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RESEARCH ARTICLE

The Rutherford-Harkins-Landau-Chadwick Key IV. Novel Reaction Channels for the d-d Fusion in the Pd/D System

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ABSTRACT

The Fleischmann-Pons experiment, despite its controversial history and challenges to reproducibility, remains a pivotal moment in the exploration of new branches for the d-d fusion where two deuterons form new nuclei at low temperatures. This paper revisits the foundational objections to these reactions at low temperature, as articulated by John Huizenga, namely the Coulomb barrier, abnormal branching ratios, and the absence of expected radiation. Drawing inspiration from historical literature (Rutherford-Harkins-Landau-Chadwick Key, Sakharov's muon catalysis, Teller's electron catalysis) and recent advances in nuclear physics (dineutron, trineutron and tetraneutron properties), this work proposes new channels that addresses these objections while adhering to rigorous scientific standards. This hypothesis builds upon the interplay between deuterons and electrons, suggesting an elegant mechanism that could bridge the gap between the current theory and experimental anomalies. Nature prepared for us a safe route for the extraction of nuclear energy while suppressed the dangerous channels with neutrons, tritium, and gamma rays. This approach aims to revitalize the discourse on the d-d fusion at low temperatures, honoring the perseverance of researchers in the field and inviting further investigation into one of the most tantalizing frontiers in energy science.

Keywords: Fleischmann-Pons experiment, Novel d-d fusion channels, Rutherford-Harkins-Landau-Chadwick key, Teller's electron catalysis.

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1. Introduction

The history of the Fleischmann-Pons experiment and its controversial aftermath stands as both a cautionary tale and a beacon for scientific curiosity, e.g., [1]–[10]. While the initial claims of the d-d fusion at low temperatures ignited a wave of excitement, they also faced significant scrutiny due to challenges in reproducibility, theoretical inconsistencies, and the deviation from well-established principles of nuclear physics. The field has since been fraught with false starts, unveiled claims, and the persistent stigma of being dismissed as pseudoscience. However, these challenges should not deter us from revisiting the question: Could there exist an as-yet-undiscovered pathway to achieving the d-d fusion at low temperatures?

It is important to acknowledge the "complicated" legacy of the Fleischmann-Pons experiment. The path forward must be paved with rigorous experimentation, open-minded theoretical inquiry, and an appreciation for the lessons of history. Indeed, history itself provides a valuable reservoir of ideas and insights. By rediscovering stimulating impulses within the vast literature of nuclear physics, we may uncover clues that could help resolve the objections so aptly summarized by Huizenga [11]–the Coulomb barrier, the anomalous branching ratios, and the absence of neutrons, tritium and gamma rays.

Nature often surprises us with its elegance, revealing mechanisms and processes that defy our initial intuitions. In the case of the d-d fusion at low temperatures, it is plausible that an elegant route to overcoming these objections already exists within the intricacies of the natural world. Such a discovery

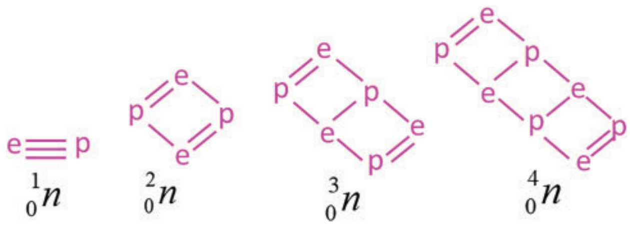


Fig. 1. Proposed structures for neutron, dineutron, trineutron, and tetraneutron. The magenta color depicts the neutron structure.

could challenge even the most influential scholars in modern nuclear physics and offer a transformative energy source for humanity. With this perspective, the work presented here seeks to propose a new scenario–one grounded in the lessons of the past yet inspired by the potential for revolutionary breakthroughs.

2. The Lost and Forgotten Key in Nuclear Physics

Stávek synthesized the work of founding fathers of nuclear physics into the Rutherford-Harkins-Landau-Chadwick Key [12]–[14] that could open a new insight into nuclear reactions. The inspiration for this contribution comes from the works of Ernest Rutherford [15], William Harkins [16]–[18]. The Harkins´ model of nuclei was discussed by historians Feather [19], Stuever [20], and Kragh [21].

