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FUSION REACTION PROBABILITY IN IRON HYDRIDE AND THE PROBLEM OF NUCLEOSYNTHESIS IN THE EARTH'S INTERIOR

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ABSTRACT

Numerical simulation of hydrogen isotopes nuclear interaction during their diffusion in α - and γ -iron was carried out on the basis of electron orbital deformation dynamic model suggested by the authors earlier [1-4]. Calculated fusion rates show a possibility of cold fusion in the Earth's interior. Geochemical indicators of nuclear fusion are $^3\text{He}/^4\text{He}$ ratio higher than usual or the presence of tritium in deep-seated rocks, minerals and natural gases.

1. INTRODUCTION

According to common notions chemical elements were synthesized during the Big Beng and star stages of the matter evolution at temperatures exceeding millions degrees Celsius. Natural generation of elements on the Earth is possible only as the result of radioactive decay of several heavy elements (mainly U, Th) and also under the action of high-energy cosmic rays. Discovery of cold fusion and elements transmutation at low-energies initiated a series of questions:

- 1) Is nucleosynthesis possible on the Earth?
- 2) In what geochemical objects and processes natural cold fusion takes place?
- 3) Are there any indicators of this phenomenon?
- 4) Can cold fusion reactions make an appreciable energetic contribution to the Earth's heat flow?

Solving these problems has principal importance not only for geology but also for planetology and cosmochemistry.

The probability of natural cold fusion was suggested in several works (see for example [5,6]). However, physico-chemical conditions in which cold fusion was experimentally found are not occurred on the Earth. A search of direct evidences of natural nucleosynthesis is hardly difficult because usual geochemical processes, which redistribute chemical elements, mask small amounts of cold fusion products.

The solution of problems relating to the natural nucleosynthesis depends mainly on the development of quantitative theory of nuclear fusion in condensed media at low energies. Such theory will allow to calculate rates of fusion for different conditions and to evaluate its possible geochemical role.

The authors developed a new model of nuclear fusion mechanism [3-6]. It is based on account of outer metal electron orbitals dynamic deformation during random motion of hydrogen isotopes ions in metal crystal lattice. Here we present preliminary results of cold fusion simulations in crystal lattice of α - and γ -iron using this model. Metallic iron forms the bulk of the Earth's core, which constitutes 31.5% of the whole planet mass, and occurs in some deep-seated basalts. Many investigators suggest the occurrence of hydrogen as the solid solutions in its crystal lattice. Therefore, calculations of fusion rates in iron hydride is important for evaluating probability of natural nucleosynthesis in the interior of the Earth and of some other planets.

2. COMPUTER SIMULATION OF COLD FUSION IN α -IRON

Atoms of hydrogen isotopes, which occupy tetrahedral sites (T-sites) in α -Fe, move along three probable trajectories: 1) through octahedral sites (O-sites) in direction (100), 2) T-sites - T-sites in direction (110), 3) T-sites - T-sites in direction (111). We calculated the probability of D nuclei approaching one another under random initial conditions, when the energies of approaching deuterons had been preset in the range of 0.01 ± 0.005 eV (this corresponds to the height of the potential barrier for diffusion of particles in α -iron). The rate of reaction was calculated for each experimental value using a shifted Coulomb potential with the shift energy equal to the energy of screening [3,4].

The sequence consists of 27800 experimental values (fig. 1). The average distance of internuclear approach in the sequence is, on the whole, 1.09 angstroms; this is significantly greater than the average distance in a DD molecule. However $\approx 5,7\%$ of all experimental values have shown an approach of less than 0.1 angstrom (0.01 nm, see fig. 2). The rate of the reaction calculated as an average of the reaction rates for the most favorable initial conditions for each variation in approach is $\approx 10^{1.5} \text{ s}^{-1}$ per DD pair. This is in four orders of magnitude lower than the similar index for Pd deuteride. This value should be corrected for the random variation of deuterons initial position in the crystal lattice [3,4]. For complete mobility of deuterons and hydrogen solubility in α -Fe $\sim 10^{-5}$, the correction coefficient according our estimation is around 10^{-17} . Taking into account the concentration of deuterium in natural hydrogen ($1.5 \cdot 10^{-4}$), the rate of D+D reaction at 900K in α -Fe will be approximately $\sim 10^{-24} \text{ s}^{-1}$ per DD pair and 10^{-22} s^{-1} per pair for the nuclear reaction $p+d \rightarrow {}^3\text{He} + \text{Q}$.

