



Possibilities for the Detection of Santilli Neutroids and Pseudo-protons

Victor de Haan

Bon Physics B.V., Laan Van Heemstede, Puttershoek, The Netherlands

Email address:

victor@bonphysics.nl

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Abstract: Following systematic mathematical, theoretical and experimental studies on the synthesis of the neutron from hydrogen, R. M. Santilli noted delayed neutron detections following the termination of tests, and attempted to represent them with the hypothesis of a new state of the hydrogen with spin zero called *neutroid* consisting of a proton and an electron at 1 fm mutual distance in singlet coupling. More recently, Santilli predicted the possible existence of a second new particle called *pseudo-proton* characterized by the synthesis of the electron with the neutron, therefore resulting in a negatively charged unstable particle with a mean life expected in the range of that of the neutron and a mass of the order of the hydride ion. Subsequently, Santilli has indicated that, in the event confirmed, the pseudo-proton could eliminate the Coulomb barrier for nuclear syntheses and trigger nuclear transmutations with large release of heat without neutron emission, thus identifying a possible novel use of hydrogen for the industrial production of a basically new clean nuclear energy. In view of the latter possibility, in this paper specific experiments are proposed for the verification or denial of the existence of Santilli neutroid and pseudo-proton and, in case of confirmation, accurate measurements of their characteristics and production in numbers sufficient for industrial application.

Keywords: Pseudo-proton, Low Energy Nuclear Transmutation, Hydrogen Energy Source, Neutron, Pseudo-protonium, Detection, Spectroscopy

1. Introduction

Recently, Santilli et al. called for the experimental verification of the so-called *pseudo-proton* [1]. The pseudo-proton is a particle predicted by Santilli [2] based on the hadronic mechanics he has derived since the 1970's (for an overview see [3,4]). The pseudo-proton is expected to play an important role in the upcoming field of low energy nuclear transmutations due to its ability to penetrate the atomic core with relative ease due to its negative charge [5]. It is expected that it plays a crucial role in the synthesis of hydrogen ions [6], [7]. Hence the experimental detection of the pseudo proton is important for future development of hydrogen energy.

2. Synthesis of Neutron from Hydrogen

The synthesis of the neutron from the hydrogen inside a star was proposed in 1920 by H. Rutherford [8],

experimentally established in 1932 by J. Chadwick [9] and formalized by E. Fermi [10] via the familiar reaction



The properties of proton, electron and neutron are well known and a summary is given in table 1. The rest mass of the neutron, n is 0.782 MeV larger than the sum of the rest energies of both proton and electron, so that this reaction can only occur in sufficiently strong fields, for instance in the inside of stars or in the arc of a very strong discharge [1]. In 1978, R. M. Santilli [11] pointed out that quantum mechanics is not applicable to the above neutron synthesis because the rest energy of the neutron is 0.782 MeV bigger than the sum of the rest energies of the proton and the electron, as shown by the energy of the rest mass for proton, electron and neutron respectively $E_p = 938.272$ MeV, $E_e = 0.511$ MeV and

$$E_n = 939.565 \text{ MeV},$$

$$E_n - (E_p + E_e) = 0.782 \text{ MeV} > 0 \quad (2)$$

thus requiring a 'positive binding energy' with a resulting 'mass excess' under which the Schrödinger equation no longer admits physically consistent solutions.

In order to explain neutron synthesis, Santilli [11] proposed the construction of a non-unitary covering of quantum mechanics under the name of *Hadronic Mechanics*. However, non-unitary theories on a conventional Hilbert space over a conventional numeric field are known to violate causality. Only following the achievement of sufficient mathematical and theoretical maturity (for more details see [5]), while visiting in 1991 the ICTP in Trieste, Italy, Santilli [12] achieved the first known, non-relativistic, exact representation of *all* characteristics of the neutron in its synthesis from the hydrogen in the core of a star. A relativistic representation was achieved in 1992 when visiting the JINR in Dubna, Russia [13].

Laboratory synthesis of the neutron from a hydrogen gas was achieved in the 1960s by the Italian priest-physicist Don Carlo Borghi and his associates [14] via a metal chamber containing hydrogen at pressure traversed by microwaves and an electric discharge used to keep hydrogen ionized.

