments and on the reasons why such a limitation is a frequent characteristic of many experimental activities reported in published papers. This approach is innovative as compared with those already available in the scientific literature. In a synoptical table, a comprehensive classification is given of the twenty experiments examined in terms of types of evidences that are ascertained by the experimenters in their published papers but are "unexpected" according to well-established physical theories. Examples of such unexpected evidences (named also non-conventional or weird) evidences are: excess heat generation, isotope production, reduction of radioactivity levels, and production of neutrons or alpha particles. These evidences are classified taking into account both the material where the evidence takes place (solutions, metals, rocks and artificial materials) and the stimulation techniques (supply of electric voltage, irradiation by photons, mechanical pressure) used to generate the evidences (which do not appear in the absence of such stimuli at an appropriate intensity). Also, in our paper, "identity cards" are provided for each experiment examined, including details that emerged during the experiment and were reported in each respective paper, that sometimes are not given adequate consideration either by the author of the experiment or in other review papers. The analysis of the details provides suggestions (also referred to as clues in this papers) used to formulate the content of the second part of each identity card, where inferences deduced from facts are outlined in view of presenting tentative interpretation at the microscopic level. This is done by concentrating attention on the clues repeated in different experiments in order to yield possible explanations of the "unexpected" evidences. The main outcome of such analysis is that, in all examined cases, a common "operation" can be identified: the stimulation techniques mentioned above can be interpreted as a sort of compression producing a ramp of energy densification (with reference to volumes in space or time coordinates). Here we use the term "compression" to indicate an operation activated by the experimenter; as such, it is objective. We consider energy densification an inference of possible consequences of the operation on the status of the system. Five types of densifications were identified. This reading in terms of energy densification is in accordance with the predictions of the Deformed Space Time theory, reported in the scientific literature, in the context of a generalization of the Einstein relativity theory, according to which the existence of energy thresholds is found to separate, for each interaction, the flat metric part from the deformed metric part and the appearance of new microscopic

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effects as a consequence of trespassing such thresholds. The phenomena occurring in the deformed part of the interaction metric are governed by the energy density in the space-time (volume and time interval). This energy density is computed from the threshold energies and is peculiar to the phenomenology under consideration. As a conclusion, it is suggested that the revealed qualified information, homogenized and elaborated on, might help in repeating, with proper adjustments and adequate additional instrumentation, some key experiments, in order to ensure systematic reproducibility, which is a prerequisite for interpretations and explanations to be sound and credible, as well in deriving from such an effort, indications for new experiments. It is uncomfortable that, after thirty years, there are still pending questions to which the most acknowledged physical theories are not capable of giving an answer. Even a definitive demonstration that all these experiments have decisive faults would be preferable than leaving the issue unaddressed. Major research agencies, for instance in the USA and in Europe, are moving in this direction.

Keywords: nuclear matter experiments; systematic reproducibility of experiments; generalization of the Einstein relativity theory; energy densification; Deformed Space Time theory; energy thresholds; energy density in the space-time (volume and time interval)

1. Introduction

1.1. LENR: An Open Controversy Is under Scrutiny Again

1.1.1. Early Phase

It is well known that the issue of Low-Energy Nuclear Reactions (LENR) has a complex, controversial history, since the original work in 1989 [1]. Since then, for three decades, the anomalous transformations of matter have gone under multiple names that have increased confusion concerning phenomena that are already complex to understand; we mention a few frequently used names: Cold fusion, low-energy nuclear reaction (LENR), condensed matter nuclear physics, and nuclear metamorphosis. Piezonuclear reactions was also used, as a consequence of experiments where unexpected evidences occurred when pressure increase was involved. We chose the last one, which seemed to us less equivocal and more responsive to the need to give a genuinely new name to a genuinely new phenomenon. Indeed, a series of experimental results on transformation of matter which are well documented in the scientific literature give rise to undeniable contradictions with established physical theories and have not been interpreted yet through models that have reached a widespread consensus. The work generated unclear expectations for the feasibility of energy production at low cost and without negative side effects, by taking advantage of previously unknown nuclear phenomena. The first phase was characterized by a huge number of attempts in the scientific community and in industrial companies, but it led to a disappointing early dismissal by the majority of the scientific research community; a typical example of criticism is the paper by Huizenga published in 1993 [2].

1.1.2. Three Decades of Experimental Efforts

The LENR experiments conducted later—efforts which nevertheless unavoidably continued for decades in various parts of the world (a list of papers can be found in Ref. [3])— were never recognized to have achieved the high level of rigor and repeatability which characterizes accepted modern science.

Among the most cited reviews are those published in the years 2007 to 2016 by two authors: Edmund Storms [4,5] and Steven B. Krivit [6–8]; both very skeptical about the quality of the results obtained by the experimenters engaged in this field. Nevertheless, activities on this subject continued.

Three updated and extended reviews have been recently published. In a paper published on Nature in 2019 [9], C. P. Berlinguette and others recognize that their "efforts, have yet to yield any evidence of cold fusion". Nevertheless, they "believe that there is exciting new science to be done within the parameter space of cold fusion experiments, and that this is an area worthy of engagement from the broader scientific community, even if the discovery of cold fusion at high enough rates for energy applications does not materialize." In the review paper by Nagel [10], besides references to several experimental papers, some classification of types of experiments is also given. The main limitation is that only experiments involving deuterium or hydrogen interacting with palladium or nickel are considered. The most recent review (December 2021) is in the paper by L. O. Freire and D. Andres de Andrade [11] who, after listing a large share of the experiments published in the literature, avoided formulating any sort of conclusion and closed their paper with two entirely open questions: the first "whether the golden dream of the fusion is approaching our time; the second, whether this is a dream or a nightmare. In case cold fusion becomes a reality, perhaps the answer to the second depends on the time that technology development starts".

Of some interest is also a list of papers named *Synopsis of Refereed Publications on Condensed Matter Nuclear Reactions* (2019) [12] which is more a bibliographical list than a synopsis since, for each paper, only the journal, title, authors, and affiliations are reported, with very limited indications of the results obtained and no detailed discussion. A site named LENR-CANR [3] (already mentioned) features a library of papers on LENR, including more than 1900 original scientific papers. The papers are linked to a bibliography of over 4500 journal papers, news articles, and books about LENR.

It is worth mentioning that initiatives dealing with LENR undertaken by official research Agencies at national and international level.

The most engaging effort is the one conducted under the auspices of the European Commission [13] through a Program named *Clean Energy from Hydrogen-Metal Systems* [14], responding to the call for proposals dealing with the objective *Developing a new source of clean energy*. The program started in 2020 with a duration of 4 years and a budget of 5.5 million euros. A possible extension due to the delays imposed by the COVID pandemic is under discussion. In the execution of this program, a large number of papers have been published and are being published in scientific journals, including the Journal of Condensed Matter Nuclear Science [15], specializing in this theme, to which an international Conference has been dedicated annually for more than twenty years [16]. Discussions on the possible prosecution of this effort are still pending.

As an example of attention paid recently to the issue of LENR within qualified scientific institutions, one might mention a paper [17], published by NASA in 2020, dealing with "novel" nuclear reactions observed in bremsstrahlung-irradiated deuterated metals.

Attention to the issue of LENR has been repetitively paid by US institutions in the realm of defense research activities under the responsibility of DARPA. A hearing on the subject of LENR was held in 2016 at the request of the *House Committee on Armed Services* (US Congress) organized by the Department of Defense. The outcomes of the hearing, reported in [18], focused on two methods considered as more extensively addressed by researchers: muon catalytic fusion and electrolysis. As a consequence of the political discussion, the foundation of ARPA-E was established.

This effort has not led until know to conclusions on the issue of LENR: from the experimental viewpoint unpredicted events of different type continue to be observed, but reproducibility is poor and a convincing explanation of the phenomena is missing even at a phenomenological level.

1.1.3. Proposals Formulated for Theoretical Interpretations

Before dealing with further developments on LENR it is worthwhile to formulate a few remarks on the situation of the theoretical considerations on the issue of LENR.

A large number of theoretical models for LENR are commented by V. A. Chechin, et al. in their paper dated 1994 entitled *Critical review of theoretical models for anomalous effects in deuterated metals* [19]. The major limitation of this review is that only interpretations dealing with deuterium are taken into consideration. A more recent (started in 2012) collection of papers dealing with Low Energy Nuclear Reactions can be found on the site *New Energy*

Times under Low-Energy Nuclear Reactions (LENR) Theory Index [20], where links are given to a variety of specific papers and mention is made to a categorization of the theories in several classes, suggested by V. A. Kirkinskii and Yu. A. Novikov, "Theoretical modelling of Cold Fusion", Novosibirsk 2002, cited as Reference [9] in Reference [21].

Among the approaches suggested for theoretical interpretation of the experimental results, mention should be made of a theoretical model [22] (named MFP after the proponents Mignani, Francaviglia, Pessa) based on the Deformed Minkowski Space, also named Deformed Space-time (DST). This model has been applied by us in a recent paper [23] (published in *Symmetry*) comparing its predictions with a limited set of experimental data available in the literature that were considered to be more accurately reported in the corresponding papers: the predictions have been found to be coherent with measured outcomes.

Even if it is undeniable that the issue of LENR is continuing to be given widespread attention, it must be recognized that the picture emerging from the review engagement deployed until now is far from being clear at phenomenological level (even reproducibility is lacking in many cases) and that attempts to deepen interpretation of experimental evidences and to indicate a theoretical explanation are very diversified and even controversial. Such a situation is to be called an open question that should not be left as such.

1.2. A Revival of Attention in View of a Definitive Clarification

1.2.1. A New Strategic Approach Adopted in USA

Recently, ARPA-E addressed again the issue of LENR after the unenthusiastic conclusion of the hearing at the US Congressional level held in 2016. A workshop was organized in 2021 [24] with the purpose to "explore compelling R&D opportunities in Low-Energy Nuclear Reactions (LENR), in support of developing metrics for a potential ARPA-E R&D program in LENR. Despite a large body of empirical evidence for LENR that has been reported internationally over the past 30+ years in both published and unpublished materials, as well as multiple books, there still does not exist a widely accepted, on-demand, repeatable LENR experiment nor a sound theoretical basis. This has led to a stalemate where adequate funding is not accessible to establish irrefutable evidence and understanding of LENR, and lack of the latter precludes the field from accessing adequate funding".

