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RESEARCH ARTICLE

The Rutherford-Harkins-Landau-Chadwick Key–II. Fusion Interpreted by Nuclear Chemistry

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ABSTRACT

Over the past century, numerous models of atomic nuclei have been proposed, each with its strengths and weaknesses. However, no nucleus model based on undefined structures of protons (usually depicted as red balls) and neutrons (usually depicted as blue balls) has succeeded in offering a straightforward predictive tool to unravel the mysteries of fusion and the fission process. A century's worth of experimental data in nuclear physics should be newly organized. Could there be a lost key to unlocking a deeper understanding of phenomena at femtometer scales? We propose to come back before the bifurcation point in nuclear physics that was defined by Pauli and Fermi with their neutron and neutrino hypothesis in the year 1934. We want to return to the classical nuclei models proposed by early pioneers-Rutherford, Harkins, Landau, and Chadwick-before that decisive year 1934. We propose to develop their models further based on the compound neutron (the composition of proton and electron). Our approach introduces a new view into the nucleus structure and their fusion and fission reactions. The potential of this model will be documented in three interconnected papers.

Keywords: Compound neutron, fusion reactions, nuclear chemistry, Rutherford-Harkins-Landau-Chadwick key.

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1. INTRODUCTION

Over the years, a multitude of nuclear models have been proposed to unravel the intricate structure and behavior of atomic nuclei. Each model has enriched our understanding of nuclear physics. Offering valuable perspectives, yet none are without their limitations, as highlighted in [1]–[10]. Together, these models form a mosaic of nuclear theory, yet there exists room for deeper insights. The vast complexity of nuclear interactions suggests that unexplored principles and pathways may still lie hidden. Modern advancements, such as applying machine learning to nuclear physics, present an exciting frontier for extending nuclear reactions, as discussed in [11]–[20].

Alternatively, inspiration might be drawn from the pioneering work of the early masters of nuclear physics. A pivotal moment occurred in 1934, when Pauli and Fermi introduced their neutron and neutrino theories [21], effectively marking the end of earlier models based on the compound neutron model–a composition of proton and electron. Revisiting the foundational works of these earlier scholars, written before 1934, could reveal overlooked ideas that serve as a key to reinterpreting events during fusion and fission reactions [22], [23]. This "lost key," buried within pre-1934 literature, offers a fresh lens for examining femtometer scales. By reimagining nuclear reactions and refining governing principles through the wealth of known nuclear data, this approach could yield a unified framework to predict and even design novel nuclear reactions. We aim to bridge the wisdom of the past with the innovation of the present, advancing our understanding of the nucleus and its boundless possibilities.

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2. The Lost and Forgotten Key in Nuclear Physics

The historical literature in the field of nuclear physics was our guide for the formulation of the “lost key.” Rutherford [24] modeled the helium nucleus as the composition of four hydrogens and two negative electrons with a resultant charge of plus two in his papers and lectures. Rutherford proposed in his models of nuclei that one electron can bind three protons, two protons, or one proton. Electrons in the nuclei always have a total of three bounds. Rutherford predicted the existence of neutrons and helium-3 and proposed models of several nuclei.

During the same period (1915–1936), William D. Harkins e.g., [25]–[27] published many inspirative papers where he proposed the composition of known nuclei as the collection of subunits (written in modern nomenclature):

$$\textit{subunits}\quad {}^{4}_{2}He,\ {}^{1}_{1}H,\ {}^{2}_{1}H,\ {}^{3}_{1}H,\ {}^{1}_{0}n,\ {}^{2}_{0}n,\ {}^{3}_{0}n,\ {}^{4}_{0}n \tag{1}$$

Harkins modeled all known isotopes as the composition of sub-units, e.g.:

$$\textit{compound nuclei}\ {}^{6}_{3}Li = \left[{}^{4}_{2}He + {}^{2}_{1}H\right] \quad {}^{7}_{3}Li = \left[{}^{4}_{2}He + {}^{3}_{1}H\right] \tag{2}$$

$$\textit{compound nuclei}\ {}^{35}_{17}Cl = \left[8 \times {}^{4}_{2}He + {}^{3}_{1}H\right] \quad {}^{37}_{17}Cl = \left[8 \times {}^{4}_{2}He + {}^{3}_{1}H + {}^{2}_{0}n\right] \tag{3}$$

Harking’s activity is now forgotten, and only a few historians in “modern” times mentioned Harking’s ideas of Harking. For example., Stuewer [23] evaluated Harkins’ contribution to nuclear physics by saying, “the Chicago physical chemist W.D. Harkins in 1915 began a program of numerical speculation on isotopic structures seldom equaled in the history of science.” Kragh [28] described the Harkins method: “In lengthy and rather speculative papers in *Physical Review* and *Journal of the American Chemical Society*, Harkins argued that atomic nuclei consisted mainly of hydrogen and helium nuclei, meaning protons and alpha particles.”