Santilli could not account for the synthesis of the neutron via microwaves. However, the same formulations predicted the laboratory synthesis of the neutron under an electric discharge suitable to force the penetration of the electron within the proton following their strong Coulomb attraction (according to Rutherford [8]) and provide 0.782 MeV needed for the synthesis according to equation (2). Extensive tests apparently confirmed the laboratory synthesis of the neutron according to the predictions of Santilli's work [15]. Thereafter, Santilli continued systematic experimental research on the laboratory synthesis of the neutron from a hydrogen gas at the laboratory of the Institute for Basic Research, Palm Harbor, Florida (see the extensive data in Ref. [16]).

Systematic experimentations and industrial realizations are now conducted by the U. S. publicly traded company Thunder Energies Corporation (TEC) [17], which is currently organizing the production and sale of a *Thermal Neutron Source* (TEC domain names and patents pending) essentially consisting of a pressure vessel containing commercially available hydrogen traversed by a suitable discharge and control of hydrogen pressure, electric power and other characteristics to obtain the desired neutron flux output (see corporate paper [18] and movie [19] on a pre-production prototype.)

A recent technical review of the synthesis of the neutron has been provided by U. Abundo [20]; a review recommended to the general physics audience was provided in 2006 by the late J. V. Kadeisvili [21]; while a general review of the various mathematical, theoretical and experimental aspects has been provided in 2011 by I. Gandzha and the late J. V. Kadeisvili [22].

3. Neutroid and Pseudo-proton

Essential the bases for the prediction of the pseudo-proton is the natural assumption that mathematical point particles do not exist in nature. In real life particles will have a finite size and there is a finite probability that particles will overlap. When particles overlap, the intrinsic properties of the particles can change and can recover when they are released again in vacuum. A more elaborate overview is given in [22]. Hence, when a hydrogen atom consisting of a proton, p^+ and an electron, e^- is sufficiently compressed (so that its radius is of the order of 1 fm) they can form a neutron via the above described procedure.

Table 1. Properties for several particles. For the pseudo-proton the range in which the property is expected is indicated. ¹ in units of $1.602177 \cdot 10^{19} \text{ C}$.

Name	Sym	Description
Electron	e^-	Elementary particle
Proton	p^+	Elementary particle
Neutron	n	Elementary particle (standard model) or bound proton and electron (Santilli)
Hydrogen atom	H	Proton + orbit electron
Hydrogen ion	H_2^+	Ionized hydrogen molecule
Pseudo-proton	\tilde{p}^-	Synthesis of neutron and electron (Santilli)
Hydride ion	H^-	Proton + 2 electrons in orbit
Anti-proton	\bar{p}^-	Anti particle of proton

	Charge ¹	Mass 10^{-27} kg	MeV	Magnetic mom. 10^{-26} J/T
e^-	-1	0.00091	0.511	928.477
p^+	1	1.67262	938.272	1.410608
n	0	1.67493	939.565	0.966237
H	0	1.67353	938.783	
H_2^+	-1	3.34615	1877.055	
\tilde{p}^-	-1	1.672...1.677	937...941	≈ 1
H^-	-1	1.67444	939.294	
\bar{p}^-	-1	1.67262	938.272	1.410608

Both tests by Don Borghi [14] and Santilli [15,16] indicated the existence of nuclear transmutations that could solely be explained via the absorption of neutrons or 'neutron-type' particles. Santilli conducted extensive studies of this occurrence based on the detection of neutron counts that were delayed for up to 15 minutes following the termination of the tests.

These delayed neutron counts occurred under certain characteristics of the reactor, such as power, hydrogen pressure and others, insufficient to provide 0.782 MeV needed for the synthesis of the neutron according to equation (2). By contrast, neutrons were detected under sufficient power, hydrogen density and other characteristics, to such an extend to require various evacuations of the laboratory.

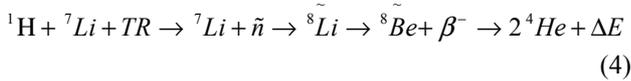
In this way, Santilli proposed the possible existence of a new particle called *neutroid* [16] with essentially the characteristics of the neutron except having spin zero which is created by the reaction



under insufficient conditions to achieve the full reaction according to equation (1). A number of nuclear

transmutations caused by the absorption of neutroids could then allow a quantitative representation of the delayed detection of neutrons (see Ref. [16] for brevity).