Subsequently, ARPA-E asked [25] "outstanding scientists and engineers from different organizations, scientific disciplines, and technology sectors to participate" in an Exploratory Topic (dealing with LENR both on scientific aspects and on implementation capabilities). Multidisciplinary and cross-sector collaboration spanning organizational boundaries enables and accelerates the achievement of scientific and technological outcomes that were previously viewed as extremely difficult, if not impossible. In September 2022, a call for proposals [26] was issued by ARPA-E, and in February 2023 the selection of 8 project teams was decided for a total funding of 10 million dollars [27]. It is interesting to read the synthetic motivation for this effort published by ARPA-E: "The teams announced today are set out to answer the question 'does this area show promise, and if so, how? Or can we conclusively show that it does not?' While others have shied away from this space, ARPA-E wants to break through the knowledge impasse and deepen our understanding".

A commented chronicle of the steps undertaken by ARPA-E has been published by the ANS (American Nuclear Society) [28] under the title "ARPA-E picks eight teams to prove—or debunk—low-energy nuclear reactions".

1.2.2. The Contribution by the Present Paper: A Collection of Experimental Data Organized in a Coherent Taxonomy to Identify Common Features in View of Possible Interpretation

The actions enforced by ARPA-E in 2021 aroused our interest towards reconsidering, with a new comprehensive approach to experimental data, this longstanding issue that we addressed almost at the same time with the paper published in Symmetry [23], already mentioned, where a theory-based viewpoint was adopted, with the discussion of experimental data limited to a small number of experiments.

The present paper, on the contrary, is not devoted to present a theoretical formalism, but to the systematic reconnaissance, deepening and classification of experimental evidences published by different authors. Most of the published papers adopt a fragmented and restricted approach in the sense not only that each one is concentrated on the single experimental layout utilized, but also that the results are very often presented as a confirmation of a theoretical interpretation suggested by that group of researchers specifically for their own results. Consequently, we considered it useful, having temporarily put aside the theoretical assumptions adhering to which any single experiment was accomplished, to provide a synopsis in view of:

- Commenting on the degree of fulfillment of high standards of design and implementation of the experiment, on the completeness of the details exposed and the extension of reproducibility achieved;
- Commenting on possible improvements to reproducibility;
- Identifying the possible presence of features common to several experiments that, beyond the details of each single experiment, may help in identifying some common action mechanisms to be considered as shared among the different experimental approaches adopted.

Hence, the basic idea of the present paper is, first of all, the identification of a typology of cases each found representative of a variety of hundreds of experiments published in journals or in international congresses using the material environment where the experiment is conducted as a primary classification logic. The second step is the examination, for each emblematic case, of a series of features as described in the following paragraph.

This work of collection, description, classification and comment of experiments already conducted may be a background providing support for the most valuable design (and possibly interpretation) of the next experiments promoted by the ARPA-E initiative mentioned above.

We are fully convinced that new experiments are necessary to exit from a sort of "suspension of judgment" on the issue of LENR; the outcome of the new experiments to be performed should be either to confirm, explain and possibly expand the indications acquired until now or to deny with convincing arguments (in primis through ad hoc experiments, in accordance with Popper's falsification principle) the credibility of the phenomena widely reported but until now controversial. To put the issue synthetically using old Greek words, *aporìa* (contradiction) has generated *epoché* (suspension of judgment). The suspension should not last indefinitely (the question was raised more than 30 years ago with the claims by Fleishman and Ponds and it is still pending); *exegesis* (explanation and clarification) should be achieved promptly.

Moreover, we give indications in the direction of identifying the densification of energy (in all its different concrete realizations involving space and/or time dimensions) as a possible unifying concept applicable to all the emblematic cases considered.

In this sense, the conclusions reached in our previous article [23], already mentioned, where we indicated that the DST theory [22] allows for the prediction of outcomes resulting from a limited set of experiments, are extended to all the experiments examined in the present paper. This result can be considered a step forward overcoming a situation characterized by the circumstance that different theoretical models are, in the available literature, used for different experimental results.

We can therefore say, from the experimental results, that this theory provides a single and unambiguous interpretation for all anomalous nuclear physics results in all unconventional experiments. The unifying concept turns out to be the densification of energy in all its different concrete realizations. On the contrary, authors of other experiments—and their related theoretical explanations—have always proposed phenomenological-level modeling hypotheses to interpret at least one experimental case without, however, being applicable to at least one other, different experimental case.

Our contribution aims to avoid the heritage associated with the wide engagement deployed for LENR over a long time being disregarded or wasted, both in terms of specific data gathered and in terms of methodologies acquired, some of which might be utilized again with proper modifications.

2. Methodology Adopted to Analyze Experimental Evidences Reported in the Literature

2.1. Characteristics Examined for the Classification of the Experiments

For the classification of the experiments, the following three characteristics are examined:

- The type of observed experimental evidence which is considered "weird" (in the sense of being unexpected or even considered impossible according to generally accepted physical theories—anomalous being a synonym of "weird" in this respect) and the instrumentation adopted for this purpose;
- The material matrix in which the evidence takes place;
- The modalities through which the onset of the evidence is stimulated.

The evidence can be either microscopic (for instance, detection of nuclei or particles not present before the onset of the phenomenon) and/or macroscopic (such as excess energy production in the form of heat or pressure generated, or visible modification in the appearance and structure of materials present in the experimental apparatus). We use the term "evidence" to refer to a single outcome detected in a given type of experiment and the term "phenomenon" when there is a systematic repetition of coherent evidences under given conditions (see Section 2.3).

We use the term "experimental approach" for the combination of item b. and item c. (for instance, palladium electrodes in an electrolytic cell where voltage is used to stimulate the evidence expected).

The use of this classification is not only taxonomic. Hence, suggestions can be obtained, in planning and performing further experimental activities, pertaining to the type of events to be searched for and detected, as well as to choices on the selection of instrumentation to be included in the experimental apparatus and even on the geometrical disposition of single detectors, since anisotropy characterizes the deployment of events resulting from this type of experiments. We underline that anisotropy of experimental outcomes can be the cause for lack of confirmation when a successful experiment is duplicated by a different group, since minor differences in the layout of the experiment (for instance, the placement of detectors) may lead to missing the outcome looked for.

2.2. Field of Investigation

The present synopsis is concentrated on experiments where transformation of matter is implied. Only "Nuclear non-conventional phenomena" are considered, while elsewhere (see, for instance, [23]), non-nuclear phenomena are also addressed. Remaining in this specific field, we notice that the label "Low Energy Nuclear Reactions (LENR)", is, to some extent, confusing, since the expression "Nuclear reactions" is well established in physics to refer to the outcomes of nuclear forces as described by the Standard Model, in the framework of which, the type of phenomena under investigation here are theroretically foreseen to be impossible. The expression "Nuclear non-conventional phenomena" preferred by us keeps the term "nuclear", since the modifications detected pertain to the nucleus, but drops the word "reaction", to be reserved to the consequences of the intervention of nuclear forces as described by the Standard Model. As a shortcut for "Nuclear non-conventional phenomena", we recommend the use of "Nuclear metamorphosis" as well. It should be noticed that in physics, the widest term (i.e., the most generic) used in such situations is "interaction".

In the present work, we do not consider the following two cases: catalytic nuclear fusion from muons (mesic atom method) (a comprehensive and up-to-date overview of the open issues and prospects for further development of this approach can be found in the Imperial College doctoral dissertation (2018) [29], where the characteristics that a reactor based on this process should have are explored in depth; a subsequent paper outlines the results and potential of an innovative method for muon production [30]) and ablation-catalyzed nuclear fusion generated by laser beams (see e.g., the review papers [31,32]). In fact, both cases do not encounter anomalies and are well encoded in the context of well-known applications of nonrelativistic quantum mechanics at the nuclear level (nuclear wave function superposition and consequent increase of tunnel probability).

The principal selection criteria were the simplicity of the layout and readability of the data describing both the experimental setup and the results substantiating the phenomenon under investigation. As already hinted, the main reasons for this choice have been, on the one hand, favouring the duplication of experiments by other researchers, and on the other hand, facilitating the identification of essential features common to the different experiments that could be useful for enlightening their nature.

2.3. Terminology Adopted to Qualify the Evidences Reported

As the title of this section underlines, the attention is focused on experimental evidences. By this term we mean what is found, highlighted, recorded and—which is decisive—measured in the experiment described in each paper; for instance, emission of particles quantitatively measured by means of adequate instrumentation properly operated and calibrated. The term “evidence”, to be interpreted as referring to a specific occasion, is not to be confused with the term “phenomenon”, which refers to a systematic repetition of coherent evidences under given conditions.

Since the different papers examined here are not based on a unique coherent terminology, it is considered useful to adopt the terminology described in the following Table 1 [33] to create a sort of hierarchy among situations with different levels of reliability as a consequence of:

- Sporadic or systematic occurrence;
- Degree of governability of the physical process characterizing the experiments;
- Multiplicity of research teams where experiments have been successful.

Table 1. Coherent terminology for the different experiments.

Term Used		Situation Occurring and Information Acquired
Evidences	Sporadic evidence	Measurements indicate that some event takes place (for instance, the detection of a particle) but the experimenter does not know when this may happen or not (i.e., control parameters are not identified clearly). Even the *recipe* of what details may lead to the events looked for, is not clear.
	Reproducible evidence	The experimenter knows under what conditions the evidences appear. A clear *protocol* indicates what the controlling parameters are and what value they should have for the evidences to appear (an input-output correlation): an empirical model is attained.
Phenomenona	Occurrence of a phenomenon	A systematic repetition of coherent evidences under given conditions is obtained. Phenomenological models are proposed to foresee the occurrence, for instance, taking advantage of analogies with other phenomena.
	Interpretation of a phenomenon	Identification of well-established physics-defined objects intervening and of their mutual interactions.
	Explanation of a phenomenon	Referring to the wider knowledge dealing with more general phenomena and laws, which can be used as a justification of the new phenomenon encountered. This knowledge can, in some cases, be only hypothesized and expecting confirmation or refutation.