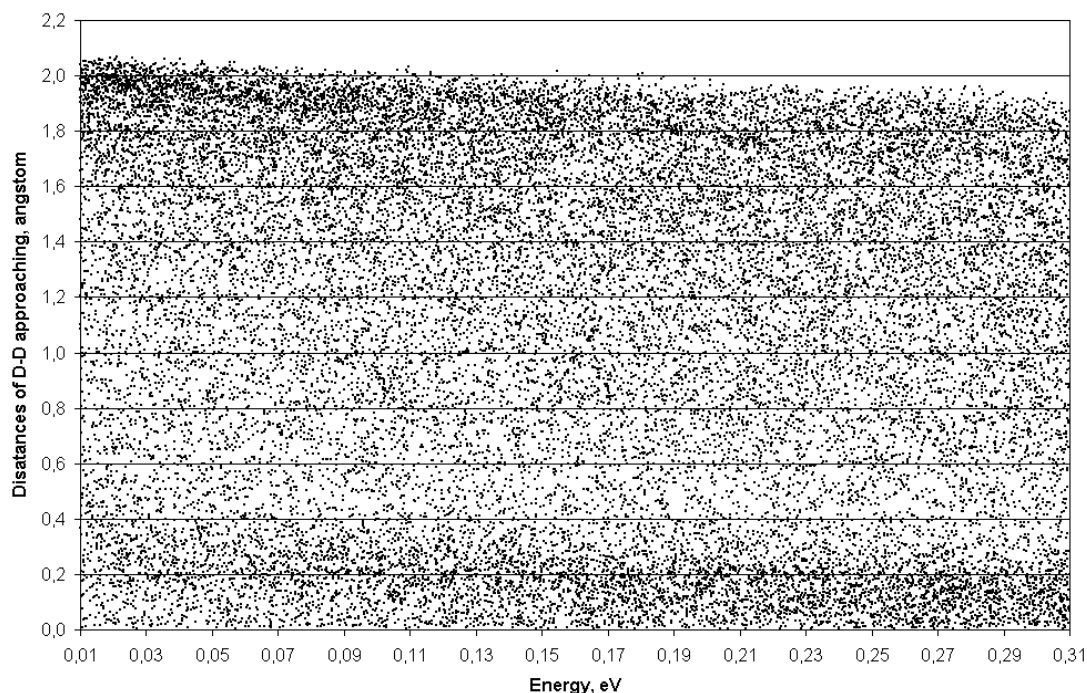


Fig. 1. Distribution of minimal distances of D-D approaching during their counter motions on the boundary of the neighboring O-sites in iron deuteride (α -modification) vs their initial kinetic energy using the most favorable initial conditions.

3. COMPUTER SIMULATION OF COLD FUSION IN γ -IRON

In γ -Fe crystal structure, where hydrogen atoms occupy octahedral sites, conditions for their coming together are less favorable. From 17800 experimental values (fig. 3) approaching for a distance of less than 0.1 angstrom occurs in 1.0% of cases (fig. 2). The average rate of the reaction for the most favorable initial conditions is $\approx 10^{-3.0} \text{ s}^{-1}$ per DD pair. In γ -Fe deuterons mobility at room temperature is lower than in α -Fe, but the hydrogen solubility is higher than in α -modification and the value of the correction coefficient for the random variation of initial conditions is around 10^{-23} . Due to the high solubility of hydrogen at elevated pressures and temperatures (up to the content $\text{FeH}_{0.7}$ at 70 kbar [7]), the probability of nuclear interaction in γ -Fe at high temperatures will be comparable with that in α -Fe. For example, at 4000 K

the reaction rate (with limiting concentration of hydrogen taken into account) will be $\sim 10^{-22} \text{ s}^{-1}$ per pair of atoms of natural hydrogen isotopes. That corresponds to the energy release of $10^{-10} - 10^{-11} \text{ Wt}$ per gram of iron hydride.

