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Research Article

Initiation of the Cold Fusion Reactions by Air Components

Sergey A. Tsvetkov *

14-13 Kurchatov St., Zarechny, Sverdlovsk Region 624250, Russian Federation

Abstract

The approach to cold fusion phenomenon based on interactions between deuterium and the components of air in titanium is considered. Experimental results which point at release of excess heat and neutrons are shown. On the basis of these results the nuclear fusion method and the device for its realization are patented. The application of this nuclear fusion method for nuclear waste transmutation, in particular caesium-137, is considered. On the basis of the calculations given conclusion about applicability of the method is made. According to the experimental data, saturation of titanium with deuterium–air mix results in temperature increase of the titanium deuteride sample by 45°C, in comparison with saturation of the same sample with pure deuterium. The calculation of excessive heat emission based on these results is given. The conditions necessary for the cold fusion reactions to occur are formulated.
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1. Introduction

Since 1989, we have been studying loading of titanium by gaseous deuterium [1]. Menlove et al. measured neutron emission from TiD in 1990 [2].

2. Experiments

Our loading sample parameters were as follows: the sample temperature was 550–580°C, deuterium pressure was 4, 32 and 50 atm. The cycling method consisted in loading and degassing of titanium sample was used. Degassing was implemented by vacuum pump and heating of the butt end of the sample by laser. The LTI-403 model of laser was used. This is a two-stage laser assembled in driving oscillator – amplifier pattern. Yttrium–Aluminum grenade crystals with Neodymium (Nd–YAG) were used as the active elements of the amplifier and driving oscillator. Optical pumping was used. The laser operated in free generation mode. In order to increase the laser radiation energy, power supply units were modernized. The experimental parameters of laser radiation were the following:

- Wavelength = 1.06 μm.

*E-mail: rossomahi@yandex.ru; Tel.:+7-9126037112

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- Pulse energy = 1 J.
- Pulse duration = 1 μs.

- Pulse repetition rate = 33 Hz
- Average power = 33 W.

The block of neutron detectors and scintillation detector with NaI (Tl) single crystal were used to record neutron and gamma radiations. The block of neutron detectors consisted of 30 mm thick polyethylene neutron moderator and 15 SI-19N- type slow neutron counters filled with 97% ^{3}He + 3% Ar gas mixture. Its rated parameters were the following:

- Efficiency of heat neutron registration: not less than 60%.
- Sensitivity to neutrons from plutonium–beryllium source: not less than 50 count/(neutron/sm^2).
- Intrinsic noise rate: not more than 0.1 count/s.
- Threshold of sensitivity to gamma radiation: not less than 200 μR/s.

Scintillation detector for registration of gamma radiation was of NaI (Tl) single crystal dimensions: 63 mm in diameter and 63 mm in height. The lateral surface of single crystal was shielded by 100 mm thick lead. Scintillation detector had the following technical parameters towards ^{137}Cs source:

- Efficiency of the registration: not less than 57%.
- Sensitivity: not less than 21 count/(gamma/sm^2).
- Intrinsic noise rate: not more than 200 count/min.

In order to calibrate the neutron detectors block, sealed pin-type californium neutron source was used. The main technical parameters of this source were:

- Radioactive element: ^{252}Cf.
- Neutron flow: 2.2×10^6 neutron/s.
- Measurement date: 06-28-1989.
- Efficient half-life: 2.638 years.
- Activity: not more than 2.4×10^7 Bq
- Average energy of neutrons under spontaneous fission: $E = 2.2 \pm 0.1$ MeV.

Scintillation detector was calibrated by the ^{60}Co source with an activity of 3.7×10^5 Bq.

During the first experiments integral track neutron detectors from DKN set were used simultaneously with continuous registration of neutrons from the sample. Three experiments were carried out using the following system of detectors: four detectors based on ^{235}U with muscovite recorder were placed behind a water moderator, 15 cm away from the sample, and three detectors based on ^{237}Np with muscovite recorder were placed in front of the water moderator. One detector based on ^{235}U was used for checking. On two detectors that were placed behind a water moderator we discovered three tracks, which are typical for fission fragments. The checking detector showed no tracks in the background. During following three experiments four track detectors based on ^{235}U with muscovite recorder and four track detectors based on ^{235}U with Lavsan recorder were used. Two of the latter were used for checking, while other detectors were placed behind the water moderator, 10 cm away from the sample. After these experiments we discovered on one of the detector, having with Lavsan recorder is discovered one track, typical for fission fragments. The checking detector showed no tracks in the background.

In the same experiments the second independent set of neutron detectors blocks with slow neutron counter, identical to the first set, was used. During degassing of the sample in one of the experiments synchronous neutron registration by both sets of neutron detectors blocks occurred.