In synthesis, a set of experimental evidences must, as a prerequisite, be compliant with the generic concept of reproducibility to be accepted as a proof of the existence of a physical phenomenon that is agreed to exist in nature. (There is not a widespread agreement on terminology used to describe different types of reproducibility; the following definitions might be useful: Repeatability applies to a given context: the same results are obtained with stated precision in multiple trials, whenever the measurement is repeated, by the same team, using the same measurement system, under the same operating conditions, in the same location. Parametric repeatability implies that the team has such a level of knowhow on managing the experiment that they can obtain coherent results under different operating conditions over multiple trials. Replicability corresponds to obtaining the same results by another team and elsewhere, but under the same experimental conditions, rigidly following the original protocol. Reproducibility indicates that other teams have fully understood the decisive features of the original test and that they can act on their own. This level of reproducibility by others acting autonomously is necessary to obtain consensus.) "Ideally, an experiment or analysis should be described in sufficient detail, so that other scientists with sufficient skills and means can follow the steps described in a published work and obtain the same results within the margins of experimental error" [33].

2.4. Characteristics of the Evidences Resulting from the Experiments Examined

The experimental cases examined are, first of all, classified according to the material where the evidence takes place:

- Solutions in a gaseous or liquid environment;
- Metals of different composition and in different shapes;
- Rocks and artificial chemical materials such as sequioxane.

2.4.1. Types of Evidences Encountered

A distinction is introduced between:

- Microscopic evidences consisting in: detection of neutrons or alpha particles not initially present; detection of nuclei not initially present; reduction in the quantity of an isotope initially present; reduction in radioactivity levels (gamma rays directly arising from a metamorphosis have not been detected, up to now);
- Macroscpic evidences based on the appearance of excess heat production and/or localized deformation of components of the experimental apparatus and/or changes in the radioactivity of a sample.

2.4.2. Identification of Techniques Used to Stimulate the Onset of the Evidences

The evidences appear only in the presence of actions that modify the conditions characterizing the environment. These actions can be classified as follows:

- Compression via electricity;
- Compression via photons;
- Compression via ultrasounds with onset of cavitation;
- Compression via gas injection;
- Compression directly by shear (mechanical compression).

We use the term "compression" to indicate an operation activated by the experimenter; as such it is objective. We consider energy densification an inference of possible consequences of the operation on the status of the system.

3. Collection of the Information Pertaining to the Experiments Considered

The information and the subsequent considerations formulated in this paper rely on a thorough examination of the most significant information available in the literature for each type of experiment that has provided evidences interpreted by the experimenters as proof of the existence of phenomena in matter involving the nucleus that can be called "weird", i.e., so far lacking widely accepted interpretation and explanation (in several cases the use of the term "phenomenon" is questionable due to weakness in repeatability, see the note in Section 2.3.

3.1. Synthesis Describing Types of Experiments and Evidences Reported

In the following, an overall synthesis table is provided. For each experiment, the evidences detected are summarized in correspondence with the stimulation techniques used to generate such evidences. It should be noted that the meaning of the last column, dealing with the modality leading to the energy densification, will be explained later (see Section 3.3). In the first column of the Table 2 reported below, the natural numbers, possibly followed by a letter, from 1 to 17, refer to the corresponding sheets in Appendix A.

3.2. Detailed Information Collected for Each Experiment

In Appendix A, for each experiment examined, a descriptive identity card is provided; this card is divided in two sections, named "objective results" and "inferences", respectively.

3.2.1. "Objective" Information for Each Experiment

The first set of information can be considered as "objective", which means that it was ascertained by the experimenters (it includes what materials were present, what procedure were adopted and what was found, depending on what was looked for and what instruments were used). Attention is focused on:

- Material where the evidence takes place;
- Stimulation technique used to "trigger" the evidence;
- Experimental evidences found;
- Techniques employed to detect the evidences.

It should be stressed that "what was looked for" and of "what instruments were used", in some cases, are presumable, in particular by comparison with the results of comparable experiments; for instance, radiation could have been released but was not detected because either it was not expected and consequently not looked for, or it was expected but not found because the necessary detection system was not installed.

3.2.2. Inferences for Each Experiment Deriving from the Interpretation of Evidences

The second set of information to be considered as inferences (in other words, deductions, interpretations) formulated by us, includes:

- Estimated degree of description completeness and of reproducibility level;
- Interaction environment;
- Interaction agents;
- Modality for energy densification;
- Phenomenon type;
- Microphysics interpretation.

The evaluation grid of repeatability of each experiment here introduced is not finalized to a judgment on the value of the paper, but is only an indication of the viability of repetition with the available information. A four-value scale is used: Improvable, Sufficient, Good, Very good.

The Interaction agent is the object, present in the apparatus, which, according to the interpretation adopted, participates to the onset of the events taking place, eventually in synergy with secondary participants.

The Interaction environment indicates where the main Interaction agent is located and where potential secondary agents come from.

Table 2. Overall synthesis of experimental evidences ande stimulation techniques.

Part A. Solutions										
	Stimulation Techniques									
	Compression via Electricity			*Compression via Photons*		*Compression Directly by Pressure*				
Material Where the Evidence Takes Place	*Electric Current*		*Electric Voltage*	*Photo Stripped Neutrons*	*Laser*	*Ultrasounds with Cavitation*	*D gas Insertion with Pressure Pulses*	*Shear*		*Specific Modality Leading to the Energy Densification Ramp*
	Electric Heating	*In Water Solutions, D Ions Insertion in Pd*	*Pulsed Discharges*	*Gamma Irradiation of ErD_3 e TiD_2*				*No Brittle Fracture*	*With Brittle Fracture*	
Solutions										
Low pressure D2 gas with various types of cathode and Pd o W as anode 0.			X-radiation having an energy nearly equal to the voltage applied to the discharge and energetic particle emission similar to deuterons having energy with peaks between 0.5 MeV and 3 MeV							Variations in space and volumes of the number of the force lines of the electric field (discharge is impulsive by definition)
Distilled water with Ti foil 1.a			Glow discharge, new elements detected (B, Cu) and increment of isotope ^{48}Ti							Pulses of electric energy and associated concentration of electric charges
Distilled water with uranyl sulfate and Ti foil 1.b			Distortion of the natural isotopic composition of uranium with consequent alteration of the secular equilibrium in uranium decay chain							Pulses of electric energy and associated concentration of electric charges
Distilled water with iron salts 2.						Detection of neutrons				Ultrasonic cavitation

Table 2. *Cont.*

Part A. Solutions										
Material Where the Evidence Takes Place	*Stimulation Techniques*									*Specific Modality Leading to the Energy Densification Ramp*
	Compression via Electricity			*Compression via Photons*		*Compression Directly by Pressure*				
	Electric Current		*Electric Voltage*	*Photo Stripped Neutrons*	*Laser*	*Ultrasounds with Cavitation*	*D gas Insertion with Pressure Pulses*	*Shear*		
	Electric Heating	*In Water Solutions, D Ions Insertion in Pd*	*Pulsed Discharges*	*Gamma Irradiation of ErD_3 e TiD_2*				*No Brittle Fracture*	*With Brittle Fracture*	
Solutions										
Distilled water with ^{228}Thorium 3.						Reduction of radioactivity levels and detection of new isotopes				Ultrasonic cavitation
Nitric acid With ^{63}Ni 4.						Reduction of radioactivity levels and detection of new isotopes				Ultrasonic cavitation
Deuterated acetone 5.						Detection of neutrons				Ultrasonic cavitation without symmetrical spherical collapse
Palladium loaded with hydrogen in the presence of calcium carbonate 6.		Detection of neutrons								Deformation of the electrodes that are the reactant

Table 2. *Cont.*

Part B. Metals Rocks and Artificial Compounds										
Material Where Evidence Takes Place	*Stimulation techniques*									*Specific Modality Leading to the Energy Densification Ramp*
	Compression via Electricity			*Compression via Photons*		*Compression via Pressure*				
	Electric Current		*Electric Voltage*	*Photo Stripped Neutrons*	*Laser*			*Shear*		
	Electric Heating	*In water Solutions, D Ions Insertion in Pd*	*Pulsed Discharges*	*Gamma Irradiation of ErD_3 e TiD_2*		*Ultrasounds with Cavitation*	*D Gas Insertion with Pressure Pulses*	*No Brittle Fracture*	*With Brittle Fracture*	
Metals										
Mercurio 7.						Detection of new elements including rare earths				Ultrasonic cavitation
Acciaio AISI 304 in aria 8.a						Detection of neutrons				Spherical symmetrical collapse of gas bubbles
Acciaio AISI 304 in aria 8.b						Production of Cu with isotopic composition different from the natural one				Spherical symmetrical collapse of gas bubbles
Acciaio AISI 304 in aria 9.								Detection of alpha particles		Time variation of pressure
Metallic powders in deuterium gas 10.							Production of excess heat			Compensation of pressure variation by pressure gauge inducing pressure shocks
Constantan in the presence of H_2 or D_2 14.	Elements generation (C, O, Cl, Ca, and Zn) Excess heat production									Temperature increase

Table 2. *Cont.*

Part B. Metals Rocks and Artificial Compounds										
Material Where Evidence Takes Place	*Stimulation techniques*									*Specific Modality Leading to the Energy Densification Ramp*
	Compression via Electricity			*Compression via Photons*		*Compression via Pressure*				
	Electric Current		*Electric Voltage*	*Photo Stripped Neutrons*	*Laser*	*Ultrasounds with Cavitation*	*D Gas Insertion with Pressure Pulses*	*Shear*		
	Electric Heating	*In water Solutions, D Ions Insertion in Pd*	*Pulsed Discharges*	*Gamma Irradiation of ErD_3 e TiD_2*				*No Brittle Fracture*	*With Brittle Fracture*	
Metals										
Palladium in the presence of H_2 or D_2 15.					Elements generation					Temperature increase due to heating via He-Ne laser and excimer laser
Deuterated materials: ErD_3 and TiD_2 10. bis				Detection of photo-dissociation neutrons and claimed neutrons consistent with DT fusion producing ^{3}He and a neutron						Pulsed neutrons (generated by photo production) produce critical energy density throughout the volume and timing of the neutron bunches.
Mixture of Ni and $LiAlH_4$ 11.	Production of excess heat									Compensation, by current regulation, of temperature variation in order to obtain heat shocks
Rocks										
Granites 12.a									Nuclear emissions: neutron detection	Fracture with cavitation through pressure shocks
Marbles 12.b								No detection		Fracture without cavitation (ineffective)