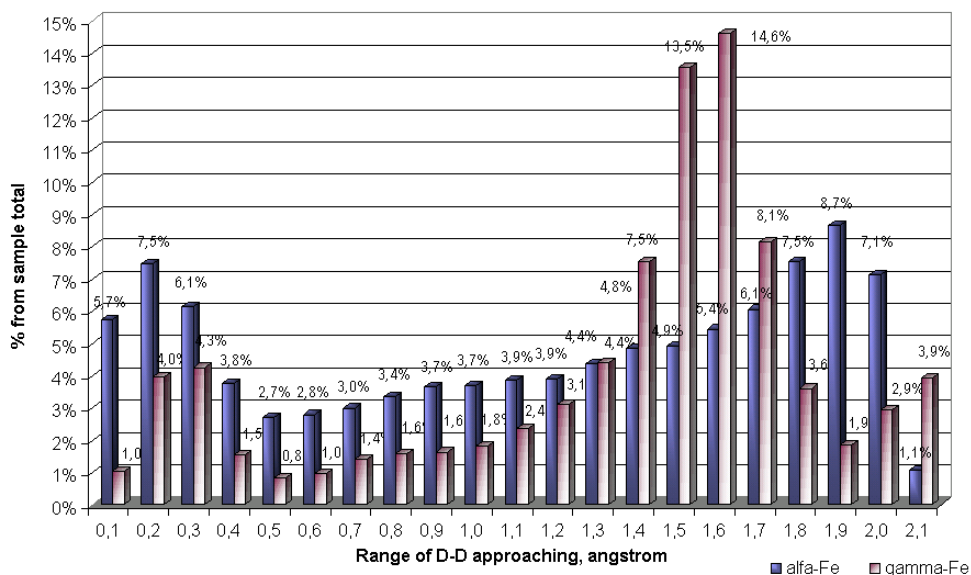


Fig. 2. Distribution of reaction D-D pairs on their range of minimal distances of approaching to one another in α - and γ - modification iron using the most favorable initial conditions.

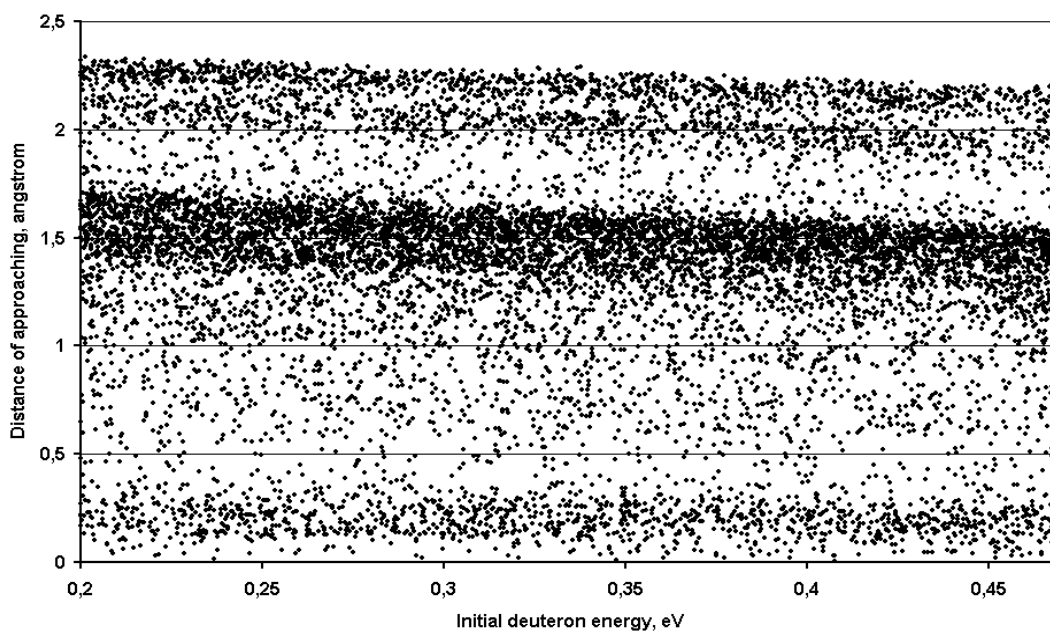


Fig. 3. Distribution of minimal distances of D-D approaching during their counter motions on the boundary of the neighboring O-sites in iron deuteride (γ -modification) vs their initial kinetic energy using the most favorable initial conditions.

4. GEOCHEMICAL CONSEQUENCES

The results of numerical modeling show that the rates of nuclear interaction of hydrogen isotopes in crystal lattices of α - and γ - polymorphic modifications of iron are of importance in geochemistry.

