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POSSIBILITY OF ^{117m}Sn PRODUCTION USING HIGH-ENERGY ELECTRON BREMSSTRAHLUNG

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Возможность получения радионуклида ^{117m}Sn
с использованием тормозного излучения электронов высоких энергий

Описан метод получения радионуклида ^{117m}Sn с использованием тормозного излучения электронов высоких энергий. Определены удельные активности и выходы фотоядерных реакций ^{117m}Sn при облучении чистого олова и обогащенного изотопа ^{118}Sn. Также оценены удельные активности и выходы фотоядерных реакций ^{117m}Sn и ^{111}In при использовании тормозного излучения электронов высоких энергий линейного ускорителя установки ИРЕН ЛНФ ОИЯИ при облучении чистого олова.

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Possibility of ^{117m}Sn Production Using
High-Energy Electron Bremsstrahlung

The method of ^{117m}Sn production using an electron accelerator is described and its photonuclear reaction yield and specific activities for ^{117m}Sn and enriched isotope ^{118}Sn are estimated. The specific activities and photonuclear reaction yields of ^{117m}Sn and ^{111}In are also estimated using the high-energy electron bremsstrahlung of the linear electron accelerator of the IREN facility, FLNP, JINR at irradiation of high-purity tin targets.

The investigation has been performed at the Frank Laboratory of Neutron Physics and the Flerov Laboratory of Nuclear Reactions, JINR.

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INTRODUCTION

At present, the requirements for an acceptable radionuclide are still considerably high and nuclear reactors and cyclotrons are mainly used for the radionuclide production. However, they are not able to produce all the required types of radionuclides, therefore, electron accelerators such as Linac and Microtron, that can produce radionuclides using the bremsstrahlung, are suitable complements.

Properties of radionuclide ^{117m}Sn are acceptable for clinical and therapeutic use: the short half-life of 13.6 d is necessary to minimize the patient exposure, the gamma emission of photons of 158.4 keV (84%) — for imaging, and abundance (116%) of low energy (127–129, 152 keV) Auger and conversion electrons — for delivering a high radiation dose to sites of a bony metastatic disease [1, 2].

The yields for a number of radionuclides produced by the bremsstrahlung beam irradiation were measured by different groups. Oka et al. [3] measured the yields of radionuclides induced by the $(\gamma,\ n)$ reactions with the 20 MeV bremsstrahlung from a linac on 37 elements. Analogous measurements were performed at the Czech microtron by Randa et al. [4] with the 19 MeV bremsstrahlung beam. Detailed measurements were also performed by Gerbish et al. [5] at the microtron in Dubna, FLNR, JINR for practically all natural nuclides at different electron (14, 18 and 20 keV) energies. Properties and activity yields of radionuclides obtained from photonuclear reaction data are based exclusively on experimentally obtained results for the majority of elements and are presented in books by Segebade et al. [6].

1. EXPERIMENTAL PROCEDURE

To estimate the activity and yield of the radionuclide ^{117m}Sn production, the natural pure Sn (0.1635 g) and enriched ^{118}Sn (98.5%) isotope (30.4 mg) have been irradiated at the Microtron MT-25 in Dubna, FLNR, JINR by the bremsstrahlung beam of 23.5 MeV with the current of 15 μA during 1 h at the radial distance of 6 cm from the tungsten target (3 mm thick). For determination of photonuclear reaction yields of Sn isotopes several experiments have been carried out: the 1st one — the samples are pure Sn granules (0.767 g) and pure gold foil monitors (Au^1 — 1.8 mg; Au^2 — 2.1 mg and Au^3 — 3.2 mg); the 2nd one — the samples are pure Sn granules (0.1635 g), enriched ^{118}Sn (98.5%)

isotope (30.4 mg), pure gold foil monitors (Au^{1a} — 3.4 mg; Au^{2a} — 3.9 mg; Au^{3a} — 4.0 mg) and pure Zr foils (Zr^1 — 5.9 mg; Zr^2 — 5.0 mg).

