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Research Article

Investigation of the Photo Neutron Reaction Threshold in Deuterium Located in a Crystal Lattice of Hf, Zr and $Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17}$

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Abstract

We present experimental observations of nuclear reactions in deuterated metals irradiated with low energy gamma quanta obtained by deceleration of an monoenergetic electron beam on a tantalum target. It was found that under gamma irradiation of deuterated materials HfD_2, ZrD_2 and $(Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17})D_{1,63}$, the threshold energy for the photo neutron reaction was 2.225 ± 0.01 MeV. This value coincided within the measurement accuracy with the threshold value of the photo neutron reaction for deuterium in a free state (2.225 MeV).
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Keywords: LENR, gamma irradiation, deuterated materials

1. Introduction

Low energy nuclear reactions (LENR) assisted by a crystalline environment have attracted a lot of attention since 1989 [1]–[5]. Experimental investigations of LENR are based on measuring abnormal heat effects [2], [3], abnormal transmutation effects [4] and abnormal generation of accelerated particles in solid matrices saturated with isotopes of light nuclei [5].

In the NASA experiment [6], it was argued that exposure of strongly deuterated materials to a low-energy ($E \leq 2$ MeV) photon beam leads to nuclear activation of both the initial hafnium and erbium metals and the test material (molybdenum) mixed with the reagents. This activation is possible due to the neutrons produced by photo neutron reaction. It is well established that the photo neutron reaction for deuterium in a gaseous state is 2.225 MeV. So, the lower threshold energy of photo neutron reaction for deuterium confined in the crystal lattice as compared to the free deuterium would have indicated at the lattice assisted low energy reactions. However, the authors used a modified linear industrial accelerator (LINAC) as a source of accelerated electrons, in which the upper energy of electrons could not be determined exactly. Therefore, it could have high energy "tales" with energies exceeding 2.225 MeV.

In the present paper we investigated this phenomenon in heavily deuterated HfD_2, ZrD_2 and $(Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17})D_{1,63}$ using electrostatic accelerator of electrons and a tantalum converter of electrons to *Bremsstrahlung* gamma quanta. In this type of accelerators, the energy of electrons (and consequently, of *Bremsstrahlung* gamma quanta) has no "tails" and can be measured with a high precision.

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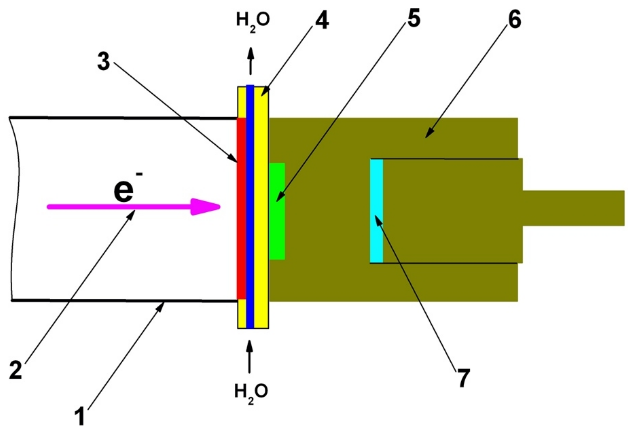

Figure 1. Schematic representation of the converter of an electron beam into a beam of gamma quanta. 1 - Output of the electrostatic electron accelerator; 2 - Electron beam; 3 - Tantalum target; 4 – Aluminum electron filter; 5 – the sample under investigation; 6 – Polyethylene neutron moderator; 7 - Silver target.

2. Experimental Setup

In the present work, irradiation was performed with electrostatic electron accelerator ELIAS manufactured by High Voltage Engineering Corporation model KS/3000. This accelerator makes it possible to obtain electrons with energies from 0.5 MeV to 3 MeV and a beam current from 1 μA to 500 μA. To produce *Bremsstrahlung* gamma quanta, we used a tantalum converter. In the converter, the main deceleration of the electron beam occurs with the emission of gamma quanta. The heat released during deceleration of electrons on a tantalum target is removed with the help of water flowing in a thin layer along the tantalum target. Behind the tantalum target and flowing water is an aluminum electron filter. This filter serves to absorb electrons that have passed through the tantalum target. Figure 1 shows a schematic representation of the experimental setup.

