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CONCEPT OF DD FUSION IN CRYSTALS

E. N. Tsyganov
(communicated by S.B. Dabagov)

The University of Texas Southwestern Medical Center at Dallas
5323 Harry Hines Blvd., Dallas, Texas 75390, USA

Abstract

This article addresses the yields of products of the reaction and the so-called non-radiation thermalization of D+D fusion in crystals. Concept of the process is proposed.

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1 INTRODUCTION

In 1989, Fleishman and Pons reported excess heat in the production of palladium electrochemical cells saturated with deuterium [1]. The paper states that the excess heat is caused by the DD fusion (cold thermonuclear fusion). Since then, more than 1000 reports have been published on cold fusion. Modern theoretical models cannot describe this anomaly. The scientific community generally rejects the interpretation that cold fusion is responsible for the data produced by these experiments, despite the fact that the experiments continue to confirm a new phenomenon.

There are several reasons why the scientific community came to this conclusion.

First, the observed phenomenon did not exhibit characteristic properties of fusion which previous nuclear fusion research expected. It still does not exhibit these properties.

Secondly, the impact of claims of a new method of fusion and its possible consequences were enormous. At the same time, conventional fusion was unable to fulfill promises of previous nuclear fusion research. The possibility of cold fusion has created a direct threat to conventional research of fusion.

Finally, cold fusion, as it was called then, or nuclear reactions at low energies, as it's called now, was and remains a complicated and challenging scientific problem.

Until now, there has been no explicit description of how the Coulomb barrier in the D+D reaction at low temperature may be overcome. I have proposed a mechanism of interaction of atoms of deuterium with the crystal lattice, which leads to such a description [2, 3], but it is necessary to conduct detailed calculations and simulations of this process.

Researchers remain uncertain as to why products of nuclear reactions that occur during the cold nuclear fusion differ from the products of well-studied DD fusion. Physicists are not able to explain the apparent lack of strong ionizing radiation in the cold fusion process.

A possible explanation of these circumstances is presented here. Despite the very sketchy and mostly hypothetical nature of the arguments, we believe this explanation will be useful for the further progress of the topic.

2 STRICT COLLIMATION OF DEUTERIUM ATOMS IN THE CHANNELS OF CRYSTAL LATTICE

As I have pointed out [3], the acceleration of the deuterium atoms by vibrations of the deformed crystal lattice and their subsequent movement in the lattice channels is the most adequate explanation of a mechanism for overcoming the Coulomb barrier. The threshold of 50 keV, after which ionization of the atom stops this process, limits acceleration of deuterium atoms. Especially important are the processes of acceleration and the subsequent motion of atoms of deuterium in the areas of so-called axial hyper channeling, through which collisions of beams of deuterium atoms moving in opposite directions can occur. In this case the impact parameter of the colliding beams is set by the average atomic potentials of the crystal lattice, and it is close to zero. Such a collimation not only increases the probability of fusion in the D+D reaction, but it also imposes severe restrictions on the angular moment and parity of the compound nucleus. The potential set of angular momenta of the compound nucleus is dramatically narrowed. It is not wise to expect the exact correspondence of fusion in crystals with well-known experimental results of under-barrier DD fusion, because in these experiments any collimation of particles below atomic size should not be considered as possible one.

In the reactions of DD fusion in plasma at temperatures of about 100 million degrees (about 12 keV for the deuteron) during a sub-threshold fusion the effective impact parameter in real is close to the size of a deuterium atom. For random collisions the probability of collisions having a small impact parameter decreases as a square of the impact parameter. That is why, I believe, there is a very small output of ^{4}He with the quantum numbers 0+ in these experiments. In the case of the fusion in crystals the impact parameter, due to the strict collimation in the crystal lattice, is about two orders of magnitude smaller than the interatomic distance, and the collision is implemented almost entirely in a state with zero orbital momentum.

3 D+D FUSION WITH THE SMALL ORBITAL MOMENTA OF COMPOUND NUCLEUS

Let us consider the fusion of two-deuterium nucleii with opposite spins in the crystal lattice environment. As was mentioned above, in connection with the strict collimation of deuterium atoms by the average lattice potential the reaction D+D-> ^{4}He** takes place entirely with the orbital momentum L=0. In the case of zero angular momentum, the conservation laws for strong and electromagnetic interactions prohibit photon emission by the excited compound nucleus, in particular by the conservation of the total angular momentum and parity. Figure 1 shows the illustration of the DD fusion process with zero orbital momentum for deuterons having opposite spins.