Landau [22]–[24] and Chadwick [25] contributed greatly to our knowledge about neutrons and polyneutrons.

In 1948 Andrei Sakharov in his classified paper [26], [27] proposed to decrease the fusion temperature using the muon catalyzed fusion reaction. In 1989 Edward Teller analyzed the Fleischmann-Pons effect and concluded that there must be an electron catalytic action under the formation of an unknown neutron structure that might overcome the Coulomb barrier [28]. Teller commented the reaction of his colleagues to his proposal as: "My friends have remarked that this proposal is "meshuga", which means crazy but not necessarily repulsive."

In the recent time many nuclear physicists have been studying the properties of dineutron, trineutron, and tetraneutron, e.g., [29]–[46]. At this moment the structures of those neutral nuclei are not known. Based on the Rutherford-Harkins-Landau-Chadwick Key we propose the polyneutrons structures as given in Fig. 1.

3. Three d-d Channels in the Hot Fusion Reactions

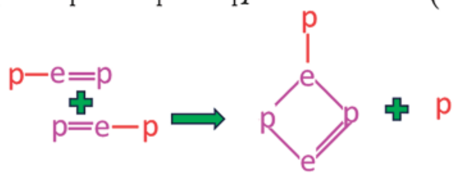
The d-d channels during their hot fusion reactions are very well-known. Fig.2 summarizes those two main channels and one minor channel. Therefore, nuclear physicists expect those outcomes (tritium, helium-3, neutrons, gamma rays, and their energies) for the d-d low energy nuclear reactions as well. We are now at the crossroads. Are these d-d channels also valid for the system Pd/D? Or can Nature present to us some unknown d-d channels without the formation of triton, neutrons and gamma rays? It would be very valuable, elegant and magnificent present from Nature: the nuclear reactions without dangerous byproducts for human operators!

4. Two Main and Two Minor Channels of the d-d Fusion in the Palladium/D System

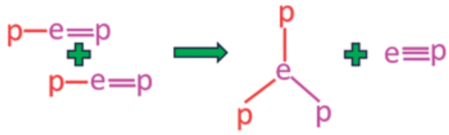
The Rutherford-Harkins-Landau-Chadwick Key and the advice from Edward Teller with his electron catalytic mechanism guided us to two main and two minor channels of the d-d fusion in the Pd/D system. Fig. 3 shows two main channels and Fig. 4 depicts two minor channels for the d-d fusion in the Pd/D system. There is one important result of these nuclear reactions: in this experiment with deuterium and palladium we can suppress the formation of dangerous byproducts as tritium, neutrons and gamma radiation. However, the actual branching ratio of formed nuclei will depend on the reaction conditions for those experimental arrangements.

There is one prediction that can be tested experimentally. The energetic yield Q per one formed helium-4 nucleus for two main channels is estimated to be Q = 33.8 MeV (28.8 MeV+5.0 MeV, see Fig. 3). McKubre analyzed all available data for the system Pd/D and found the value 32 ± 13 MeV per one observed helium-4 [47]–[50]. The hot fusion channel predicts the value Q = 23.9 MeV per one formed nucleus helium-4.

$$^{2}_{1}H + ^{2}_{1}H \Rightarrow ^{3}_{1}H + ^{1}_{1}p + 4.03\ MeV\ (50\%)$$



$$^{2}_{1}H + ^{2}_{1}H \Rightarrow ^{3}_{2}He + ^{1}_{0}n + 3.27\ MeV\ (50\%)$$



$$^{2}_{1}H + ^{2}_{1}H \Rightarrow ^{4}_{2}He + \gamma + 23.9\ MeV\ (10^{-4}\%)$$