Table 2. *Cont.*

Part B. Metals Rocks and Artificial Compounds										
Material Where Evidence Takes Place	***Stimulation techniques***									***Specific Modality Leading to the Energy Densification Ramp***
	Compression via Electricity			***Compression via Photons***		***Compression via Pressure***				
	Electric Current		***Electric Voltage***	***Photo Stripped Neutrons***	***Laser***	***Ultrasounds with Cavitation***	***D Gas Insertion with Pressure Pulses***	***Shear***		
	Electric Heating	***In water Solutions, D Ions Insertion in Pd***	***Pulsed Discharges***	***Gamma Irradiation of*** ErD_3 ***e*** TiD_2				***No Brittle Fracture***	***With Brittle Fracture***	
Metals										
Marbles 12.b								No detection		Fracture without cavitation (ineffective)
Artificial compounds										
Silesquioxane 13.			Excess heat (°) (°) Besides pulsed discharges, also photonic and ultrasound stimulations were used							Pulsed time variation of the electric field. Ultrasonic cavitation

Experiments providing microscopic evidences of *Nuclear Metamorphosis* (concerning element(s) production, or variation from one starting element to another, or isotopic variations that occur in an appropriate and appropriately stressed environment without the use of radiation) (As already mentioned, "nuclear" is used here in the sense that a nucleus is transformed, but the adjective indicates "where the transformations occur", not the intervention of nuclear forces as commonly defined) are categorized as follows:

Reduction of radioactivity (In a previous work (Refs. 4.1, 4.2, cited in the card dealing with the experiments of type 4 in Appendix A) this phenomenon of reducing the radioactivity level of the sample subjected to sonication has been called "neutralization".)

From a substance containing at least one radioactive element or one radionuclide, stable elements are produced as a result of transformation of the starting radionuclides and reduction of the activity level of the starting substance from that before the treatment. Possible application area: Removal of radioactivity from nuclear waste.

Isotopic change

From a multi-isotopic starting element, stable isotopes are produced with alteration of the natural isotopic abundances. Possible application area: Removal of radioactivity from nuclear waste, as demonstrated in experiments conducted with thorium and nickel (see, in Appendix A, experiment type 4 and 5, respectively).

Production of elements

From a stable starting element, stable elements previously not present in the sample (normally lighter than the starting one) are produced.

Possible application area: Production of valuable elements, for example, rare earths or helium.

Nuclear emissions (The distinction between Nuclear Emission and Nuclear Metamorphosis is valid if one remains at the level of found evidence. Specifically: neutron and/or α emission is to be assumed to involve that some nucleus has been modified in that it "lost" the emitted neutron or particle, unless one imagines no conservation of the total number of hadrons. Emission involves nuclear metamorphosis while metamorphosis does not necessarily involve emission.)

Occurrence of neutrons or α particles that are NOT α radiation from nuclear decay.

Possible application area: Neutron or α particle source productions; power generation.

This classification aims also at justifying the use of the term "phenomenon" (see Section 2.2) since a certain type of evidences are repeated in different conditions.

Microscopic interpretation is a tentative description of the phenomenon in terms of interactions among well-established physical objects, such as particles and nuclei.

In the analysis of the literature, additional information, besides what is listed above, was acquired, when available, dealing with:

- Experimental conduct ("how it was proceeded" also in view of reproducibility considering the parameters influencing the outcome;
- The possibility of adjusting and controlling the process);
- Additional outcomes during the experiments.

This information contributes, as source of clues, to substantiate the inferences deduced. Among the additional outcomes one should mention:

- Production of air bubbles;
- Production of debris;
- Deformation of electrodes;
- Light emission;
- Presence of hysteresis phenomena;
- Pulse nature of the phenomenon;
- Occurrence of micro explosions;
- Effects of positioning of detectors;
- Effects of geometry of the stimulator device (electrode or sonotrode) or of its surface treatment.

By inter-comparing the occurrence of these clues, suggestions can also be derived about additional instrumentation to be used to detect other evidences in further, hopefully conclusive, experiments.

Even though, in many cases, the additional data mentioned above have been valuable to provide clues to formulate the inferences, they were not reported in the data sheets for lack of space. Interested readers may have access to these data by looking at the References mentioned for each experiment.

We underline that, for each experiment type, three different levels of details are made available, corresponding, respectively, to:

- The synthesis presented in Section 3.1;
- The dedicated data sheet reported in Appendix A;
- The bibliographic references to the original papers describing each experiment mentioned in each data sheet.

3.3. An Interpretation of the Energy Densification Mechanisms

3.3.1. The Process of Energy Densification

We call energy densification the process of reaching energy densities that are critical—in space and time—for the occurrence of the phenomenon (the label "quadridimensional densification" is suggested to express that both energy density in the space volume and energy density in the time interval must be considered), which may have entirely new and peculiar characteristics, even to the point of apparently contradicting well-known and acquired laws, such as, for example, the conservation of total energy and the second principle of thermodynamics. But such violations are only apparent and are resolved in the context of DST theory [22,23], which treats space-time as an energy-dependent elastic medium and contextually energy reservoir, without invoking any concept involving the vacuum state.

The existence of energy thresholds is found to separate, for each interaction, the flat metric part from the deformed metric part. The phenomena occurring in the deformed part of the interaction metric are governed by the energy density in the space-time (volume [34] and time interval [35] and Chap. 16, par. 16.3.1 pp. 242–245, par. 16.3.5 pp. 249–251 of [22]).

From the mathematical standpoint, the energy E has to be considered as a dynamic variable, because it specifies the dynamic behavior of the process under consideration, thus providing, through the metric coefficients, a dynamic map in the energy range of interest of the interaction ruling a given process, with regards to the energy density in the space volume [34]. At the experimental and practical level, the outcome of energy densification results in reaching the values of critical pressure, i.e., energy per unit volume, and critical power, i.e., energy in the interval of time defined as unit, at which the phenomenon is triggered and produces measurable effects. With respect to the energy density in the time variable, the power density for piezonuclear reactions was also estimated, as an order of magnitude, starting from the DST theory [35].

3.3.2. Modes to Obtain Stimulation in Different Configurations

In particular, in the case of a liquid medium, densification occurs by employing ultrasound to induce critical conditions in phase space with a mechanism that can be traced back to cavitation, which gives conditions for energy thickening. (Cavitation arises when a plane wave of pressure of given wavelength impinges on a gaseous bubble internal to matter if the diameter of the bubble is much less than the wavelength: by Pascal's principle, it produces a spherical-symmetric collapse in that bubble.) In metals, it can be imagined that the confinement function can be fulfilled by Ridolfi cavities and the ultrasonic wave can be generated by fracture propagation (it is well known that there are very high stress and therefore energy concentrations at the tip of a propagating crack). In rocks, it can be imagined that Ridolfi cavities would intervene, but only in the presence of a brittle fracture and subsequent pressure wave. More on this subject is set forth in reference [21], chapter 16, paragraph 16.3, pages 242–251. There it is reported that the orders of magnitude of cell sizes are those in the range of 4 to 8 microns for space and microseconds for time, respectively. (We mean microcavities, with diameters between 1 and 10 microns, in the material rather than cells in the sense of the Liouville space, nor commonly known voids in metallurgy, e.g., the well-known Kirkendall voids (40–60 microns)).

In the case of a gas pressure on metal powders, it is the gas pressure that acts directly on the matter, producing the acceleration in phase space that leads to the critical cell and thus to the conditions of nuclear metamorphosis of matter.

In the case of a massive material subjected to hydrogen loading, mechanical stresses arise. They can change the microstructure of the material until local microfractures develop. The latter can occasionally give rise to an accelerated increase of the pressure, thus leading to the microcavity reaching critical conditions, and hence to the nuclear metamorphosis occurring into corresponding the phase space cell. Since the development of such local fractures is occasional and cannot be linked in a predictable way with hydrogen loading, the critical conditions in phase space are difficult to reproduce.

For a solid material directly subjected to mechanical stress, up to a critical load, its overcoming by fracture is produced. In the event that the fracture is "brittle", there is an acceleration leading to nuclear metamorphosis into the phase space inside the critical cell. Should the fracture be "ductile", the acceleration is insufficient and never reaches the critical conditions in the cell needed for nuclear metamorphosis.

For the purpose of obtaining an energy densification method useful to generate the phenomena of nuclear metamorphosis in condensed matter, in particular in solid matter, it is also possible to consider the class of processes consisting in "loading" light elements into the bulk of a solid matrix also of crystalline type. This loading process has been widely used in experiments conducted in the framework of experimental activities dealing with so called "cold fusion", for instance, using hydrogen or deuterium as gases to be introduced in a metal bulk material. Nevertheless, such a process is highly unpredictable with respect to the aim of reaching the critical energy density necessary to obtain nuclear metamorphosis. Even if the deformation of the material undergoing loading can supply clues on the energy densification process, any single loading operation has its own dynamic and is characterized by its own history that does not necessarily ensure a highly reliable reproducibility when targeting the onset of nuclear metamorphosis; this is shown by the discordant results to be registered in experimental layouts that appear to be overlapping.

4. Comments and Contributions for Further Steps towards Scenario Clarification

4.1. Issues and Topics Showing Weaknesses in the Execution of Research Programs

Difficulties in replication in other laboratories has been the Achilles' heel of this research area

As already noticed, a problem displayed by the existing literature on this topic is that the experimenter himself sometimes fails to reproduce what he has achieved. Moreover, when the experiment is repeated elsewhere, there are difficulties in obtaining results coherent with the outcomes of the original experiment (see Section 2.2 above). This can be due to the adoption of experimental procedures which are incorrect with respect to those adopted in the experiment to be repeated.

An important aspect to be kept in mind is that, in the designing and performing of the considered experiments, there has been a remarkable lack of modeling support from which to draw guidance on what to look for. Additional problems can arise, as a consequence of the intrinsic characteristics of the phenomena considered here, such as anisotropy, asymmetry, asynchrony, and inhomogeneity of emission, that lead to specific difficulties in defining the experimental layout that are not universally perceived by experimenters.