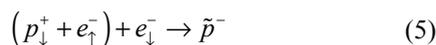
Abundo [20] noted that, in the event confirmed, Santilli neutroids would not experience the notorious Coulomb barrier opposing nuclear syntheses and can, therefore, trigger nuclear transmutations with large release of heat without the emission of neutrons, such as



where $\Delta E > \approx 15.3$ MeV per ${}^7\text{Li}$ nucleus and TR represents Santilli's trigger, namely, a mechanisms triggering the transmutation, such as instantaneous increase of power or pressure. Note that the symbol ${}^1\text{H}$ in the above reaction represents the hydrogen atom. Therefore, to our best knowledge, Abundo's transmutation [20] is the first in scientific records in which *the hydrogen atom, rather than the proton, triggers a nuclear transmutation, thus stimulating potential new technologies centrally based on hydrogen.*

To understand the occurrence, one should note that Santilli neutroid is essentially a new (unstable) form of the hydrogen atom with the proton and electron in singlet coupling kept together by the very strong Coulomb attraction at 1 fm mutual distance. Santilli's trigger is, therefore, a mechanism essentially triggering the transition from the hydrogen to the neutroid that, as such, has a number of possible engineering realizations.

Following the systematic studies on the synthesis of the neutron from hydrogen, Santilli predicted in the Appendix of Ref. [2] the possible existence of a second new particle under the name of *pseudo-proton* with symbol \tilde{p}^- , generated by the synthesis of the electron, this time, with the hydrogen atom, according to the reaction

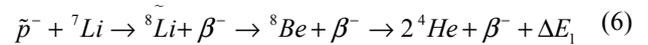


Note that, in comparison with Fermi's reaction (equation (1)), Santilli's reaction does not require the emission of a neutrino. The pseudo-proton will have a spin 1/2, a negative unit charge, essentially the same charge radius and rest energy of the proton, and a mean life (when isolated) of the order of that of the neutron. The properties of the pseudo-proton are summarized in table 1. It is expected that the magnetic moment is of the same order as that of the proton and neutron as the charge radius and rest energy are also of the same order. It will be determined by the precise shape and velocity of the constituting charge distribution. The charge and mass of the pseudo-proton will be similar to that of the anti-proton or hydride ion.

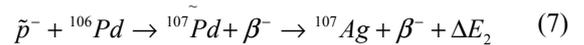
More recently, Santilli [5] indicated that, in the event confirmed, *the pseudo-proton would not only eliminate the Coulomb barrier for nuclear syntheses, but could actually be attracted by nuclei, thus triggering esoenergetic nuclear transmutations without neutron emission and significantly increase the possibilities for the industrial development of a*

basically new and clean nuclear energy [5] (TEC domain names and patents pending).

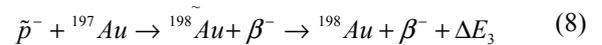
In order to illustrate the significance of the possibility, Santilli indicated the possible triggering by pseudo-protons of nuclear transmutations, such as [5] the transmutation of Li-7



with $\Delta E_1 = 2.887 \cdot 10^{-12}$ J, or Pd-106



or Au-197



where Au-198 is unstable and decays in 2.69 days into betas and Hg-198 with the release of 1.372 MeV, and others, all releasing a rather significant amount of heat, none of them emitting neutrons, while beta emission being easily trapped by a metal shield.

In summary, the above studies indicate possible, basically new and clean nuclear energies centered on the use of hydrogen, and its processing via suitable reactors first into neutroids and/or pseudo-protons and then their use to trigger esoenergetic nuclear transmutations. Due to the evident significance of these studies, both per se, as well as with respect to the emerging new hydrogen era, in this paper experiments are studied aimed at the confirmation or denial of the existence of Santilli neutroids and pseudo-protons and, in case affirmative, reach accurate measurements of their characteristics and their production in number sufficient for industrial applications. It should be noted that in this paper the possible connection between Santilli pseudo-proton and the anti-protons produced at various laboratories is ignored, since such a topic has been preliminarily studied in Refs. [2,5], although the technologies for the production of the two particles can benefit each other, thus warranting additional studies.

