FIRST OBSERVATION OF THE TRITIUM PHOTOPRODUCTION IN HIGH PRESSURE GASEOUS DEUTERIUM

Author: Yu. L. Ratis

Institute of the power engineering for the special applications

Abstract

We theoretically predict [1], [2] and experimentally prove the existence of the exoatom "dineutroneum" [3]. The dineutroneum is the low-laying extremely narrow resonance in the elastic electron-deuteron scattering. This resonance is caused by the weak interaction and corresponds to the transition of the initial state of the system «electron + deuteron» into the bound state of the neutron and neutroneum [3]. The first direct confirmation of the dineutroneum existence we get in the tritium photoproduction reaction in high pressure gaseous deuterium [3], [4].

1. Introduction

All theoretical predictions based on the effective Hamiltonian $h'(\vec{r})$ [3]:

$$h'(\vec{r}) = \frac{G}{\sqrt{2}\cdot L^3} e^{i\vec{k}_e\cdot\vec{r}} \cdot \left[i\tilde{f}_1 \cdot b_4 - \tilde{g}_1 \ \vec{b}\cdot\vec{\sigma}^N \ \right] \cdot \tau_+ \cdot \delta(\vec{r}-\vec{r}_n) + h.c.. \tag{1}$$

where $G_\beta = \tilde{f}_1 \cdot G$, G - a constant of the weak interaction, L^3 - normalization volume, and $\tilde{f}_1$, $\tilde{g}_1$ - formfactors, $\vec{\sigma}^N$ - is the Pauli matrix in the nucleon space. The Hermite-conjugate term in Hamiltonian (1) corresponds to well-known electron's capture reaction. One can show that non-relativistic leptonic matrix elements are equal

$$b_4(\underline{m}_e,\underline{m}_\nu) \approx \delta_{j_\nu\,1/2}\left[ig_{-1}(r)(4\pi)^{-1/2}\delta_{\underline{m}_e\underline{m}_\nu} + f_1(r)\sum_{m_l} C^{j_\nu \underline{m}_\nu}_{1m_l\;1/2\underline{m}_e} Y_{1m_l}(\vartheta_\nu,\varphi_\nu)\right]. \tag{2}$$

$$b_k(\underline{m}_e,\underline{m}_\nu) \approx \delta_{j_\nu\,1/2}\sqrt{3}\left[g_{-1}(r)(4\pi)^{-1/2} C^{1/2\,\underline{m}_e}_{1k\;1/2\underline{m}_\nu} - if_1(r)\sum_{m_l,\sigma} C^{j_\nu \underline{m}_\nu}_{1m_l\;1/2\sigma} C^{1/2\,\underline{m}_e}_{1k\;1/2\sigma} Y_{1m_l}(\vartheta_\nu,\varphi_\nu)\right]. \tag{3}$$

The designations of [3] are used in this paper.

2. Dineutroneum electroproduction

In an accordance of conservation laws and selection rules, hypothetical «neutroneum» can be created in ed - collisions, or in eD - collisions. Electron capture of the orbital electro (i.e., reaction $D \to D_\nu$) is strictly forbidden by conservation laws.

At the non-resonances energies the contribution of the weak interaction to the amplitude of the elastic ed - scattering ($e^- + d \to D_\nu \to e^- + d$) is negligible.

Let's consider continuous spectrum electron capture by the hydrogen atom

$$D(e,e')D_\nu . \tag{4}$$

According to the main idea [3] we can consider resonance contribution of the weak interaction into the cross-sections of the inelastic eD - scattering, as it is shown at fig. 1.

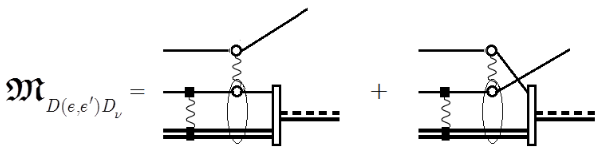

Fig. 1. Contribution of the weak interaction to the amplitude of the reaction of the dineutroneum creation

Singularities position of the dineutroneum propagator on the complex energies plane is unknown. The nature of this problem - nonperturbative effects in the framework of the Standard Model (SM) at the low energies. But according estimation $U_{D_\nu} \sim 0.1-1\ eV$, the two-particle electron-deuteron's propagator has a pole, correspondent to dineutroneum mass

$$m_{D_\nu} = m_d + m_e + U_{D_\nu} c^{-2} > m_D \tag{5}$$

To calculate the cross-section of the electron capture (4) at the dineutroneum excitation region, we have to take into account three-body effects. The third particle at the collision of the electron and the deuterium atom play a role of the significant amplifier of the dineutroneum creation cross-section. In the framework of the three-body problem we have to integrate the two-particle propagator of the electron and deuteron (i.e., excited deuterium) over the virtual states. This convolution gives us enormous amplification ($\sim 10^{14}$) not only for the total cross-section, but also for the width of the resonance, and its properties can be investigated experimentally.