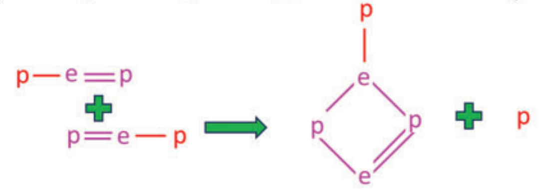
Lev D. Landau, in 1932, proposed [29]–[31] the existence of a gigantic nucleus composed of neutrons: “Indeed we have always protons and electrons in atomic nuclei very close together, and they do not annihilate themselves.” The existence of poly-neutron nuclei is still a hot, open topic in nuclear physics.

James Chadwick, in 1932, discovered the neutron and interpreted this particle as the compound of proton and neutron [32]. There exist some arguments for the existence of compound neutrons. However, there are many arguments against this model.

The Rutherford-Harkins-Landau-Chadwick Key will be used as a new tool for the nucleus model: nuclei are formed as the ring of alpha particles with attached subunits given in (1). Several rules describing the structure of nuclei as the composition of protons and electrons based on the known fusion and fission reactions can be postulated as:

1. An electron in stable nuclei always has three bonds with protons.
2. An electron in unstable proton-rich nuclei has four bonds with protons. During electron capture, one proton converts into a neutron that is attached to the ring.
3. Proton has three, two, or one bonds with electrons–it depends on the context of that situation.
4. The nucleus ring is composed of a polymer of open alpha particles: -[alpha]$_x$-.
5. During alpha decay, one alpha unit is released from the ring to decrease the rotational energy of that nucleus (alpha decay).
6. The attached subunit dineutron in the neutron-rich nuclei can release one electron—the beta decay—and the subunit deuteron is formed. The energy is shared between the energy of the formed electron and the rotational energy of the nucleus (β^- decay). (No need for the neutrino postulate).
7. The attached subunit deuteron can capture one electron under the formation of one dineutron attached to the ring. Two γ rays are formed simultaneously in opposite directions (“β^+ emission”).
8. In unstable proton-rich nuclei, the subunit deuteron can absorb one electron under the formation of two neutrons, both of which are attached to the ring (EC-electron capture).
9. The alpha particle hitting a nucleus can release a neutron from that nucleus (neutron emission).
10. Several unique reactions occur on the nucleus ring, e.g., on the ring of the nucleus C-12, one alpha particle can grow in several steps (this reaction is known as the Bethe-Weizsäcker CNO cycle). This is one example of the epitaxial growth on the nucleus ring.
11. During the fusion and fission reactions, the rotational energy of formed nuclei decreases, and the released energy can be observed and applied by nuclear physicists.

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



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

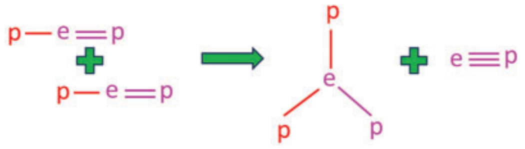


Fig. 1. Mutual orientation of two deuterons leads to two different nuclei during the primary fusion reactions.

$$ {}_{1}^{2}H + {}_{1}^{3}H \Rightarrow {}_{2}^{4}He + {}_{0}^{1}n + 17.6\ MeV $$