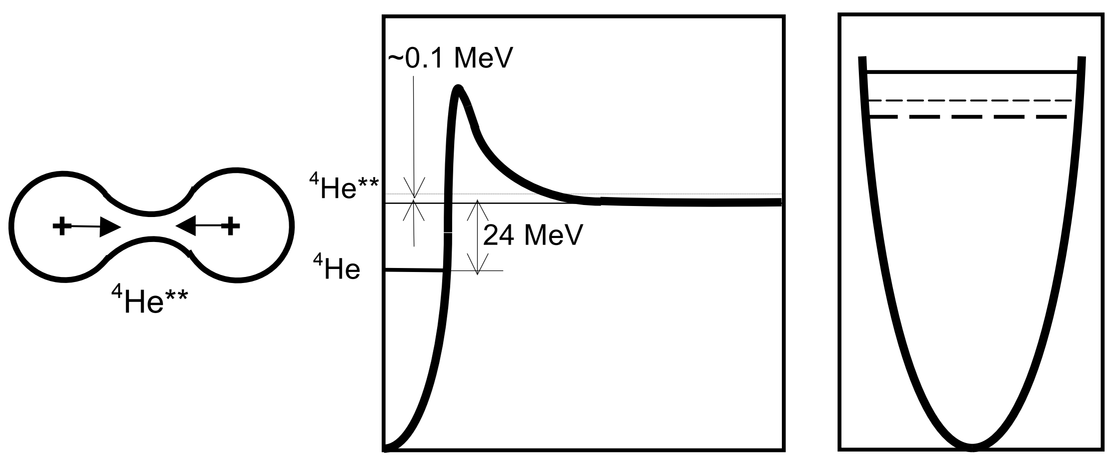

Figure 1. Left – schematic drawing of the excited DD composition ^{4}He** with L=0. In the center – schematic drawing of D-D potential, the levels of ^{4}He** and ^{4}He are indicated. Vertical axis – potential energy, horizontal axis – the distance between DD nuclei (not to scale). Right – a schematic drawing of the excited state ^{4}He** with zero orbital momentum (see the explanation in the text).

The main difficulty in explaining the results of experiments [4] on DD fusion in the crystal is that evidence of ^{3}H+p and ^{3}He+n decays is not observed or is only observed very weakly. What is the difference between the processes of DD fusion in crystals from other similar experiments? I cannot give a definite answer to this question, but I believe that the solution to this problem lies in the zero angular momentum of the initial compound nucleus $^4He^{**}$. In DD fusion in crystals, the crystal lattice potentials are an effective filter for orbital momenta, providing head-on collisions of two deuterons.

We conclude that the decay of $^4He^{**}$ to ^3He+n or ^3H+p must be strongly suppressed by the mechanism of formation of these states due to the low excitation energy (small phase space of these reactions near the threshold). It should be noted, in particular, that for these reactions at zero angular momentum one nucleon from the former deuteron should be attached to another former deuteron without a spin flip.

Another possible explanation for the suppression of channel ^3H+p and ^3He+n, as noted in the discussion by Dr. V. A. Kuzmin, could be the emission of a large number of soft photons during the formation of the ^4He nuclei from the colliding nuclei of deuterium. It seems to me that these losses may indeed be important at the stage of the deuteron entering into the potential well of the strong interaction. Since the angular momentum of the system is zero, these losses may be anomalously large. In the case of nonzero angular momentum such a rapid spatial convergence of two deuterons does not take place, and these losses will be significantly less. If these total loss amounts to greater than 2 MeV per deuteron, the level of the excited state of $^4He^{**}$ is below the level of strong decays, and decay with the emission of nucleons will not happen. The mechanism of the deuteron bremsstrahlung energy loss in the case of zero angular momentum of the system requires more detailed consideration, which is beyond the scope of this article.

In Figure 1 (right) the upper solid line represents the nominal energy level of the system of two deuterons after passing through the Coulomb barrier. The narrow dotted line denotes the level of decays with the emission of nucleons ^3H+p and ^3He+n (about 4 MeV below the nominal level of the excited state). The lower dashed line indicates the level of $^4He^{**}$ after the possible deuteron bremsstrahlung radiation.