"Flashes" of neutron and gamma radiation were observed during the experiment. Their duration was no more than 0.5 s, and their intensity was 500 neutrons/s in terms of neutron detectors block sensitivity to neutrons from ^{252}Cf source and 5400 gamma/s in terms of scintillation detector sensitivity to ^{60}Co source. Using the magnitude of deuterium pressure alterations at loading and velocities of the pump down at degassing the calculations were made. It showed that the moments of these radiation "flashes" correspond to phase transitions in titanium–deuterium system. The pulse type of radiation registered confirms the hypothesis about influence of phase transitions in titanium deuteride sample on the nuclear reactions taking place.

Thus, the mechanism of this effect becomes clear. During phase transitions the metal crystalline lattice undergoes rearrangement. For example, in pure titanium the atoms are arranged in structure of hexagonal close packing with the lattice period of 2.952 Å, but titanium deuteride with composition $TiD_{1.97}$ has face-centered cubic lattice of metal atoms with lattice period of 4.440 Å [4]. Therefore, while loading of titanium with deuterium and degassing, discontinuous changes in internal energy, electronic thermal capacity, magnetic receptivity and other parameters occur.

Simultaneously with the experiments, simulation of phase transitions in palladium–deuterium system was carried out using molecular dynamics methods. Deuterium behavior in this process was determined [5,6]. According to the calculation results, it was found that in the process of phase transition in a micro crystallite that consists of 500 Pd atoms and 250 D atoms, single deuterium atoms with energy more than 10 eV appear, as well as pairs of deuterium atoms that are drawn together within palladium micro-crystallite to the distances up to 0.70 Å. Normal distance between deuterium atoms in palladium deuteride is about 3 Å.

In the experiments, we used samples made by heat pressing method from titanium hydride powder with particles diameter 100 μm. This resulted in very large surface of the interaction between titanium and deuterium. Surfaces area of the sample was calculated to be more 80 cm^2/g.

It was observed that neutron "flashes" were registered only in cases when oxide film was found on the samples surface after the experiment. In cases of oxide film absence neutron ""flashes" were not registered. Therefore, we carried out experiments on the influence of air additives in gaseous deuterium on neutron and gamma-radiation intensity and frequency under phase transition [3]. The following results were received: when loading the sample with 1.5% air + deuterium mixture, separate gamma and neutron ""flashes" were registered. The nature of the radiation, intensity and frequency of "flashes" changed according to velocity of alteration of deuterium content in titanium, i.e. to absorption velocity of the gas mixture. At low absorption velocities gamma-radiation "flashes" were registered in amount of two "flashes" per absorption process. With increase of the absorption velocity the amount of neutron "flashes" increased up to 7 per absorption process. Neutron "flash" intensity was found to vary in direct proportion to the sample mass: since the sample masses in the experiments differed approximately in 2 times ($m_1 = 15.20$ g and $m_2 = 6.98$ g), neutron "flash" intensities differed approximately in 2 times as well (m_1 – in 60 and m_2 – in 32 times above background).

Results of these experiments were the basis for Russian patent "Method of the nuclear fusion and device for its realization" No. 2145123 [7].

Other experimental data reported [8] include neutron pulse registration with neutrons energy of 2.5; 4.5; 13 and 17 MeV with flow density 10^4 neutrons/(cm^2·s) and gamma-radiation with energy up to 4.5 MeV. Considering this and the fact that we used neutron sensors with ^{3}He for neutrons registration, we may suppose that as reactions described in patent [7] take place, interactions between deuterium and nitrogen and oxygen isotopes increased in air result in neutrons with higher energies [2].

Possible nuclear reactions between deuterium and nitrogen or oxygen isotopes are listed in Table 1 [9]. To judge from the products registered in the reaction of "cold fusion", the reaction ^{17}O + D are more likely to occur. But this suggestion requires experimental proof.

Full cross-sections of ^{3}He for neutrons with energy 2.4 and 14 MeV are known to differ nearly in three times [10], while cross-sections of (n,p)-reactions differ in 6 times. That is the neutron counter sensitivity to neutrons with energy more than 2.4 MeV is far less.

So it was considered necessary to recalibrate the neutron detectors block by neutron source with higher energy. For this purpose ^{239}Pu-α-Be source with external radiation in 2π angle 2.12×10^5 α-particles/s and surfaces area $S_{\text{source}} = 160\,\text{cm}^2$ was chosen. In our earlier work [7], the magnitude of neutron flow was found to be about 500 neutrons/s in terms of sensitivity to neutrons from ^{252}Cf source (the average energy of neutrons $E = 2.2$ MeV), while in case of ^{239}Pu-α-Be source, average energy of neutrons $E = 4$ MeV. So, experimental data allow us to define, which neutron flow was registered to this source.

As the result neutron detectors block sensitivity to neutron ^{239}Pu-α-Be source turned out to be $\chi = 5.974$ count·cm^2/s, which corresponds to the rated parameters of the neutron detectors block.

The magnitude of the neutron flow to ^{239}Pu-α-Be source was found to be $I = 1.68 \times 10^5$ neutron/s.