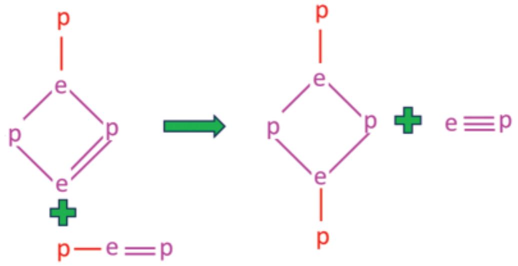
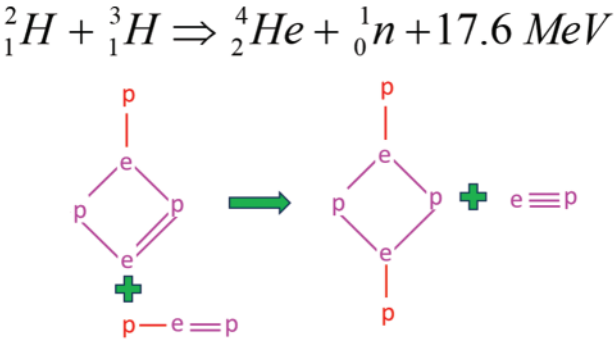


Fig. 2. Ruhlig's observation of the DT fusion as the secondary reaction at low temperature: a big surprise.

3. THE FIRST HUMAN OBSERVATION OF THE DT FUSION PROCESS BY RUHLIG IN 1938

Nuclear fusion is a reaction in which two or more atomic nuclei combine to form one or more different atomic nuclei and subatomic particles (neutrons and protons). American chemist William Draper Harkins was the first to propose the concept of nuclear fusion in 1915 [25]. The laboratory fusion of hydrogen isotopes was accomplished by Mark Oliphant in 1934 [33], [34]. Recently, Mark Paris rediscovered the finding of Arthur Ruhlig's 1938 paper on the first human observation of DT fusion [35]–[39]. This Ruhlig's DT fusion reaction occurring at low temperatures might open a new road to this reaction. The final result of this primary DD reaction and the secondary DT fusion depends on the mutual orientation of both reacting nuclei during their fusion reaction. We can document this hypothesis in Figs. 1 and 2.

Ruhlig's experiment with the primary DD reaction and the following immediate secondary DT reaction at low temperatures reveals a big surprise because all of our DT fusion experiments proceed at temperatures on the level of $\sim 10^8$ K. The possible interpretation of this anomaly can be taken from old chemistry textbooks–there are known many chemical reactions with the **hydrogen in a nascent state** [40] that react eagerly in comparison with the "old hydrogen" that is very passive in the same reactions. We expect that, in analogy with this old chemical know-how, the tritium in a nascent state can also be very active in fusion reactions (see Fig. 3).

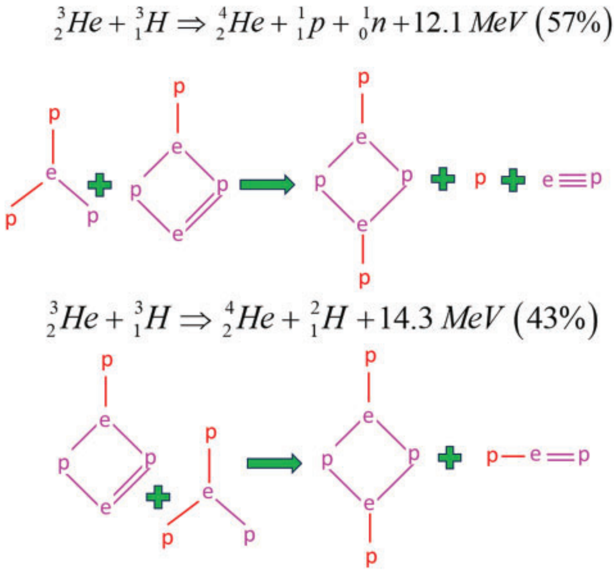


$$ {}_{1}^{2}H + {}_{1}^{3}H \Rightarrow {}_{2}^{4}He + {}_{0}^{1}n + 17.6\ MeV $$

Fig. 3. Ruhlig's preparation of tritium in a nascent state formed in the primary reaction can react eagerly with deuterium in the secondary reaction at low temperatures.

