ABOUT THE POSSIBILITY OF THE REACTION OF NUCLEAR SYNTHESIS IN CRYSTALS IN THE NARROW RANGE OF EFFECTIVE TEMPERATURE/ KINETIC ENERGY OF THE NUCLEI

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Abstract

The possibility of nuclear fusion reaction as a function of the effective temperature of the crystal in the one-dimensional approximation is considered. The possibility of changing of the wave function and the reaction when choosing the effective temperature / kinetic energy of the nucleus from some rather narrow range is shown. An estimate of the possible number of reaction events depending on the crystal size and its actual temperature is made.

INTRODUCTION

The main task that arises when attempts are made to realize the synthesis of light nuclei is to overcome the Coulomb barrier. In the case of "hot" thermonuclear fusion, the problem is solved by increasing the nuclei energy to values that allow it to overcome the barrier, which leads to problems in organizing the process in such a way that the energy received is more then expended.

The search for the possibility of realizing the reaction of nuclear fusion at low temperatures is a very peculiar field of scientific research (and pseudoscientific "research").

We set the problem as follows, at high temperatures the situation is obvious, but it is difficult to realize an energetically efficient process. At low temperatures, reliable results have not yet been achieved. Question: why? The answer can be: either there is no effect, or the conditions of the experiments are such that the effect is difficult to track- some significant characteristic changes during the experiment, as a result, we get beyond the conditions under which the process is going on.

The following reasoning should be regarded as suggestive considerations-in fact, it is answering the question- where and how to seek real confirmation of the possibility (or impossibility) of LENR.

MODEL OF EFFECTIVE POTENTIAL

We will consider the following quantum system. There is a one-dimensional chain of deuterium nuclei, the distance between which is determined by the density and structure of matter. As a "model" substance, we select a crystalline lithium deuteride. The density of lithium hydride LiH ρ= 820 kg/ m3. We assume that the density of lithium deuteride differs slightly from the indicated density. The distance between deuterium nuclei in a one-dimensional chain is estimated as (m-proton mass):

$$L = \left(\frac{\rho}{(9+2)m}\right)^{-\frac{1}{3}} \cong 4{,}65 \cdot 10^{-10}\, m. \quad (1)$$

We assume that the nuclei are in a constant effective potential that is the same for each nucleus, in the one-dimensional case, inside the potential lattice, the potential distribution will be considered analogous to the Kronig-Penney potential for an electron in a one-dimensional lattice (Fig. 1). In this case, the width of the potential barrier V0≅ 0.5 MV will be considered equal to

twice the characteristic deuteron dimension D (the potential decreases approximately by two times), D≅2 Fm.

We assume that the energy of the nucleus E is close to the kinetic energy of the nucleus, and the effective temperature of the crystal will be T: E≅3/2 kT (k is Boltzmann's constant). We emphasize that the temperature in our case is a measure of the kinetic energy, which is the same for all nuclei. Actually, the kinetic energy is different, it is possible to make it approximately the same by external action (for example, laser radiation).