In the work [11] possible use of the cold nuclear fusion method for transmutation of nuclear wastes, in particular, for cesium-137 "destruction" was considered. The values of the neutron flow density obtained using oxygen and nitrogen isotopes are of the same order, but still 27 times less than the value of the neutron flow density for efficient cesium-137 "destruction" in fast neutrons reactor. It's possible to rise working mixture pressure up to 50 atm and working volume of the installation up to 10 m^3. This would enable to increase the weight of used hard body to 700 kg, which would lead to the neutron flow density increase by one more order of magnitude and reduce efficient half-life to $T_{1/2\text{c.f.}} = 0.338$ years.

It means that it would be necessary to irradiate the radioactive waste with ^{137}Cs for 12.9 years in order to achieve the minimum significant specific ^{137}Cs activity. Such timing and technical features of the process and installation are suitable for making the industrial installation.

In the experiments on loading the samples with deuterium + air mixture and degassing we observed a 45°C increase in temperature of the samples in comparison with the temperature at which absorption of pure deuterium by this sample takes place [3]. The calculated amount of excess heat in the process of loading of titanium sample with deuterium + 1.5% air mixture was found to be $Q = 85.002\text{cal} = 355.88$ J or about 50 kJ/kg sample.

Four nuclear reactions can occur between D and ^{17}O (refer Table 1). But only in one of four cases neutrons may be observed. Relation between registered amount of neutrons and tritium amount in "cold fusion" reactions is experimentally defined and is T/n = 10^9 [12].

The value of energy released in one act of the supposed fusion reaction between deuterium and oxygen-17 isotope should be 13.22 MeV per fusion act which is commensurable with reference data. Thermonuclear fusion reactions D + T lead to release of 17.7 MeV per fusion act.

3. Conclusion

Thereby, we can say that addition of air in deuterium has initiating influence on reactions of cold fusion when loading titanium with gaseous deuterium.

The review of works in other branches of cold fusion shows that in all the system described, aside from deuterium and metal, oxygen is present, either in gaseous or in bounded form. Thus we can expect the cold fusion phenomenon to be connected with the fusion reactions between oxygen and deuterium nuclei within solid. Moreover, both the reaction products and their energy spectrum point at oxygen isotopes: ^{17}O and ^{18}O. Apparently, presence or absence of these isotopes in system subjected to deuterium loading defines reproducibility of experimental results and intensity of the cold fusion reactions.

We may describe the conditions necessary for the cold fusion reaction to occur:

(1) Presence of materials which are capable of absorbing deuterium in greater amount and undergoing phase transitions during this process, and also have large surface area.
(2) Presence of oxygen isotopes.
(3) Optimum phase transition rates should exist.

Table 1. Possible nuclear reactions of deuterium with nitrogen and oxygen isotopes, nitrogen and oxygen isotopes prevalence in nature.

Nuclear reactions	Nitrogen and oxygen isotopes in nature (%)
$^{14}N + D \rightarrow 4\,^{4}He + 6.3$ MeV	99.63
$\rightarrow {}^{12}C + {}^{4}He + 13.57$ MeV	
$\rightarrow {}^{15}N + p + 8.61$ MeV	
$\rightarrow {}^{15}O + n + 5.06$ MeV	
$\rightarrow {}^{16}O + \gamma + 20.73$ MeV	
$^{15}N + D \rightarrow {}^{13}C + {}^{4}He + 7.68$ MeV	0.37
$\rightarrow {}^{16}N + p + 0.262$ MeV	
$\rightarrow {}^{16}O + n + 9.901$ MeV	
$^{16}O + D \rightarrow {}^{14}N + {}^{4}He + 3.11$ MeV	99.76
$\rightarrow {}^{18}F + \gamma + 7.527$ MeV	
$\rightarrow {}^{17}O + p + 1.918$ MeV	
$^{17}O + D \rightarrow {}^{15}N + {}^{4}He + 9.802$ MeV	0.04
$\rightarrow {}^{16}O + {}^{3}H + 2.115$ MeV	
$\rightarrow {}^{18}O + p + 5.822$ MeV	
$\rightarrow {}^{18}F + n + 3.384$ MeV	
$^{18}O + D \rightarrow {}^{15}N + {}^{4}He + n + 1.755$ MeV	0.20
$\rightarrow {}^{16}N + {}^{4}He + 4.245$ MeV	
$\rightarrow {}^{19}O + p + 1.732$ MeV	
$\rightarrow {}^{19}F + n + 5.768$ MeV	

The equipment used for registration of the nuclear radiation must be capable to register pulse neutron and gamma-radiation. Otherwise in process of loading and degassing of the solid experimental conditions should be created in such a way that the largest possible volumes would undergo phase transition. Thereby, the cold fusion phenomenon does exist, but it is necessary to follow certain conditions for its observation.

We suppose that it is necessary to continue works on loading and degassing of titanium with mixture of deuterium with oxygen isotope in combination with spectrometry in order to increase the intensity and duration of the radiation, as well as check the nitrogen and carbon isotopes in mixture with deuterium at titanium loading for exact determination of the nuclear reaction channels.

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