The thickness of the tantalum target, the flowing water, and the aluminum filter were chosen to optimize the coefficient of conversion of the electron beam into a flux of gamma quanta. Figure 2 shows the spectrum of gamma quanta at the output of the electron beam converter into the flux of gamma quanta during deceleration of electrons of various energies with a beam current density of 5 μA/cm^2.

When deuterium is bombarded with a flux of gamma with energy of 2.225 MeV or higher, the deuterium neutron is knocked out, resulting in the formation of a hydrogen atom. The resulting neutrons, after moderation with polyethylene, irradiate a silver target containing 51.35% of the Ag^{107} silver isotope and 48.65% of the Ag^{109} silver isotope. As a result, the Ag^{107} isotope, upon neutron capture, forms the radioactive silver isotope Ag^{108} with a half-life of 142.2 seconds. The silver isotope Ag^{108} emits an electron with the energy of 1.649 MeV with a probability of 95.5%, and an electron with the energy of 1.918 MeV with a probability of 2.07%, and an electron with the energy of 1.016 MeV with a probability of 1.76%, turning into a stable cadmium isotope Cd^{108}. The Ag^{109} isotope, upon neutron capture, forms the radioactive silver isotope Ag^{110} with a half-life of 24.6 seconds. This isotope emits an electron with the energy of 1.199 MeV with a probability of 94.91% and an electron with the energy of 0.8942 MeV with a probability of 4.41%, turning into a stable cadmium isotope Cd^{110}. The beta radioactivity of the silver target was determined using an electron detector as a Geiger-Muller counter. Figure 3 shows a schematic representation of the installation for measuring the time dependence of radioactivity of a silver target after irradiation. A silver target weighing 2.5234

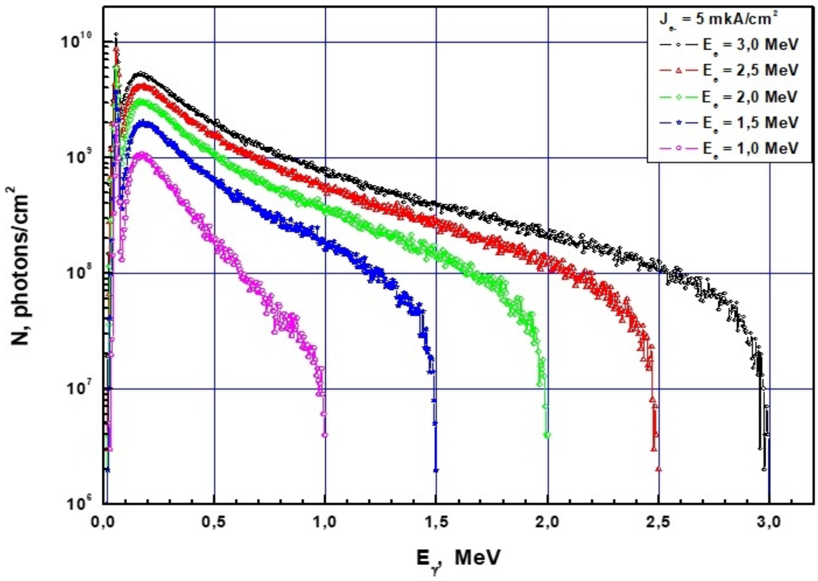

Figure 2. The Schiff spectrum of *Bremsstrahlung* gamma quanta produced by electrons of different energies passing through a Tantalum converter.