From the above it is clear that it is expected that neutrons and pseudo-protons will be produced in a sufficiently strong discharge in hydrogen gas as has been performed by Santilli [1]. That neutrons can be produced in hydrogen gas is well known and experimentally verified by many experiments [23-26] and developed for industrial applications [27]. In general it is assumed that neutrons are produced as a by-product of the fusion of two protons, deuterons, tritons or their combinations resulting in the production of neutrons with high kinetic energies, so-called fast neutrons. The discharge acts as a means to accelerate the hydrogen ions to such high energies that the Coulomb repulsion can be overcome so that the fusion reaction can occur. However, the energy needed to overcome the Coulomb repulsion so that two ions can come as close to each other as several femtometer (the size of the proton, or range of the strong

force) is of the order of 1.4 MeV which is much larger than the kinetic energy available. As a recourse for this problem it is assumed that quantum tunneling exists. In that case the ion nuclei need to overlap and the tunneling probability will be large enough to give a reasonable yield. In such a case also the possibility for the above mentioned reactions exists and neutron or pseudo-proton production can occur.

4. Detection Possibilities

In the above it has been made clear that it is possible that neutrons or pseudo-protons can be created in a hydrogen gas discharge. In the following it is discussed how these particle might be detected.

4.1. Neutrons

Neutrons are neutral and have limited interaction with most materials. One should differentiate between fast neutrons that are created during fusion of fission reactions and thermal neutrons that are created by the Santilli synthesis or by moderation (i.e. slowing down) of fast neutrons. The kinetic energy of fast neutrons is of the order of MeV while the kinetic energy of thermal neutrons is of the order of several tens of meV. When fast neutrons have collisions with cores of the material constituting atoms or molecules, part of their energy will be released to the core and the neutrons energy decreases. After many collisions the fast neutron is slowed down to a speed comparable to the speed of the atoms or molecules of the material. At room temperature this corresponds to an average kinetic energy of 25 meV. Only after the neutrons are slowed down their energy is low enough to be absorbed during the interaction with the nucleus.

Thermal neutrons are detected by a nuclear absorption process inside the detector. The nuclear absorption creates a charged particle pair that is detected by means of an appropriate mechanism. This can be an avalanche detector in case of a gas-filled detector like a ^3He or BF_3 detector. This can also be a photo-multiplier in case of a scintillator detector like a LiF crystal or Li-glass. The key point is that one can discriminate between fast and slow neutrons by means of a time-of-flight technique or by means of an appropriate thermal neutron absorbing material or fast neutron moderator.

The time-of-flight technique is based on the measurement of the arrival time of the neutron in the detector after it has been created. During this time the neutron has to travel the known distance from source to detector. As the travel time and travel distance are measured, the velocity of the neutrons can be determined. Slow neutrons will travel with speeds of the order of 1 km/s while fast neutrons will travel with speed of at least 10000 km/s. To determine the travel time it is needed to know when the neutrons are emitted from the source. One method is by using a pulsed source so that the time interval in which the neutrons are created is known.

When the source is surrounded by a thermal neutron absorber (like for instance Cadmium, Gadolinium, Lithium or Boron) no thermal neutrons can escape the source. Then

any excess neutron detected by the detector after turning on the source is due to the moderation of fast neutrons created in the source. When the source is also surrounded by a fast neutron moderator the number of excess neutrons in the detector will increase as more neutrons will be moderated. With this scheme it is possible to determine a) whether or not neutrons are created and b) whether fast neutrons or slow neutrons are created and c) when slow neutrons are created a indication of their energy distribution can be measured. The cost for a time-of-flight detection including the needed materials for absorption and moderation is estimated between 20 and 50 kUSD.

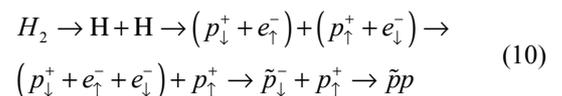
4.2. Pseudo-protons

Pseudo protons are negatively charged particle with a mass comparable with that of the hydrogen atom or proton. It can be discriminated from an electron in a mass spectrometer due to the large mass difference and from a proton because of its reversed charge. In a hydrogen discharge also hydride ions will be produced. The mass and charge of the hydride ion is comparable to that of the pseudo-proton. Hence, it is possible that already in experiments that have been performed in the past the pseudo-proton was detected, but interpreted as hydride ion [25-28]. The mass difference between the hydride ion and the pseudo-proton is expected to be very small of the order of 0.1 % (see table 1). Hence, when using a mass spectrometer to determine what kind of particle is detected, the accuracy should be high enough to measure this small difference. An additional test might be done by measuring the magnetic moment of the detected negatively charged particle by means of an appropriate device as for example a penning trap. Mass spectrometers can be bought from the shelves, but one with an accuracy of 0.1 % for a mass of approximately 1 amu is not readily available and must be developed. In such a case it can be combined with the magnetic moment measurements. Estimated costs for such a development are between 500 kUSD and 1 MUSD.