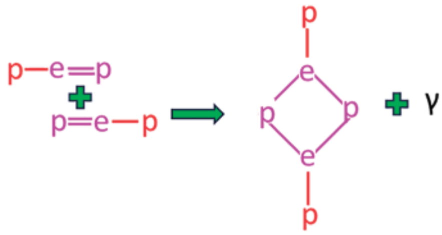
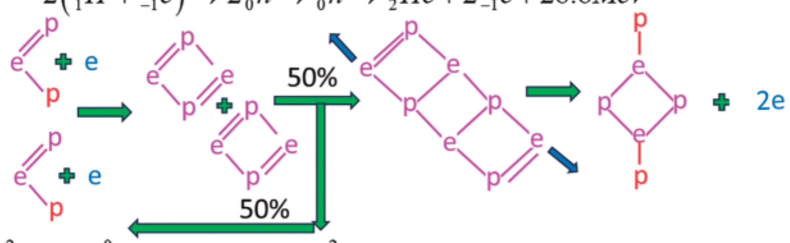


Fig. 2. Three d-d channels during their hot fusion reactions, magenta color depicts the neutron part, red color depicts the proton part of those nuclei.

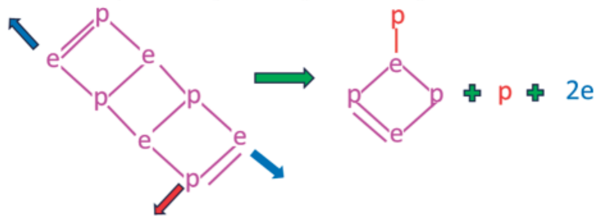
$$2\left(^{2}_{1}H + ^{0}_{-1}e\right) \rightarrow 2\,^{2}_{0}n \rightarrow ^{4}_{0}n \rightarrow ^{4}_{2}He + 2\,^{0}_{-1}e + 28.8MeV$$



$$2\,^{2}_{1}H + 2\,^{0}_{-1}e + 5.0MeV \leftarrow 2\,^{2}_{0}n$$

Fig. 3. Two main d-d channels during their fusion reactions in the Pd/D system, magenta color depicts the neutron part, red color depicts the proton part of those nuclei, blue color depicts electrons.

$$^{4}_{0}n \rightarrow ^{3}_{1}H + ^{1}_{1}p + 2\,^{0}_{-1}e + 9.0MeV$$



$$^{4}_{0}n \rightarrow ^{3}_{2}He + ^{1}_{0}n + 2\,^{0}_{-1}e + 8.3MeV$$

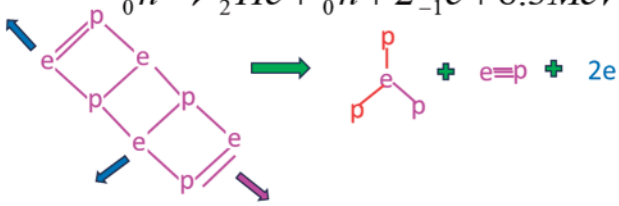
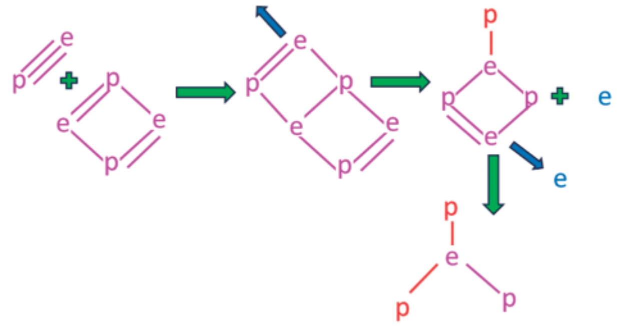


Fig. 4. Two minor d-d channels during their fusion in the Pd/D system, magenta color depicts the neutron part, red color the proton part of those nuclei, blue color depicts electrons.

$$ {}^{1}_{0}n + {}^{2}_{0}n \rightarrow {}^{3}_{0}n \rightarrow {}^{3}_{1}H + {}^{0}_{-1}e + 8.8 MeV $$



$$ {}^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e + 18.6\, keV $$

Fig. 5. The third main d-d channel during the fusion in the Pd/D system for the formation of triton via beta decay of trineutrons, magenta color depicts the neutron part, red color the proton part of those nuclei, blue color depicts electrons.

$$ {}^{3}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{2}_{0}n + 11.3\ MeV $$

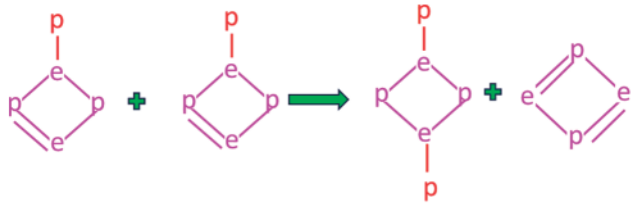


Fig. 6. The reaction of two energetic tritons might remove tritium from the Pd/D system [51] under the formation of the helium-4 and dineutron that will enter into the nuclear reactions again.