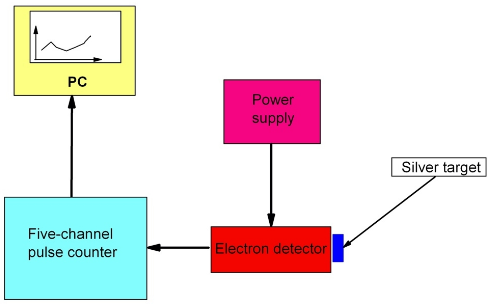

Figure 3. Schematic representation of the installation for measuring the time dependence of the change in the activity of a silver target after irradiation.

g, 24.5 mm in diameter, and 0.5 mm in thickness was used to detect neutron radiation by the activation method. In all irradiation cycles, the electron beam current was 50 ± 1 μA.

Figure 4 shows dependence of the electron beam current on time on a tantalum target for one of the irradiation runs.

Figure 5 shows a photograph of the electron beam shape at the tantalum target.

3. Investigation of the Photo Neutron Reaction Threshold in Metallic Beryllium

Metallic beryllium was chosen as a sample for conducting a test study. It is known that of all the stable isotopes, Be^9 has the lowest photo neutron reaction threshold of 1.665 MeV. A sample of beryllium weighing 7.5457 g, 28.6 mm in

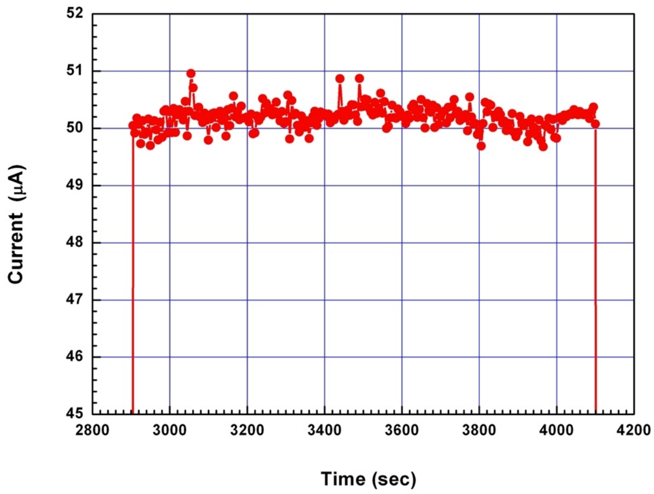

Figure 4. Dependence of the electron beam current at the tantalum target on time.

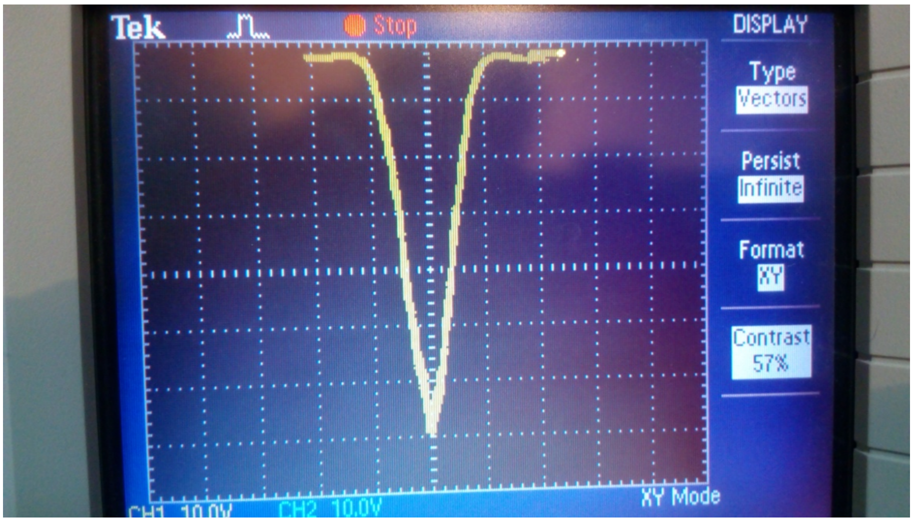

Figure 5. Electron beam shape at the tantalum target.