According to [3] and evident inequality $m_d \gg m_e$ we evaluate dineutroneum creation threshold:

$$\varepsilon_{tr} \approx U_{D_\nu} + \varepsilon_D . \tag{6}$$

where $\varepsilon_D \approx 13.6\ eV$ - electron's binding energy for the deuterium atom.

Dineutroneum electroproduction cross-section looks like:

$$\begin{cases} \dfrac{d\sigma_{D(e,e')D_\nu}}{d\Omega_{D_\nu}} = \sigma^{(0)}_{D(e,e')D_\nu} F_c^2(\eta_p) \cdot \sqrt{\xi^2_{D_\nu} - \xi^2_{\hat{D}_\nu}} \cdot \sum\limits_{+,-} \left\{ (x^{(\pm)}_{D_\nu})^2 \left| \Phi(x^{(\pm)}_{D_\nu}) \right|^2 \right\} \\ \sigma^{(0)}_{D(e,e')D_\nu} = (2j_{D_\nu}+1) \begin{Bmatrix} 1/2 & 1/2 & 1 \\ j_{D_\nu} & 1/2 & j_{n_\nu} \end{Bmatrix}^2 \cdot \left[\dfrac{2m_e^2}{\pi} \dfrac{a_B^3}{V_{eff}^{D_\nu}} G_\beta^2 \tilde{\phi}^2_{ep}(j_{n_\nu}) \right] \end{cases} \tag{7}$$

All details and designations see [3].

The energy dependence of the total cross-section $\sigma^{tot}_{D(e,e')D_\nu}$ of the dineutroneum creation is resonant (fig. 2, 3). The resonance shape essentially differs from Breit-Wigner.

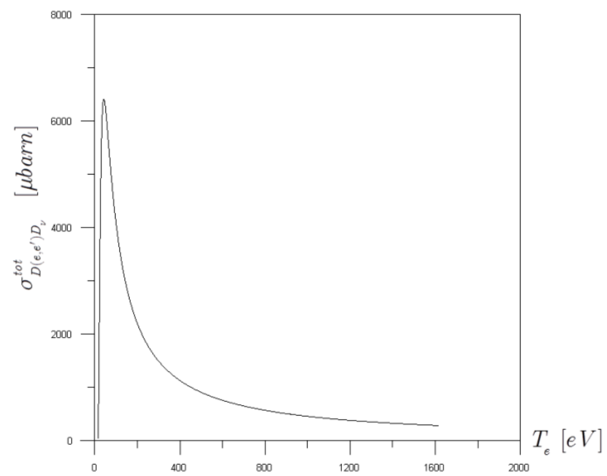

Fig. 2. Energy dependence of the total cross-section $\sigma^{tot}_{D(e,e')D_\nu}$ of the dineutroneum creation ($U_{D_\nu} = 0.1 eV$)

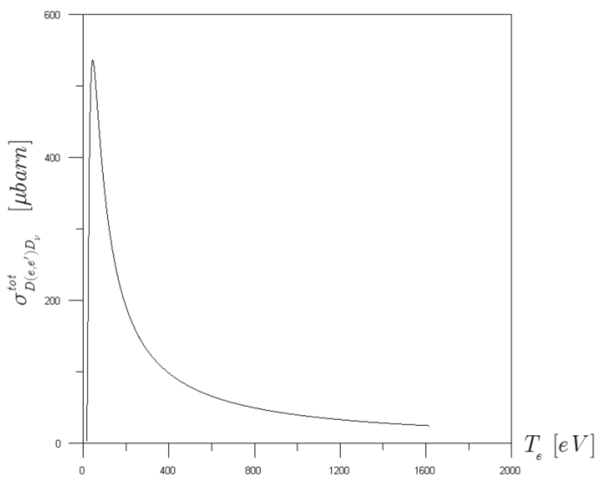

Fig. 3. Energy dependence of the total cross-section $\sigma^{tot}_{D(e,e')D_\nu}$ of the dineutroneum creation ($U_{D_\nu} = 1\ eV$)

3. Dineutroneum photoproduction and experimentum crucis

Let's consider the process of the dineutroneum photoproduction [3], [4]:

$$D(\gamma, \gamma')D_\nu . \tag{8}$$

The correspondence Feynman's diagrams $\mathfrak{M}_{D(\gamma,\gamma')D_\nu}$ see fig. 4.