The reaction rate for p+D reaction in the temperature range up to 4000 K occurring in the Earth's interior 2-3 order of magnitude lower than for D+D reaction. For p+p nuclear reaction the fusion rate is 17-18 order of magnitude lower than for D+D fusion, therefore, an interaction of light hydrogen isotopes does not

play any role in the Earth interior. Taking into account a low concentration of deuterium in natural hydrogen ($\sim 1.5 \cdot 10^{-4}$) a probability of the reaction $p+D \rightarrow {}^3\text{He} + 5.5 \text{ MeV}$ in spite of its lower rate is 1-2 order of magnitude higher than for D+D reaction. Hence, the light helium isotope is the predominant product of natural fusion reactions. A geochemical indicator of such fusion reactions may be increased ${}^3\text{He}/{}^4\text{He}$ ratio.

Many measurements of helium isotopes content were made (see for example [8]). Elevated ${}^3\text{He}/{}^4\text{He}$ ratios in ocean island basalt derived at melting of deep-seated rocks in comparison with mid-oceanic ridge basalts are traditionally considered as the result of conservation of primordial helium isotope content, which was formed under the action of high-energy cosmic particles during the Earth's formation. However, this viewpoint is badly agrees with the notions on the convection of the Earth's matter during long geochemical history resulting in release of primordial noble gases to the atmosphere. Moreover, in some deep-seated diamonds ${}^3\text{He}/{}^4\text{He}$ ratios are discovered, which significantly exceed the primordial ratio of these isotopes in cosmic objects and on the Sun. It is hardly difficult to explain this fact by any geochemical or cosmochemical causes. Recognizing a possible role of conservation of primordial helium we believe that the increased ${}^3\text{He}/{}^4\text{He}$ ratios in some deep-seated rocks minerals and gases may be partly the result of nucleosynthesis in the Earth's interior. This process is going, in particular, in crystal lattice of metallic iron.

Nuclear fusion reactions can be considered as an additional source of the Earth's heat energy. The importance of this source is yet to be evaluated.

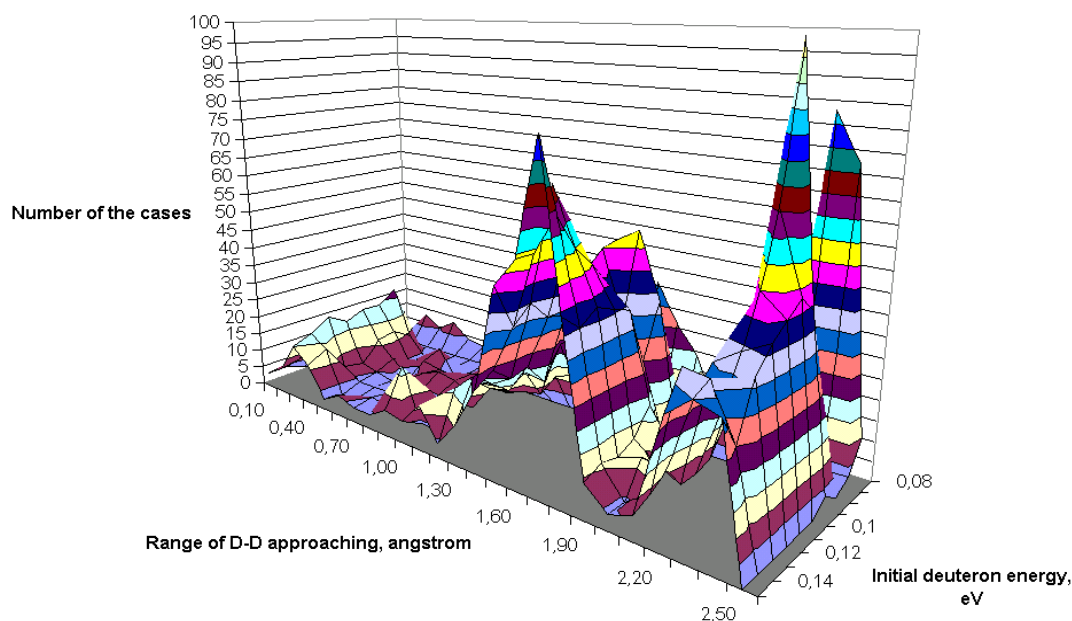


Fig. 4. Distribution of minimal distances of D-D approaching during their counter motions on the boundary of the neighboring O-sites in iron deuteride (γ -modification) vs their initial kinetic energy and the range of their minimal distances of approaching.

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