Typical irradiation scheme of the second experiment, disposition of samples and beam monitors on the bremsstrahlung of the Microtron MT-25 are shown as follows:

$\gamma \rightarrow$							
	Zr^1	Au^{1a}	^{118}Sn	Au^{2a}	Sn	Au^{3a}	Zr^2

Activity of the irradiated natural Sn, enriched ^{118}Sn samples and monitors were measured by HP Ge detectors of the gamma spectrometer of FLNP, JINR with the energy resolution of 2 keV at gamma lines of 1332 keV for ^{60}Co radionuclide. To monitor the flux for bremsstrahlung of electron energies of 23.5 MeV with the current of 15 μA, pure metal foils of Au and Zr have been used. Gamma lines of the radionuclides, which must be detected from samples and monitors [2, 4], are given in the table below and level scheme of the simple energy of ^{117m}Sn is shown in Fig. 1. From the decay scheme one can see that ^{117m}Sn is not a beta emitter; it decays by isomeric transition with the emission of abundance (116%) of conversion electrons (M4) and a gamma line (M1) of 158.4 keV (84%). Radionuclide of this class is therapeutically and diagnostically useful in skeletal imaging and for the radiotherapy of bone tumors and other disorders.

From the measured gamma spectrum data the experimental photonuclear reaction activity and yield (Fig. 2, a, b) have been determined for radionuclides ^{117m}Sn and ^{111}In. Their experimental values are shown in the last columns of the table.

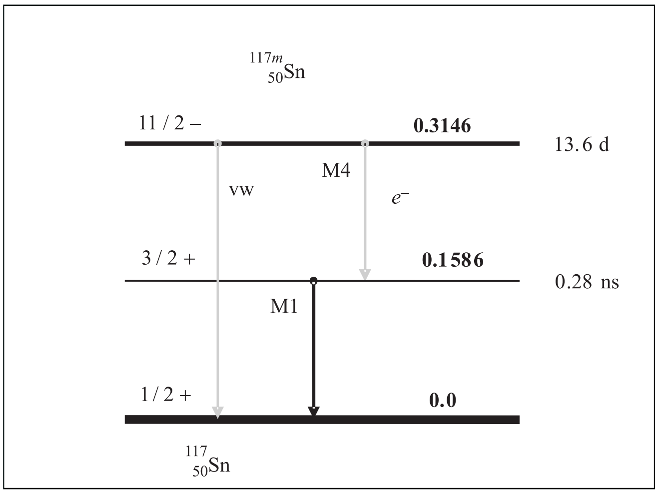

Fig. 1. The level scheme of simple energy of ^{117m}Sn

Nuclear data of Sn (tin) radioisotopes and experimental values of activity and yields

Radio-nuclide and half-life	Main E_γ, keV	Inten-sity, %	Reaction	Reac-tion E_γ, MeV	Abun-dance of target, %	Specific activity, Bq/mg	Yields, Bq/ μA mg
^{117m}Sn 13.6 d	158.4	84.00	^{117}Sn (γ, γ') ^{118}Sn (γ, n) ^{119}Sn $(\gamma, 2n)$	–0.32 –9.65 –16.13	7.57 24.01 8.5	2.0E+4	1.0E+3
^{117m}Sn 13.6 d	158.4	84.00	^{118}Sn (γ, n)	–9.65	98.5	8.8E+4	6.0E+3
^{111}In 2.83 d	171.3 245.3	91.00 94.00	^{112}Sn(γ, p)	–7.73	0.95	1.9E+5 2.0E+5	1.3E+4 1.4E+4

2. DISCUSSION AND CONCLUSION

Results of these experiments have shown a possibility of the ^{117m}Sn radionuclide production using the bremsstrahlung of high-energy electron accelerators. In case of irradiation of the natural pure Sn, radioisotopes ^{117m}Sn and ^{111}In have been produced, which are both useful for medical purposes.