diameter and 6.5 mm in thickness was placed in the target device. Figure 6 shows the dependence of the electron beam energy on time for each cycle of irradiation of the beryllium sample. Figure 7 shows the change in the radioactivity of the silver target as a function of time after each irradiation cycle of the beryllium sample. Figure 8 shows the dependence of the radioactivity of the silver target on the energy of the electron beam. The ordinate shows the number of pulses from the irradiated silver target measured 100 seconds after the end of irradiation for 100 seconds. The abscissa shows the energy of the electron beam on the tantalum target. As can be seen from the dependence, with

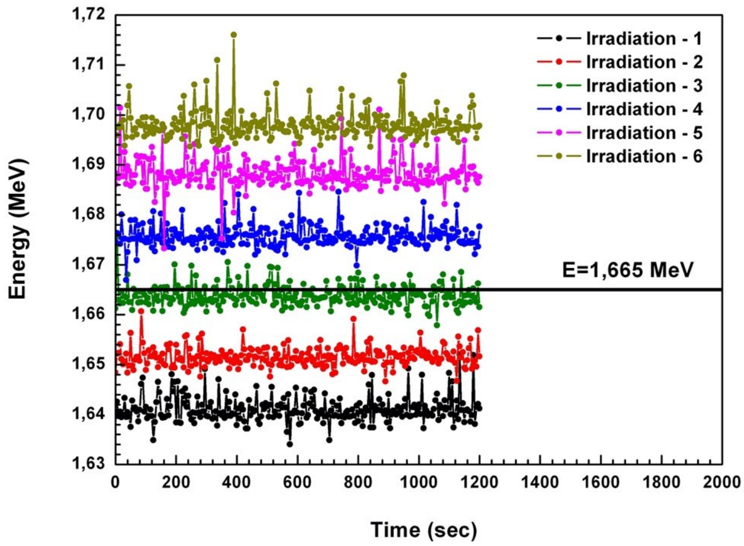

Figure 6. Time dependences of the electron beam energy upon irradiation of the beryllium sample

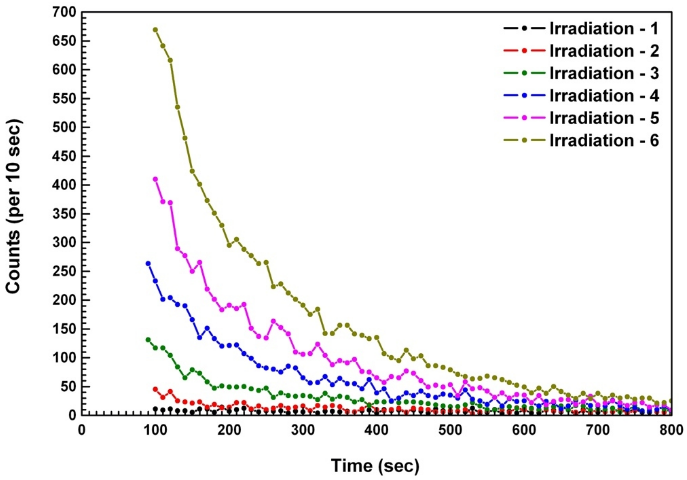

Figure 7. Dependences of the change in the radioactivity of the silver target on time after each irradiation cycle.

increase in the energy of accelerated electrons above the threshold value of 1.665 MeV, the radioactivity of silver targets increases monotonically, as expected. The presence of a small excess over the background after irradiation with electron energy equal to the threshold and slightly lower is explained by the presence of a small spread in energy from the absolute value of accelerated electrons (Fig. 6). The fraction of electrons with energy exceeding the threshold contributes to the activation of the silver target.

These results show that the method used for the measuring photo neutron reaction threshold is correct.