4. Known Fusion Reactions Described by Nuclear Chemistry

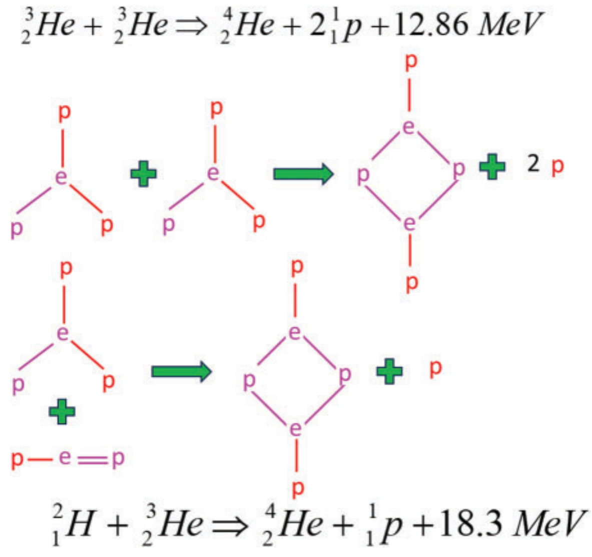
Nuclear chemistry offers a new insight into the fusion reactions in order to release energy for peaceful applications. This nomenclature describes events in the femtometer scales and serves as a guide for some new possibilities on how to handle nuclei during their fusion reactions. The final reaction products formed by fusion reactions depend on the mutual orientations of reactants, as shown in Figs. 4–7.



$$ {}_{2}^{3}He + {}_{1}^{3}H \Rightarrow {}_{2}^{4}He + {}_{1}^{1}p + {}_{0}^{1}n + 12.1\ MeV\ (57\%) $$

$$ {}_{2}^{3}He + {}_{1}^{3}H \Rightarrow {}_{2}^{4}He + {}_{1}^{2}H + 14.3\ MeV\ (43\%) $$

Fig. 4. Mutual orientation of reactants determines the structure of formed nuclei.



$$ {}_{2}^{3}He + {}_{2}^{3}He \Rightarrow {}_{2}^{4}He + 2\,{}_{1}^{1}p + 12.86\ MeV $$

$$ {}_{1}^{2}H + {}_{2}^{3}He \Rightarrow {}_{2}^{4}He + {}_{1}^{1}p + 18.3\ MeV $$

Fig. 5. Mutual orientation of reactants determines the structure of formed nuclei.

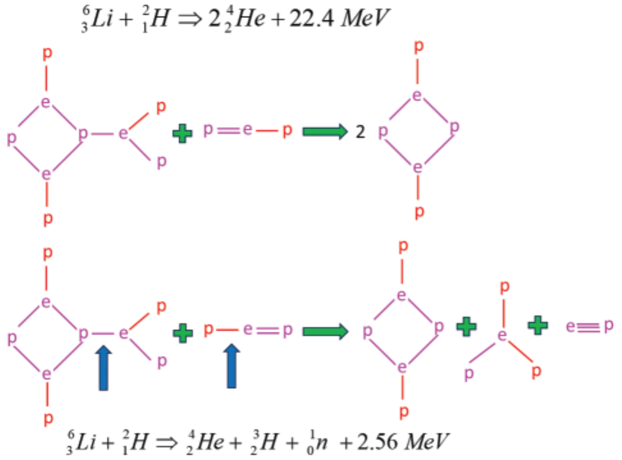


Fig. 6. Mutual orientation of reactants determines the structure of formed nuclei.

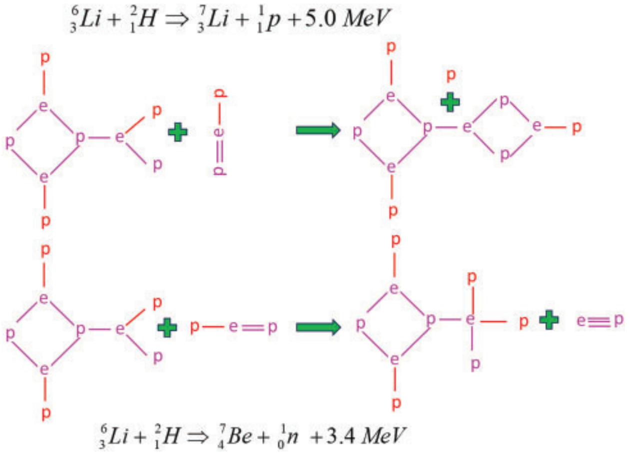


Fig. 7. Mutual orientation of reactants determines the structure of formed nuclei.