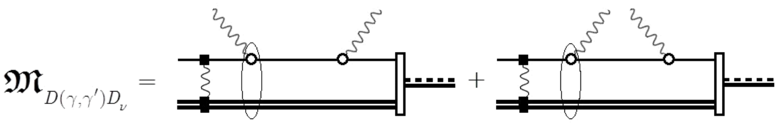

Fig. 4. Dineutroneum photoproduction

The cross-section $\sigma^{tot}_{D(\gamma,\gamma')D_\nu}$ for $D(\gamma,\gamma')D_\nu$ reaction is equal:

$$\sigma^{tot}_{D(\gamma,\gamma')D_\nu} \approx \sigma^{(0)}_{D(\gamma,\gamma')D_\nu} \cdot \frac{\varepsilon_{00}^2}{\varepsilon_\gamma^2} \tag{9}$$

where $\varepsilon_{00} = 1\ MeV$, ε_γ is the energy of γ- quanta, and $\sigma^{(0)}_{D(\gamma,\gamma')D_\nu} \approx 8.3 \cdot 10^{-15}\ mbarn$ for the atomic gaseous targets. The value of $\sigma^{(0)}_{D(\gamma,\gamma')D_\nu}$ is so small that the tritium photoproduction in atomic gas targets is forbidden. But preliminary analysis of this fact will be very useful.

The X-ray-transparent volume with high pressure deuterium gas was irradiated by γ-quanta from «cobalt gun». According to initial hypothesis tritium photoproduction should begin. Registration of this tritium would be the accurate signal of the existence of dineutroneum.

Gaseous deuterium was irradiated by «cobalt gun» γ- quanta in the Mendeleev's Chemistry University. The X-ray-transparent stainless steel AISI cilinder with the deuterium under the pressure of 110 atm has volume 50 ml. The target irradiation was made during 15 days [3].

Experimental installation includes:

1. The cylindrical chamber with the "cobalt gun": diameter 130 mm, height 210 mm.

2. Ten tubes of 30 sources by activity $0.58 \cdot 10^{12}\ Bq$ everyone around the chamber.

3. Each source is the cylinder: diameter 11 mm, height 81 mm

4. Cylinder with deuterium V=50 ml, the walls thickness 2 mm, pressure 110 bar.

The tritium concentration was measured by liquid scintillation method (TriCarb 2810 TR). The measurement results are presented in table 1.

Table 1

Change of activity of water as a result of influence γ - radiations on the deuterium

Activity to an irradiation, Bk/0,5ml	Activity after an irradiation, Bk/0,5ml
6,688±0,201	8,234±0,247
6,539±0,196	8,335±0,250

The exposed cylinder contains $\nu_{D_2} \approx 0.65\, mol$ of deuterium or $N_0 \approx 7.8 \cdot 10^{23}$ atoms. After deuterium burning we get $\nu_{D_2O} \approx 0.65\ [mol] \approx 13\, g$ of heavy water with tritium.

In the framework of the hypothesis of $D(\gamma,\gamma')D_\nu$ dominating role

$$\dot{N}_{D_\nu} = N_0 \cdot j_\gamma \cdot \sigma^{tot}_{D(\gamma,\gamma')D_\nu} \qquad (10)$$

where N_0 - the quantity of targets (deuterium atoms), a j_γ - the γ - quanta current

$$j_\gamma = J_\gamma \cdot S^{-1}, \qquad (11)$$

J_γ - the total γ - quanta current, S - the square of the irradiated surface of the cylinder with deuterium.

The probability of the tritium production we designate by $P_{d(D_\nu,n_\nu)t}$. As a result

$$\dot{N}_T = N_0 \cdot j_\gamma \cdot P_{d(D_\nu,n_\nu)t} \cdot \sigma^{tot}_{D(\gamma,\gamma')D_\nu} \qquad (12)$$

The tritium decay rate equal

$$\dot{N}^{dec}_T = -\lambda_T N^{dec}_T \qquad (13)$$

where

$$\lambda_T \approx 1.8 \cdot 10^{-9}\ s^{-1} \qquad (14)$$

For increasing rate $\dfrac{\Delta \dot{N}_{count}}{\Delta V} \approx \dfrac{2\ Bq}{0.5\ ml} = 4\ Bq \cdot ml^{-1}$ it is necessary that decaying of tritium nuclei in the cylinder during 15 days should be equal

$$\Delta N^{dec}_T \sim \frac{50}{1.8 \cdot 10^{-9}} \sim 2.5 \cdot 10^{10} \qquad (15)$$