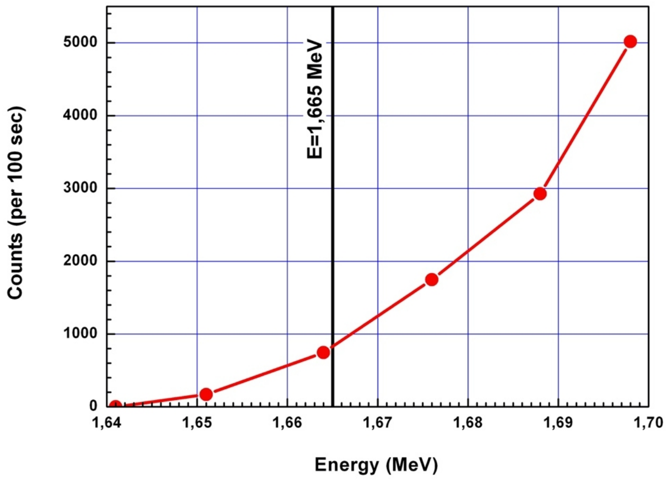

Figure 8. Dependence of the radioactivity of a silver target on the electron beam energy.

Figure 9. Photograph of the 17% HfD_2 and 83% ZrD_2 sample.

4. Investigation of the Photo Neutron Reaction Threshold in Deuterium Located in the Crystal Lattice of Hafnium and Zirconium

To study the photo neutron reaction threshold in deuterium located in the crystal lattice of hafnium and zirconium, a sample was prepared containing 17% by weight of HfD_2 and 83% by weight of ZrD_2. A sample weighing 20.2228 g, 30.3 mm in diameter and 5.5 mm thick was placed in the target device. Figure 9 shows a photograph of the sample. Figure 10 shows the dependence of the electron beam energy on time for each irradiation cycle. Figure 11 shows the change in the radioactivity of the silver target as a function of time after each irradiation of the sample. Figure 12 shows the dependence of the radioactivity of the silver target on the energy of the electron beam. As can be seen from the dependence, with an increase in the energy of electrons above the threshold value, which for a free deuteron is 2.225 MeV, the radioactivity of the silver target increases monotonically. Below the threshold energy of the photo neutron reaction in a free deuterium, the induced radioactivity of the silver target was not observed.

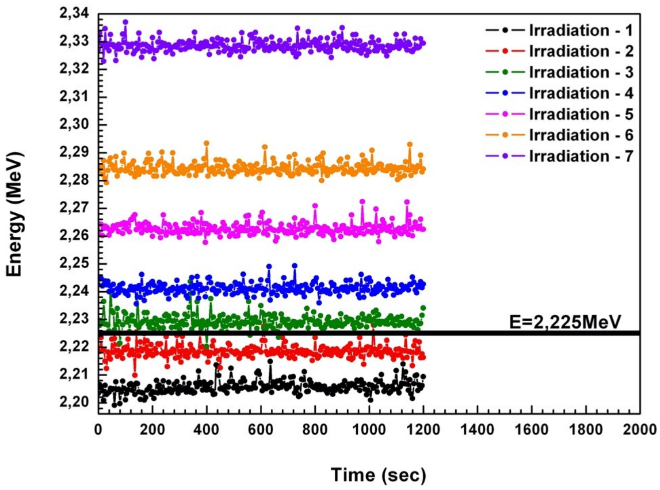

Figure 10. Time dependences of the electron beam energy upon irradiation of the 17% HfD_2 and 83% ZrD_2 sample.

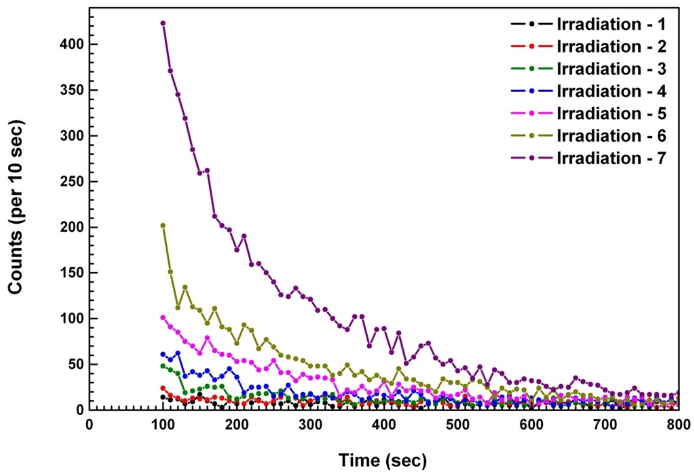

Figure 11. Dependences of the change in the radioactivity of the silver target on time after each irradiation cycle.

