FORMATION CROSS-SECTIONS OF ^{149}Tb NUCLIDES AT IRRADIATION OF MEDIUM-HEAVY NUCLEI BY PROTONS WITH ENERGIES IN THE RANGE OF 60–1000 MeV

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Nuclides of ^{149}Tb are formed in proton disintegration reactions with rather high thresholds of some tens or hundreds of MeV's. The lifetime of ^{149}Tb is 4.15 ± 0.03 hours, $16.7 \pm 1.4\%$ of intensity being due to α-decay with energy $E_\alpha = 3.967 \pm 0.003$ MeV. These nuclear properties of ^{149}Tb nuclide make reactions with its production very convenient to use at a pertinent threshold for the proton beam monitoring at moderate and high energies. However formation cross-sections of ^{149}Tb are required for various targets irradiated by protons with a definite energy. Moreover ^{149}Tb nuclei are as usual formed in complex nuclear reactions whose mechanisms are of interest at present experimental studies [2]. In this case except formation probabilities kinematics is also of importance.

Gatchina synchrocyclotron was used for measurements of production cross-sections of ^{149}Tb nuclides from targets of ^{nat}Gd, ^{159}Tb, ^{165}Ho, ^{169}Tm, ^{181}Ta and ^{197}Au at external and

internal proton beams. All the targets except ^{nat}Gd were monoisotope elements. Experimental details of manipulations with external and internal proton beams were published elsewhere [3, 4]. In both cases the same nuclear reaction $^{27}Al\ (p, 3pn)\ ^{24}Na$ was employed as a monitor of the proton beam flux. Induced α-activity rate of ^{149}Tb nuclides was measured with the help of silicon semiconductor surface-barrier detectors whose sensitive squares varied from 0.2 to 14.5 cm^2, energy resolution being equal correspondingly to 70 and 180 keV for α-particle energy $E_\alpha = 5$ MeV. Detector sizes were determined by the counting rate of the irradiated targets.

Experimental results are contained in the Table.

Table

Proton energy $E_p \pm 20$, MeV	Cumulative formation cross-sections of ^{149}Tb, 10^{-27} cm^2					
	Target					
	^{nat}Gd	^{159}Tb	^{165}Ho	^{169}Tm	^{181}Ta	^{197}Au
1000	0.44±0.06	1.38±0.15	3.5±0.4	9.6±1.0	18.0±1.8	5.6±0.6
940	0.53±0.06	1.38±0.15	3.7±0.4	7.8±0.9	13.8±1.4	4.5±0.5
840	0.55±0.07	1.62±0.20	3.5±0.5	7.2±0.8	12.3±1.6	2.9±0.3
780	—	1.56±0.16	4.2±0.4	9.3±1.0	11.4±1.2	1.74±0.19
625	0.66±0.08	1.50±0.19	5.7±0.7	9.7±1.1	7.2±0.8	0.46±0.06
440	1.20±0.16	3.3±0.4	5.4±0.6	10.2±1.2	2.8±0.3	0.042±0.007
235	2.5±0.3	5.9±0.7	3.7±0.4	2.16±0.25	0.006	—
130	4.4±0.7	8.8±1.2	0.5±0.07	0.03±0.006	—	—
76	7.5±1.1	0.2±0.03	—	—	—	—
60	5.2±1.0	0.16±0.04	—	—	—	—

Unlike the recently published α-branch cross-section values [3, 4], the total cumulative formation cross-sections are present. From the experimental cross-section data it follows that there is the most probable value of the Z/N ratio for a missing mass of complex nuclear reactions in the definite proton beam energy interval. At the small proton energy only neutron emission is possible. With the proton energy increase charge particle emission together with neutron emission begins to be the most probable. In the proton energy region of 780–1000 MeV the most probable value of the missing mass Z/N ratio turns out to be 1/3. This value confirms the nucleon composition chosen for massive nuclear-unstable fragments formed at the collinear tripartition of heavy nuclei by 1-GeV protons [5].

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