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Evidence of light multineutron bound systems formation in the 159Tb (p,x)157Dy nuclear reactions

In the last few years, we continued to study light multineutron systems [1] in bound states that were predicted by Migdal [2]. Such possibility, for at least the dineutron, is based on the theoretical substantiation that in the outgoing channel as the product of the nuclear reaction a bound system of two identical nucleons exists beyond the volume of the heavy core of the other nucleons of the target nucleus but within the potential well of the core. This prediction has been confirmed in our previously published papers [3-5] by means of the observation of the induced activity of residual nuclei in neutron induced nuclear reactions for energies of impinging neutrons below the threshold of corresponding (n,2n) nuclear reactions. We have extended the scope of our research for other nuclear reaction conditions to make sure that the generation of bound dineutrons is valid not only for one nucleus and one nuclear reaction type.
Therefore, in our new experiment, a stack of Tb, Ti and Cu foils was irradiated by beam of Ep = 17 MeV ± 0.3% energy protons that is below the Eth = 17.14 MeV threshold of the 159Tb(p,3n)157Dy nuclear reaction. The Ti and Cu foils were used for monitoring the proton flux and the energy loss of the protons in the stack. Polyethylene foils were placed in between the metal foils to avoid cross contaminations. After irradiation the induced gamma-activities of the irradiated t = 33 μm thick Tb foils were counted on a Canberra HPGe coaxial detector. In the case of the Tb foil activated in the stack by protons of Ep = (16.23 ± 0.23) MeV energy, the gamma-peak of Eg = 326.3 keV energy was counted for tLIVE = 56,951 seconds live time and net peak area of Snet = (2,154 ± 274) counts was observed due to the decay of 157Dy. This observation can be explained by the presence in the outgoing channel of the 159Tb (p,x)157Dy nuclear reaction beside the 157Dy heavy nucleus either the dineutron in a bound state and one more neutron or a bound trineutron. The estimate for the nuclear reaction cross section of the 159Tb (p,n2+n)157Dy nuclear reaction was obtained as (0.31±0.04) μb. Two other Tb foils irradiated together in the stack with protons of Ep = (16.77 ± 0.23) MeV and Ep = (15.67 ± 0.24) MeV energies were counted on an Ortec Ge planar detector and no any signs of the Eg = 326.3 energy peak. This result actually proves one more prediction in [2] regarding the resonant behaviour of nuclear reactions with the formation of a bound dineutron. Moreover, in [6] under similar conditions but for Ep = (14.86 ± 0.85) MeV proton energy the Eg = 326.3 keV gamma-peak was also observed in the instrumental gamma-spectrum. As the upper estimate of a bound dineutron is well established as Bdn = 3.01 MeV [7], we also irradiated two Tb foils with Ep = (13.87 ± 0.26 MeV) and Ep = (13.24 ± 0.25) MeV energy protons, correspondingly, followed by counting each foil separately. The measurement of the first foil, again, resulted in appearance of the Eg = 326.3 keV gamma-peak with small statistics while the second Tb foil showed no any signs of the Eg = 326.3 keV peak. This means that we observed a weak but expected sign of the existence of a bound trineutron with the corresponding cross-section estimate of the 159Tb (p,n3)157Dy nuclear reaction being equal (0.45 ± 0.23) μb for Ep = (13.87 ± 0.26) MeV proton energy and an interval binding energy estimate: 3.27 MeV < Btn < 9.26 MeV.
Thus, the trineutron and possible dineutron in bound states were evidenced in this study to be further confirmed.

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