5. Investigation of the Photo Neutron Reaction Threshold in Deuterium Located in the Crystal Lattice of Ti41,5Zr41,5(Ni-Pd)17

To study the threshold of the photo neutron reaction on deuterium located in the crystal lattice of $Ti_{41,5}Zr_{41,5}$(Ni-Pd)$_{17}$, ($Ti_{41,5}Zr_{41,5}$(Ni-Pd)$_{17}$)$D_{1,63}$ was prepared containing 4.546% by weight of deuterium. A sample weighing 24.8692 g, 30.5 mm in diameter and 9.3 mm thick was placed in the target device. Figure 13 shows a photograph of a sample. Figure 14 shows the dependence of the electron beam energy on time for each sample irradiation cycle. Figure 15 shows the change of the radioactivity of the silver target as a function of time after each irradiation of the sample.

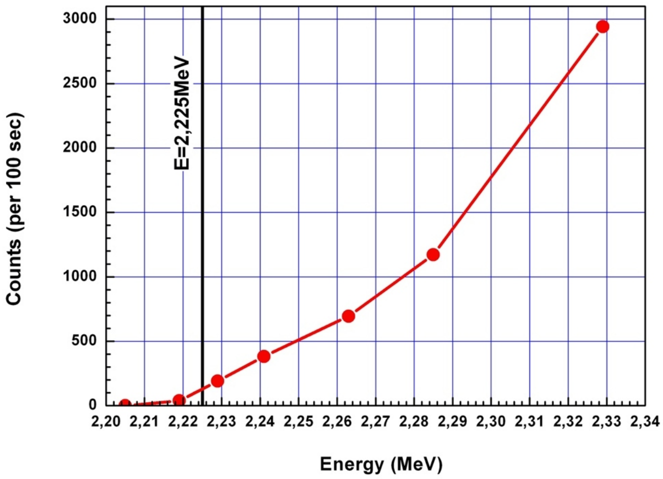

Figure 12. Dependence of the radioactivity of a silver target on the electron beam energy.

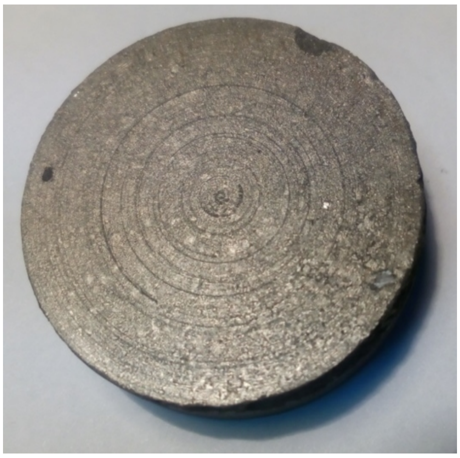

Figure 13. Photograph of the $Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17}$ sample.

Figure 16 shows the dependence of the radioactivity of the silver target on the energy of the electron beam. As can be seen from the dependence, with an increase in the energy of accelerated electrons above the threshold value, which for deuterium is 2.225 MeV, the radioactivity of the silver target increases monotonically. Below the threshold energy of the photo neutron reaction in deuterium, induced radioactivity of the silver target was not observed.