5. Aneutronic Fusion

Aneutronic fusion is any form of fusion power in which very little of the energy released is carried by neutrons. Since it is simpler to convert the energy of charged particles into electrical power than it is to convert energy from uncharged particles, aneutronic reactions would be attractive for power systems. Some of those aneutronic reactions are given in Figs. 4–7. Figs. 8 and 9 depict four aneutronic reactions that are the focus of many research teams.

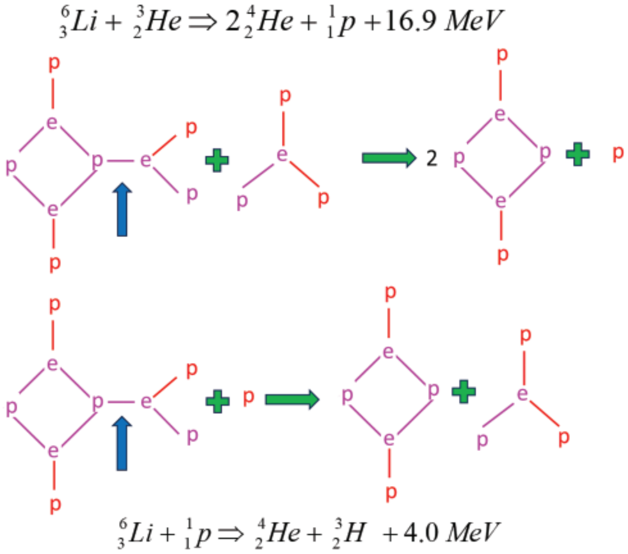
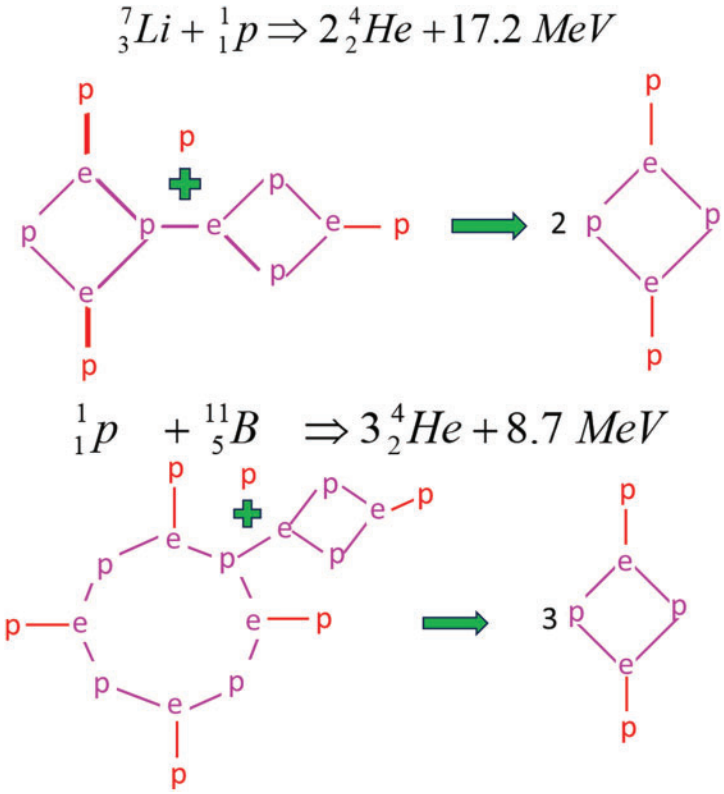


Fig. 8. Aneutronic reactions of lithium-6 with helium-3 and proton.