4.3. Pseudo-protonium Atom

The pseudo-proton can quickly capture a proton to form a *pseudo-protonium* atom, $\tilde{p}p$ where the proton and pseudo-proton circle around each other like in a 2-body system.

Hence, one can imagine that in a strong electrical discharge in hydrogen gas the following reaction might occur



Hence, in the event confirmed, pseudo-protons can form pseudo-protonium atoms during the discharge process. These atoms have energy levels determined by the energy levels of a two body system. The reduced mass of this system is about 1836 times larger than that of the hydrogen atom, comparable to those of protonium [32], resulting in energy levels in the keV range. These levels can be detected by means of X-ray spectrometry. The Lyman [33] (transitions from level $n > 1$

to 1) and Balmer [33] series (transitions from level $n > 2$ to 2) for this atom are shown in table 2.

The intensity of the spectral lines depends on the number density of the pseudo-protonium atoms and hence will depend strongly on the discharge parameters and the pressure of the hydrogen gas. If these series can be found in the spectra of hydrogen gas discharges with sufficient accuracy, then also the reduced mass of the pseudo-protonium atom and hence the mass of the pseudo-proton can be measured. It should be noted that in some Energy-dispersive X-ray spectroscopy experiments peaks are recorded that are close to the estimated value giving clues under what conditions pseudo-protonium might be formed [34]. The estimated costs of such an experiment are between 100 and 200 kUSD.

Table 2. The energy differences and wavelength in nm of the Lyman and Balmer series for pseudo-protonium atom.

Lyman Transition of n	2→1	3→1	4→1	5→1	∞→1
Energy difference in keV	9.367	11.102	11.71	11.99	12.49
Wavelength in nm	0.1318	0.1112	0.1054	0.1030	0.0989

Balmer Transition of n	3→2	4→2	5→2	6→2	7→2	∞→2
Energy difference in keV	1.735	2.342	2.623	2.776	2.868	3.122
Wavelength in nm	0.712	0.527	0.471	0.445	0.431	0.395

5. Conclusions

Following lifelong mathematical, theoretical, and experimental studies on the synthesis of the neutron from hydrogen [19] Santilli proposed the possible existence of two new unstable particles: the neutroid [16], which is essentially a new, spin zero bound state of a proton and an electron in singlet coupling at 1 fm mutual distance, and the pseudo-proton [2,5], which is characterized by the 'compression' of two electrons with opposite spins inside the proton, rather than a single 'compression' according to Rutherford [8].

By remembering that the synthesis of the neutron from the hydrogen exists in nature, and that the probability for the synthesis of the pseudo-proton is smaller yet close to that of the neutron, Santilli neutroids and/or pseudo-protons may generate basically new applications of hydrogen for industrially meaningful, and environmentally acceptable new energies. Since these possibilities are already under industrial development [34], it appears advisable to conduct joint scientific studies.

In this paper experimental means to verify or deny the existence of Santilli neutroids and pseudo-protons are described. In the affirmative case, these means can achieve accurate measurements of the particles characteristics and provide information to produce them in sufficient number to have industrial significance. Since the charge and mass of the pseudo-proton are comparable to those of the hydride ion, it is possible that in previous experiments the pseudo-proton has already been measured but not identified.

For the identification, sufficiently accurate measurements of its mass are needed (accuracy at least 0.1 %) or a

measurement of the magnetic moment by means of a penning trap should be performed. It is also possible that another kind of hydrogen molecule, called a pseudo-protonium atom, is formed when a pseudo-proton and proton are in orbit around each other. When a sufficient density of pseudo-protonium is realized, it is possible to measure its Lyman and Balmer series. When this property can be measured with high accuracy, it can be used to determine the reduced mass of the pseudo-protonium atom and hence the mass of the pseudo-proton.

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