Other spin combinations of incident deuterons with zero orbital angular momentum are not addressed here, since the ^4He nucleus has no bound states with spin and parity different from 0+. I believe that for the other spin combinations of deuterons with zero orbital angular momentum the potential wells of strong interactions are not formed.

4 ELECTROMAGNETIC RELAXATION OF THE COMPAUND NUCLEUS

The process of electromagnetic relaxation of compound nuclei in the case of DD fusion with orbital momentum L=0, which is forbidden in the case of an isolated $^4He^{**}$ system, can occur, however, via the interaction of the system with an orbital electron or with lattice electrons. The diagram of such a process is shown in Figure 2.

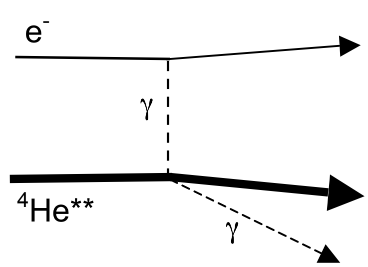

Figure 2. Diagram of the interaction of an excited compound nucleus $^4He^{**}$ with an orbital electron.

We believe that the spectrum of emitted photons resulting from the relaxation of ^{4}He** compound nuclei should be soft. The basis for such an expectation is the virtuality of the exchange photon. The relation $\Delta E \times \Delta \tau \cong \hbar$ limits the energy of the outgoing photon to several keV.

Time of the relaxation of the compound nucleus ^{4}He** could be of about 10^{-15} seconds. We plan to perform detailed calculation of the process of ^{4}He** relaxation due to interaction with orbital electrons at a later date. The quantum structure of ^{4}He** electromagnetic potential must be taken into consideration.

5 CONCLUSION

In this article, we offer a mechanism to explain low-temperature D+D fusion in crystals. In connection with strict collimation of deuterium atoms by the lattice potential the reaction (sub-threshold barrier penetration) takes place entirely with zero orbital momentum with the final creation of primarily ^{4}He nuclei. It is assumed that for zero angular momentum processes ^{3}H+p and ^{3}He+n, though not prohibited by the conservation laws, nevertheless are strongly suppressed by the formation mechanism. These reactions may also be suppressed by the mechanism of bremsstrahlung radiation as deuterons with zero orbital momentum enter the potential well of the strong interaction. Then the excited helium nucleus is in a metastable state and relaxation occurs through the emission of the low-energy photons coupling with the orbital electrons or the electrons of the crystal lattice. This unusual process could be called "photo-nuclear glow discharge."

The mystery of the lack of channels ^{3}H+p and ^{3}He+n in the experiments [4] of DD fusion in crystals, which has puzzled physicists, in our opinion, should not be an obstacle to the further development of this scientific direction. The only criterion for success of the physical experiment should be its accuracy.

The mechanism of DD fusion in crystals, due to its enormous application possibilities should be studied in more detail in the near future, both experimentally and theoretically. For calorimetric experiments it is necessary to try to increase the energy release and to achieve good repeatability of results. The use of other experimental techniques, such as the use of semiconductor crystal detectors, transparent crystals (quartz) can help to explore details of the process, which have been inaccessible until now.

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REFERENCES

1. M. Fleischmann, et al., *J. Electroanal. Chem*. **287**, 293 (1990).
2. E. Tsyganov, "Thermal equilibrium of light atoms and ions in heavy crystals", in Proceedings of the Workshop "Channeling 2008", Erice, Italy, October 25 - November 1, 2008. Proceedings will be published a separate volume of World Scientific Publishing, as well as in the *International Journal of Modern Physics A*.
3. E. Tsyganov, "Thermal equilibrium of light contaminant atoms in a crystal", Preprint Laboratori Nazionali di Frascati **LNF 09/08 (P)**, July 20, 2009, p. 1-5.

4. M. C. H. McKubre, et al. "The Emergence of a Coherent Explanation for Anomalies Observed in D/Pd and H/Pd System: Evidence for ^{4}He and ^{3}He Production", In 8th International Conference on Cold Fusion". 2000, Lerici (La Spezia), Italy: Italian Physical Society, Bologna, Italy.
Michael C. H. McKubre, "Review of experimental measurements involving dd reactions", Presented at the Short Course on LENR for ICCF-10, August 25, 2003.