During those two main branches some energetic electrons are released and might be used for the direct electricity production [51]. For the more precise quantitative determination of these four channels more experimental data are needed.

This proposed model with four new channels of the d-d fusion in the Pd/D system (two main channels, two minor channels) should be tested by specialists working in the field of low energy nuclear reactions [52].

5. The Third Main Tritium Channel in the Palladium/D System

From the experimental data obtained from the Pd/D system we know that amount of tritium is almost seven orders of magnitude more than that of neutron. Therefore, the minor channel producing triton described in Fig. 4 cannot create those observed amount of tritium. There must exist one more channel producing triton. This third triton channel is depicted in Fig. 5 where tritons are formed by the beta decay of trineutrons. Triton is unstable in free space and decays by beta emission to be helium-3 with a half-life of 12.3 y. It is possible that this slow beta decay process proceeds in the Pd lattice much more rapidly [47]. It will be very valuable to analyze the vast literature on the Pd/D system in order to determine reaction conditions when this third triton channel is active in the Pd/D system. In the recent study Mosier-Boss and Forsley [53] surveyed experiments of four different groups on the subject "The case of missing tritium" in the Pd lattice. One of the conclusions of this study was a proposal that energetic tritons can consume both thermal and energetic tritons under formation of nucleus helium-4 in the Pd lattice. Fig. 6 shows reaction of two energetic tritons in the Pd lattice. This reaction is very significant because this channel will remove that hazardous tritium.

6. The Critical Loading and the Reproducibility of the Fleischmann-Pons Effect

To reproduce the Fleischmann-Pons effect is not easy even for very skilled experimentalists. There are several hidden traps to be overcome. Therefore, it is not possible to reproduce this d-d fusion reaction in several situations. Fig. 7 documents the most famous trap caused by the loading of the Pd/D system. In order to achieve the Fleischmann-Pons effect, a **critical loading** of the Pd/D has to be fulfilled. The **critical loading** Pd/D is the smallest concentration of deuterons, electrons, dineutrons, trineutrons,

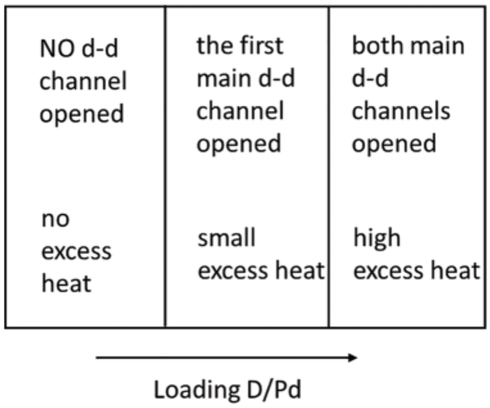


Fig. 7. The most famous trap protecting the Fleischmann-Pons reaction: the critical loading of Pd/D system (based on the McKubre papers [54], [55]).

TABLE I: The Energetic Yield from Three Channels of the D-D Fusion Reactions in the Palladium/D Lattice