Another sensitive issue is related to the sensitivity of instrumentation with respect to false signal geometries and background intensities. The decisive impact of the interaction between theoretical models and experiments, within this context, shows the existence of two opposing errors: total lack of a theoretical model to drive the design of the experiment, and inability to capture unexpected evidence.

Some role is also played by equivocal and unsupported terminology, for example, piezonuclear metamorphosis, LENR, and cold fusion, a non-unified terminology to denote the same set of experiments, with different, sometimes provisional names. There has been historically, in the development of the field, closure and opposition between research groups, as well as interference between sharing scientific heritage and protecting intellectual heritage [2,4,7,8].

4.2. Some Features Simultaneously Present in All the Experiments

4.2.1. A Possible Reversal of the Most Common Story Telling of LENR

The most common reading of a LENR mechanism is that light nuclei, properly stimulated and in the presence of a properly chosen piece of matter (most frequently a properly-treated metal), are allowed to react with each other in contradiction with consolidated physics laws. Looking at the following table (which is simply a collection of data reported in the second section of the sheets describing the experiments considered) an alternative exposition appears to be consistent with experimental results: under proper conditions, when the nuclei of elements having a high value of binding energy per nucleon are properly stimulated by nuclei of light elements, they undergo phenomena of nuclear metamorphosis. Among the consequences of such a formulation, one might mention possible hints on the most promising choice of materials to be utilized for additional experiments. In the following Table 3, we mention only experiments where new isotopes of already present nuclei, or new nuclei altogether, are produced.

Table 3. Experiments where new isotopes of already present nuclei, or new nuclei altogether, are produced.

Experiment Type	Interaction Environment	Interaction Agent	Products, as Reported by Experimenters
1	Deuterium gas and/or deuterium in anode metal lattice	Deuterium and/or atoms in metals	Several isotopes not present before
2 a	Distilled water	Elements present in Ti foils	Several isotopes not present before
2 b	Titanium in water containing uranium salts	Elements present in Ti foils and uranium	Several isotopes not present before
3	Water	^{56}Fe	Several isotopes not present before
4	Water	^{228}Th	Several isotopes not present before
5	Nitric acid solution	^{63}Ni nitrate	Several isotopes not present before
6	Deuterated acetone	Deuterated acetone	Several isotopes not present before
7	Palladium electrodes in water solution of electrolytic salts	Elements present in Pd metal	Several isotopes not present before
8	Mercury	Mercury	Several isotopes not present before
9 a	Air present in the internal microcavities of AISI 304 austenitic steel	Elements present in AISI 304 austenitic steel	Several isotopes not present before
9 b	Air present in the internal microcavities of the material	Elements present in AISI 304 austenitic steel	Copper with isotopic composition different from that of natural copper
10	AISI 304 austenitic steel	Elements present in AISI 304 austenitic steel	Several isotopes not present before
11	Deuterium gas	Metal powders	Several isotopes not present before

Table 3. *Cont.*

Experiment Type	Interaction Environment	Interaction Agent	Products, as Reported by Experimenters
12	Constantan lattice deformed, at the surface of the wire, by the presence of deuterium or hydrogen	All elements present	Several isotopes not present before
13	Pd lattice deformed by the presence of deuterium or hydrogen	All metals present	Several nuclides not present before
14	Deuterated Erbium and deuterated Ti	Deuterium and possibly erbium and titanium as well	Several nuclides not present before
15	Hydrogen atmosphere	Nickel hydride	Several nuclides not present before
16 a	Air but not free air; metamorphosis takes place in the air enclosed in cavities contained in granites	Granites with iron in air	Several nuclides not present before

4.2.2. A Hypothesis on the Mechanism of Action Applicable across All Configurations: Densification

As seen in Section 3.3., in order to enunciate a unified interpretation of the above findings, it has been useful to resort to language analogous to that employed in the phase space formalism. Indeed, as we have seen, we defined "cells" as appropriate portions of space identified by defined intervals of the spatial coordinates and the time coordinate, and introduced the concept of energy density as the amount of energy present per unit volume of the (just defined) cell. The external action consists of interventions to increase this density in the cells, until a critical threshold is reached at which nuclear metamorphosis phenomena with nucleosynthesis and nucleolysis allowed by generalized Lorentz invariance are triggered between nuclei. Since densification occurs in a critical volume or critical time interval or both, by analogy with phase space, a cell that has reached critical conditions is called a "critical cell". It can be viewed as an energy-confinement space.

In the presence of pressure wave-induced cavitation, one can imagine that bubbles serve the function of confinement space. The unifying element of the different experiments considered in the reconnaissance can be defined thus with regard to the intervention leading to the phenomenon under study: a steep enough ramp of thickening (densification) of the energy in the time interval and in the volume of active space occurs, until a sufficiently high value of energy concentration is reached (like a threshold to be exceeded).

Finally, in Table 4, we underline a classification of the experiments examined, assuming as a criterion the way adopted in attaining the energy densification.

Table 4. Experiments classification, according to the way adopted in attaining the energy densification.

Experiment Identification	Way Adopted in Attaining the Energy Densification (Densification Type)
1	A. Variation in volume and time of the number of the force line of the electric field
2.a, 2.b, 3, 4, 5, 6, 8, 9.a, 9.b, 17	B. Pulses of electric energy and concentration of the electric charges
7, 10, 11, 16.a, 16.b, 17	C. Pressure variations
12, 13, 15	D. Temperature variations
14	E. Action by pulsed neutrons

As complementary information, we remind that a thorough treatment of densification thresholds from a theoretical view point can be found in Chap. 16, par. 16.3.1 pp. 242–245, par. 16.3.5 pp. 249–251 of Reference [22].

5. Concluding Considerations and Suggestions

We have conducted a comprehensive selection, classification and comparative analysis of what we consider the most significant experiments dealing with LENR reported in the literature and have derived a broad reconnaissance of the experimental results aiming at the construction of a systematic phenomenology. The unifying concept has turned out to be the densification of energy in all its different concrete realizations. We have observed that the experimental outcomes are in accordance with theoretical predictions of a single theory for all experiments, the DST theory, which was the object of a recent paper published by us in Symmetry [23]. Noticed that, on the contrary, authors of other experiments—and their related theoretical explanations—have always proposed phenomenological-level modeling hypotheses to interpret one experimental configuration case or, in some instances, only several experimental configurations.

Even some of the reviews of experiments and their corresponding evidences are marred by being biased and too much aimed at proving a prejudicial thesis, with the characteristics of being an overly specific phenomenological-level modeling. This interpretive landscape highlights a proliferation of uncoordinated experimental attempts lacking reasonable mutual integration at the level of results. In addition, many experimental attempts used multiple tools to stress the matter in order to stimulate the occurrence of events; such a situation jeopardized a clear, hierarchical separation of the effects of each stress.

In essence, little use has been made, in most of the literature so far, of the ability to link cause to effect. Thus, the first of our purposes here has been that of providing an opportunity for the international scientific community to move from the level of individual evidence to that of identifying elements for a properly articulated and hopefully shared view of the phenomena considered here—a transition crossed in similar circumstances in the history of physics, for example at the discovery of the neutron and the discovery of nuclear fission.

The second purpose is to promote a research program that brings clarity with an overall assumption of responsibility by the scientific community, aimed at working together for a systematization of the various theoretical contributions made by different research groups. In particular, it is noted that the inference of the existence of a mechanism common to all experiments consisting of an energy densification ramp is coherent with the theory of deformed space-time leading to the identification of energy thresholds, which are used to calculate the critical densities triggering the phenomena.

From this viewpoint, it is useful to distinguish the two concepts of the critical density of energy and the energy densification. The latter is the practical and technical way to obtain the critical density of energy in each experimental setup, with respect to the phenomena to be investigated. For this reason, we refer to energy densification in each identity card given in Appendix A, concerning the different experiments we examined and listed.

It is not coherent with a systematic investigation of physical phenomena that, after thirty years, questions are still pending on the existence, significance and impact of LENR to which the most acknowledged physical theories are not capable of giving an answer. Even a definitive demonstration that all these experiments have decisive faults would be preferable than leaving the issue unaccounted for. Welcoming the decision of ARPA-E to launch an initiative to investigate the issue of LENR in a coordinated manner with specific tasks assigned, we consider that the organized review of previous experiments on this subject and the other considerations presented in the present paper can give a useful background, helping in the design, execution and interpretation of the next experiments promoted by the ARPA-E initiative mentioned above.

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Appendix A. Identity Card for Each Experiment

The identity cards of the experiments are summarized in the sheets named "experiment type" from 1. to 17.; sometimes, when needed, there are subtypes denoted by letters, e.g., 1.a. The acronyms of the detectors and the techniques of analysis related to the experiments reported in the sheets are given hereafter.

Detectors of neutrons

Thermodynamical detector BTI (Bubble Technology Industry) using hydrocarbon, name: Defender, DefenderXL

Electronic detector using BF3 (boron trifluoride)

Electronic detector using He3 (Helium-3)

Photographic imaging by PADC (polyallyl diglycol carbonate) type CR39-Boric Acid

Detectors of charged particles:

Photographic imaging by PADC (Polyallyl Diglycol Carbonate) type CR39

Electronic detector using ZnS (Ag) (Zinc Sulphide with Silver doping)

Silicon barrier detector SBD

Analysis techniques:

HF Detector (Gas Analyzer of hydrogen fluoride), name: GASTiger2000 HF 3

X Ray Spectroscopy by NaI (sodium iodine)

XRF (X Ray Fluorescence)

ICP-OES (Induced Coupled Plasma–Optical Emission Spectroscopy)

ICP-MS (Induced Coupled Plasma–Mass Spectrometry)

SEM (Scanning Electron Microscope)

ESEM-EDS (Enviromental Scanning Electron Microscope–Energy Dispersion Spectroscopy)

BSE imaging (Back Scattered Electrons)

INAA (Instrumental Neutron Activation Analysis) using gamma ray spectroscopy

Appendix A.1. Experiment Type 1

Objective results

MATERIAL	Low-pressure D2 gas with various types of cathode and Pd or W as anode
STIMULATION TECHNIQUE	Electric discharge in gaseous or vapor atmosphere
EXPERIMENTAL EVIDENCES	X-radiation having an energy nearly equal to the voltage applied to the discharge and energetic particle emission similar to deuterons having energy with peaks between 0.5 and 3 MeV
TECHNIQUES TO DETECT THE EVIDENCES	Silicon barrier detector (SBD) and Geiger Muller counter

References

[1.1] *Detection of Radiation Emitted from LENR* Storms, E. and B. Scanlan. in *ICCF-14 International Conference on Condensed Matter Nuclear Science*. 2008. Washington, DC.