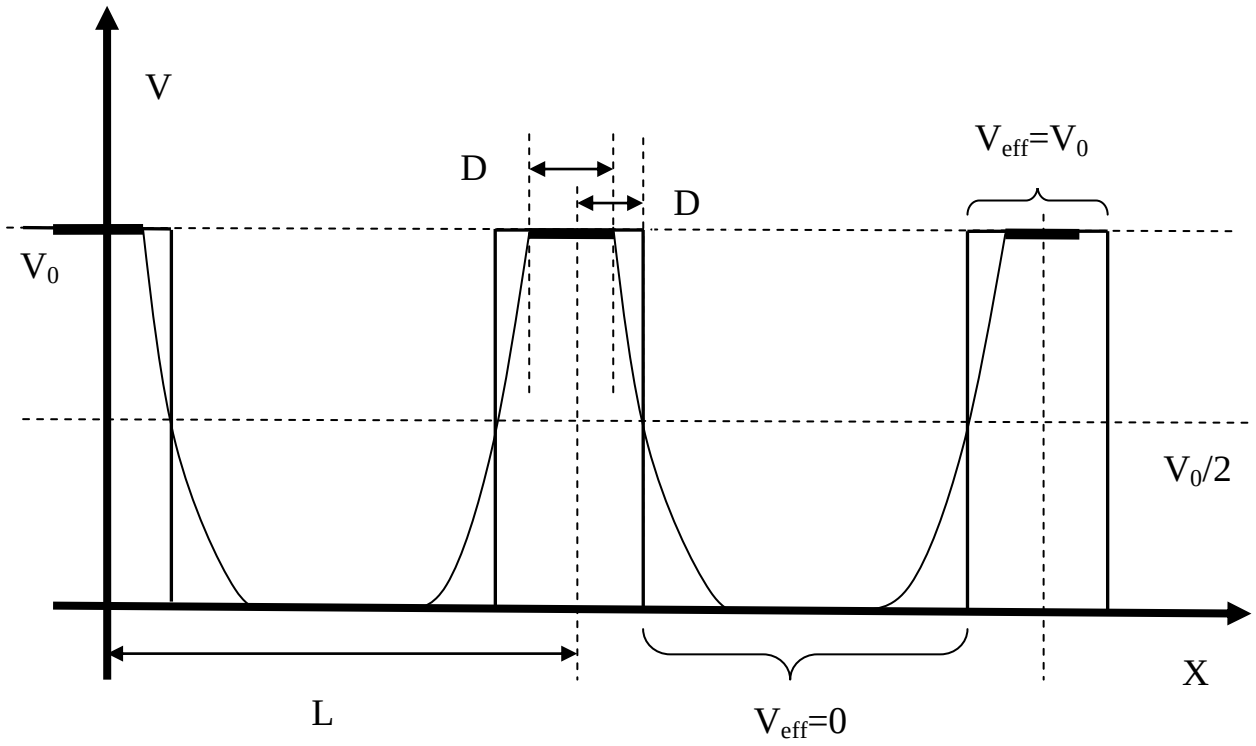

Figure 1.- Towards an effective potential model $V_{eff}(x)$

It is known that a periodic solution of the Schrodinger equation for the motion of the deuterium nucleus in the effective potential exists if (a=L, b=2D<<L):

$$-1 \le \frac{\beta^2-\alpha^2}{2\alpha\beta}\sinh\beta b \sin\alpha a + \cosh\beta b \cos\alpha a \le 1, \quad (1)$$

$$\alpha = \sqrt{\frac{2ME}{\hbar^2}}; \beta = \sqrt{\frac{2M(V_0-E)}{\hbar^2}}.$$

Here M is the mass of the deuteron, E =3/2 kT. Let us construct the dependence of expression (1) on temperature (Fig. 2):

$$G(T) = Q\sinh\sqrt{\frac{2M\left(V_0-2M\frac{3}{2}kT\right)}{\hbar^2}}b\sin\alpha\sqrt{\frac{2M\frac{3}{2}kT}{\hbar^2}} + \cosh\sqrt{\frac{2M\left(V_0-2M\frac{3}{2}kT\right)}{\hbar^2}}b\cos\alpha\sqrt{\frac{2M\frac{3}{2}kT}{\hbar^2}}. \quad (2)$$

$$Q = \frac{\frac{2M\left(V_0 - \frac{3}{2}kT\right)}{\hbar^2} - \frac{2M\frac{3}{2}kT}{\hbar^2}}{2\sqrt{\frac{2M\frac{3}{2}kT}{\hbar^2}}\sqrt{\frac{2M\left(V_0 - 2M\frac{3}{2}kT\right)}{\hbar^2}}}$$