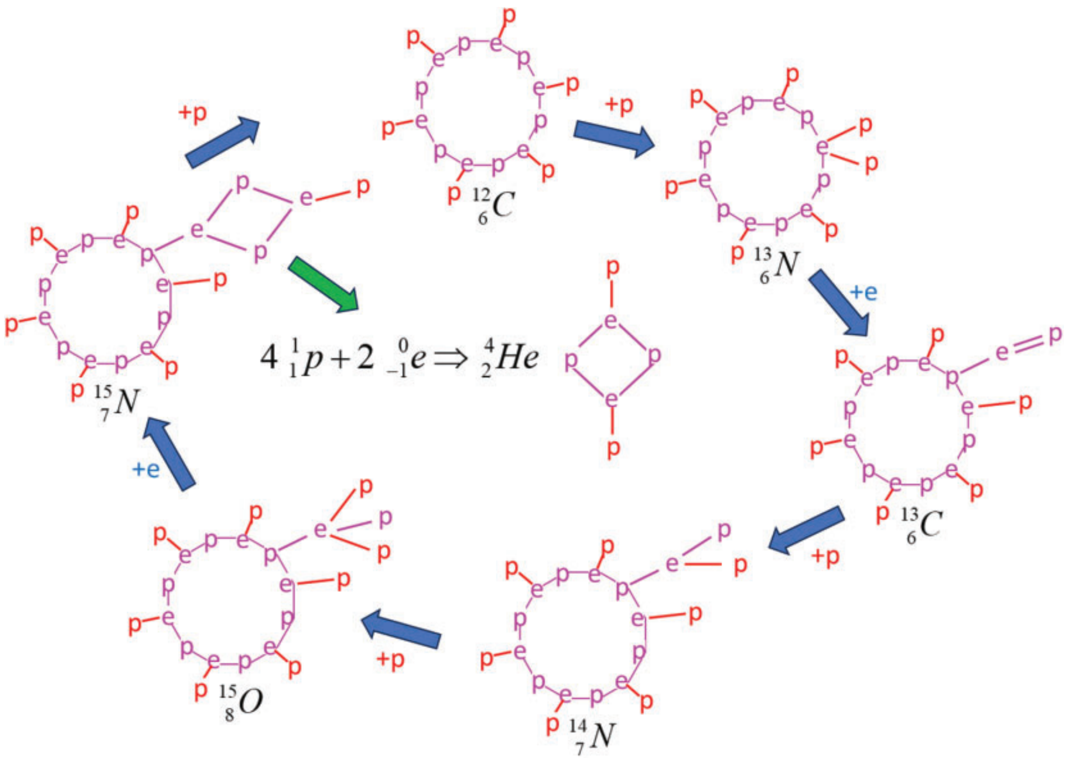
$$ {}_{3}^{7}Li + {}_{1}^{1}p \Rightarrow 2\,{}_{2}^{4}He + 17.2\ MeV $$

$$ {}_{1}^{1}p + {}_{5}^{11}B \Rightarrow 3\,{}_{2}^{4}He + 8.7\ MeV $$

Fig. 9. Aneutronic reactions of lithium-7 with proton, and the aneutronic reaction of boron-11 with proton.

6. The CNO Cycle Interpreted as the Epitaxial Growth of the Alpha Particle on the Ring of Carbon-12 Nuclei

The CNO cycle (for carbon-nitrogen-oxygen cycle called the Bethe-Weizsäcker cycle [41], [42]) is one of two known cyclic reactions by which stars convert hydrogen to helium. In the CNO cycle, four protons fuse on the ring of carbon-12: we term this fusion reaction as the epitaxial growth of alpha particles on the ring of carbon-12. This epitaxial growth is shown in Fig. 10.



$$ 4\,{}_{1}^{1}p + 2\,{}_{-1}^{0}e \Rightarrow {}_{2}^{4}He $$

Fig. 10. The CNO cycle interpreted as the epitaxial growth of alpha particles on the ring of carbon-12.

7. Conclusion

This contribution is based on the works of the founding fathers of nuclear physics-Rutherford, Harkins, Landau, and Chadwick-who published their nucleus models before the bifurcation point defined by the neutron and neutrino models of Pauli and Fermi in 1934.

1. We have postulated rules for the description of nucleus structures based on the compound neutron (the compound of proton and electron).
2. Examples of nuclear structures of several small nuclei were documented.
3. Examples of several very well-known fusion nuclear reactions were presented in this novel nucleus nomenclature.
4. The most famous DT fusion reaction was observed by Ruhlig at low temperatures in the year 1938. We assume that tritium in a nascent state was created and eagerly reacted with deuteron at low temperatures in that experiment.
5. The CNO cycle (carbon-nitrogen-oxygen) was interpreted as the epitaxial growth of the particle alpha on the ring of carbon-12.
6. This nucleus nomenclature rediscovered from works of Old Masters might bring a new view into the femtometer size scales of atomic nuclei and guide us to some new fission and fusion reactions.
7. The new terminology of nuclear chemistry should be developed.
8. It will be very useful to create software for drawing these nucleus models and nuclear reactions as it was done in organic chemistry.

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Conflict of Interest

The author declares that there is no conflict of interest.

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