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Reported as very good and with 100% reproducibility, but documentation is undisclosed at present
INTERACTION ENVIRONMENT	Deuterium gas and/or deuterium in anode metal lattice
INTERACTION AGENT	Deuterium and/or atoms in metals
MODALITY FOR ENERGY DENSIFICATION	Variations in space and volumes of the number of the force lines of the electric field (discharge is impulsive by definition)
PHENOMENON TYPE	Emission of energetic particles
MICROPHYSICS INTERPRETATION	In the presence of nuclei of hydrogen ^{1}H, deuterium ^{2}D, and of various metal in the electrodes under proper stimulation, several isotopes not present before are produced in coherence with the Baryons Conservation law pertaining to nuclear reactions, which is considered to be valid also in this case.

Appendix A.2. Experiment Type 2. a

Objective results

MATERIAL	Titanium in distilled water
STIMULATION TECHNIQUE	Impulsive electric discharge and fast rupture of one Ti electrode shaped as a foil
EXPERIMENTAL EVIDENCES	Glow discharge, new elements detected (B, Cu) and increment of isotope Ti 48
TECHNIQUES TO DETECT THE EVIDENCES	OES, XRF, ICP-MS

References

[2.1] *Observation of transformation of chemical elements during electric discharge* L. I. Urutskoev, V. I. Liksonov, V. G. Tsinoev, Annales Fondation Louis de Broglie, Volume 27, no 4, 2002

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Good
INTERACTION ENVIRONMENT	Distilled water
INTERACTION AGENT	Elements present in Ti foils
MODALITY FOR ENERGY DENSIFICATION	Pulses of electric energy and associated concentration of electric charges
PHENOMENON TYPE	Nuclear Metamorphosis: Production of elements and nuclides
MICROPHYSICS INTERPRETATION	In the presence of nuclei present in Ti foils, under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.3. Experiment Type 2. b

Objective results

MATERIAL	Solution of uranyl sulfate in distilled water
STIMULATION TECHNIQUE	Impulsive electric discharge and fast rupture of one Ti electrode shaped as a foil
EXPERIMENTAL EVIDENCES	Distortion of the natural isotopic composition of uranium with consequent alteration of the secular equilibrium in uranium decay chain.
TECHNIQUES TO DETECT THE EVIDENCES	α, β, γ-spectrometry and mass-spectrometry

References

[2.2] *Study of the Electric Explosion of Titanium Foils in Uranium Salts*, Leonid I. Urutskoev, Dmitry V. Filippov, ***J.*** Mod. Phys., 2010, 1, 226-235

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Good
INTERACTION ENVIRONMENT	Titanium in water containing uranium salts
INTERACTION AGENT	Elements present in Ti foils and uranium
MODALITY FOR ENERGY DENSIFICATION	Pulses of electric energy and associated concentration of electric charges
PHENOMENON TYPE	Nuclear Metamorphosis: Production
MICROPHYSICS INTERPRETATION	In the presence of nuclei present in Ti foils and of uranium, under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.4. Experiment Type 3

Objective results

MATERIAL	Water with iron
STIMULATION TECHNIQUE	Ultrasound 20 Khz
EXPERIMENTAL EVIDENCES	Emission of neutrons
TECHNIQUES TO DETECT THE EVIDENCES	Thermodynamic BTI Defender, DefenderXL; Electronic BF3 Photographic PADC CR39-Boric Acid

References

[3.1] *Deformed Space Time* Chap. 17 p.257-272, F. Cardone, R. Mignani, ed. Springer, Dordrecht 2007
[3.2] *Piezonuclear Neutrons*, F. Cardone, G. Cherubini, A. Petrucci, Phys. Lett. A 373, 8-9, 862, 2009
[3.3] *Neutrons from piezonuclear reactions*, F. Cardone, G. Cherubini, R. Mignani, W. Perconti, A. Petrucci, F. Rosetto, G. Spera Ann. De la Fondation L. de Broglie 34, 2, 183, 2009

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Good

INTERACTION ENVIRONMENT Water
INTERACTION AGENT ^{56}Fe
MODALITY FOR ENERGY DENSIFICATION Ultrasonic cavitation

PHENOMENON TYPE Nuclear Emissions
MICROPHYSICS INTERPRETATION In the presence of nuclei of iron under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryons Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

^{56}Fe 91.7% ^{54}Fe 5.82%, ^{57}Fe 2.19%, ^{58}Fe 0.28%.

Appendix A.5. Experiment Type 4

Objective results

MATERIAL Water with ^{228}Th

STIMULATION TECHNIQUE Ultrasounds 20 Khz

EXPERIMENTAL EVIDENCES Reduction in radioactivity of the original sample. Reduction in the presence of original radionuclides

TECHNIQUES TO DETECT THE EVIDENCES ICP-MS, Photographic PADC CR39

References

[4.1] *Deformed Space Time Chap*. 17 p.253-256, F. Cardone, R. Mignani, ed. Springer, Dordrecht 2007
[4.2] *Piezonuclear decay of Thorium* F. Cardone, R. Mignani, A. Petrucci, Physics Letters A 373, 22, 1956, 2009

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Sufficient
INTERACTION ENVIRONMENT Water
INTERACTION AGENT ^{228}Th
MODALITY FOR ENERGY DENSIFICATION Ultrasonic cavitation

PHENOMENON TYPE Nuclear metamorphosis: neutralization of radioactivity

MICROPHYSICS INTERPRETATION In the presence of nuclei of ^{228}Th under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case). This is an application of nuclear metamorphosis with transformation of radioactive substances, an application that has been called neutralisation of radioactivity.

Appendix A.6. Experiment Type 5

Objective results

MATERIAL Solution of nitric acid with nitrate of ^{63}Ni

STIMULATION TECHNIQUE Ultrasounds 35 Khz

EXPERIMENTAL EVIDENCES Reduction in radioactivity of the original sample. Detection of new isotopes not present in the original sample.
First group: ^{60}Ni, ^{59}Co, ^{11}Be, ^{9}Be, ^{7}Li.
Second group: ^{23}Na, ^{39}K, ^{44}Ca, ^{51}V, ^{69}Ga, ^{75}As, ^{77}Se, ^{85}Rb, ^{88}Sr, ^{95}Mo, ^{107}Ag, ^{111}Cd, ^{115}In, ^{118}Sn, 1^{121}Sb, ^{133}Cs, ^{137}Ba, ^{139}La, ^{140} Ce, ^{205}Tl, ^{208}Pb, ^{209}Pb, ^{238}U.

References

[5.1] *The astonishing ^{63}Nickel radioactivity reduction in radioactive wastes by means of ultrasound* application, A. Rosada, F. Cardone, P. Avino, Springer Nature Applied Science 1, 1319, 2019
[5.2] *Reduction of the radiation in radioactive* substances, G. Albertini, F. Cardone, G. Cherubini, E. Guerriero, A. Rosada, International Journal of Modern Physics B, Vol. 34, 4, 2050001, 2020
[5.3] *Neutralization of radionuclides*, G. Albertini, D. Bassani, F. Cardone, G. Cherubini, E. Guerriero, A. Rosada, International Journal of Modern Physics B, Vol. 35, 2, 2130001, 2020

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Good

INTERACTION ENVIRONMENT Nitric acid solution
INTERACTION AGENT ^{63}Ni nitrate
MODALITY FOR ENERGY DENSIFICATION Ultrasonic cavitation

PHENOMENON TYPE Nuclear metamorphosis: neutralization of radioactivity

MICROPHYSICS INTERPRETATION In the presence of nuclei of ^{63}Ni under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case). The nuclides of the first group derive from the metamorphosis of ^{63}Ni; the nuclides of the second group derive from the metamorphosis of other elements that are present.

Appendix A.7. Experiment Type 6

Objective results

MATERIAL Deuterated acetone
STIMULATION TECHNIQUE Variable-frequency ultrasound
EXPERIMENTAL EVIDENCES Neutron Emission

TECHNIQUES TO DETECT THE EVIDENCES Electronic ^{3}He

References

[6.1] *Evidence for nuclear emissions during acoustic cavitation*, R. P. Taleyarkhan, et al. Science 295, 1868–1873 (2002).
[6.2] *Additional evidence for nuclear emissions during acoustic cavitation*, R. P. Taleyarkhan, et al. Physical Review E 69, 036109 (2004).