On the other hand

$$\Delta N_T = N_0 \cdot j_\gamma \cdot P_{d(D_\nu,n_\nu)t} \cdot \sigma^{tot}_{D(\gamma,\gamma')D_\nu} \cdot \tau \qquad (16)$$

where $\tau \approx 1.3 \cdot 10^6\ s$. We also knows that

$$J_\gamma \approx 1.3 \cdot 10^{12}\ s^{-1} \qquad (17)$$

$$S \approx 60\ cm^2 = 6 \cdot 10^{-3}\ m^2 \qquad (18)$$

Thus experimental cross-section is

$$\sigma^{exp}_{D(\gamma,\gamma')D_\nu} = \frac{\Delta N_T}{P_{d(D_\nu,n_\nu)t} \cdot j_\gamma \cdot N_0 \cdot \tau} \sim \frac{1\ \mu barn}{P_{d(D_\nu,n_\nu)t}} \quad (19)$$

The value $P_{d(D_\nu,n_\nu)t} < 1$ by definition, and the energy of "cobalt gun" γ - quanta $\varepsilon_\gamma > 1\ MeV$. In in accordance to it

$$\sigma^{tot}_{D(\gamma,\gamma')D_\nu}(\varepsilon_\gamma > 1\ MeV) < 10^{-11}\ \ \mu barn \quad (20)$$

The great discrepancy of (19) and (20) clearly says us: we deals with multi-step process of tritium photoproduction.

The alternative hypothesis on the tritium photoproduction mechanism is based on the known fact: the deuterium in the cylinder is not in atomic, but in the molecular state.

In molecular gaseous deuterium the catastrophic suppression of dineutroneum photoproduction cross-section due to extremely small atomic form-factor is absent, and mechanism of dineutroneum and tritium photoproduction becomes multi-step.

In the framework of our approach this mechanism looks-like:

1. The deuterium molecule ionized by hard γ - quanta.
2. Collision of the preliminary knocked-outed electron with the second orbital electron in the D_2 molecule results the dineutroneum electroproduction.
3. Nuclear interaction of dineutroneum and deuteron witin initial D_2 molecular target results the tritium production.

At the "cobalt gun" energy region of the γ - quanta ($\varepsilon_\gamma \sim 1\ MeV$) the cross-section of the knocked-out electrons with the energy $T^{ko}_e > 20\ eV$ approximately equal Thomson's limit of the Compton's cross-section:

$$\sigma_{Compt} = \frac{8\pi}{3}\left(\frac{\alpha}{m}\right)^2 = 65.7\ fm^2 \quad (21)$$

Thus dineutroneum photoproduction cross-section in the molecular deuterium ($D_2(\gamma,\gamma')DD_\nu$ reaction) one can estimates in "geometrical" approximation:

$$\sigma^{tot}_{D_2(\gamma,\gamma')DD_\nu} = \frac{\sigma_{Compt}}{S} N_{D_2} \left\langle \kappa_{ion} \right\rangle \left\langle \sigma^{tot}_{D(e,e')D_\nu} \right\rangle \quad (22)$$

where S - is the square of the surface of the irradiated cylinder, N_{D_2} - is the full number of deuterium molecules in the cylinder, $\left\langle \kappa_{ion} \right\rangle$ - is the average of the knocked-out electrons with the energy $T^{ko}_e > 20\ eV$, and $\left\langle \sigma^{tot}_{D(e,e')D_\nu} \right\rangle$ - is the average cross-section of the dineutroneum electroproduction.

This approximation brings us the follows estimation, based on the results [3].

$$\sigma^{tot}_{D_2(\gamma,\gamma')DD_\nu} \approx 4.3 \cdot 10^{-3} \left\langle \kappa_{ion} \right\rangle \left\langle \sigma^{tot}_{D(e,e')D_\nu} \right\rangle \quad (23)$$

It is evident that $\left\langle \kappa_{ion} \right\rangle > 1$, direct calculation gives us estimation $\sigma^{tot}_{D(e,e')D_\nu} \sim 6\ mbarn$, but the value of probability $P_{d(D_\nu,n_\nu)t}$ is unknown.

Conclusion: preliminary analysis of the experiment on the deuterium irradiation in the «cobalt gun» has shown that the results do not contradict the hypothesis on the existence of the neutroneum and dineutroneum.

Summary

Summarize the aforesaid as follows.

1. The direct "experimentum crucis" on tritium photoproduction in gaseous deuterium confirmed the theoretical predictions of the dineutroneum existence.
2. The alternative explanation of tritium photoproduction is absent.

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