6. Summary

The above results show that under gamma irradiation of deuterated materials HfD_2, ZrD_2 and $(Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17})D_{1,63}$, the threshold energy for the photo neutron reaction was 2.225 ± 0.01 MeV. This value coincides within

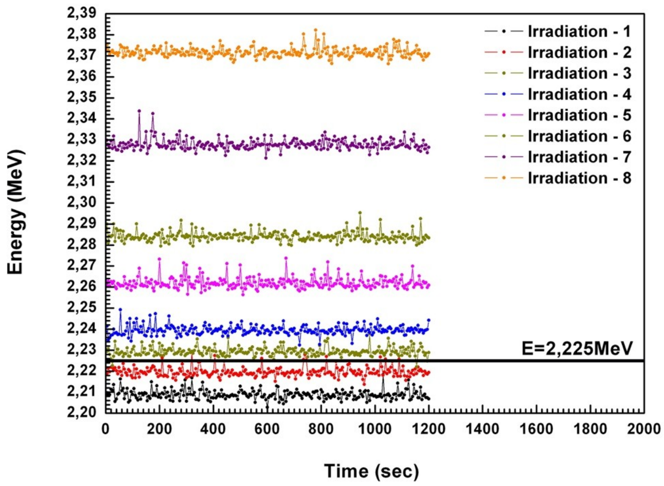

Figure 14. Time dependences of the electron beam energy upon irradiation of the $Ti_{41,5}Zr_{41,5}(Ni\text{-}Pd)_{17}$ sample.

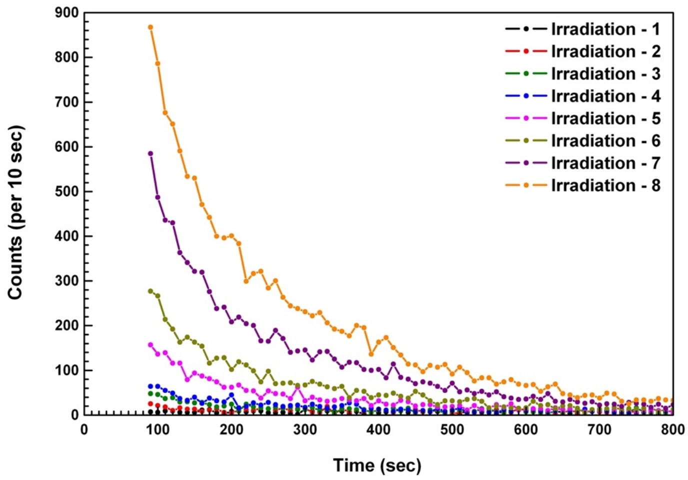

Figure 15. Dependences of the change in the radioactivity of the silver target on time after each irradiation cycle.

the measurement accuracy with the threshold value of the photo neutron reaction for deuterium in a free state (2.225 MeV) in the marked contrast with results obtained in the NASA experiment [6] where the threshold value of the photo neutron reaction for deuterium confined in the crystal lattice was measured to be 2 MeV. A possible reason for this discrepancy is that the authors [6] used a modified linear industrial accelerator (LINAC) as a source of accelerated electrons, in which the upper energy of electrons could not be determined exactly. Therefore, it could have high energy "tales" with energies exceeding 2.225 MeV, resulting in the photo neutron reaction.

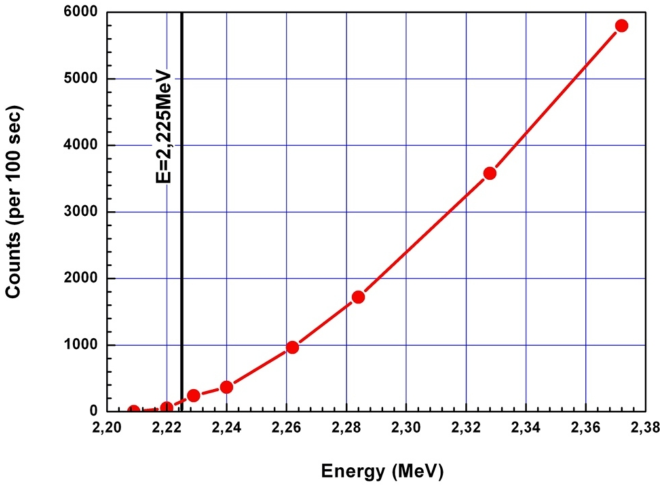

Figure 16. Dependence of the radioactivity of a silver target on the electron beam energy.

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