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Improvable
INTERACTION ENVIRONMENT	Deuterated acetone
INTERACTION AGENT REAGENT	Deuterated acetone
MODALITY FOR ENERGY DENSIFICATION	Ultrasonic cavitation without symmetrical spherical collapse
PHENOMENON TYPE	Nuclear emissions
MICROPHYSICS INTERPRETATION	In the presence of nuclei of Deuterium under proper Stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.8. Experiment Type 7

Objective results

MATERIAL	Palladium electrodes charged with hydrogen or deuterium and electrolyte salts (calcium carbonate)
STIMULATION TECHNIQUE	Electrolytic current
EXPERIMENTAL EVIDENCES	Neutron emission
TECHNIQUES TO DETECT THE EVIDENCES	Photographic PADC CR39

References

[7.1] *Comparison of Pd/D co-deposition and DT neutron generated triple track observed in CR-39 detectors*, P.A. Mosier-Boss et al. European Physical Journal of Applied Physics 51,2, 20901-20911 (2010)
[7.2] *Condensed Matter Nuclear Science Using Pd/D Co-Deposition* P.A. Mosier-Boss L. Forsley Research Gate 2015 https://www.researchgate.net/publication/283569283_Condensed_Matter_Nuclear_Science_Using_PdD_Co-Deposition

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Sufficient
INTERACTION ENVIRONMENT	Palladium electrodes in water solution of electrolytic salts
INTERACTION AGENT	Elements present in palladium metal
MODALITY FOR ENERGY DENSIFICATION	Deformation of the electrodes that are the reactant
PHENOMENON TYPE	Nuclear emissions
MICROPHYSICS INTERPRETATION	In the presence of hydrogen in the palladium bulk under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.9. Experiment Type 8

Objective results

MATERIAL	Liquid mercury
STIMULATION TECHNIQUE	20 Khz and 35 Khz ultrasounds
EXPERIMENTAL EVIDENCES	Presence of elements absent before the stimulus, among which some rare earths are revealed: ^{89}Y, ^{138}Ce, ^{151}Eu, ^{152}Gd, ^{158}Gd, ^{174}Yb, ^{176}Lu
TECHNIQUES TO DETECT THE EVIDENCES	ICP-OES, ICP-MS, SEM, ESEM-EDS, XRF, INAA

References

[8.1] *Generalized nuclear reactions* F. Cardone, R. Mignani, A. Petrucci Journal of Advanced Phys. 3, 2, 150-152, 2014

[8.2] *Nuclear Metamorphosis in Mercury*, F. Cardone, G. Albertini, D. Bassani, G. Cherubini, E. Guerriero, R. Mignani, M. Monti, A. Petrucci, F. Ridolfi, A. Rosada, F. Rosetto, V. Sala, E. Santoro, G. Spera International Journal of Modern Physics B, Vol. 29, 15502391-13, 2015

[8.3] *Deformed space-time transformation in Mercury*. F. Cardone, G. Albertini, D. Bassani, G. Cherubini, E. Guerriero, R. Mignani, M. Monti, A. Petrucci, F. Ridolfi, A. Rosada, F. Rosetto, V. Sala, E. Santoro, G. Spera International Journal of Modern Physics B, Vol. 31, 23, 17501681-20, 2017

[8.4] *Nuclear Metamorphosis in Mercury: rare earths production*, F. Cardone, G. Albertini, D. Bassani, G. Cherubini, E. Guerriero, R. Mignani, M. Monti, A. Petrucci, F. Ridolfi, A. Rosada, F. Rosetto, V. Sala, E. Santoro, G. Spera, Journal of Condensed Matter Nuclear Science 27, 1–9, 2018

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Very good

INTERACTION ENVIRONMENT Mercury
INTERACTION AGENT Mercury
MODALITY FOR ENERGY DENSIFICATION Ultrasonic cavitation

PHENOMENON TYPE Nuclear Metamorphosis: Production of elements and nuclides

MICROPHYSICS INTERPRETATION In the presence of nuclei of mercury under proper stimulation, several isotopes not present before are produced together with nuclear particles in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.10. Experiment Type 9.a (Investigation Focused on the Environment Surrounding the Sample)

Objective results

MATERIAL AISI 304 austenitic steel in air

STIMULATION TECHNIQUE 20 kHz ultrasounds

EXPERIMENTAL EVIDENCES Detection of neutrons

TECHNIQUES TO DETECT THE EVIDENCES Electronic ^{3}He; Photographic PADC CR39-Boric acid

References

[9.1] *Piezonuclear neutrons from iron*, F. Cardone, R. Mignani, M. Monti, A. Petrucci, V. Sala, Modern Physics Letters A, Vol. 27, 18, 1250102, 2012
[9.2] *Violation of local Lorentz invariance for Deformed Space-Time neutron emissions* F. Cardone, G. Cherubini, M. Lammardo, R. Mignani The European Physical Journal-Plus 130, 35, 2015
[9.3] *Energy spectra and fluence of the neutrons produced in Deformed Space-Time conditions* F. Cardone, A. Rosada, Modern Physics Letters B 30, 28, 16503461-7, 2016
[9.4] *Deformed Space-Time neutrons: spectra and detection*, F. Cardone, G. Cherubini, A. Rosada, Journal of Advanced Physics 7, 1, 81-87, 2018

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Good

INTERACTION ENVIRONMENT Air present in the internal microcavities of AISI 304 austenitic steel
INTERACTION AGENT Elements present in AISI 304 austenitic steel
MODALITY FOR ENERGY DENSIFICATION Ultrasonic cavitation
PHENOMENON TYPE Nuclear emissions

MICROPHYSICS INTERPRETATION In the presence of nuclei of elements present in AISI 304 austenitic steel under proper stimulation, several isotopes not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.11. Experiment Type 9.b (Investigation Focused on the Sample)

Objective results

MATERIAL AISI 304 austenitic steel in air

STIMULATION TECHNIQUE 20 kHz ultrasounds

EXPERIMENTAL EVIDENCES Production of copper having isotopic composition different from that of natural copper

TECHNIQUES TO DETECT THE EVIDENCES ESEM-EDS, BSE-imaging, INAA

References

[9.5] *Ultrasound damages in iron*, F. Ridolfi, F. Cardone, G. Albertini, Journal of Advanced Physics 2, 1, 40-44, 2013
[9.6] *Chemical changes induced by ultrasound in iron*, G. Albertini, V. Calbucci, F. Cardone, A. Petrucci, F. Ridolfi, Applied Physics A 114, 1233-1246, 2014
[9.7] *Isotopical changes induced by ultrasound in iron*, F. Cardone, A. Petrucci, A. Rosada International Journal of Modern Physics B 28, 17, 145071-13, 2014
[9.8] *Atomic and isotopic changes induced by ultrasound in iron*, G. Albertini, F. Cardone, M. Lammardo, A. Petrucci, F. Ridolfi, A. Rosada, V. Sala, E. Santoro, Journal of Radioanalytical and Nuclear Chemistry 304, 2, 955-963, 2015
[9.9] *Ultrasonic piezonuclear reactions in steel and sintered ferrite bars*, F. Cardone, A. Manuello, R. Mignani, A. Petrucci, M. Sepielli, A. Carpinteri Journal of Advanced Physics Special Section: New Nuclear Reactions 5, 1, 69-75, 2016
[9.10] *Isotopic changes in piezonuclear iron*, F. Cardone, M. Lammardo, A. Petrucci, A. Rosada, E. Santoro, Journal of Advanced Physics Special Section: New Nuclear Reactions 5, 1, 90-96, 2016

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Good
INTERACTION ENVIRONMENT	Air present in the internal microcavities of the material
INTERACTION AGENT	Elements present in AISI 304 austenitic steel
MODALITY FOR ENERGY DENSIFICATION	Ultrasonic cavitation
PHENOMENON TYPE	Nuclear metamorphosis: Nuclide production
MICROPHYSICS INTERPRETATION	In the presence of nuclei of elements present in AISI 304 austenitic steel, under proper stimulation, several isotopes not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.12. Experiment Type 10

Objective results

MATERIAL	AISI 304 austenitic steel in air
STIMULATION TECHNIQUE	Series of pressure cycles at variable rate
EXPERIMENTAL EVIDENCES	Alpha particles
TECHNIQUES TO DETECT THE EVIDENCES	Electronic ZnS (Ag); Photographic PADC CR39

References

[10.1] *Possible evidences of piezonuclear alfa emission* F. Cardone, V. Calbucci, G. Albertini Journal of Advanced Physics 2, 1, 20-24, 2013
[10.2] *Evidence of alpha emission from compressed steel bars* G. Albertini, V. Calbucci, F. Cardone. G. Fattorini, R. Mignani, A. Petrucci, F. Ridolfi, A. Rotili, International Journal of Modern Physics B 27, 23, 1350124, 2013
[10.3] *Anisotropy angle of the DST-emission*, F. Cardone, S. Duro, Modern Physics Letters B 28, 19, 14501561-8, 2014

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Good
INTERACTION ENVIRONMENT	AISI 304 austenitic steel
INTERACTION AGENT	Elements present in AISI 304 austenitic steel
MODALITY FOR ENERGY DENSIFICATION	Time variation of pressure
PHENOMENON TYPE	Nuclear emissions
MICROPHYSICS INTERPRETATION	In the presence of nuclei of elements present in AISI 304 austenitic steel, under proper stimulation, several isotopes not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.13. Experiment Type 11

Objective results

MATERIAL Metal powders in deuterium gas

STIMULATION TECHNIQUE Increased pressure of deuterium gas

EXPERIMENTAL EVIDENCES Excess of heat

TECHNIQUES TO DETECT THE EVIDENCES Heat transfer to drive a Sterling motor

References

[11.1] *Anomalous difference between reaction energies generated within D2O cell*, Y. Arata and Y. C. Zhang, Japanese Journal of Applied Physics 37, L1274 (1998).

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Good

INTERACTION ENVIRONMENT Deuterium gas
INTERACTION AGENT Metal powders
MODALITY FOR ENERGY DENSIFICATION Compensation of pressure variation by pressure gauge inducing pressure shocks

PHENOMENON TYPE Energy generation

MICROPHYSICS INTERPRETATION In the presence of deuterium inside the bulk of metallic powders, under proper stimulation, excess heat develops and several nuclides not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.14. Experiment Type 12

Objective results

MATERIAL Constantan (Cu55 Ni44 Mn alloy)—both nanostructured via electrodeposition and not nanostructured) in the presence of H_2 or D_2

STIMULATION TECHNIQUE Electric heating reaching temperature up to 350 °C.

EXPERIMENTAL EVIDENCES Elements generation (C, O, Cl, Ca, and Zn) in Constantan cavities. Excess heat production.