The experimental yield of photonuclear reaction is 6 times higher than when an enriched ^{118}Sn (98.5%) isotope is used in the target, and from the gamma spectrum in Fig. 2 (a, b) one can see the gamma line of 158.4 keV of only one radionuclide ^{117m}Sn. The photonuclear reaction yields of ^{111}In were compared with the data determined in other works [7–9] and they have sufficient coincidences.

The isomeric ratio of ^{117m}Sn was estimated from the experimental data of activities of 158.4 (^{117m}Sn); 391.7 (^{113}Sn) and 1089 (^{123}Sn) keV energy gamma lines. The isomeric ratio was estimated and determined to be 0.15 and 0.44, for the radionuclides ^{113}Sn and ^{123}Sn correspondingly.

The activities and yields of the ^{117m}Sn and ^{111}In radionuclides will be increased at the bremsstrahlung beam of the 100–200 MeV Linac of the IREN facility, which is constructed in FLNP, JINR [10, 11].

The specific activity and yields on the bremsstrahlung of high-energy electron accelerators of the facility IREN have been estimated of ^{117m}Sn for pure Sn — 3.0E+4; enriched ^{118}Sn — 1.3E+5 and for pure Sn — 1.5E+3; for enriched ^{118}Sn — 1.3E+5; 9.0E+3, accordingly.

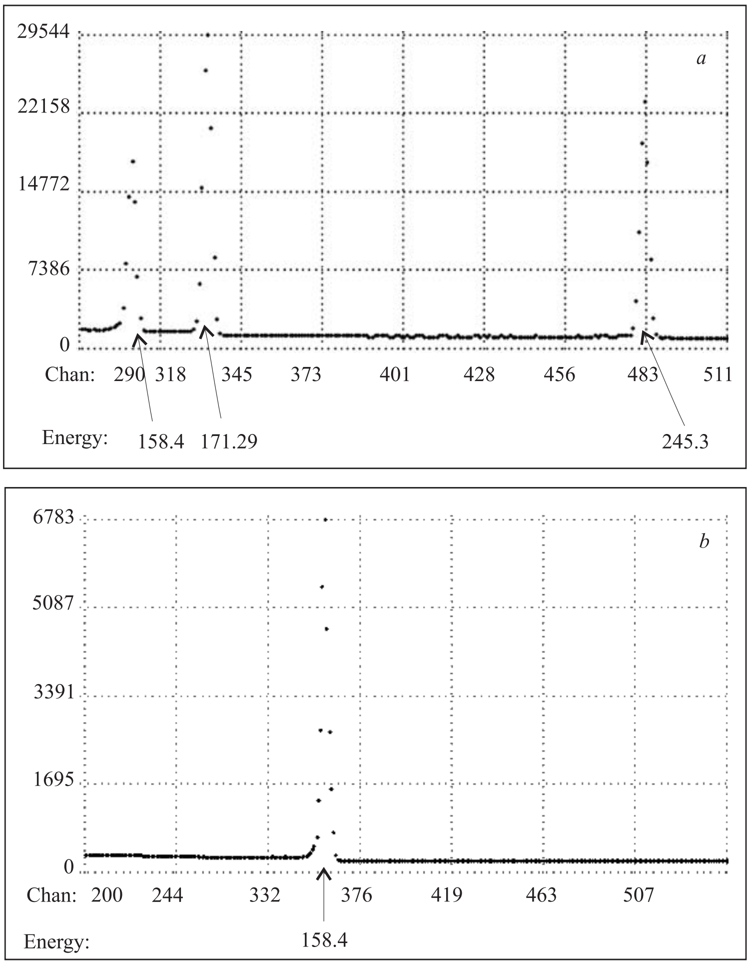

Fig. 2. *a*) A part of radioisotope spectrum of the irradiated natural pure Sn granule (163.5 mg); *b*) a part of radioisotope spectrum of the irradiated enriched ^{118}Sn (98.5%) foil (30.4 mg)

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