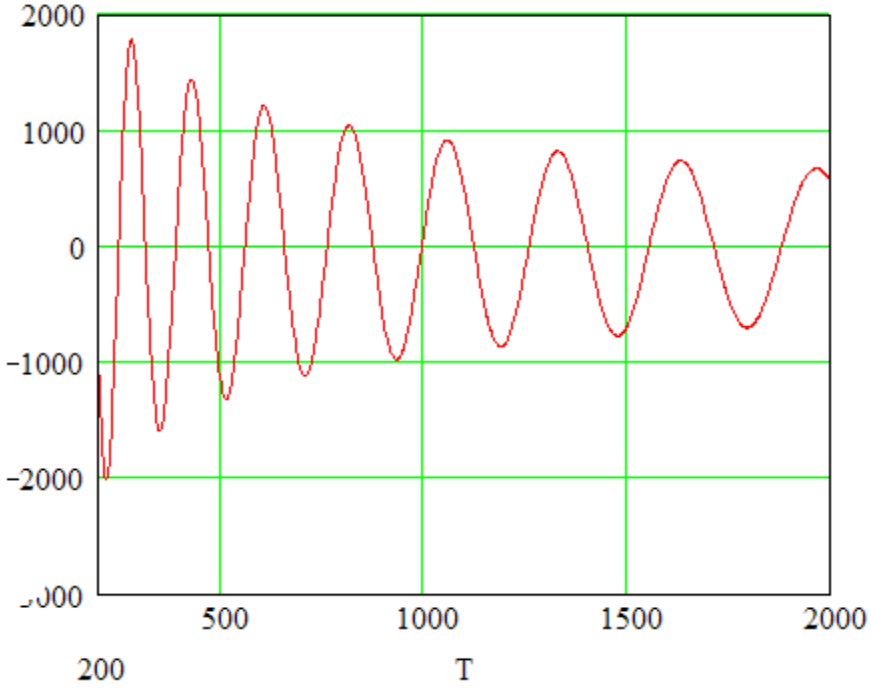

Figure 2.- Towards the possibility of periodic solution of the Schrödinger equation for the deuteron in the effective potential (1)

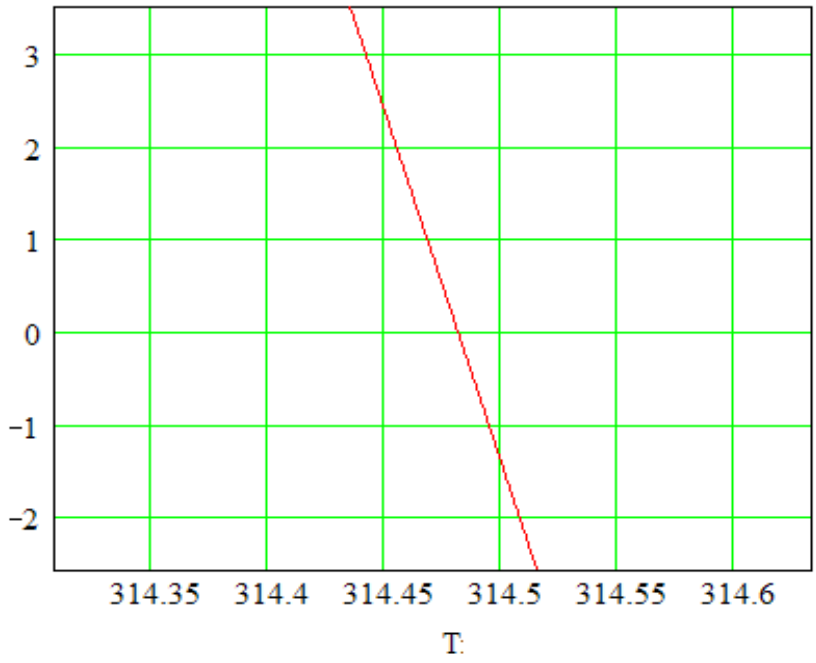

Figure 2.- Towards the possibility of periodic solution of the Schrödinger equation for the deuteron in the effective potential (1)

It is easy to see that a periodic solution is possible for some small segments $T_i \pm \Delta T_i$, i = 1, 2, ... on the temperature axis (near G (T) = 0), where the effective temperature at which a periodic solution is possible lies in a convenient for setting the experiment range. Let us change the scale of the graph of Fig. 2 in such a way that it is possible to estimate the dimensions of one of the segments $T_i \pm \Delta T_i$, i = 2 (Fig. 3).

It is easy to see that a periodic solution is possible if the effective temperature lies inside the segment $T_i \pm (\Delta T_i \cong 0{,}03\ 0K)$, i = 2. With increasing effective temperature, the dimensions of ΔT_i grow (see Fig. 1), but, obviously, the experiment is more difficult to set up.

In the case when the effective temperature does not belong to the range $T_i \pm \Delta T_i$, i = 1, 2, ..., it should be expected that the nuclei will be localized inside the potential well (there is no periodic solution in this case). Otherwise, the nucleus can be located anywhere within a one-dimensional potential lattice (with a higher probability in the region $V_{eff} = 0$), and this assertion is valid for all lattice nuclei, so their interaction (dd-reaction) becomes possible.

ASSESSMENT OF THE QUANTITY OF ACTS OF REACTION

We assume that the distribution of deuterium nuclei in terms of velocities is Maxwellian. Then, in order for nuclear collisions to occur at an average temperature of Fig. 3, it is necessary that:

- the quasi-one-dimensionality of the process took place, the situation when the nucleus moves in a direction that differs little from the axis of the crystal (Fig. 4, arrows conditionally show the nuclear velocities) on the scale L0 >> L.
- the actual kinetic energy of the nucleus differed little from 3/2 kT.