Dineutron channel
${}^{2}_{0}n \rightarrow {}^{2}_{1}H + {}^{0}_{-1}e + 2.5MeV$
Trineutron channel
$2{}^{3}_{0}n \rightarrow 2{}^{3}_{1}H + 2{}^{0}_{-1}e + 17.6MeV$
${}^{3}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{2}_{0}n + 11.3MeV$
${}^{2}_{0}n \rightarrow {}^{2}_{1}H + {}^{0}_{-1}e + 2.5MeV \quad Total\ 31.4MeV/{}^{4}_{2}He$
Tetraneutron channel
${}^{4}_{0}n \rightarrow {}^{4}_{2}He + 2{}^{0}_{-1}e + 28.8MeV$
${}^{4}_{0}n \rightarrow 2{}^{2}_{1}H + 2{}^{0}_{-1}e + 5.0MeV \quad Total\ 33.8MeV/{}^{4}_{2}He$
McKubre experimental data [47]
Gradient analysis: (31 ± 13) MeV/^{4}He
Differential analysis: (32 ± 13) MeV/^{4}He
Hot fusion channel
${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He + \gamma + 23.9MeV$

and tetraneutrons in the palladium lattice for a sustained nuclear reaction. The value of the critical loading depends on the properties of the lattice and the design of experiment [54], [55]: time of loading, lattice structure, shape, purity, temperature, surroundings, assembly, current density, etc. This concept of the critical loading is very important for the explanation of many failed attempts to reproduce this effect. Experimentalists have to be patient and to be able to rationally investigate all these important parameters. The accumulated evidence strongly supports that nuclear reactions take place under all these fulfilled conditions.

7. The Energetic Yield from Three Channels

The loading of the Pd/D system dramatically changes the resulting excess heat in these experiments. Table I summarizes the possible energetic yield in these three channels. It is remarkable to compare the experimental data of McKubre [47] with the trineutron channel, tetraneutron channel, and the hot fusion channel.

8. Edward Teller´s Electron Catalysis [28]

The function of electrons during these d-d fusions is to increase rate of these reactions. Electron catalysts are not consumed by the reaction. The electron catalysts recycle quickly during these reactions. Therefore, a small concentration of catalytic electrons is needed. Electron catalysts react with deuterons under the formation of unstable polyneutrons. During the following beta decays these electron catalysts are freed from the final helium-4 and react with other deuterons: the regenerating of the catalysts.

9. Conclusion

This paper was inspired by the works of the founders of nuclear physics–Rutherford, Harkins, Landau, and Chadwick-who proposed their nucleus models before the bifurcation point defined by the neutron and neutrino models of Pauli and Fermi [56] in 1934. Two impulses came from two leading scientists in the field of hydrogen isotopes: Andrei Sakharov (muon catalysis in 1948) and Edward Teller (electron catalysis in 1989).

1. We have postulated rules for describing nucleus structures based on the compound neutron (the compound of proton and electron).
2. We have newly interpreted three d-d channels for the hot fusion reactions using the Rutherford-Harkins-Landau-Chadwick Key.
3. We have newly proposed three channels for the d-d fusion in the Pd/D system: the dineutron channel, the trineutron channel, and the tetraneutron channel.
4. There must exist one triton channel for the formation of this nuclei via the beta decay of trineutrons and with the following reaction leading to the formation of triton.
5. These new channels predict the energetic yield of those fusion reactions that could be experimentally tested and differ from the energetic yield of the d-d hot fusion. For the tetraneutron channel the energetic yield is in a remarkable correspondence to the McKubre experimental value. The active tetraneutron channel correspondences to the McKubre experimental data very well.
6. The **critical loading** of the Pd/D system has to be overcome in order to achieve d-d nuclear reactions: optimal concentrations of deuterons, electrons, dineutrons, trineutrons, and tetraneutrons.
7. These nuclear reactions proceed in two stages: 1. deuterons fuse together with electrons (i.e., electron catalysis) under the formation of unstable polyneutrons, 2. unstable tetraneutrons via beta decays decompose into the helium-4 nuclei and release the useful energy. 3. electrons serve as catalysts to enable those reactions as it was predicted Edward Teller in 1989.
8. Nature prepared for us some new elegant and safe routes of the d-d fusion reactions without dangerous byproducts.
9. McKubre´s quote [57] in 2016: "The notion of competition—other than friendly competition among like-minded individuals – is absurd in this field."
10. Fleischmann, Pons and Hawkins´ quote [58] in 1989: "The bulk of energy release is due to hitherto unknown process or processes (. . . presumably again due to clusters of deuterons) . . . ".

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Conflict of Interest

The author declares that there is no conflict of interest.

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