TECHNIQUES TO DETECT THE EVIDENCES SEM equipped with an EDS microprobe
Measurements of electric power provided

References

[12.1] *Hydrogen Absorption and Excess Heat in a Constantan Wire with Nanostructured Surface*. U. Mastromatteo, A. Bertelè, F. Celani J. Condensed Matter Nucl. Sci. 15 (2015) 240–245

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Very good
INTERACTION ENVIRONMENT Constantan lattice deformed, at the surface of the wire, by the presence of deuterium or hydrogen

INTERACTION AGENT All elements present
MODALITY FOR ENERGY DENSIFICATION Temperature increase

PHENOMENON TYPE Isotope generation
Excess heat production

MICROPHYSICS INTERPRETATION In the presence of nickel and other metals, under proper stimulation, several nuclides not present before are produced in absence of emissions of both nuclear particles and gamma rays and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).
Power is generated as well

Appendix A.15. Experiment Type 13

Objective results

MATERIAL Palladium in the presence of H2 or D2

STIMULATION TECHNIQUE Temperature increase due to heating via He-Ne laser and excimer laser
EXPERIMENTAL EVIDENCES Elements generation (for instance: C, O, Cl, Ca, and Zn) in cavities with dimensions around tens of micrometers,
TECHNIQUES TO DETECT THE EVIDENCES Coupled plasma mass spectrometry or SEM equipped with an EDS microprobe
Measurements of electric power supplied in some cases

References

[13.1] *Experimental results of transmutation of elements observed in etched palladium samples by an excimer laser* V. Nassisi, Maria L. Longo, Fusion Technology Volume 37, 2000 - Issue 3 DOI:10.13182/FST00-A138
[13.2] *Analysis of nuclear transmutations observed in D- and 3 H-loaded Pd films* M. Di Giulio, E. Filippo, D. Manno, V. Nassisi 1 May 2002, International Journal of Hydrogen Energy Volume 27, Issue 5, May 2002, Pages 527-531 DOI:10.1016/S0360-3199(01)00168-9
[13.3] *Modification of Pd-H2 and Pd-D2 thin films processed by He-Ne laser*, V. Nassisi, G. Caretto, A. Lorusso, D. Manno, L. Famà, G. Buccolieri, A. Buccolieri, U. Mastromatteo JCMNS, Journal of Condensed Matter Nuclear Science Vol. 5, Issue 1, 2011 June 01, 2011
[13.4] LENR Anomalies in Pd–H2 Systems Submitted to Laser Stimulation, *U. Mastromatteo, 173_ J. Condensed Matter Nucl. Sci. Vol. 19 (2016)*
[13.5] B. Barrowes-New US Army LENR Replication ICCF-24 x Solid-State Energy Summit · 19 ago 2022 https://www.youtube.com/watch?v=jpn8Oz_g9tE

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Very good
INTERACTION ENVIRONMENT Pd lattice deformed by the presence of deuterium or hydrogen

INTERACTION AGENT All metals present
MODALITY FOR ENERGY DENSIFICATION Temperature increase due to laser stimulation

PHENOMENON TYPE Isotope generation

MICROPHYSICS INTERPRETATION In the presence of palladium, under proper stimulation, several nuclides not present before are produced in absence of emissions of both nuclear particles and gamma and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.16. Experiment Type 14

Objective results

MATERIAL ErD_3 and TiD_2

STIMULATION TECHNIQUE Gamma irradiation of deuterium provides photo-stripped neutrons

EXPERIMENTAL EVIDENCES Detection of photo-dissociation neutrons and claimed neutrons consistent with DT fusion producing ^{3}He and a neutron

TECHNIQUES TO DETECT THE EVIDENCES Neutron detection by EJ-309 liquid scintillator and Stilbene solid state organic scintillator; neutron spectrometry by unfolding methods using HEBROW algorithm

References

[14. 1] *Novel Nuclear Reactions Observed in Bremsstrahlung-Irradiated Deuterated Metals*, Steinetz B. M. et al.ii, NASA/TP-20205001616; Phys. Rev. C 101, 044610 (2020).

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Very Good
INTERACTION ENVIRONMENT	Deuterated Erbium and deuterated Ti
INTERACTION AGENT	Deuterium and possibly erbium and titanium as well
MODALITY FOR ENERGY DENSIFICATION	Pulsed neutrons (generated by photoproduction) produce critical energy density throughout the volume and timing of the neutron bunches.
PHENOMENON TYPE	Metamorphosis: Production
MICROPHYSICS INTERPRETATION	In the presence of deuterium inside the bulk of metallic samples, under proper stimulation, several nuclides not present before are produced, in absence of gamma emissions, together with neutrons and other nuclear particles, and in coherence with the Baryon number conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.17. Experiment Type 15

Objective results

MATERIAL	In hydrogen atmosphere, mixture of nickel and Lithium Aluminum hydride
STIMULATION TECHNIQUE	Temperature rise with electrical joule effect
EXPERIMENTAL EVIDENCES	Excess of heat
TECHNIQUES TO DETECT THE EVIDENCES	Thermocouples

References

[15.1] *Investigation of the heat generator similar to Rossi reactor*, A. G. Parkhomov, International Journal of Unconventional Science. Reports on Experiments 2015
[15.2] *LENR as a manifestation of weak nuclear interactions,* A. G. Parkhomov, International Journal of Unconventional Science. Original research workers 2019 https://drive.google.com/file/d/1UEEBqBpLhiJBBdPbhagQQSWLkmazzJLz/view

Inferences

ESTIMATED DEGREE OF DESCRIPTION
COMPLETENESS & OF REPRODUCIBILITY LEVEL Sufficient

INTERACTION ENVIRONMENT Hydrogen atmosphere
INTERACTION AGENT Nickel hydride
MODALITY FOR ENERGY DENSIFICATION Compensation, through current regulation of temperature variation in order to obtain heat shocks
PHENOMENON TYPE Thermal energy generation

MICROPHYSICS INTERPRETATION In the presence of hydrogen inside the bulk of Mixture of Nickel and Lithium Aluminum Hydride, under proper stimulation, excess heat develops and several nuclides not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case).

Appendix A.18. Experiment Type 16.a

Objective results

MATERIAL Granites with iron in air

STIMULATION TECHNIQUE Impulsive brittle fracture pressure

EXPERIMENTAL EVIDENCES Neutron emission

TECHNIQUES TO DETECT THE EVIDENCES Electronic He^3 (long counter) thermodynamic BTI

References

[16.1] *Piezonuclear neutrons from fracturing of inert solids*, F. Cardone, A. Carpinteri, G. Lacidogna, Physics Letters A 373 (2009) 4158–4163, 0375-9601 – © 2023 Elsevier B.V. doi:10.1016/j.physleta.2009.09.026
[16.2] *Fracto-emissions as seismic precursors*, A. Carpinteri, O. Borla Engineering Fracture Mechanics 177 (2017) 239–250

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Improvable
INTERACTION ENVIRONMENT	Air but not free air; metamorphosis takes place in the air enclosed in cavities contained in granites
INTERACTION AGENT	Granites with iron in air
MODALITY FOR ENERGY DENSIFICATION	Fracture with cavitation through pressure shocks
PHENOMENON TYPE	Nuclear emissions: neutron detection
MICROPHYSICS INTERPRETATION	In the presence of iron inside the bulk of granite, under proper stimulation, several nuclides not present before are produced together with nuclear particles, in absence of gamma emissions and in coherence with the Baryon Number Conservation law pertaining to nuclear reactions (which is considered to be valid also in this case). This interpretation, however, is still controversial.

Appendix A.19. Experiment Type 16.b

Objective results

MATERIAL	Calcium carbonate without iron in open air
STIMULATION TECHNIQUE	Non-impulsive ductile fracture pressure
EXPERIMENTAL EVIDENCES	No evidence
TECHNIQUES TO DETECT THE EVIDENCES	Electronic He^3 (long counter), Thermodynamic BTI

References

[16.2] *Fracto-emissions as seismic precursors*, A. Carpinteri, O. Borla, Engineering Fracture Mechanics 177 (2017) 239–250

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Improvable
INTERACTION ENVIRONMENT	Expected: the air enclosed in cavities present in granites
INTERACTION AGENT	Expected to be calcium carbonate (without iron)
MODALITY FOR ENERGY DENSIFICATION	Fracture without cavitation (ineffective)
PHENOMENON TYPE	Nuclear emissions that were expected but did not occur
MICROPHYSICS INTERPRETATION	In the absence of proper energy densification, no nuclear phenomena occur.

Appendix A.20. Experiment Type 17

Objective results

MATERIAL	Artificial compounds (silesquioxane) in water with Li and SiC
STIMULATION TECHNIQUE	Electrical, photonic and in some cases ultrasonic stimuli
EXPERIMENTAL EVIDENCES	Increases in temperature and pressure. Damage to components
TECHNIQUES TO DETECT THE EVIDENCES	Calorimetric

References

[17.1] *A Method to Initiate an LENR Reaction in an Aqueous Solution*, B. Roarty. The 21St International Conference for Condensed Matter Nuclear Science (2018) https://www.youtube.com/watch?v=G5GHtzI7BGI

Inferences

ESTIMATED DEGREE OF DESCRIPTION COMPLETENESS & OF REPRODUCIBILITY LEVEL	Sufficient
INTERACTION ENVIRONMENT	Artificial compounds (silesquioxanes) in water. (Silsesquioxanes are inorganic-organic hybrid materials that combine the mechanical, thermal, and chemical stability of ceramics with the solution processing and flexibility of traditional soft materials.)
INTERACTION AGENT	Lithium, (Li), SiC (Silicon Carbide)
MODALITY FOR ENERGY DENSIFICATION	Pulsed time variation of the electric field. Ultrasonic cavitation
PHENOMENON TYPE	Production of excess heat
MICROPHYSICS INTERPRETATION	In the presence of multiple causes of energy densification, an excess of heat occurs

References

1. Fleischmann, M.; Pons, S. Electrochemically induced nuclear fusion of deuterium. *J. Electroanal. Chem. Int. Electrochem.* **1989**, *261*, 201. [CrossRef]
2. Huizenga, R. *Cold Fusion: The Scientific Fiasco of the Century*; University of Rochester Press: Rochester, NY, USA, 1993.
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14. Clean Energy from Hydrogen-Metal Systems. Available online: https://www.cleanhme.eu/ (accessed on 21 July 2023).

15. See all articles published in Journal of Condensed Matter Nuclear Science. Available online: https://www.iscmns.org/idxjcmns.htm (accessed on 21 July 2023).
16. In Proceedings of the 23rd International Conference on Condensed Matter Nuclear Science (ICCF-23), Virtual, 9–11 June 2021. Available online: http://ikkem.com/iccf-23.php (accessed on 21 July 2023).
17. Steinetz, B.M.; Benyo, T.L.; Chait, A.; Hendricks, R.C.; Forsley, L.P.; Baramsai, B.; Ugorowski, P.B.; Becks, M.D.; Pines, V.; Pines, M.; et al. Novel Nuclear Reactions Observed in Bremsstrahlung-Irradiated Deuterated Metals. *Phys. Rev. C* **2020**, *101*, 044610. [CrossRef]
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