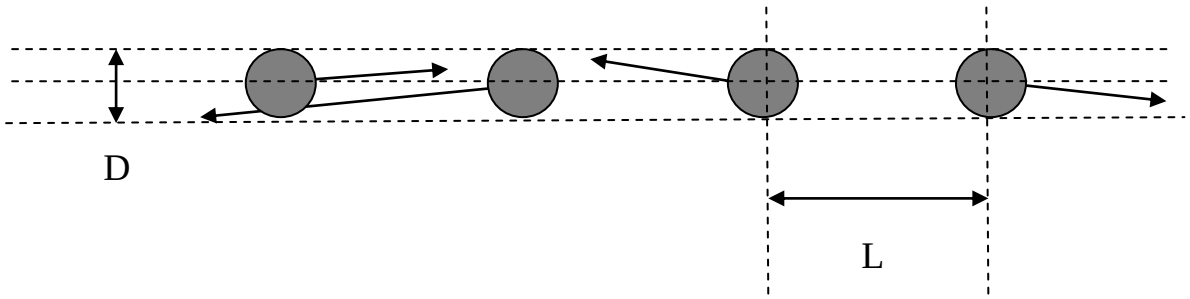

Figure 4- To the evaluation of the reaction in a crystal

The probability that the nuclei velocity lies in a narrow interval dv, taking into account our assumptions, is:

$$f(v)dv = 4\pi v^2 \left(\frac{M}{2\pi kT}\right)^{\frac{3}{2}} e^{-\frac{Mv^2}{2kT}} dv. \quad (3)$$

Taking into account $\Delta T << T$, we have:

$$P = \theta \frac{\Delta T}{T}, \theta = \frac{3\sqrt{3}}{\sqrt{2\pi}} \cong 0{,}463. \quad (4)$$

Here P is the probability that the kinetic energy of the nucleus differs little from 3/ $2kT_i$. The coefficient θ varies insignificantly with the change in the real temperature T_{real} (by assumption T_{real} is determined by the kinetic energy and the Maxwellian distribution), so there is

no need to ensure that in the experiment $T_{real} = T_i \pm \Delta T_i$, i = 1, 2, ... The effect, possibly, takes place at temperatures differing from T_i by more than $\pm \Delta T_i$. In other words, the fraction of nuclei whose kinetic energy lies in the required range varies insignificantly compared with the estimate (4).

The number of acts of the dd- reaction W per unit volume of the crystal is estimated ($T = T_2$, $\Delta T = \Delta T_2$):

$$W = \frac{3}{\tau L^3}\frac{\theta \Delta T}{T}\left(\frac{D}{L_0}\right)^2 = 2{,}7 \cdot 10^5 \frac{1}{\text{см}^3 \cdot \text{с}};\ \tau = \frac{L^3}{D^2\sqrt{\frac{2kT}{m}}}. \quad (5)$$

Here L_0 is the crystal size, in the estimate (5), $L_0 = 100L = 46$ nm. The important question is why the crystal size (nanocrystal) is chosen so. The fact is that the Kronig-Penny model for an electron and the model for a deuterium nucleus are valid in the case of a one-dimensional infinite crystal. By choosing the shape of the potential at the crystal boundary, it is easy to provide the desired asymptotic behavior of the wave function. If there is a one-dimensional finite chain, "built-in" into a non-dimensional crystal, the task is much more complicated. Therefore in (5) it is necessary to substitute exactly the nanosize crystal, if it is too large, it is difficult to say that either the possibility (or impossibility) of the reaction.

ABOUT POSSIBLE EXPERIMENTAL CONFIRMATION OF THE EFFECT

The analysis performed shows that the reaction is possible only in a very narrow range of effective temperatures/ kinetic energies of the nuclei. If the nanocrystal is slowly heated (or cooled), one should expect the appearance of the effect and the termination of the process when it exceeds the limits of the range. The assumption of the Maxwellian character of the energy distribution partly allows us to weaken the requirement that the temperature range of the nanocrystal is narrow.

Another variant of the experiment is an external action (for example, a laser) on the crystal. It is necessary to select the intensity of the laser radiation so that the energy of the nuclei belongs to the range $E_i = 3/2k(T_i \pm \Delta T_i)$, i = 1,2, ... Such an experiment is more promising also because:

-the "one-dimensionality" of the lattice is achieved,

- probably less is the deviation of the energy of the nucleus from the mean.

It should, of course, take precautions in case the assumptions expressed by the author are confirmed.

CONCLUSIONS

Apparently, we can assume that in a certain narrow range of temperatures / kinetic energies of the nanocrystal nuclei there is the possibility of a nuclear fusion reaction and other nuclear reactions.